Crop protection in medieval agriculture

Studies in pre-modern organic agriculture

Jan C. Zadoks

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Photograph cover: July in a Psalter from N France, c. 1180, National Library of the Netherlands, The Hague: ms 76 F 13, p 7v.

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Chapter 1

Introduction, pre-modern crop protection

The *raison d'être* of this book is the contribution of three famous medieval authors to crop protection lore and science. Some predecessors, contemporaries, and followers are mentioned. Crop protection today is a science in its own right but crop protection in pre-modern times was embedded in the then current agricultural tradition, a stubborn tradition indeed. An overview of medieval crop protection is presented by means of a variety of selected examples. This introduction gives an outline of the book.

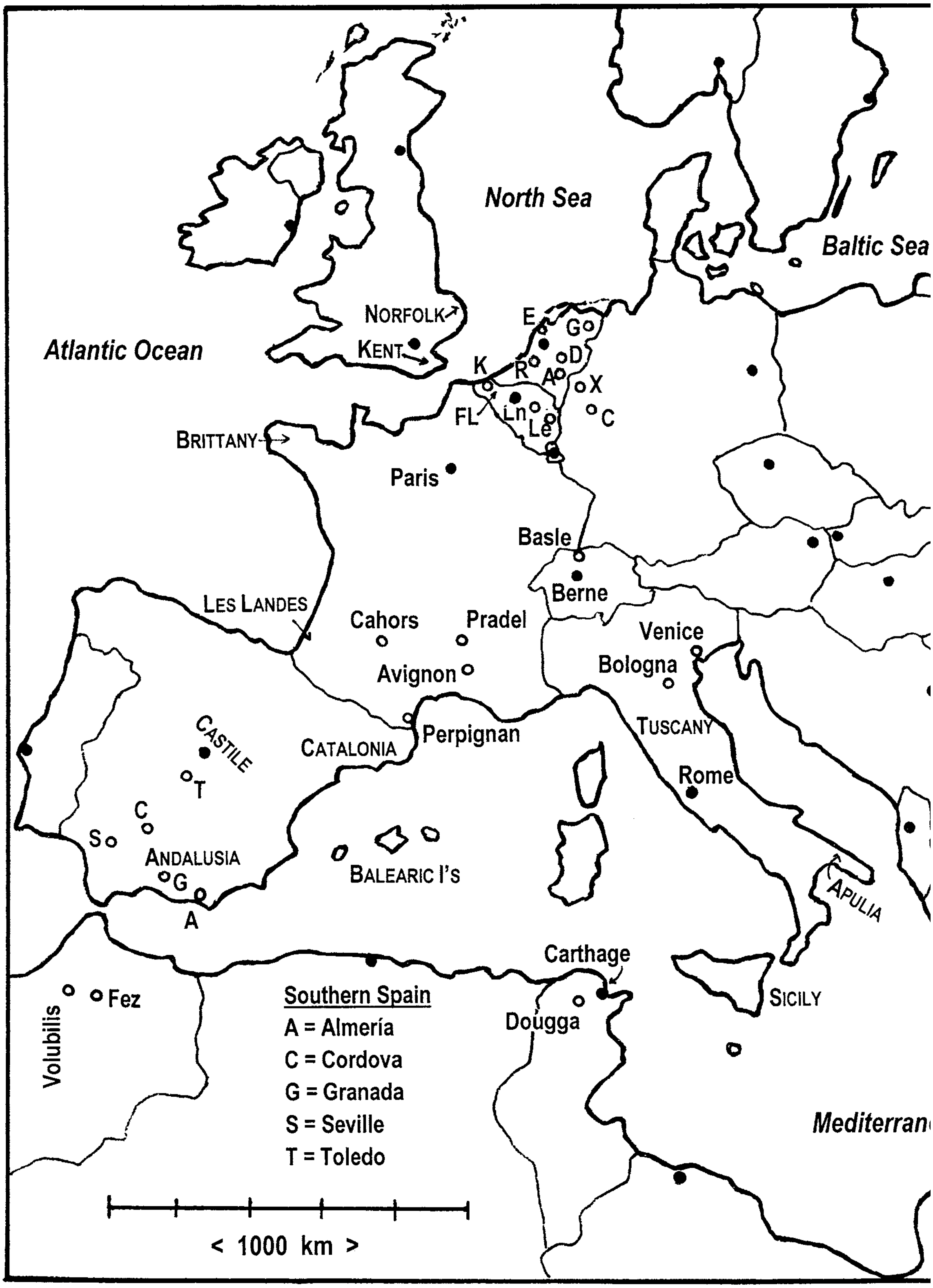
1.1 Why this book?

Crop protection is, in my perception, a fascinating area of interest. Apart from the biological approach, with its multi-level ecological interactions, there is an economic side, a sociological view, a historical development, and all of these aspects are entwined. In this book I focus on crop protection during the Middle Ages, mainly in the Mediterranean Area (Fig. 1.1). Clearly, it is hardly possible and certainly unwise to keep strictly to the indicated limits of space and time. Since medieval agricultural wisdom leans heavily on the Greek and Roman classics, I often use the term pre-modern, grasping therewith the period from the Greek beginnings until the onset of modern times, say 1600 (Fig. 1.2).

The history of crop protection is not an unexplored area. Meritorious reviews cover the field, at least in part, but few are those that gather their harvest from primary sources.[1] Several of these sources are difficult to access, and if accessible they are written in languages not lightly read by a Western public relying on English mainly. Translations, if existent, cannot always be trusted. At times interpretation, or re-interpretation, is needed to solve a linguistic problem.

The delineation of my subject is somewhat arbitrary. What is general crop husbandry, what is fantastication, what is - indeed - crop protection? To answer these questions I selected a few sheaves, books that I examined in detail, and I reaped some ears, scattered papers, following my fancy. As I collected only what

Figure 1.1 (next pages) Map of Europe and the Mediterranean area with locations mentioned in the text. For orientation of the reader the modern country borders and country capitals are indicated.


North Sea
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NORFOLK
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Paris
Basle
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LES LANDES
Cahors
Pradel
Venice
Avignon
Bologna
CASTILE
CATALONIA
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TUSCANY
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Fez
Volubilis
Dougga
SICILY
Southern Spain
A = Almería
C = Cordova
G = Granada
S = Seville
T = Toledo
Mediterran
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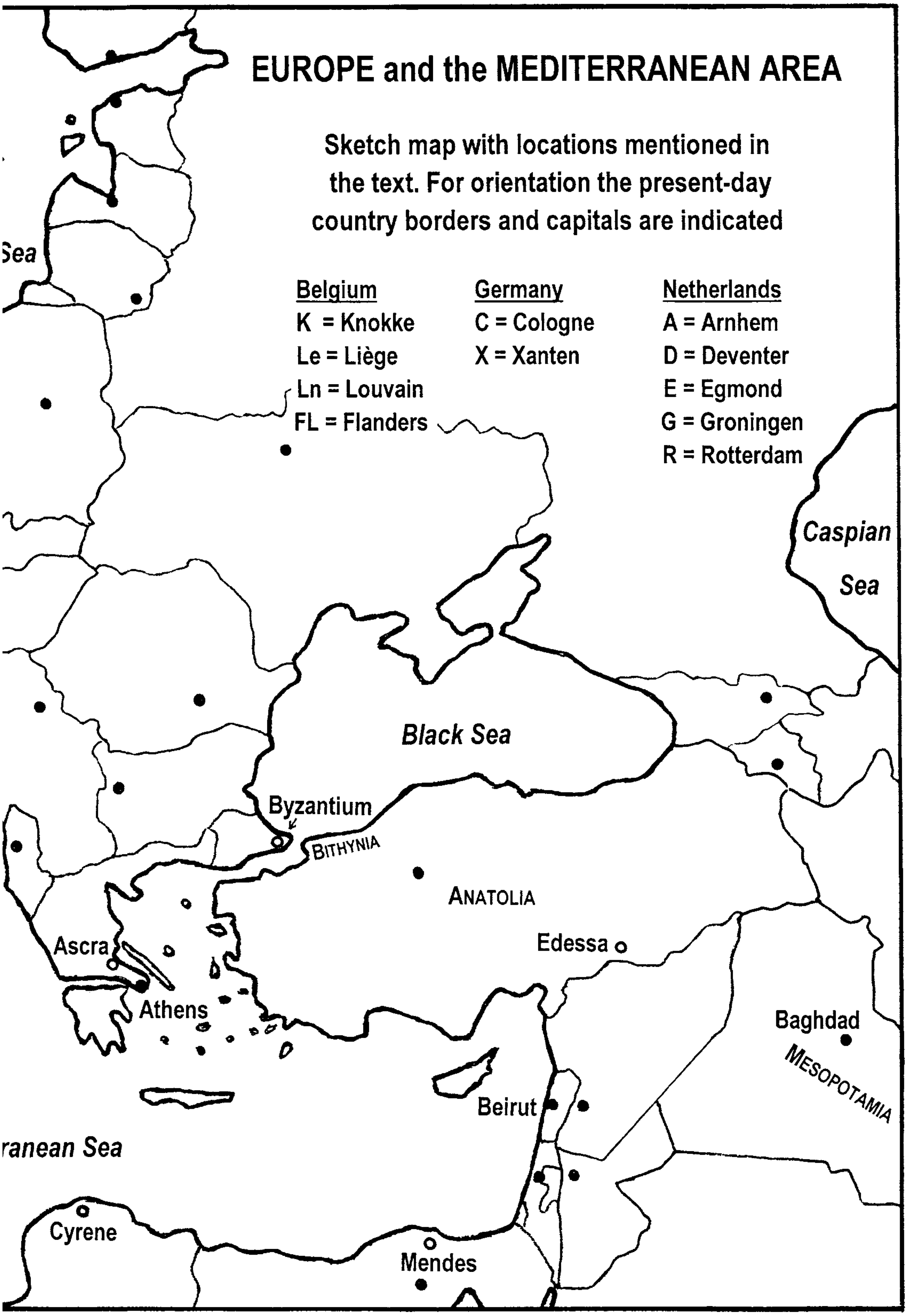
EUROPE and the MEDITERRANEAN AREA
Sketch map with locations mentioned in the text. For orientation the present-day country borders and capitals are indicated
Belgium
K = Knokke
Le = Liège
Ln = Louvain
FL = Flanders
Germany
C = Cologne
X = Xanten
Netherlands
A = Arnhem
D = Deventer
E = Egmond
G = Groningen
R = Rotterdam
Caspian Sea
Black Sea
Byzantium
BITHYNIA
ANATOLIA
Edessa
Ascra
Athens
Baghdad
MESOPOTAMIA
Beirut
ranean Sea
Cyrene
Mendes
Sea

caught my eyes my gleanings are highly personal. Nonetheless, I believe that my harvest provides a general picture of pre-modern crop protection as embedded in general crop husbandry.

1.2 The period of interest

In historical perspective modern times begin around 1600. This book focuses on the preceding period, 900 to 1600. Its beginning is marked by the production of an agricultural vademecum, the 'Geoponika', published ~950 CE in Byzantium (= Istanbul, Turkey) and originally written in Greek. A sequence of agronomic treatises from Andalusia (S Spain) was written in Arabic, and appeared between 1100 and 1450. I chose the 'Book on Agriculture' by Ibn al-ʿAwwām from c.1200. Another famous book on agriculture, written in medieval Latin, 'On common agriculture', appeared in Bologna (Italy), c.1306.

These books did not appear out of the blue. They revert to predecessors written in various languages among which Arabic, Aramaic, Greek, Latin, Punic, and Syriac. Most of these books got lost in the course of time, but enough material survived to see resemblances, differences, and developments. Illustrious Greek and Roman authors phrased ideas that stayed alive throughout the pre-modern epoch, and beyond.

Some books of our period of interest, especially the Greek 'Geoponika' and the Latin 'On common agriculture' had an enormous effect on later developments in European agriculture. The advent of printing, in Europe just before 1450, opened new perspectives, among which the relatively cheap reproduction of books, in their original language and in translation. The 'Geoponika' and 'On common agriculture' were translated in several north west European languages, amended, and illustrated. More or less new books were published using, today we would say abusing, the names of illustrious authors.

To understand the medieval authors and their impact the student of pre-modern crop protection has to look backward and forward. Babylonian and Greek sources fall back as far as 700 BCE and before. The impact of the medieval writings is visible well into the 18th and, sometimes, even in the 19th century.

1.3 Crop protection – a special issue?

'Crop protection' as a discipline was an innovation of the 19th century. 'Crop protection' as an area of public interest came into being around 1900, to be developed in the course of the 20th century.[2] Should pre-modern crop protection be seen as a special issue?

Of course, the ancients tried to protect their crops but they did not necessarily consider 'crop protection' as a subject *per se*. As curative methods were few and of questionable efficacy the emphasis was on prevention. Preventive methods were embedded in general crop husbandry. In this respect, pre-modern agriculture is on a par with today's 'organic agriculture'. Nonetheless, pre-modern authors paid much attention to specific crop protection methods and techniques. Their

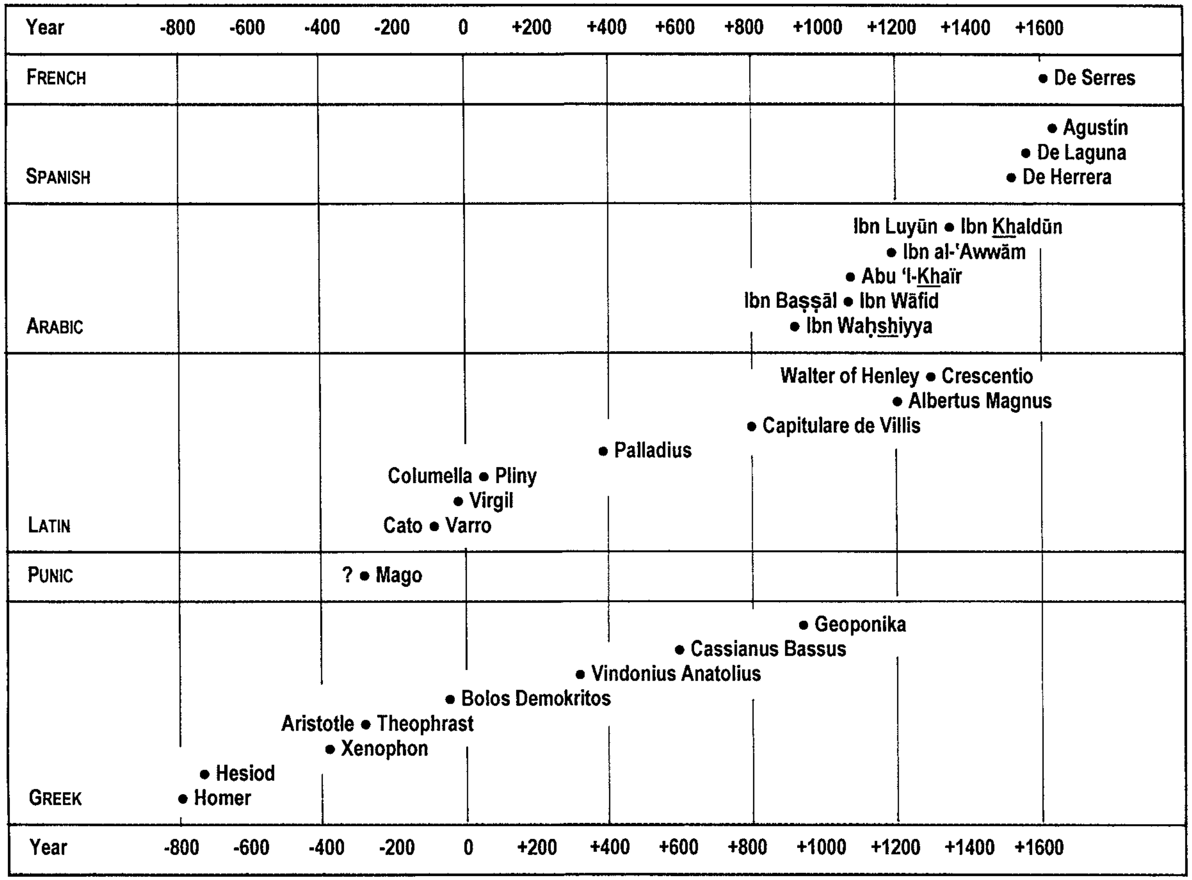

Figure 1.2 Time table arranging important sources according to time and language of origin or first publication.

recommendations are a curious mix of superstition and reason, the latter gradually gaining the upper hand.

A disclaimer is warranted here. Authors may omit or limit information on matters they think to be general knowledge, shared by everybody, and hence not worth mention. One example is the omission to recommend hand picking of weeds insects, snails, and diseased leaves. It is a nearly sub-conscious gesture of any grower looking at his plants. Hand picking is something that can be readily commissioned to slave, labourer, or child.

Singling 'crop protection' out, separating it from its agronomical context, is an anachronism, a sequel of the analytical approach by the natural sciences in the 20th century. In another framework, the history of science, here the history of the science of crop protection, it is perfectly warranted to turn the spotlight on pre-modern crop protection with its many limitations and its unexpected approaches. Pre-modern crop protection as an area of intellectual interest has a special flavour, it has its own charm.

1.4 The approach

A central position is given to the three publications mentioned above. Lines of continuity from predecessors to successors have been indicated. Where appropriate, authors are quoted translating their own words. Existing translations into English were used when available.

Items of interest were selected with a view to provide a broad overview of pre-modern crop protection, but no attempt was made to be comprehensive. The approach to illustration was eclectic. Medieval books offer a choice of crop and garden plants. However, medieval illustrations related to crop protection are rare. They were chosen from a few handbooks and reference books disregarding the colourfully illuminated manuscripts meant for display rather than for regular consultation. A few photographs of recent situations were added.

Chapter 2 introduces the three central books and their writers, and mentions several other relevant books and authors. Chapter 3 sketches pre-modern agriculture with emphasis on Mediterranean practices.

These introductory chapters are followed by the body of the subject matter, arranged in three chapters. Chapter 4 discusses the noxious agents of the period, in so far as identifiable in retrospect. Chapter 5 is on the pre-modern crop protection methods, rational and irrational, in a systematic arrangement. Chapter 6 lists botanicals and minerals applied in pre-modern crop protection. Following the illustrious examples of Crescentio and de Herrera items in Chapter 6 are arranged in alphabetical order.

Chapter 7 reflects upon pre-modern scientific crop protection lore and science. Chapter 8 ponders over two questions. First, can we compare pre-modern crop protection with its counterpart in modern organic agriculture? Second, how real were pest and disease outbreaks in pre-modern times, and how effective the control methods? Chapter 9 summarizes some tentative conclusions.

The author is an amateur, not a professional historian. He limited himself to printed documents only. He did not intend to make an exhaustive search for pre-modern crop protection. Rather, the selection of items should be considered as the somewhat haphazard result of browsing in the supermarket of historical literature. Variety was the aim. The illustrations, some old and others recent, are meant to highlight a few crop protection details, without any attempt to cover the area completely.

Chapter 2

Books and authors

Chapter 2 introduces the authors that were consulted because they paid attention to crop protection. The primary informants are three medieval agronomists, one anonymous, the other two well-known. They are flanked by some contemporary writers. To understand these medieval agronomists, the works of their predecessors were explored and subsequently the writings of their successors were considered. Different traditions in crop protection lore merged as time went by and the economic centre of gravity shifted from the Mediterranean area to NW Europe. Ideas, today considered fantastications, were left behind and modern agricultural science was foreshadowed. The chapter finally considers what audience was addressed by the pre-modern writers on agronomy and crop protection.

'There are many books on agriculture by recent scholars. They do not go beyond discussion of the planting and treatments of plants, their preservation of things that might harm them or affect their growth, and all the things connected with that. (These works) are available'.

Ibn Khaldūn (1377) – The muquddimah.[1]

2.1 A body of literature

In pre-modern times books were hand-written and hand-copied. A great number of manuscripts must have existed and, although many got lost, enough have been salvaged to get an idea of pre-modern agriculture, including crop protection. Pre-modern agricultural literature has multiple sources and follows different lines of development that split and merge. Where does one begin? I chose to ignore Egyptian and Babylonian sources. Biblical texts are mentioned in passing only. A large body of early Greek writings was lost. Roman agricultural writers have been studied in detail (e.g. White, 1970). In this book I will mention the ancients where relevant to medieval literature on crop protection.

The agricultural history of Europe and the Mediterranean area is well developed.[2] The fine book '*Le travail à la campagne au Moyen Age*', 'The farm work in the Middle Ages', by Ms Perrine Mane gives a good overview of the medieval agricultural literature, including the use of the classics in the Middle Ages.[3]

2.2 Traditions in agronomy

Two traditions can be distinguished in the older pre-modern agronomic writings: a Graeco-Roman tradition and a Near-Eastern tradition.[4] These traditions are not strictly separated. On the contrary, several cross-links weld them together.[5]

2.2.1 The Graeco-Roman tradition

The Graeco-Roman tradition has two roots. Firstly, some fifty Greek authors were mentioned by Varro. Nearly all of their writings were lost. Notable exceptions are the poem by Hesiod (c.750 BCE) and two books on botany by Theophrastus (c.300 BCE) that contain much agronomical information. Secondly, the book on agriculture called '*Rusticatio*' and attributed to Mago the Carthaginian, now lost. It was written in Punic and translated into Greek and Latin c.200 BCE. This book may have been the source of both the Near-Eastern and Graeco-Roman traditions.[6] The pedigree of books within the Greco-Roman tradition is clear. The key names are Theophrastus and the 'Roman Agronomists'; Cato, Varro, Columella, and Palladius.

2.2.2 The Near-Eastern tradition

Classic Egyptian and Babylonian agronomy is not discussed here but some of the Babylonian wisdom trickled through by way of Vindonius Anatolius (4th century CE), who wrote in Greek. His book was summarized and amended by Cassianus Bassus (c.600 CE), again in Greek. The latter book forms part of the substance of another compilation called 'Geoponika' (c.950 CE), which the Byzantine emperor Constantine VII Porphyrogenitus (905-959) wrote or ordered to be written.[7] The Geoponika set a standard and was soon translated into Armenian, Syriac, and Arabic.

The Abbasid Caliphate (beginning 750 CE) in Baghdad created an outburst of scientific exploration. A translation service was set up to translate all available Greek works into Arabic, often with Syriac as a relay language.[8] In this way much of Aristotle's work was saved for mankind. Another important step was the book 'Nabatean Agriculture' by Ibn Waḥshiyya (c.900 CE).[9] According to the author, major sources were hidden manuscripts written in Aramaic, at the time the commercial language of the Near East. These old sources may reflect Babylonian agricultural lore. Ibn Waḥshiyya knew the work of Vindonius Anatolius.

2.2.3 Cross-links between East and West

Among the oldest treatises on agriculture in the Western World, once translated into Greek and Latin but no longer existent, is the one attributed to Mago (2nd century BCE), a – possibly fictitious – Carthaginian who wrote in the Punic language [VA-1.1.10]. His views are reflected in several Greek and Roman books. We may wish to believe that Mago, in turn, knew the older Greek writers including Hesiod, with his moralistic view on agriculture, and Theophrastus, with his telling observations on agricultural matters.

One path leads from Baghdad via North Africa to the Muslim states in southern Spain. Indeed, Ibn al-ʿAwwām (c.1200) quoted Roman authors as well as Ibn Waḥshiyya. A connection between the Byzantine Greek and the Muslim Spanish worlds may have existed as the emperor Constantine VII of Byzantium had diplomatic relations with ʿAbd al-Raḥmān III, caliph of Cordoba (Spain). Later in the Middle Ages, north west European scientists went to Spain to study Muslim science and culture, and many books written in Arabic were translated into Latin. Another trail runs from Byzantium directly to Italy. In the twelfth century Burgùndio of Pisa brought several manuscripts from Byzantium to Italy, possibly including the 'Geoponika'.[10] A fourth line goes from Nicolaus of Damascus (c.0 CE), a compiler of Greek writings, and Palladius through Albertus Magnus to Pietro Crescenzi.

My distinguishing of two traditions is perhaps somewhat artificial, as indicated by the remarkable continuity of several recommendations in time and space. This continuity in agricultural lore and science, from Hesiod in the 8th century BCE until well into the 18th century CE ended when modern agricultural science came into being, founded on solid experimentation.[11] In the course of time Babylonian and North African knowledge and lore were removed from the West European body of knowledge together with all superstition and most of the magic. Western Europe, however, created its own metaphysical approach to crop protection.

2.2.4 A medieval tradition

Estate management was part and parcel of the works by Varro and Columella, but some early medieval writings from north western Europe took a different line, leaning toward administration and accounting. The '*Capitulare de villis vel curtis imperii*' ('Chapters on the manors or courts of the empire') was written in 812 at the order of the Emperor Charlemagne.[12] In England several manuals on estate management and accounting appeared in the 13th century, the most prominent being that of 'Walter of Henley'. As these manuals offer little information about practical farm work, we turn to SW Europe.

The treatises on agriculture by the Moorish agronomists of Andalusia, southern Spain, written in Arabic in the 11th to 14th century CE are very different.[13] They largely followed Columella.[14] The most prolific author among them was Ibn al-ʿAwwām, c.1200. He quoted extensively from 'Nabatean Agriculture', but also from Roman authors and from his Andalusian predecessors. Ibn al-ʿAwwām welded the Near-Eastern and the Graeco-Roman traditions into one. Several other Andalusian agronomists are known, among them Abū 'l-Khayr, Ibn Wāfid, and the late-comer Ibn Luyūn.

In north western Europe plants were studied as sources of medicines. Albertus Magnus (c.1200–1280) wrote a book on plants and agriculture in Latin, following Palladius. In present-day Italy, Piero Crescenzi (1233-1320) published a 'Treatise on agriculture', also in Latin. He borrowed from Palladius and Albertus Magnus, and indirectly from the Geoponika. In the later Middle Ages both the 'Geoponika' and Crescenzi's book were translated into various European languages, often with amendments, additions and illustrations.

In 1513 the chaplain Gabriel Alonso de Herrera published a comprehensive treatise on agriculture. The book integrates the classics, the experience of the Moors, and whatever the author had read, seen, heard, or experimented. As a youth the author spent some ten years in Granada. The book was used during many centuries.

Andrés de Laguna, personal physician of Pope Julius III, translated Dioscorides into Spanish and drew many illustrations (1556). The book, a pharmacopeia, contains numerous additional comments, some relevant to crop protection.[15]

This review of pre-modern books on agriculture and crop protection has to stop around 1600, when the 'modern period' of history sets in. The Frenchman Olivier de Serres (1600) marks the transition. The last book to be mentioned is the Spanish manual known as 'The Book of the Prior' (1617), in which the 'Geoponika' is still recognisable notwithstanding many deletions and additions. For two centuries at least the 'Book of the Prior' was common reading in Spain.

2.3 Three medieval authors

2.3.1 Selected authors

Three medieval authors are singled out here. The first wrote in Greek, on the NE side of the Mediterranean. The second, writing in Arabic, worked at the NW side of the Mediterranean area. The third, using Latin, lived in Italy, the north central area along the Mediterranean. Their three books were hand-written, copied many times, translated into various languages, and finally printed. These books, which set the standard for centuries, contain much information relevant to crop protection.

2.3.2 Anonymus – c.950 CE – 'Geoponika'

Byzantium or Constantinople, present-day Istanbul in Turkey, was the imperial capital and the centre from which religion, culture, and science radiated during a full millennium, from 330 CE until its fall in 1453.[16] Greek became the language of the Byzantine Empire. The Emperor Constantine VII Porphyrogenitus (ruled 913-959), had a scientific interest, wrote some books himself, and composed or ordered the composition of a few compendia, among which one on agriculture, the 'Geoponika' (G: τὰ γεωπονικά = 'On Agriculture'). The 'Geoponika' bridges the period between the classics on agriculture, in Greek and Latin, and the medieval authors, writing in Arabic and Latin. Or, as Meana put it graphically, a ford rather than a bridge.[17]

The Geoponika is a compilation of fragments taken from numerous authors mentioned by name. Many of the earlier Greek and the later North African texts, now lost, are known only because of quotations in the 'Geoponika'. The book is based on a work by Cassianus Bassus who, in turn, used the 4th century *Eclogae* by Vindonius Anatolius (see below). The text may have been re-edited by an unknown editor but some personal notes by Cassianus Bassus were maintained. History's remnants are a few hand-written 'codices' and early translations. These codices are not completely uniform. In the typical 19th century linguistic tradition Heinrich Beckh (1895) reconstructed a 'basic' or 'original' text named '*The eclogae on agriculture by Cassianus Bassus Scholasticus*'.

In Western Europe the Geoponika was first printed in Latin in Venice, 1538, and in Greek in Basle, 1539. A French version appeared in 1543, translated by Antoine Pierre from Narbonne. Several newer translations exist. Here I used the Spanish translation by Meana *et al.* (1998) with its excellent commentary. Recently, Dalby (2011) published an elegant translation into English. Though the two translations do not differ materially, some differences exist in details such as species identification.[18]

The Geoponika is somewhere between an encyclopaedia and a do-it-yourself manual. It contains twenty 'books', we would now say chapters, each with a table of contents. Each book is divided into a large number of short 'chapters' (paragraphs rather, 621 in total) containing up to 90 numbered statements. The chapters are often ascribed to an authority, a classical Greek or Roman author, sometimes a North African writer. The Spanish translators carefully compared statements in the Geoponika with their originals in classical Roman writings. Many quotations are correct, at times even *verbatim*, and several are incorrect. The order of the chapters and of the statements therein are, at times, somewhat random, going from agriculture to medicine, from sound crop protection to magic and fantasy.

The information on crop husbandry is lacunary. Quantitative data are rare, as are data on implements and tools. Crop protection items, scattered throughout the book, range from precise recommendations, understandable today, to utterly useless ideas. Book 13 is devoted to crop protection and medicine. Crop protection formulae are not yet separated from medical recipes. Some of these transcend the realm of reality and reach into the spheres of homeopathy and magic, belonging to the *paradoxographica*, the fantastic literature, often of African origin.[19]

The Geoponika set a standard. Its impact was tremendous, as evidenced by the existence of over 50 manuscripts dating from the 11th century onward. Translations exist in Syriac (6th century), and in Arabic, Armenian, Pahlevi, and Syriac again (9th and 10th century). When the Abassids reigned in Baghdad (749-1258 CE) many of the Greek classics were translated into Arabic. Burgùndio da Pisa (1110-1193), ambassador of Pisa (Italy) in Constantinople in 1136/1157, brought home a number of manuscripts, among which apparently one of the Geoponica. He translated the part on viticulture (books 6, 7 and 8) as *Liber de vindemiis* (= Book on wine production), used by Piero Crescenzi.[20]

2.3.3 Ibn al-ʿAwwām – c.1200 – 'Book on Agriculture'

Muslim invaders from North Africa crossed the Street of Gibraltar in 711 and rapidly conquered Spain and parts of France. In the southern part of the Iberian Peninsula, called *al-Andalus,* they established the Caliphate of Córdoba, that later split into a number of fiefdoms. A long period of prosperity created an ambiance favouring culture and science, including agronomy. The medical sciences flourished with chirurgical, pharmaceutical and dietary treatments. Botany was studied, not least because the Byzantine emperor Constantine VII sent a copy of Dioscorides' pharmacopeia to the Caliph of Cordoba, ʿAbd al-Raḥmān III (ruled 929-961) and – later – he sent a Byzantine monk, named Nicholas, to translate the book into Arabic.

Several agronomists are known, the most prolific being Ibn al-ʿAwwām. His full name is Abū Zakariyyā Yaḥyā ibn Muḥammad ibn Aḥmad Ibn al-ʿAwwām al-Ishbili. He lived in Seville (southern Spain) toward the end of the 12th century, where he wrote the comprehensive *Kitāb al-filāḥa* or 'Book on Agriculture' (Fig. 2.1). This treatise covers all aspects of agriculture. Special attention was given to soils, tillage, and the various kinds of manure. It was the most extensive medieval book on agriculture. Not until the 19th century did the book become known in North West Europe when it was translated into Spanish (1801) and French (1864).[21]

Ibn al-ʿAwwām knew about the Roman classics and the Geoponika. He leaned heavily but not uncritically upon Ibn Waḥshiyya and he quoted extensively, and almost literally, from his Hispano-Muslim predecessors, writing '*I report the opinions of these authors textually, as they have consigned them in their works, without ever seeking to modify their expression*' [IA-1.9]. Yūniyūs is cited frequently as a 'revered' name, this is Junius Columella.[22] Ibn al-ʿAwwām was intentionally repetitive in order to familiarise the readers with the enduring elements in the theories [IA-1.390]. Ibn al-ʿAwwām related the experience of others and of himself. He performed experiments on the mountain ash-Sharaf near Seville, and possibly in the palace gardens of Seville's ruler. Ibn al-ʿAwwām drastically cut down on the number of astrological and superstitious prescriptions in 'Nabatean Agriculture'. He carefully quoted his predecessors by name, but Christian authors remained unnamed.[23]

2.3.4 Pietro Crescenzi – c.1306 – 'On common agriculture'

Pietro de' Crescenzi (1233-1321) was born and died in Bologna, Italy.[24] At the university he studied philosophy, natural sciences, medicine, and law. He worked as a travelling judge, sitting in court in various cities. Italian cities liked judges from elsewhere to avoid favouritism. During his travels he learned much about North Italian agriculture. He was a landowner himself, but this fact in itself does not explain his deep interest in agriculture, which was not so common at the time. His major publication is 'On common agriculture', in Latin *Ruralium Commodorum*

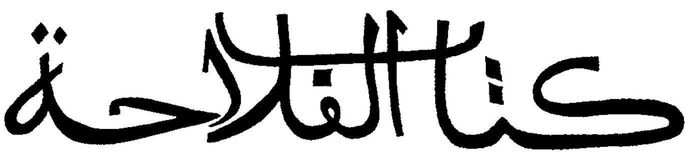

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Figure 2.1 Calligram of the 1876 translation into French of Ibn al-`Awwām's `Kitāb alfilāḥa' = 'Book on Agriculture'. Scale 1:1.

libri XII, c.1306.[25] He called himself *septuagenarius*, a seventy-year-old. Advanced age, combined with the benefits of agriculture, was his explicit motivation for writing the book.

Crescenzio dedicated his book to Charles II, King of Sicily and Jerusalem.[26] He also appealed to Amerigho and other scientists of Bologna University whom he had shown the manuscript.[27] In many ways his was a modern book, though still written in Latin. He quoted the classics where he considered them applicable, used recent medieval literature (primarily Albertus Magnus), and included his own insights obtained by observing and listening to a variety of experts, during his travels or on his own estate.[28] Modern traits were an alphabetical arrangement in three out of twelve chapters, a censoring of classical 'pagan' passages, a division in books and chapters, a summary preceding each book, a clear résumé of the ten foregoing books in book eleven, and a table of contents.[29] Book twelve summarized agricultural procedures according to their month of execution.[30]

'On common agriculture' was first printed in Latin as *Ruralium Commodorum libri XII*, in Augsburg and in Strasbourg, both in 1471.[31] The first edition in Italian was printed in 1478. The book is '*a well-organized manual of procedure*'.[32] It is divided into twelve chapters, each with a specific subject. The chapter on gardens, aimed at kings and noblemen but also useful to middle-class people, was largely copied from Albertus Magnus.[33] Many medieval, hand-written copies of Crescentio's book exist (Fig. 2.2). The work was translated into several West European languages, amended and illustrated.[34]

An early translation into French was '*Les profits champâtres de Pierre de Crescens*', 1373, at the order of King Charles V. The book made a triumphal procession through Europe, was translated into several languages, and reprinted repeatedly. It became a European standard, reworked, amended, variously illustrated, and reprinted many times under different titles.[35] The rich could afford beautifully illuminated copies, from which Mane (2006) published many illustrations.

The name Crescenzi had such fame that, for advertising purposes, it was added to books that had little to do with the original. The loosely translated title of such a 'Pseudo-Crescentius' from 1602 runs as: *New field and plough land cultivation, therein regularly included how one from correct understanding of nature, also long-term experience, these two here described in fifteen books, every estate, foremost the fields and crop lands according to regional character and opportunity, at the right time and as good as possible, and cultivate with all types of field work, next various pleasure and fruit gardens …*[36]

Pietro Crescenzi was at the root of a type of literature called *Hausväterliteratur* in German, literally 'reading for the father of the family'.[37] They were easy-to-read, practical manuals for the common farmer dealing with subjects such as crop husbandry, gardening, cattle breeding, horses, hunting, good manners, health, and nutrition. Such books, with appropriate modifications, were held in esteem until far into the nineteenth century.[38]

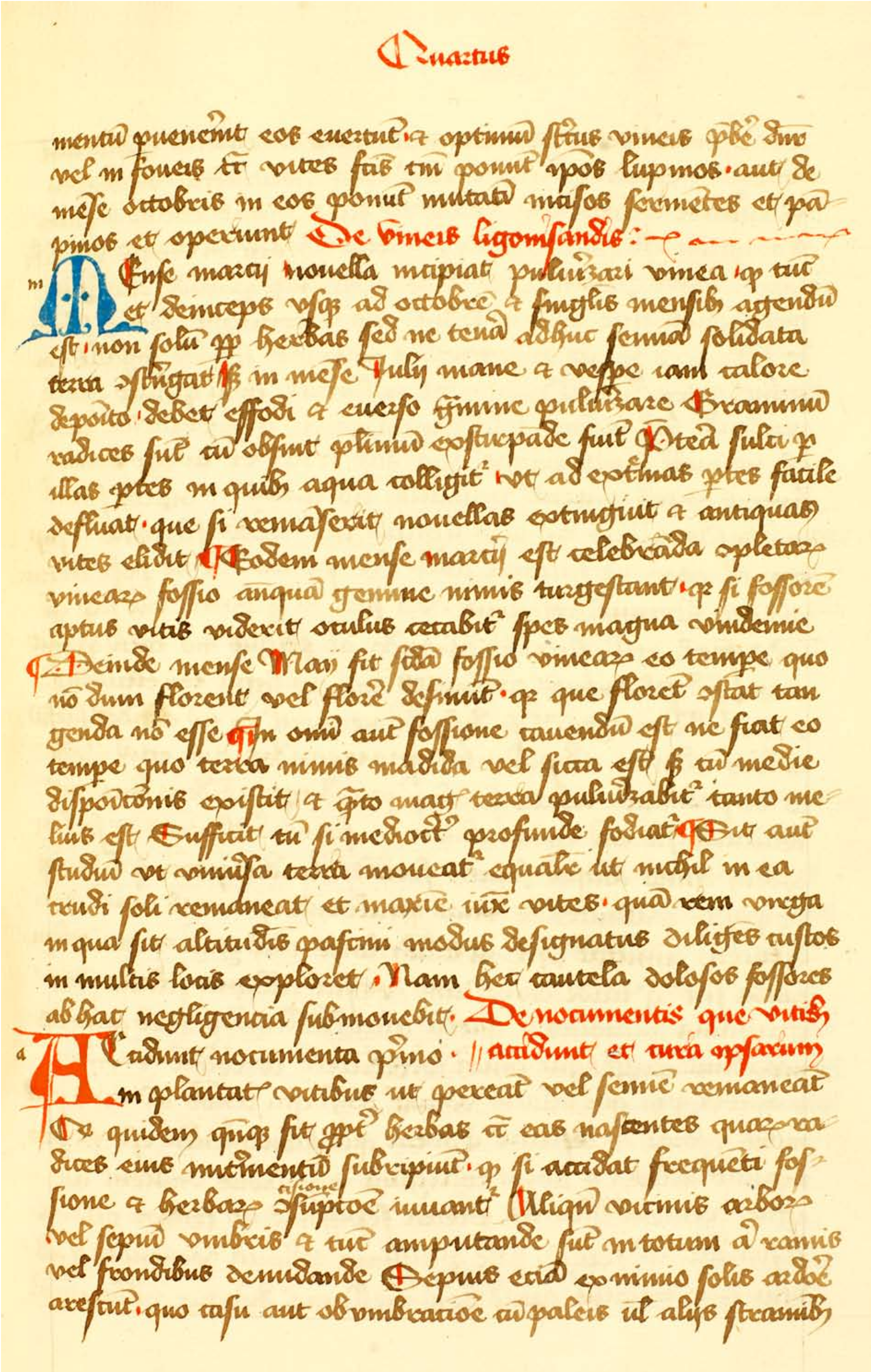

Figure 2.2 Sample page from a Latin Crescentio manuscript in the Atheneum Library, Deventer (NL), probably from S Germany, around 1440 (Lieftinck (1964) p12 #28. Scale 1:1.25.

2.4 Predecessors

2.4.1 Selected authors

Several authors were selected because they gave interesting information on crop protection. This selection is not exhaustive. Other authors are mentioned in passing only. One of them is Xenophon (c.430-354 BCE) who wrote the dialogue '*Oeconomicus*' on estate management.[39] The philosopher Aristotle (384-322 BCE), who had great interest in zoology, made some observations. Several Romans have written on agriculture, including the poet Virgil and the encyclopedist Pliny the Elder.[40]

2.4.2 Hesiod – c.750 BCE – 'Days and works'

Two oral poets shaped our knowledge of the ancient Greek language, Homer and Hesiod. Whether they were real or imaginary persons, their legacy is very real. Before writing was commonplace people had mnemonic techniques to memorize lengthy poems, undoubtedly supported by the rhythm of the verses, the *hexameter*. Two long stories are attributed to Homer, the Iliad and the Odyssey, describing the Trojan war and the subsequent peregrination of the hero Odysseus, beautiful tales full of bloodshed and feasts, cunning, and fun (Bérard, 1924).

Hesiod is the more relevant bard for agriculture. Hesiodos (Ἡσίοδος = 'he who emits the voice'), Hesiod in English, was an oral poet living in Greece around 750 BCE. His poem 'Works and days' (G: Ἔργα καὶ ἡμέραι) describes the days and activities of the farmer in about 800 verses (lines). Hesiod's father came from Anatolia, in present-day Turkey. Hesiod lived on a farm in the village of Ascra, near Thespiae in Boeotia. He must have known the fatigue and toil of the farm. His didactic and somewhat moralistic work presents a vivid description of farm life in antiquity, seen from the viewpoint of a small independent farmer.[41]

The farm calendar is marked by natural phenomena such as the sounds of the cranes migrating south in the autumn, a characteristic and impressive noise [HE-448]. Another telling signal is given by the 'house-bearers' [HE-571], the snails, appearing massively in spring, often causing serious damage to vegetables and cereals. Indeed, I saw such an outburst of snails in Sicily, in spring 2008, up to hundreds per square meter, climbing the grass stems.[42]

We read about all kinds of farm work, about the economies made in feeding cattle during the winter, and about the restful period and the festivities around harvest time. The maxim: *'Work is not a disgrace at all, but not working is a disgrace.'* [HE-311]. Don't envy riches obtained by hard work. *'Shame goes along with poverty, and self-confidence goes along with wealth'* [HE-319]. *'Property is not to be snatched: god-given is better by far.'* [HE-320]. And so on.

2.4.3 Theophrastus – c.300 BCE – 'Enquiry into plants' and 'On the causes of plants'

Theophrastus lived in Greece from c.370 to c.285 BCE. He came from Eresus on the island of Lesbos in the Aegean Sea. He was a pupil and friend of Aristotle. Theophrastos (G: Θεόφραστος, godly phrased) is a nickname coined by Aristotle because of his 'divine style of expression'. His given name was Tyrtamus (Τύρταμος). Theophrastus was the successor of Aristotle as the leader of the Peripatetic School in Athens, Greece. He was highly successful and greatly honoured.

Of his many writings only a few survived (nearly) entire. Aristotle was much interested in zoology. Theophrastus studied some areas left aside by Aristotle, including botany. His approach was more empirical than that of Aristotle. Two works are relevant here, 'Enquiry into plants' (G: Περὶ φυτῶν ἱστορία, L: *Historiae plantarum*) (Hort, 1961) and 'On the causes of plants' or 'On plants: the explanations' (G: Περὶ αἴτιων φυτικῶν, L: *De causis plantarum*) (Einarson & Link, 1976). The 'Enquiry' is seen as the first systematic treatise on botany whereas the 'Causes' concentrate more on the economic value of plants.

These books, possibly lecture notes, still make good reading. They show an amazing insight into plant life and offer a wealth of facts, interlarded with magic and absurdities. The content is based on his own observations made in his botanical garden and during his travels throughout Greece (with Aristotle, 347-344 BCE), supplemented by information, for example on wild trees, provided by woodcutters from Mount Ida.[43] Theophrastus may have used travelling students. He received reports and plant material from Asia sent to Athens by trained observers in the retinue of Alexander the Great. Predecessors were cited but quoting the living was not conventional. Theophrastus's botany dominated the sciences throughout the Middle Ages. He was quoted by several Roman authors, and by Ibn al-ʿAwwām, with or without mention of his name.

The oldest available manuscript of 'Enquiry' and 'Causes' is the Vatican's '*Codex Urbinas*', 11th century. The 'Enquiry' was first published in Latin translation in Treviso, Italy, 1483. A publication in Greek followed 1495/8, printed in Venice.

2.4.4 The Roman agronomists – c.100 BCE - c.400 CE – 'On agriculture'

A group of four authors is designated as *scriptores rei rusticae*, 'writers on agriculture': Cato, Varro, Columella, and Palladius.

Cato. Marcus Porcius Cato, Cato the Elder (234-149 BCE), wrote *De agricultura*, 'On agriculture'. About one third deals with agriculture proper. This part gives practical recommendations on estate management, without scientific pretence. Another part deals with religious obligations. Cato became well known in the 15th century (Hooper & Boyd Ash, 1967).

Varro. Marcus Terentius Varro (116-27 BCE) wrote *De res rusticae*, 'On agriculture', in 37 BCE, when he was eighty years old. The book deals with estate management and practical agricultural matters. Varro mentioned some 50 Greek authors; nearly all of their works are lost. He was often quoted in the Middle Ages (Hooper & Boyd Ash, 1967).

Columella. Lucius Iunius Moderatus Columella, born in southern Spain, produced *De re rustica*, 'On agriculture', between 62 and 70 CE. He described the ideal estate and its buildings, and went into great technical detail on agriculture and animal husbandry. He was known in the 9th century, then forgotten, and rediscovered in the 15th century (Boyd Ash, 1941), at least in Christian Europe. He was an important source for his compatriot Ibn al-ʿAwwām.

Palladius (4th century CE), '*who knows his Columella by heart*'.[44] Little is known about him except that Palladius was the nickname of Rutilius Taurus Aemilianus. The name Palladius has several connotations, among which 'olive branch'. He possessed estates near Rome and on Sardinia. He wrote his '*Opus agriculturae*' ('Work on agriculture'), a hands-on manual, probably toward the end of the 4th century CE. Book 1 is a general introduction with chapter 35 on crop protection, in which Eastern elements (from Vindonius Anatolius?) can be recognized. In fact, several comments are near-identical to [an early version of] the Geoponika.[45] Twelve books describe the agricultural work to be done in each of twelve months. The book, popular in the Middle Ages, was used by Albertus Magnus and Piero Crescentio.[46]

2.4.5 Vindonius Anatolius and Cassius Bassus – 4th to 6th century CE

Vindonius Anatolius from Beirut, 4th century CE, wrote a 'Collection of agricultural practices' in Greek. The writer may have been the praetor of the Roman province Illyricum. This work, used extensively by Palladius (4th century CE), goes back to earlier Greek authors. His book was translated into Syriac (6th or 7th century CE), and the Syriac version was translated into Arabic and Armenian in the 9th and 10th centuries). Only a minor fragment has been conserved.

Cassianus Bassus, the lawyer (*Scholasticus*), lived around 600 CE. He compiled a treatise called 'Selections on farming' (L: *Eclogae*, G: Ἔκλογαί περὶ γεωργίας, *Eklogai peri georgias*). He used two older works, the collection of Vindonius Anatolius from Beirut and the *Georgicas* by Didimos or Didymos of Alexandria, c.500 CE.[47] Cassianus Bassus is presumed to have owned a property with vineyards and trees near Maratonimos, in the neighbourhood of Antiochia, in northern Syria. He must have been knowledgeable on viticulture and arboriculture, and he added some of his own views.[48] The book is lost, but much of its content survives in the 10th century 'Geoponika' (§ 2.3.2). Translations exist in Persian (7th century) and Arabic (8th and 9th century).

2.4.6 Ibn Waḥshiyya – c.900 CE – 'Nabatean agriculture'

Ibn Waḥshiyya, born in present-day Iraq, supposedly lived around 900 CE. Though not an Arab, he wrote in Arabic on a variety of subjects, including agriculture. His book *Kitāb al-filāḥa al-nabaṭiyya*, 'Book on Nabatean agriculture', written in 903/4 CE and dictated to his scribe in 930/1, is a voluminous treatise covering both agricultural practices and philosophical subjects.[49] At the time, 'Nabatean' was the Arabic word for the rural population of Iraq and Syria that spoke Syriac and Aramaic.[50]

The author identified himself with the Mesopotamian rural population. Apparently he knew their language and could read their hidden scriptures. Superstition, magic and sorcery related to agriculture, mainly of Chaldean and Babylonian origin, is amply discussed. The author knew about Egyptian culture and lore, and some of that may have been incorporated in his book on agriculture.

The author must have known Vindonius Anatolius's work, thus recycling old information. The book, with its Islamic style of expression, is not a literal translation of earlier manuscripts. The author himself and the copyists may have added their own comments. Ibn al-ʿAwwām, citing Ibn Waḥshiyya, quotes several earlier writers such as Koutsami, Sagrit, and Jambouschad, providing quotes within quotes.

Box 2.1 – Ibn Waḥshiyya – on grafting a tree on another

'If you want to graft a tree on another so that the grafted one would receive something which we have mentioned (above) you must take a branch from one tree and graft it onto the body of another. In the action there is a subtle special property which belongs to the art of the people of talismans.

They say that if one wants to do this, he should take a beautiful (servant) girl who must be of outstanding beauty. He takes her by the hand and lets her stand at the root of the tree where he wants to graft the branch. Then he prepares the branch like people do when they want to graft it and then he comes to the tree onto which he wants to graft it. The girl stands under the tree. He cuts a hole in the tree for the branch and takes off the girl's clothes and his own clothes. Then he puts the branch in its place while having intercourse with the girl, in a standing position. While having intercourse he grafts the branch to the tree, trying to do it so that he ejaculates at the same time as he grafts the branch. He should avoid the girl after having grafted the branch. If she becomes pregnant, that branch will possess all the tree's odour and taste. If she does not become pregnant, the branch will possess only some features of the tree.' The farmer may use his wife if just married. And so on. (Translation Hämeen-Anttila, 2006 p 281/2). ■

'Nabatean agriculture' is a complex book, partly philosophical and partly agrotechnical. Its philosophical content is largely Aristotelian. '*All living beings have souls. The plants have souls or faculties by which they grow*'. For centuries Ibn Waḥshiyya's was an influential book. Many are the magical remedies, sometimes even scabrous (Box 2.1), and numerous are the sensible recommendations.

The Encyclopedia of Islam seriously questions the existence of a person called Ibn Waḥshiyya. It states that the origin of the book is faked; it originated probably in the 5th or 6th century CE, maybe in Mesopotamia.[51] Alves Carrara (2006) concluded that both the 'Nabatean agriculture' and the 'Geoponika' are descendants of Mago's book, a major difference being that in the 'Geoponika' the superstitions had been filtered out. Notwithstanding the archaistic elements in the text, the influence of 'Nabatean agriculture' in the Muslim world was great.

2.5 Contemporaries

2.5.1 Selected authors

This book aims at an overview of pre-modern crop protection without any attempt at completeness. As the three selected authors of § 2.3 are fairly comprehensive, there is little need to probe deeper. Nonetheless, several contemporary medieval authors in Western Europe, from Spain to Britain, deserve a mention.

2.5.2 Three Andalusian authors

Ibn Wāfid (c.1007-1075) was a well-born gentleman, a medical man born and living in Toledo. He wrote in Arabic on medicine, mathematics, and agriculture. He had at least some personal experience in agriculture as the director of the Royal Garden of Toledo's Prince, al-Ma'mūn. This garden was a pleasure garden as well as a trial field. Ibn Wāfid's 'Treatise on Agriculture' is lost but a fragmentary copy, made c.1400, of an early translation in Castilian was found in Toledo. The text often quotes Anatolius, then recently available in Arabic translation (10th century), but not the 'Nabatean Agriculture'. Ibn Wāfid, ignored by Ibn al-ʿAwwām, was quoted frequently and often literally by de Herrera, who apparently had access to a Spanish text, probably the Toledo copy. It was published by Millás Vallicosa (1943). The book is concise, without medical and nutritional excursions. It offers little new information on crop protection.

Ibn Baṣṣāl al Ṭulayṭulī (= the Toledan) lived in the 11th century. He went on hadj to Mecca, also visiting Egypt and Sicily. His interest was largely botanical. He was also in the service of al-Ma'mūn. His book '*Kitāb al-Ḳasd wa 'l-bayān*' (= 'Book of concision and clarity'), an abridged version of a more extensive work, deals primarily with horticulture. He imported seeds from the Near East and he engaged in variety testing and acclimatisation. When Alfonso VI of Castille conquered Toledo in 1085 he moved to Seville. There he designed a botanical garden for ruler al-Muʿtamid. The book was translated into Spanish by Millás Vallicrosa & 'Azīmān (1955).

Abū 'l-Khayr al-Ishbīlī (= the Sevillan), wrote his book '*Kitāb al-filāḥa*' (Treatise on agriculture) in ~1073. His nickname was 'al-shadjdjār', 'the arboriculturalist' or 'the tree planter'. Little is known about his life. The book discusses at least 86 crops with many details on tree crops. At least four copies of his book have survived. Carabaza (1991) translated the book into Spanish.

2.5.3 Walter of Henley – c.1286 – 'Husbandry'

Walter of Henley lived in England from c.1240 to c.1300. He was probably an English knight, a *dominus miles*, in the following of the Clare family which owned several manors and estates in Gloucestershire. He may have been a bailiff on some large estate, probably in the West Midlands. Walter was fluent in French, spoke English, and understood Latin. He wrote '*Hosebondrye*' ('Husbandry') in French, c.1286. The book was translated into Latin and English. I used the English translation by Oschinsky (1971).

The text was fashioned in the format and style of a sermon. Its artistic form was an 'advice given by a father in old age to his son'. Walter may have attended the then current courses in business administration, with instructions in the art of letter writing, the formulation of writs, deeds, and accounts. As a 'visiting lecturer' he may have lectured on estate management on such a course, probably at Oxford. The book would then be an extended course syllabus. The treatise discusses the management of the manorial farm rather than farming itself. The author entered the Dominican Order in the latter part of his life.

2.5.4 Albertus Magnus – c.1200-1280 – 'On plants'

Albertus Magnus was born around 1200 in Lauingen (Bavaria) on the Danube as the son of the Count of Bollstädt. Right from childhood he was a keen observer of all living things. He studied in Padua (Italy) where he learned about Aristotle's philosophy. He entered the Dominican Order. He received his degree of Doctor in Theology in Paris. In Cologne he was the teacher of Thomas Aquinas, the famous theologian. Albertus travelled widely, performed several important commissions for the Church, and was Provincial of the Dominican Order in Germany. He died in Cologne (Germany), in 1280.

Albertus Magnus, a prolific writer, was the most prominent philosopher and scientist of the early Middle Ages. His contemporaries called him reverently *doctor universalis*. Among his numerous writings was a book on animals and one on botany.[52] The latter, '*De vegetabilibus*' ('On plants'), was based on two authors, Nicolaus of Damascus, who compiled older Greek works, and Palladius, the last of the Roman authors on agriculture.[53] He amplified these data with his own extensive observations, experiments, and reflections.[54] Book VII, on agriculture, hardly mentions crop protection issues.

2.5.5 Ibn Luyūn – 1348 – 'Book on agriculture'

Ibn Luyūn was born in Almería, in present-day Spain, 1282. His own name was Saʿd and his complete name was Abū ʿUthmān Saʿd b. Abū Djaʿfar Aḥmad Ibn Luyūn al-Tudjībī. He worked as a notary public, supposedly travelled in Al-maghrib (= north west Africa) and the Orient, and obtained a licence as a Qur'anic teacher.[55] With his wide knowledge he was renowned in Almería. Celibate, he was known as an ascetic, mystic, philosopher, lawyer, mathematician, mediocre poet, and excellent calligrapher. A polymath, he wrote at least 25 books. His 'Book on agriculture', *Kiṭāb … al-filāha*, dates from 1348. Ibn Luyūn died from plague in Almería, 1349.

The full title of the book is 'Book on the principle of the beauty and the end of the science that treats the fundamentals of the art of agriculture'. It is the last known medieval study on agriculture written in Arabic. The book was written as a poem in a metre intended for easy memorisation. The book is highly concise, treating agriculture broadly, in stark contrast to the long-winded treatise by Ibn al-ʿAwwām. A few drawings of equipment were added. Ibn Luyūn often quoted Ibn Baṣṣāl, also much cited by Ibn al-ʿAwwām, but he did not mention the latter.

The book is a brief manual for the informed grower in Andalusia (S Spain). The user is supposed to be knowledgeable about Andalusian agriculture, its crops, relief, soils, and sources of water. Agricultural crops are discussed but the emphasis is on horticulture. Much attention is paid to irrigation. Animals are of interest only as producers of manure. Estate building is treated briefly. Very little is said about workers.

A characteristic feature is the author's soberness, without magic or figments of the imagination. Most of the text is prescriptive, appealing to the readers' common sense. In a few cases Ibn Luyūn deemed it necessary to state that a recommendation is of 'confirmed' or 'proven' effect.[56] The author, known to be an excellent compiler, was able to condense information on well over 200 plant species into only 1365 lines. The book abounds of simple practical recommendations and refrains from theoretical considerations. I used the Spanish translation by Joaquina Eguaras Ibáñez (1988).

2.6 Successors

2.6.1 Selected authors

Among the pre-modern successors of our major medieval authors (§ 2.3) three go deep into the technicalities of agriculture and crop protection. Two of them, the Spaniard Gabriel de Herrera and the Frenchman Olivier de Serres, knew the classics but relied largely on their personal experience in the practice of agriculture. This is a decidedly modern element in their work. Both contributed to the creation of a national language and both were much read. The third, the Catalonian Agustín, used more second hand knowledge but, due to the didactical presentation of the content matter, his book was a forerunner of modern textbooks.

2.6.2 Gabriel de Herrera – 1513 – 'Treatise on agriculture'

The chaplain Gabriel Allonso de Herrera (1474-1540) was born in Talavera de la Reina (Spain).[57] As a child he learned about agriculture from his farming father and, apparently, became fascinated. As a youth he studied in Granada, just conquered by the Spanish from the Moors. He spent much time in the *vega*[58] of Granada, learning how the Moors, at the time far more advanced in agriculture and horticulture than the Spanish, cultivated their land and tended their crops. Besides Spanish he knew Latin and he may have understood at least some Arabic. He studied the classics on agriculture, including Ibn al-ʿAwwām and Pietro Crescenzi. He quoted repeatedly and often literally from Ibn Wāfid.[59]

After ten years in Granada he wandered through France and Italy, maybe to prepare his extensive compilation on agriculture '*Obra de agricultura, copilado de diversos autores … de mando del muy ilustre y reverendísimo Señor Cardenal de España Arzobispo de Toledo*', 'Treatise on agriculture, compiled from various authors … on the authority of the very illustrious and most venerable Cardinal of Spain Archbishop of Toledo', published in 1513 (Martinez Carreras, 1970). The book, modestly presented as a compilation, is an original and surprisingly 'modern' treatise combining classic and Arabic knowledge with his wide personal experience. De Herrera's Maecenas, Cardinal Francisco Ximénez de Cisneros, was so pleased with the book that he had it printed at his own expense, to be distributed free of charge among the farmers of his domains.

The *Obra* appeared during the formative years of the Spanish nation and language. The book treats agriculture extensively, including veterinary science, meteorology and, according to the custom of the times, food for health. The book covers all the crops of the period and reaches into areas now called pedology, soil fertility, and crop physiology. It was written in a clear and simple language so that it could be consulted by unsophisticated farmers as well as by the landowners and their managers. As a reminiscence he describes rotation '*as the Moors do it in the* vega *of Granada*' [DH-4.5.213]. The book was much acclaimed, variously illustrated, and translated into several languages. The book was used well into the 20th century (Diaz-Plaja, 1951). I used the edition by Carreras (1970).

2.6.3 Olivier de Serres – 1600 – 'Theatre of agriculture'

Olivier de Serres (1559-1619) was born in a well-to-do merchant family in the Languedoc, southern France. Well-educated, he travelled abroad and widened his outlook. He was a protestant, studied law, participated in the civil war ravaging France at the time, then bought a mill and grounds at Pradel in 1575.[60] In 1578 he moved to his estate to dedicate himself to agriculture as a gentleman-farmer. Twenty-two years later, in 1600, he published his book '*Théâtre d'agriculture et mesnage des champs*' ('Theatre of agriculture and management of the fields').[61] De Serres had read the Roman agriculturalists and used some of their information, but rejected and even ridiculed their superstitions. He did not mention Crescentio, de Herrera, or any of his French predecessors.

Open-minded, he relied primarily on his own experience, which he laid down in beautiful French, clear and precise, easy to read. The book was an immediate success, reprinted 19 times within a span of 75 years. In 1675 the '*Édit de Nantes*' evicted the French protestants and, indirectly, the books written by them. He was forgotten. During the Napoleonic revival of agriculture in France the book was transcribed in then-modern French and published once more (Gisors, 1802).

2.6.4 Miguel Agustín – 1617 – the 'Book of the Prior'

Brother Miguel Agustín (*1560), Prior of the Temple de la Fidelissima Villa de Perpiñan, del Orden y Religión de San Juan de Jerusalén, wrote '*Libro de los secretos de agricultura, casa de campo y pastoril*', 'Book on the secrets of agriculture, country house and herding'.[62] The original version appeared in Catalan, but the author produced a translation into Spanish in the same year, 1617. The book is often indicated as the 'Book of the Prior'.

Fra Agustín addresses the '*Padre de Familias*', the family father, in his '*Casa de Campo*', his manor and estate. The book is comparable but certainly not identical to the Geoponika which the author must have known (in the French translation?). The text is compact and systematically organised, well-considered, and few authors are mentioned by name. The text is adapted to the writer's area, greater Catalonia (NE Spain), including Perpignan (S France). Among the crops newly introduced from the Americas he describes tobacco, but not potato or tomato.[63]

The book shows the progress in scientific publication. The subject matter is presented in a didactical manner, with chapters, subchapters, and paragraphs. The 1762 copy that I consulted had the topics printed in marginal glosses for easy handling.[64] An extended 'summary' explains the content of the book. Each chapter has a heading that briefly indicates its content. The book has a detailed index, a vocabulary in six languages, a perpetual calendar, a list of errata, and a few illustrations. The book, printed over and over again, had a great impact on Spanish agriculture until at least the end of the 18th century.

2.7 Fantasy and reality

On the Greek side we see realism based on solid observation, as with Hesiod who phrased his words in a poetical way, and Theophrastus. On the Near-Eastern side we see a curious mix of sound observation and recommendations highly fantastic to the modern eye. These have partly Babylonian and partly North African origin. Among these fantasies my favourite is the Geoponika's recommendation on how to avert lightning damage to the crop, '*Bury the hide of a hippopotamus in the field, and lightning will not strike there*' [GE-1,16].

To the modern eye, some of the fantastic recommendations are clearly pornographic such as Ibn Waḥshiyya's one about grafting a tree (Box 2.1). His rude directness was too much for pious Ibn al-ʿAwwām, who quoted the passage in a shorter and bowdlerized version, suggesting that the girl might be the just-married spouse.[65] He added: '*I reported these things, says the Author [=Ibn al-ʿAwwām],* *without having faith in their efficacy*' [IA-1.464]. Later more level-headed authors skipped the passage. In the course of time the most improbable recommendations were weeded out.

'Nabatean Agriculture' also contains reality, maybe possibly even more than I could identify in the scattered quotations. Among the real elements are, for example, how to find water and a contraption for drip irrigation. Weakened trees were treated by digging up the root system with a two-pronged fork, the Roman *bidens* (Fig. 3.4). Then the roots were covered by fresh soil mixed with manure. I am not quite sure when and how the treatment works but I suppose that a fresh and ample dose of micronutrients is part of it. One theory states that systematic wounding of the roots, 'scarification', stimulates the trees to produce again. This would be the underground mirror image of above ground pruning. Fantasy or reality?

Ibn al-ʿAwwām mentioned many practices, now seen as fantastic or magical, for completeness sake without necessarily putting faith in them. The Muslim historian Ibn Khaldūn (1332-1406) commented that the 'Nabatean Agriculture' contained much sorcery, forbidden by Islam and hence omitted by Ibn al-ʿAwwām .[66] Ibn Luyūn skipped all fantasy and magic, apparently considering it ineffective or even sinful. Crescenzi too was practically free from superstition.

Modern times began in Spain with Gabriel Alonso de Herrera (1513) and in France with Olivier de Serres (1600). These authors, well versed in the classics, nonetheless relied largely on their personal experience in agriculture. Their reflexions and explanations have a decidedly modern tinge. Whereas de Herrera does not address anybody in particular, de Serres specifically addresses the *Hausvater*, his first words being '*Le père de famille*', i.e. the head of the family, the *pater familias*. Similarly, Agustín's first words are '*El Padre de Familias*', *pater familias* again.[67]

2.8 The audience

'*For the majority of mediaeval Muslim authors, peasants were totally invisible, be they pagans, Christians or Muslims. Arabic literature is urban in character, which has contributed to a distorted view of medieval Near Eastern society*'.[68] Indeed, all the classical writings on agriculture are aimed at estate owners, be they private persons or officials of state and church. Most estate owners were literate and sufficiently affluent to buy books or to be read to.

Cato the Elder, a man used to managing people, was a landowner addressing landowners. Palladius too wrote for the rich who, at the time, tended to withdraw to their comfortable country houses trying to develop their estates and produce value (Martin, 1976). The 'Geoponika', clearly targeted at the owners of estates and large farms [GE-2.44/49], discussed 'human resource management' in some detail with specifics on food and drinks for the workers. Indications on the lay-out of an estate were given by all authors quoted here. Crescentio addressed the affluent citizens of Bologna, who began to invest money in land and wanted a return on their investment. The trend continues up to and including Agustín, who pleased the lord of the manor with a chapter on hounds and hunting and the lady of the manor with a medical chapter, contributed by two invited physicians.

All along the Mediterranean and through the centuries large estates and peasant farms existed side by side in varying proportions.[69] The estate owners often tried to oust peasant farmers from their properties but several rulers had a political interest in peasant farming, allotting land to individuals either to reward military services (Roman policy) or to create a populace from which to recruit soldiers (Byzantine policy). Peasant farmers were, on the whole, illiterate and had to rely on experience only.[70] They met and talked at religious ceremonies or, in winter time, at the fire place. '*Pass by the bronze-worker's bench and his warm lounge in the wintry season, when the cold holds men back from fieldwork …*' [HE-493]. Farmers shared their experiences, as they do today. Their knowledge and lore were handed down by word of mouth.

We may suppose that some exchange between oral and written tradition took place, through conversation and by example. Bolens considered the Andalusian Arabic writings to be typical court literature, but I doubt it.[71] The work of Ibn Baṣṣāl was said to have been copied and quoted frequently in North Africa from Tunisia to Morocco. The agronomist Ibn al-ʿAwwām may have talked with or at least listened to farmers. Sometimes he mentions local practice. Phrases such as '*they say*' or '*some say*' could refer to farmers. Ibn Luyūn is said to have included local knowledge in his text.[72] De Herrera not only looked at and talked with farmers, he had participated in farming as a farm hand at home, and as an estate manager in the *vega* of Granada. I venture to suggest that a continuous two-way flow of information existed between estate owners and peasants mediated by neighbours and hired labour. Up to this very day farmers within a neighbourhood tend to follow the example of an innovative lead farmer, in ancient times probably the estate owner.

Ibn Khaldūn (1332-1406) wrote: '*As we know, the (people of Spain) of all civilized people, are the ones most devoted to agriculture. It rarely happens among them that a man in authority or an ordinary person has no tract of land or field, or does not do some farming.*'[IK-2.279]. Civilized people could read, of course. The same Ibn Khaldūn had no high opinion of farming in 14th century North Africa, where agriculture was in decline. '*Estates and farms do not yield their owner a sufficient income for his [luxury] needs*' [IK-2.284]. This was not due to lack of information as indicated by the quotation at the start of this chapter.[73] In passing Ibn Khaldūn hinted at plant protection.

Of course, the 'trickle down' effect, the gradual dispersal of elite knowledge to the commoner, peasant or gardener, did exist in pre-modern times. But how effective was it? Imamuddin (1962 p 59) saw the agriculture of the Moors in Andalusia through rose-tinted spectacles. Discussing the impact of the great agronomists of the period (c.1200 - c.1400 CE) he wrote '*Their technical knowledge and practical experiences turned the country into a green land full of trees, cereals, gardens and orchards.*'

Chapter 3

Pre-modern agriculture

The view from some hill tops in the Mediterranean area shows a rural landscape as it may have been in pre-modern times. A wide variety of crop species was grown. Soil tillage was even more important then than it is today. This chapter discusses the management in pre-modern times of a selection of the planted and sown crops. Much attention was given to manual-based weed control. Many crop varieties were known. Threshing had to be done carefully on well-prepared threshing floors which are still visible in some mountain areas. Selection of seeds and seed treatments were considered important. Ideas about inheritance of characters existed, as did a notion of 'transmutation'. Climate and weather, where relevant to crop growth and protection, are discussed. Ecosystem services are indicated.

… that the first thing which God our Lord taught us to be necessary for human life, is Agriculture; and so, for reasons said above, Agriculture be praised and Farmers should be preferred above all other Makers.

Miguel Augustín: Libro de los secretos de agricultura, 1617[1]

3.1 Geography and climate

3.1.1 Geography, two scenes

The first scene in the 'theatre of agriculture' presented here is the Mediterranean area with its Mediterranean climate.[2] Agriculture, at least 10,000 years old in the eastern part of the area, spread at an early date and was well established all along the Mediterranean Sea at the time of the earliest sources for this book, c.1000 BCE. Mediterranean geography, highly fragmented by seas and mountain ranges, created great variation in local topography and weather, making generalisations less valid. Originally, most of the area was covered by forests, with oak forests in the lower coastal areas and pine forests in the mountains and drier areas. Forest destruction began early and could create local imbalances in climate and water supply.[3] The main food crops were wheat and barley, with wheat on the better and barley on the poorer or dryer lands. The tree crops included olive, grapevine, fig, and various fruit species. Several vegetables were grown in gardens. Our three major sources, Geoponika, Ibn al-ʿAwwām, and Crescentio, describe Mediterranean agriculture.

The second scene in the 'theatre of agriculture' is Western Europe. Toward the end of the first millennium CE the economic centre of gravity in Europe shifted from the Mediterranean area to Western Europe, stretching from Spain and Italy to the British Isles and Scandinavia. In the area north of the Pyrenees and Alps a maritime climate prevailed with cold winters and rainy summers. New land was reclaimed, often heavy clay soils, to which agriculture had to be adjusted.

3.1.2 Climates[4]

Mediterranean scene. It is generally thought that the Mediterranean climate has not changed much over the last 4000 years.[5] Cool and rainy winters alternate with hot and dry summers. Spring is relatively short with a beautiful outburst of flowers. Autumn rains begin at the end of September and the mild autumn weather allows for extensive tillage of the moistened soil.

About the beginning of the Common Era (year 1 CE), North Africa and the Near East received somewhat more precipitation than today, as evidenced by the extensive croplands. During the High Middle Ages the rainfall in the Mediterranean area increased, with the rivers north of the Mediterranean and the *wadis* in North Africa containing more water than today.

The Muslim realm, stretching from the Atlantic Ocean to the Caspian Sea and beyond, had a fairly uniform ecology, a Mediterranean climate with land exposed to drought but watered by rivers.[6] The geographic fragmentation of the area and the large orographic differences do not allow much generalisation. Ibn al-ʿAwwām made the point that environmental conditions in Babylonia and southern Spain were comparable so that the recommendations from 'Nabatean Agriculture' were applicable in southern Spain [IA-1.66]. The northern fringe of the present Sahara received more rain than today from the 6th to the 12th century as suggested by the many '*ksour*' in southern Tunisia.[7]

North Western European scene. At the beginning of the Common Era the north western European climate did not differ much from today. In the next few centuries, up to around 400, Europe became warmer and dryer, so that Brittany reached self-sufficiency in wine around 300. This warm period ended with more precipitation. The epoch of Charles the Great, 770- 800, had rather cold winters. After this period of cooling, North Western Europe warmed up again around the 10th century with much anti-cyclonic weather in a belt from the Azores to Germany, resulting in cold winters and warm summers. Europe was relatively dry from the 9th to the 11th century. During the 12th century average annual temperatures slowly increased. The Medieval Climate Optimum ranged broadly from 1170 to 1430.[8]

In the 13th century Western Europe experienced relatively pleasant weather. A colder trend set in after 1400. The 14th century was rather cool and had many mild and relatively wet summers. The 15th century was relatively cool with many cold winters but good summers. The Alpine glaciers began to grow after about1450.

The first half of the 16th century was pleasant but the cooling beginning around 1560 led to the 'Little Ice Age', with cold winters from c.1550-1800.[9]

So far, these climatic variations are irrelevant to the present discussion since, if there were crop protection consequences, these have not been found. With a few exceptions, crop yields did not suffer from the winter cold, wet winters being far worse than cold ones.[10] In the Atlantic fringe, where cyclonic circulation with heavy rains came in from the south west, wet summers could be disastrous for the cereal crops. Cool and wet summers caused lodging and moulding of the grain crops, fungal diseases, sprouting in the ear, poor yields, and scarcity or even hunger during the following season.[11]

3.1.3 Landscapes

The large wheat fields of today's Andalusia (southern Spain), on the vast plains between Granada and Seville, may be just slightly too large in comparison to the fields of pre-modern estates, but the landscape and field sizes in hilly Tuscany (Italy) between Florence and Pisa may recall the *latifundia*, the large estates of antiquity. The view from the ruined Roman hilltop-town of Dougga (Tunisia), overlooking cropped valleys, is reminiscent of ancient agricultural scenery. The ancient agricultural landscape is recalled in Volubilis, a delapidated Roman town in present-day Morocco, viewing the fertile wheat-growing plain in the west and the olive groves on the hills in the east.

Writers from Varro (c.30 BCE) to Agustín (1617 CE) inform us about the estates, their location and lay-out. Roman mosaics in present Tunisia beautifully illustrate the classic authors.[12] In the Mediterranean area pre-modern peasant farming probably occurred in large patches, arranged around villages. Within these patches fields may have been densely clustered.[13] The view from Granada, southern Spain, over the intensely cultivated '*vega*' suggests how such patches might have looked.[14] Ibn Khaldūn mentioned clusters of numerous villages with running water and date palms in north west Africa, a description that brings to mind the present-day palm groves in the Dadès, Draā, and Ziz valleys of Morocco. The hill districts of Spain, Morocco, and Turkey perhaps model the ancient dry-land subsistence farming.

Western European medieval farming is splendidly illustrated in various Books of Hours. The monumental publication by Perrine Mane (2006) describes and illustrates medieval farming in detail. Less is known about the peasants' housing. I have seen peasant dwellings ranging from sod-covered dug-out holes to nice houses with antique furniture, pottery and silver, but I do not know what pre-modern peasant housing looked like.

In pre-modern times forests and woods, scrub and rough areas were more abundant and larger than today. Deforestation was rampant in antiquity and during the Middle Ages, when wood was needed for cooking and heating, construction of buildings and ships, for firing the kilns of the potters, and fuelling the furnaces of the bronze and iron smelters. During periods of recession, secondary woodland recaptured lost ground.[15] Forests had many different uses, for timber, fuel, hunting, feeding pigs, and collecting berries or mushrooms. Scattered woods and shrub lands will have interacted with crops, in a negative or a positive sense, by affecting the microclimate and the interchange of insects, noxious or beneficial, fungi, usually noxious, and other plant pathogens.

Another landscape element, hardly visible nowadays, consisted of marshes. These marshes were feared because they were malaria-ridden.[16] Over the centuries the marshes were drained and reclaimed and protected against flooding by dikes, and malaria disappeared.

3.2 Farms and farming systems

3.2.1 Pre-modern farming

Crop protection cannot be understood without some knowledge of agriculture in pre-modern times. For a long time, population numbers and agricultural production must have been in balance. When large cities came into existence the demand for food increased and the 'source area' of food production had to be extended, often overseas. Wars were waged to conquer or defend food sources, wars that could also destroy crops in the source areas. By comparison with warfare, the vagaries of the weather were of less importance; food storage was the answer. Crop pests and diseases came and went, a few known by name, many *incognito*.

Agricultural production in the Mediterranean area, and its variability, was determined by geography, climate, soil fertility, and socio-economic factors. Agriculture was, of course, the key industry of the period. Wheat was the staple food, followed by barley. Vineyards and olive groves produced the cash crops, wine and oil. Leguminous crops were grown primarily for home consumption. Vegetables could be marketed where markets were nearby. In periods of affluence, ornamental gardens and parks were in favour in and near the cities and – combined with vegetable gardens and orchards – around the country houses.

Agriculture in North Western Europe, north of the Alps and far north of the Pyrenees, differed from Mediterranean agriculture as it was determined by a climate with mild springs, wet summers, mild autumns, and cold winters. Many coastal regions and river valleys had heavy soils that could not be ploughed by the

Figure 3.1 Ploughing with a wheeled plough, drawn by a pair of oxen. The ploughman holds a long, pointed stick, the stimulus, *here with the scraper at the lower end. In front of the contraption a coulter is suggested. Orchard in the background. From: Crescentio (1511) f 14 v°. Scale 1:1.*

customary scratch plough. The wheeled plow came into use (Fig. 3.1). Extensive marshes were unfit for agriculture unless heavily drained. Forests had to be cleared to use the land for agriculture. In the Middle Ages, monks, especially Cistercians, were active in opening up new lands.[17]

The proportion of cultivated to virgin land varied over the course of time, in accordance with population size. In the 12th and 13th centuries the Western European population increased rapidly and agricultural production could hardly keep pace with population growth. The 14th century was ridden by calamities and as a result the population plummeted, land under agriculture decreased, and forests expanded. The Great Plague of 1347/51 killed about one third of the European population. The subsequent scarcity of labour changed the social relations drastically and stimulated technical innovation in agriculture.

Land tenure relations ranged from freemen peasants using family labour to large estates based on slave labour. These relations varied considerably with place and time. State policies had a decisive effect on land tenure relations, and thus on land productivity. Rulers could improve agricultural production by stimulating peasant farming or, inversely, exploit their farmers to the extent that they stopped producing for the market.[18] Estate farming and peasant farming existed side by side, in ever-varying proportions.[19] The legal and social arrangements between land owners and land users, subject to change according to period and region, are not considered relevant to the present discussion.

Pre-modern agriculture was 'organic agriculture', in today's legal sense.[20] It was Low External Input Sustainable Agriculture, LEISA.[21] The *latifundia* with their *villa*s of the former Western Roman Empire had not enough manure, exhausted the soil, and were not sustainable. Arable land was turned into pasture as cattle breeding became the more profitable business. Pliny was very clear about estate farming [NH-18.7.35]. '*And if the truth be confessed, large estates have been the ruin of Italy, and are now proving the ruin of the provinces too – half of Africa was owned by six landlords, …*'. Much of the North African agricultural land, once so productive, became subject to desertification.

3.2.2 Farm and field sizes

Surface archaeology has provided new insights into ancient Greek farming (5th-2nd century BCE), a form of (near-) subsistence farming, with family farms of about 4-5 ha.[22] Cultivation was relatively intensive, with a cereal-pulse rotation providing food and fodder. As manure had to be carried to the field in baskets the nearby vegetable garden received much and the distant grain field little manure.[23] This farm size of a few hectares was probably the optimum, as larger farms could not be handled by a single family, and smaller farms could not produce enough to feed a family.

Farm and field sizes were variable according to the environmental and social conditions. The main determining factor of farm size was the workload that a single household could support. Peasant farms in the Roman area may have been up to some seven *iugera* or about 2 hectares, smaller than the older Greek farms, labour and water being limiting factors.[24]

Old Roman law recognized three types of land: private land, common pasture, and public land. Wealthy landowners rented large tracts of public land, handling it as if it were private property, and forced out the peasant farmers. Such was the trend in the Mediterranean area for well over a thousand years, from about 200 BCE to 1000 CE. At times, enlightened rulers introduced land reforms with the aim of stimulating peasant farming at the expense of estate farming, but such attempts were rarely long-lasting. [25]

In the Roman tradition small holdings were handed out to former soldiers. Byzantine rulers established small holdings, mainly in Anatolia, to breed future soldiers. Small holdings and large estates used to occur side by side, in proportions varying with the political tide.[26] Peasant farming in the Byzantine period was stimulated by the Emperors Constantine VII (c.940) and Basilios II (c.1000).[27] In other periods many freemen exchanged their freedom for protection by estate owners, or to settle their debts. The local churches and the numerous monasteries often possessed large estates.

Islamic law permitted heritable private property but rulers encouraged expansion of territories owned by highly placed persons. Common lands were designated for grazing. Some land was granted to mosques and other charities. Land property and water rights were coupled. In Muslim Spain serfs became lease-holders, a change that stimulated production.[28]

3.3 Crops and cropping systems

3.3.1 Crops

The Romans distinguished planted crops and sown crops. The planted crops were tree crops, first and foremost grapevine and olive, followed by fig trees and various kinds of fruit trees, and trees planted as ornamentals or for timber. The number of crops increased with time. The eastward expansion of Alexander the Great (c.300 BCE) brought Asian crops from India to the Mediterranean area. The Muslim expansion reached from Spain and Morocco in the west to India in the east. Muslims traded with China. Foreign crops were imported and adapted to the new circumstances.

Among the sown crops were cereals and legumes, which in Roman writings are often taken together as grain crops. Common wheat was the main cereal crop on the better soils. Barley and other wheat species were grown in less favourable areas. Most cereal crops were autumn-sown winter types, but spring-sown wheat was known too. Millets were cultivated, but to what extent is not known. The Geoponika discussed wheat at some length, barley only in passing, whereas rice and rye were not mentioned. The following discussion concentrates on wheat, with a few remarks on other cereals and on some leguminous crops. Among the sown crops of antiquity, flax was important, but flax is not considered here.

3.3.2 Planted crops

Grapevine. Wine production stands for peace and prosperity, with economic production beginning about five years after planting.[29] The acquisition of planting material, the planting, and the tending of the crop during the preliminary, unproductive stage represent high investment costs. Making good wine requires another investment in equipment and experimentation.

Vine and wine received much attention, the grapevine producing the number one cash crop. The *Geoponika* devoted five chapters to vine and wine (Box 3.1). In Eastern Europe, with Byzantium as its centre, wine was obviously held in high esteem, as evidenced by the weight given to wine production, processing and storage. Ibn al-ʿAwwām gave ample space to vines but, as a good Muslim, not to wines. De Herrera wrote one 'book' on vines and wines. The best plants from the best lines were to be chosen since a vineyard may last for forty to two hundred years. At least three varieties should be planted per field to spread the risk of losses. The cultivars should be planted separately since the harvesters are not able to distinguish them [DH-2.5.56]. Grapevines and other trees should be planted in neat rows [VE-2.24; 2.276]. The grape harvest was one of the highlights of the year (Fig. 3.2).

The grape bunches were handled with some subtlety**.** In cool locations the leaves surrounding the bunches were to be removed to let the grapes ripen in the sunshine. In warm places bunches were to be shaded to avoid them drying out. '*In this month [October] it is good to begin pruning and, after the grape harvest, to turn the soil over so that it, trampled down by the pickers, will be loosened and will receive the autumn rains down to the roots without obstacles. But also the weed will be less high due to the atmospheric condition, having cut all the roots before that time and having decayed with the frosts*' [GE-3.13.7].

Instead of manure the crop residues of faba bean and other legumes can be used that not only protect the vines against frost damage but also against insects [GE-5.26.6].

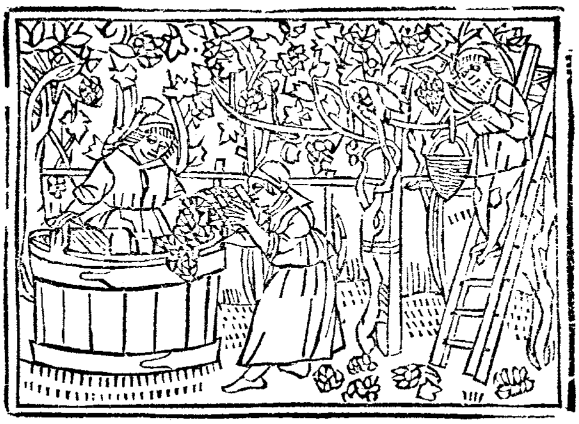

Figure 3.2 Grape harvest. One man cuts the bunches and puts them in a basket. The woman empties a basket into a barrel in which a man tramples the grapes. The vines are supported by poles and trellis. Curiously, the canopy with the bunches is at about 2 m height so that the harvester needs a ladder. From: Crescentio (1511) p 75 r°. Scale 1:1.

Box 3.1 Grapevine and vineyard

The wild form is the Mediterranean ssp *sylvestris* Gmel., a deciduous woody climber, liana, up to 20 m high. It grows in humid forests. Vines were creeping, climbing on trees or stakes, or trellised. Several varieties were available and many types of wine were made, often seasoned with herbs.

Wine making began before 5000 BCE. The grapevine was domesticated c.3500 BCE in the Near Eastern uplands or in Transcaucasia.[30] Homer (c.800 BCE) mentioned wine production and Hesiod (c.750 BCE) went into some detail. The Greeks spread vine and wine over the Mediterranean area. Wine was the major commercial commodity in antiquity and much was written about it. Pliny mentioned many 'varieties' [NH-14.21/39]. During the Roman period wine became democratized, a daily necessity for all, from governor to slave. The peak production of the Roman Empire was estimated at 1.8 million hectolitre per year, the average consumption per person (all ages, both sexes) was thought to be 0.5 litre per person per day. Wine was stored and traded in *amphorae*, vessels of baked clay, the inner side often lined with fine clay or a bituminous substance.

During the so-called Dark Ages of Western Europe, 5th to 10th century, the vineyard area in Western Europe shrank so much that the noble art of wine making became practically restricted to scattered monasteries. When the worst was over, the people turned to wine drinking for two reasons. Wine was healthier than water, and wine drinking had a religious connotation that beer and cider had not. During the 12th century the vineyard area increased again, reaching saturation toward 1300. Medieval *calendaria* often depict scenes from vineyard and vinery.[31]

Vineyards were capital and labour intensive enterprises that warranted good protection against the caprices of the weather. The advantage of a vineyard, once established with much effort, is its regular production, every year, providing a regular income. Vineyards were placed where the people lived, since transportation of wine-filled casks was cumbersome and expensive. Vineyards were found as far north as Norway.

Three types of vineyards existed. (1) Support of the vines by trees was an old practice, the trees moderating wind, irradiation, and eradiation (and possibly yield). Grapes growing far above the soil might escape the ill effects of night frost, low fog, and too strong an insolation. (2) At the north eastern fringe of the European wine area the vines were usually unsupported. The advantage of prostrate vines is their capturing as much sunlight and heat as possible and their relative safety from strong winds, the disadvantage being damage by foxes and rodents, and a poor quality wine. (3) Trees were supported by poles, one per tree, or trees were trellised with fewer poles per tree (Fig. 3.2, 4.15).

Protection against the intemperances of the weather took many forms. Stone walls were expensive but they reflected the heat so that grapes could be harvested earlier. They broke the force of the winds and they kept thieves and browsing animals out. The more modest fences and hedges were much more common. ■

Olive. The *Geoponika* devotes chapter 9 to the olive (Box 3.2). It contains extensive recommendations for the nursery and for transplanting, pruning, and harvesting. When planting an olive nursery '*The lower part of the sprig must be coated with a mixture of manure and ash …*' [GE-9.5.7], thus providing fertiliser and bio-protection. For the control of vermin the author [GE-9.10.9] refers to the chapter on grapevine [GE-5.48/49]. '*… if you find dry and diseased roots, you must know that the culprits are the worms living in the base of the roots, that you can make disappear in many ways, as*

Box 3.2 Olive

The olive tree is native to the Mediterranean area and the Near East. It is a long-lived tree (c.1000 years), up to 8-15 m high. Var. *sylvestris* is the wild and var. *europea* the domesticated form. Ibn al-ʿAwwām: '*There are two species of olive trees, the wild olive that grows naturally in the mountains, and never on the side of rivers (running water), nor where the roots could meet*' [IA-1.207]. His other species is the domesticated form. Most modern 'wild' olive trees are, in fact, not wild but feral. However, in the western Mediterranean area some wild olive trees survive.[33] The wild form, also named oleaster, is interfertile with the domesticated form; it has smaller fruits, is self-incompatible, and grows from seed.

Cultivated clones are heterozygous so that they must be clonally propagated. Scores of cultivars existed then and now. Pliny mentioned some 15 'varieties' [NH-15.4]. Olive trees show heavy alternate bearing unless trimmed in the 'on' year. Cultivated olive trees are often pruned into flat cylindrical form for easy picking. An olive branch never produces fruit twice.

Olive consumption began in the Near East around 9000 BCE. The production of olive oil began c.5000 BCE in the Near East. In the Southern Jordan valley olives were grown under irrigation (as today) c.3600 BCE. During the Bronze Age olive oil was exported from Palestine to Egypt, where no olives were grown. The Phoenicians brought the tree to Italy, c.1200 BCE.

The olives are hand-picked or harvested by hitting the branches with reeds and reaping the fallen fruit (Ramsay, 1875). Table olives are picked early when firm, oil olives when the oil content attains 20-30 %. During the 'first pressing' a bitter tasting, dark, watery liquid is produced, olive lees or *amurca*.[34] The later pressings produce the olive oil.

Olive oil had three major applications, in cooking, in lighting, and in personal care. It was also used to preserve food and wine, since a cover of oil in a container protected the content against aerobic decay.

Christ prayed among the olive trees in the Garden of Gethsemane (H: Gat Šmānê = oil press). ■

said before, but primarily by planting sea squill at the side' [GE-9.10.10]. The preparation of table olives is discussed at length. Oil yields were in the order of 0.8-3 tonnes. ha^{-1}.[32]

3.3.3 Sown crops - Cereals

Wheat. Wheat species were domesticated around 10,000 BCE in the Near East. Wheat was widely cultivated in Biblical times. The Romans knew several wheat species among which *Triticum spelta* and more primitive species such as *T. monococcum* (einkorn) and *T. dicoccoides* (emmer). These three species are hulled and need pounding. Free-threshing tetraploid and hexaploid wheats appeared in Neolithic and early Bronze times. *T.durum* and *T. aestivum* were naked, free-threshing wheat species.[35]

Which wheat species were grown in classical and medieval times around the Mediterranean is not perfectly clear. Pliny distinguished hard wheat (L: *triticum*) and common wheat (L: *siligo*), approximately equivalent to *T. durum* and *T. aestivum*, respectively [NH-18.10.61]. '*'Hard' flour is made from hard wheat, the most highly esteemed coming from Africa*' [NH-18.20.89]. Free-threshing tetraploid wheat (*Triticum durum*) is thought to have been the main wheat crop in the relatively warm area with its dry summers on the southern side of the Mediterranean since classical times.[36] *T. durum* arrived in France as late as the 16th century.[37]

The better soils were sown with wheat at densities adjusted to the availability of water and nutrients. Pre-modern sowing densities were of the order of 105-150 kg/ha.[38] '*Wheat is to be sown in deep and flat soils, …*' [GE-2.12.1]. '*In turn wheat should be sown in muddy and wet soil, since it will grow better therein; the wheat sowing should not be delayed*' [GE-2.13.2]. Begin sowing wheat about mid October [GE-2.14.3]. Some people sow on two to four dates to spread the risk of failure [GE-2.14.8]. Pliny complained that common wheat (which species is not known) never ripens evenly so that it is susceptible to shedding [NH-18.20.91].[39]

The Geoponika states that wheat seed should be of good quality, heavy, hard, without wrinkles, golden, and very fertile. Grains with holes and shrunken grains should be removed [GE-2.16.1]. To check the correct seed density spread your fingers, make an imprint of your hand in the soil and count the seeds, for wheat five to seven, for barley between seven and nine, and for faba beans six to four [GE-2.20.1/2].[40] The seed rate for poor soils should be somewhat lower, for rich soils slightly higher. Ibn al-ʿAwwām may have had in mind the richer soils of Andalusia as his numbers were higher: wheat eight to nine, barley nine to ten, faba bean five to six [IA-2.49]. If the land is continuously under a snow cover, sow somewhat more. Good land may have 'parasitic' weeds, thus sow more. — Ibn al-ʿAwwām's seed rate for wheat is, recalculated, about 74 kg/ha [IA-2.50], a low seed rate possibly adequate for well-tilled weed-free soils.

Little reference is made to diseases. I have ignored astrological comments, except one that justifiably links rain and rust.[41] When the Dogstar (= Sirius) rises around 20 July one has to observe the moon when it appears in the east. '*When she is in the sign of the Bull there will be abundant rain, hail, rust and numerous acts of revenge*' [GE-1.8.11]. Three grasses figure among the weeds, darnel, goatgrass, and wild oats. '…

darnel ruins the wheat and, when mixed into the bread, blinds the consumers' [GE-2.43]. Cereal rust epidemics, known in antiquity, apparently made little impression on medieval authors, if they occurred at all.

The Romans used to hoe the winter cereals twice, with multiple purposes. The upper soil layer was loosened to avoid evaporation by capillary rise of valuable soil moisture; a loosened, friable top layer protected the seedlings from overheating by the strong Mediterranean sun; the weeds were killed and the seedlings could be earthed up to stimulate tillering. A round of hand weeding took place at about heading time.[42]

Weeding was essential and De Herrera provides the arguments [DH-1.9.26]. The weeds will smother the crop. With good weeding the plants will sprout more, develop better and fuller ears, heavier kernels, and a cleaner product. The straw will be sweeter to cattle. Weeding is more important on better soils and in wetter years. Weeding should be done on a fine day with little wind. Wheat should not be weeded before it has four leaves and barley five leaves.[43] At that stage the crop has rooted sufficiently without having a canopy that impairs weeding. De Herrera does not indicate the weeding method here.

Medieval book illuminations often show harvest operations (Fig. 3.3). Frequently, the cereal crop is about as tall as the harvesters are, say 1.60 m. Medieval people were, on average, shorter than people today and, at the same time, wheat and rye were taller than today. The advantages were several. First, the straw was a valuable commodity, being used for roof thatching, litter for cattle in stables, mattress stuffing, cattle fodder, and so on. Second, a tall crop may suppress the weeds. Third, a tall crop may avoid 'climbing diseases' such as caused by the fungi *Septoria* and *Fusarium* in wheat and, possibly, by *Fusarium* and ergot in rye.[44]

Barley, a winter or spring annual grass of 0.3-1.2 m height, originated somewhere in the Fertile Crescent. The earliest barley was two-rowed; six-rowed barley, a mutant, was also grown in antiquity.[45] Barley was grown for consumption in Egypt c.15000 BCE and in Turkey c.7000 BCE. The tough rachis, that did not fall apart in many fragments at ripening, was selected around 6500 BCE. Barley was used for bread making, fodder, and brewing beer. The Geoponika gave no information

Figure 3.3 Grain harvest. Two men handle sickles, cutting the grain at mid-height. A woman prepares the sheaves. Supervisor to the left. Note that the crop is at least as tall as the people, 160 cm or more. From: Crescentio (1511) p 50 r°. Scale 1:0.82.

on two-rowed versus six-rowed barley. '*Barley can be sown in medium deep soils*' [GE-2.12.1], '*Barley must be sown when the soil is not wet, but not dried out*' [GE-2.13.1]. Begin sowing barley in early October [GE-2.14.3]. Barley is spoiled by goat grass.[46] Barley used to be grown, in antiquity and in the Middle Ages, on the poorer and more drought-prone soils. It ripened some two weeks before wheat.

Millet (common or proso millet) is an annual grass, about 1m high. It originated in Transcaucasia ca. 5000 BCE; its ancestor has not yet been clearly identified. The common millet was cultivated in Transcaucasia from 5000 BCE onwards. It is a good dry-land crop requiring little water. According to the Geoponika, however, millet likes a muddy and moist soil, even sandy soil if irrigated regularly. A little seed suffices for a whole field. Sow in March [GE-3.3.12] and weed continuously [GE-2.38.1]. A heavy crop should be thinned. De Herrera confirmed that millet requires thin seeding and much weeding. Spain is too dry, he wrote, for Crescentio's recommendation to alternate rows of millet with rows of faba bean, but millet can be sown in the vineyard between rows of grapevine [DH-1.22.42].

Oats are rarely mentioned. The Geoponika sees oats only as a minor source of beer [GE-7.34.1]. Crescentio clearly distinguishes the green, large and hairy wild oats from the cultivated form [CR-3.3]. The wild form is a weed of wheat fields that drops its seed just before the wheat ripens. Quoting Albertus Magnus he states that oats are more suited to lighter and dryer soils. Oats, both green and as seed, are good fodder for cattle, horses, and donkeys.

Rice is an annual herb, coming from East Asia. Theophrastus [HP-4.4.1]: '…, *and for most of its time of growth it is in water; however it shoots up not into an ear, but as it were into a plume*,….'. Rice, grown in Mesopotamia in the 4th century BCE, was known by the Greeks though not much appreciated.[47] Its production expanded in the 9th century in present Iraq, but rice was not mentioned in the Geoponika.[48] Rice cultivation was spread by the Arabs and became important in Southern Spain [IA-2.27]; intensive weeding was essential. Agustín [AG-182] described rice cultivation in some detail and rice is still grown that way.

Rye probably began as an annual weed in the higher altitude wheat and barley fields of the Iranian mountains; the higher the fields the more dominating the weed that became rye.[49] In the Middle Ages it became a popular cereal north of the Alps being rustic, winter hardy, and tolerant to more acidic soils.[50] Rye gradually replaced wheat as food for the masses, a replacement which changed only in the second half of the 19th century.

Rye is ignored in the Geoponika and by Ibn al-ʿAwwām. Crescentio knew that in the Alps rye was sown early in September and harvested late in September of the following year. De Herrera and Agustín discussed rye as a crop in Castille and Catalonia, respectively.[51]

3.3.4 Sown crops - Legumes

Legumes were an important part of the people's diet. They were also used to improve soil fertility, as today. The Geoponika is clear: '*legumes can be sown in shallow soils*' [GE-2.12.1]. '*Legumes can also be sown in flat soils after the wheat harvest, in the following period, since once sown they give a rest to the soil … chickpeas excepted*' [GE-2.12.2].[52] Faba beans and peas should be sown in muddy soil [GE-2.13.3]. '*The other leguminous crops even support being sown in a very dry soil but they will be more luxuriant and better developed if sown in moist soil*' [GE-2.13.4]. Legumes must be harvested well before parts of the field begin to yellow; they will be easier to cook and more savoury [GE-2.25.1]. '*At sowing, they have to be mixed with manure and also saltpetre as thus you make them ready for cooking*' [GE-2.41.1]. — Easy cooking of legumes was a legitimate concern, but it is questionable whether organic seed coating is of any use for this purpose.

Faba bean is an annual legume, up to about 1 m high, fixing nitrogen, from North Africa and South West Asia.[53] It became part of the Mediterranean diet around 6000 BCE.[54] Faba beans have to be planted late as they like a muddy soil [GE-2.12.3; 2.35.1]. In seeming contrast the Geoponika says for July: '*It is appropriate also to plough the land in which are sown faba beans or grass pea, since all land should be ploughed immediately after [grain] harvest, before it dries out*' [GE-3.10.5]. Sowing density should be 4-6 seeds per hand print [GE-2.20.2]. — The July planting utilises the residual moisture left over in the soil after the cereal harvest.

Crescentio, who was apparently interested in faba beans, prefered moist soil or soaking the seed before sowing [CR-3.8]. These recommendations are sensible. Since germination and emergence are quite slow (around 20 days) the beans should be in permanent contact with wet soil. The wetness may also protect germinating seed from insect damage. De Herrera added that faba beans should not be sown in foggy places as these generate aphids (i.a. *Aphis fabae*). They should not be weeded before they are four inches high and should be weeded when the weather is good but dry. After threshing the beans should be left overnight on the threshing floor to cool and then be stored when still cool, to avoid infestation by bean weevils.[55]

Chickpea is an annual, about 0.6 m high from west Asia. Its wild ancestor is unknown, possibly *Cicer reticulatum*. Chickpea was already grown around 3500 BCE. It was a staple of classical Greece though the ancients warned that chickpea exhausts the soil but, writes Theophrastus, '*it destroys weeds, and above all and soonest caltrop*'.[56] Neither did the Romans think highly of chickpea, '*No legume is less hurtful to land*' [CO-2.10.19]. Later writers agreed. '*If you soak the chickpea seed in lukewarm water one day before sowing they will emerge larger*' [GE-2.36.1] with better growth and yield, but - in contrast to the other legumes - chickpea does not improve the soil so that it is rejected by good farmers.[57]

Lentil is an annual, up to 0.4 m high, with wild types found in north eastern Turkey. One of the earliest crops domesticated, it was grown in Asia Minor c.6500 BCE, in northern Greece ca. 5500 BCE.[58] '*Lentils emerge better and earlier if they are covered with horse or cattle manure before sowing. They will grow bigger in the pods* *if [the seed is] soaked in lukewarm water and then sown with saltpetre*' [GE-2.37.1]. Lentil suffers from a weed, crown vetch [GE-2.43]. — The recommended seed treatment approaches today's 'seed coating' and 'pre-soaking'. Crown vetch, toxic to horses, is known as a very competitive weed.

Lucerne (alfalfa) is a perennial legume from the Caspian Sea area. Via Greece it was spread across the Mediterranean area. Lucerne is up to 1 m high, deeply rooting and drought tolerant. It was the first cultivated forage crop.[59] In February the land to be sown with alfalfa was to be ploughed again [GE-3.2.4], maybe to control weeds.

Lupine (white lupine) is an annual, up to about 1.2 m high, growing wild in the Mediterranean area. It was probably domesticated in Greece. Geoponika: '*Lupine has to be sown in exhausted soil, not needing manure, because it serves as fertilizer: in effect, it fertilizes whatever devitalized soil and makes it productive again*' [GE-2.39.6]. '*Lupine can be sown before the other crops, in the second part of October, without waiting for the rains*' [GE-2.39.1]. '*Shallow seeding is recommended, it germinates without precautions …; but it fails when it notices somebody working the soil* [GE-2.39.9].[60] — Lupine is typically a poor man's food, reserve food in times of scarcity. It also served as cattle fodder. Lupine flour could be used as an admixture in bread [GE-2.39.5].

Lupines were used as green manure to restore soil fertility. '*And in this month [May] it is appropriate to turn the lupines over that were sown to improve or clean up the field; therefore to cut them before the mid-month, before the shoots flower, when they are still flexible, and once cut to leave them, so that they decay somewhat; in continuation to plough so that the cut part of the lupines is turned under, and in this way all the roots disintegrate*' [GE-3.5.7]. Lupines were recommended to clean a field from grass roots. Action should be taken in July. '*Crush lupine in flower with poison hemlock and apply it to the cut of the roots that have remained in the soil, since it will dry them*' [GE-3.10.7].[61] — It is not clear how this herbicidal action worked.

Pea is an annual, up to 1 m high, the vining type being up to 2 m long, originating in the Mediterranean area and the Near East. Peas were found in northern Greece c.5400 BCE; in Mesopotamia peas came into use c.4600 BCE.[62] Peas should be sown in muddy soil to avoid insect damage [GE-2.13.3]. — Pea is considered a cool season crop.

Vetch is an annual, up to about 1m high, from Asia and East Africa.[63] It is still grown in Asia and East Africa for food and feed. Being sturdy and drought resistant it is considered an 'insurance crop' in case other crops fail. '*Virgil recommended treating vetch seed with nitron and water*' [GE-2.18.12]. Vetch is part of pigeon fodder [GE-14.1.5]. — Vetch contains a neurotoxic, non-protein amino acid that can cause neurolathyrism in man. It takes 3 to 6 months to develop full symptoms, spasm, muscle weakness, and permanent paralysis of the legs, due to degeneration of locomotory nerves in the spine.

3.3.5 Sown crops - Vegetables, herbs, ornamentals

The Geoponika mentions many herb species, mainly because of their medicinal and veterinary use, and several vegetables. Some general instructions are provided on gardens [GE-12]. A water source must be nearby. The garden should be near to the living quarters. It should not be located down-wind of the threshing floor, as the plants may be spoiled by the chaff. Separate gardens were laid out for utilitarian use (medicinal herbs, kitchen herbs, and vegetables) and for pleasure (ornamentals, sometimes a special scent garden with fragrant flowers).

Ibn al-ʿAwwām treated vegetable growing at length, with recipes to prevent and control insects. Seeds can be steeped in the sap of 'house leek' or of squirting cucumber to deter birds, ants, and other vermin [IA-2.139]. Grapevine ash suspended in water and poured over the plants once a day during three successive days controls worms (and caterpillars), aphids, ants and other small noxious animals [IA-2.138]. All worms on pumpkin can be killed by water in which a sachet with asafoetida is immersed [IA-2.139]. Fumigation with vine twigs, deer antler, goat hoofs, or iris root deters the insects [IA-2.139].

Here I discuss only two crops. For species also used in crop protection see chapter 6.

Onion and shallot are herbaceous, biannual bulbous plants up to about 1 m high, from Central Asia. They produce edible bulbs. They were cultivated around 1000 BCE. Considered a stimulant, their cultivation was discussed by various Roman authors. Onion still is a major commodity in some countries. The Geoponika discussed transplantation and storage [GE-12.31.1/3]. '*To keep onions without rotting, submerge them in hot water and let them dry in the sunshine, and – when dry – place them in barley straw so that they don't touch each other*' [GE-12.31.4].— Onion is not mentioned as a phytomedicine. It has antibacterial, antifungal, and antiviral (TMV) properties.

Saffron crocus, mentioned by many pre-modern authors, was grown as a commercial crop. It was also planted in parks between the trees as an ornamental, nice to see and smell, and good for bees [GE-10.1.3]. Brief but correct indications for cultivation are given i.a. in the Geoponika [GE-11.26]. The Geoponika [GE-15] and other books amply discuss bee-keeping and nectar producing plants. Bees were kept for honey, the only sweetener available before the introduction of sugar cane into the Mediterranean area. I doubt whether the role of bees and other insects as pollinators was known.

3.4 Crop selection and plant improvement

3.4.1 Crop selection

The old books are quite specific about selecting the site of the farm or manor house. They are less detailed on the selection of crop species. Some general points are clear. In the Mediterranean area wheat was grown on the better soils, barley on the poorer and dryer lands. Rye, held in low esteem, could be grown in mountain areas with an extreme local climate. Later it was found that rye was more productive than wheat on the sandy and somewhat acidic soils of the north. Oats became popular in North West Europe when bullocks were replaced by horses. Millets were found suitable as summer crops in the Mediterranean area. In warm river plains, where water was plentiful, rice could be grown.

Soil improvement by growing leguminous crops, chickpea excepted, was common. Faba bean, lentil, pea, and chickpea were grown for food. Lupines were sown and ploughed in as green manure. Lupine and vetch were also grown as an emergency food. Lucerne was found to be good as cattle fodder.

Muslim botanists experimented with many imported crop plants. Adaptation to new growing conditions, probably by natural hybridisation and mutation, was a slow process, carefully watched. Crops such as banana, sugar cane, and cotton were carefully matched with climatically suitable locations. Flax became the dominant fibre crop.

3.4.2 Varieties

In modern agriculture varietal purity has great commercial value. In fact, modern trade in and processing of agricultural commodities would be next to impossible without varietal identity and purity. The situation in older times is difficult to assess but the concept of variety, certainly of clonal variety, was well known in antiquity. Various forms of vegetative multiplication were in use for asexual reproduction of desirable types, as with olive and date trees. The numbers of varieties were considerable in pre-modern times. Pliny the Elder mentions some 71 grape varieties and 15 olive varieties (White, 1970). The Geoponika mentions some types of cereals and many types of grapes. Crescentio and de Herrera discussed several grape varieties and their properties.[64]

In the old days farmers went for yield stability rather than for top yields. Old varieties had a certain 'rusticity', which implied that they did not produce top yields but produced an acceptable yield under a wide range of environmental stresses of abiotic and biotic nature. Old varieties had properties that are nearly forgotten nowadays. Tall wheat and rye have already been mentioned. Let me quote two other examples. In Algeria, 1980, Sunn Pest became threatening in newly introduced varieties but the classical variety of the area, Florence-Aurore, remained nearly free from these insects.[65] In Amazonian Peru, 1974, I stumbled upon a local rice variety, tall and leafy, that produced a fair yield notwithstanding a moderate attack by foliar blast due to the blast fungus, whereas nearby modern high-yielding varieties had been killed by the fungus.

3.4.3 Seed selection

Columella recommended methods for seed selection which today we would call positive mass selection. Either '*we should select all the best heads and store the seed from them by itself*' or '*the grain that settles to the bottom because of its size and weight should always be kept for seed*.' Ear selection was advocated by several authors including Ibn al-ʿAwwām and Agustín: '*put the best ears aside*'.[66]

The best seed is that which is the most healthy, the most filled. Reject what is pinched and meagre.[67] De Herrera is explicit. Never will a good crop grow from bad seed. Take fresh seed of cereals and vegetables from plants heavy with seed. See to it that the seed is dry and free from weed seeds. Take seed from the bottom of the heap as this seed is heavier. If possible select your seed grain for grain. If you find a plant with many ears, collect and clean its seeds, and multiply the seed in a separate piece of land. Be careful to maintain the purity of the seed, do not mix it up.[68]

De Herrera proposed testing the germinative capacity of old seed by adding boiling water. Like his predecessors Agustín advises an old Egyptian seed test: sow separate samples of the seeds intended for sowing in consecrated soil some 20 to 30 days before the rising of the Dogstar.[69] Water them if need be, and check after the rising of the Dogstar. Sow more of the best grown samples and less of the poorly growing samples; the predictive power of the test is due to the influence of the Dogstar. — The test is sensible but it is not clear why it should be done in the heat of summer and why boiling water should be used.

3.4.4 Exchange of seeds and planting stock

Seed exchange is a controversial topic. '*Some say that the act of sowing seed in sites opposite to those that produce it contributes to an abundant harvest; for example that from a mountainous zone in the plains, that from humid sites in dry locations vice versa, …*' [GE-2.17.1; 2.19.2]. Whereas Pliny, Crescentio, and De Herrera caution against such an exchange, Ibn al-ʿAwwām, Walter of Henley, Agustín, and de Serres recommend it.[70] — Exchange of seed and planting material may indeed have some merit in annual crops.[71]

The same idea, exchange of propagation material, is applied to planting stock. Ibn al-ʿAwwām repeats the recommendation of 'Nabatean Agriculture' on grapevine, namely to plant in a light field plants coming from a heavy one, and those from a heavy field to a light one; from black soil to red soil, and the opposite; from a fertile field to one that is not; from mountain to plain and from plain to mountain, '*because it is in the essence of a site to give strength to what has grown in a contrasting site.*' [IA-1.346]. — I am doubtful about the exchange of perennial crops such as grapevine. '*Neither farm workers nor plants should be transferred from better to worse ground*' [GE-2.48].[72]

3.4.5 Genetics

Many species taken into cultivation must have been somewhere in between the original wild types and the domesticated forms of today. The ancients were aware of the differences between wild and cultivated forms. In the Geoponika the distinction is sometimes made, usually by means of the term for 'wild' (ἀγρίος), as for example with figs.[73] For medical purposes the wild garlic was thought to be more effective than the cultivated form [GE-12.30.7]. The general idea that domestication was a matter of good care, was worded by the poet-scientist Lucretius: '*Next one after the other tried ways of cultivating the little plot they loved, and saw wild fruits grow tame in* *the ground with kind treatment and friendly tillage*'.[74] Virgil agreed [VE-2.50]. Olivier de Serres disagreed and held that however you try to improve an originally wild plant, you will never get such exquisite fruit as by way of seeding [OS-6.18.585] and subsequent selection.[75]

The domestication of many annual plant species in the Fertile Crescent was facilitated by their being self-hybridising with true breeding as the result. Several tree species are, however, cross-hybridising. Theophrastus already knew that several tree species do not breed true.[76] '*The main part of it is this: that the seeds of trees are unable to maintain their kind and unable to produce fruit like the parent; … tree seeds always change for the worse, …*'. The Geoponika says: '*Some believe that planting seeds is a simple matter; one should know that all seed produces its own type except the olive, that gives a wild type and not a [cultivated] olive*'.[77]

Ibn al-ʿAwwām repeats the comment [IA-1.145]. About the date palm he explains: '*… If you take seeds from a single type you will get different types, even bad ones. If you plant a sucker you will obtain dates similar to the original ones.*' [IA-1.323]. In both cases the author quotes Vindonius. Ibn al-ʿAwwām explains '*Every tree multiplied from seed will yield fruits equal to those of its species. The olive tree is the exception; if sown in a strong soil, a species will sprout from the seed called* qothinon.[78] *This is confirmed by Ibn Ḥadjdjādj from his own observation, …*'. Indeed, an olive seed is a hybrid of hybrids that does not necessarily develop into a productive olive tree. This important fact was stated over and over again, as for apple, date palm, fig, grapevine, pear, and pomegranate.

3.4.6 Transmutation

The ancients believed in transmutation, that is a rapid transition from one species to another one. Their 'evidence' was the gradual replacement of wheat by darnel (= tare, false wheat). Theophrastus: '*Among seed crops the change to a quite different plant occurs chiefly in the stronger ones, as wheat and barley, for they alone turn into darnel, and wheat, the stronger of the two, does so more*'.[79] The replacement of real wheat by poisonous false wheat was a well-known risk in antiquity as illustrated by St. Matthew 13:30. '*Let both grow together until the harvest: and in the time of harvest I will say to the reapers, Gather ye together first the tares, and bind them in bundles to burn them: but gather the wheat into my barn*'.

In herbs a desirable transmutation was effectuated by simple means. Curly celery was to be obtained by peeling the seed carefully and flattening it with a roller [GE-12.23.2]. — Apparently a theory of opposed forces was applied, by flattening here you obtain curls there. Suggestions for similar man-made transmutations are scattered throughout the literature. Their effectiveness is so questionable that they do not merit attention here.

Crescentio went into some detail in '*On transfiguration and mutation of one plant into another*' [CR-2.8], borrowing from Albertus Magnus.[80] One 'mutation' refers to the succession following the cutting of oak forest. Less noble trees appear, and sometimes mushrooms, grasses, and so on. A second 'mutation' refers to the change of wild plants into cultivated plants and vice versa.[81] Wild trees have more fruits than cultivated trees but the fruits are smaller and less tasty, and cultivated trees have fewer but sweeter and larger fruits. In a third 'mutation', wheat changes into rye and, sometimes, rye into wheat; the main reason being the cultivation method, and the location.[82] — Of course, none of these effects are 'mutation' in the modern genetic sense.

3.5 Environment

3.5.1 The abiotic environment – weather[83]

Astro-meteorology. In the pre-modern period astronomy and meteorology were one. Both necessitated looking at the sky with the naked eye. In the annual cycle the summer emergence of the Dogstar gave the sign for the flooding of the Nile. As to crop protection, the Romans associated the appearance of cereal rust with the spring disappearance of the Dogstar and then celebrated their rust festival, the *Robigalia*.[84] On a daily basis the biblical passage in St. Matthew 16: 2,3 is still in use. '*When it is evening, ye say, it will be fair weather: for the sky is red. And in the morning, it will be foul weather to day: for the sky is red and lowring.*'

Daily variation. Dew was the well-known consequence of nightly cooling. One disadvantage of dew was quoted by Theophrastus: dew was conducive to a disease of the standing crop called 'rust'.[85] Farmers made use of the coolness of the night and the nightly dew, especially at the critical transition of crop in the field to product in store. It was said that several crops should be harvested early in the morning, when still moist, to avoid loss of seed by dehiscence of pods and shedding of seeds. '*… the best hour to cut [the wheat] is at day-break, when the grains are soaking wet of dew*' specifies Agustín [AG-175].

Beans and grain were to be left overnight on the threshing floor, where necessary in small heaps, and stored early in the morning when they were still cool.[86] — Cooling the threshed grain was considered essential for good keeping quality. The nightly dew should however have evaporated because grain stored in moist condition attracts storage insects or moulds heavily.

Ibn al-ʿAwwām considered the scorching sun a positive factor. The clods crumble and the soil recovers. The heat of the sun will deeply penetrate into the furrows, divide the particles and heat them, with three combined advantages: aspiration of air, fineness and softness in all parts of the soil, and prevention of weeds that would absorb the richness of the earth and its fine saps [IA-1.484/5].

Annual variation. Ibn Wafid stated that large stones in the soil damage tree roots and vegetables because they become too hot in summer and too cold in winter [IW-?.21.301]. Ibn al-ʿAwwām elaborates the point and indicates that when clearing an area for planting vines all stones on the soil surface should be removed, especially those that are cutting, because stones scattered over the surface can burn the plant when continuously heated by the summer sun, since they tend to concentrate the heat. The same stones get cold in winter, transfer the cold to the plant and damage it. The problem is due to large stones that are partly buried and partly exposed. Accordingly, big stones should be removed from the soil surface.[87]

The explanation lies in the great heat capacity of stones, which can be either a nuisance or a benefit. Moderation of soil temperature extremes was obtained by exploiting the heat capacity of large stones buried in the soil. '*To let the roots [of trees] profit from the rains in winter and be cooled in summer (since provision should be made for both seasons), stones are placed at the bottom [of the planting hole] to allow rain water to collect and to keep the roots cool in summer*' [CP-3.4.3]. The heat capacity of stones could be exploited in new vineyards. '*In the bottom of the planting-hole you should place stones about five pounds in weight in such a way as not to press upon the vine but so as to be near the roots.*'... '*The stones give the roots space into which they can creep and in winter they keep away the water while they provide moisture in the summer*'.[88] '... *and in summer they refresh the roots*' [GE-5.9.8]. — Soil temperature regulation, drainage and rooting space, three sound points.

Weather persistence. The weather changes from day to day but nonetheless some weather types persist. Under a high pressure area a sequence of hot and dry days may develop. When a train of depressions crosses the Atlantic from west to east, a sequence of windy and rainy days will occur. Daily weather types are usually clustered. In a similar way years may be clustered, in accordance with long-term continental circulation patterns. Cold, wet, or dry years may occur more or less clustered. Historically the most prominent cluster of wet years with more or less continuous downpours of rain was from 1315 to 1321. It caused a continent-wide famine. Whereas unfavourable weather was the proximate cause of the mishaps, plant disease may have contributed.[89]

Concatenation of mishaps. In the Atlantic climate continuous summer rains can occur. They may cause lodging of the grain crops, moulding and rotting of foliage and heads, and sprouting in the ear. The lodging and moulding reduce grain filling, so that the yield is low, and the sprouting reduces the quality of the produce including the seed to be used for the next season.[90] This seed will be infected by various pathogens as for example *Fusarium*-type fungi. If the rains continue and tillage is next to impossible the seed bed will not be crumbly and well aerated but compacted and water-saturated. Inevitable late sowing on an inhospitable seed bed makes the next crop, already weak because of the poor seed, susceptible to winter frost. When the crop freezes out, recourse has to be taken to spring-sown crops, if seed is available. If not frozen the crop may give only a modest yield, unless boosted by a very good spring and summer. Inoculum of *Fusarium* and other fungi may then accumulate. Such concatenations of mishaps did occur. They contributed to the serious crop failures in the period 1315-1321. — It should be noted that the contribution of plant disease to the mishaps is concluded by inference only, as the records did not mention plant disease.[91]

3.5.2 The abiotic environment – soils

Plants are firmly rooted in the soil that provides support, water, and nutrients. Pre-modern agronomists were aware of the merits of various soils. The Andalusian authors especially had a detailed knowledge of soils, and of the ways to handle them. The physical aspects of soils are manifold but in the present context only one major distinction is relevant. In the Mediterranean area many soils were shallow, light, and often full of stones. In North West Europe heavy and water-soaked soils abounded.

Soils team with life - microorganisms, nematodes, invertebrates, vertebrates, plant roots, and seeds. Such organisms are very relevant to modern crop protection and they may have been equally relevant to ancient crop protection but, unfortunately, the data fail. The vertebrates include mice, moles, and mole rats. Among the invertebrates are snails and insects, that hibernate in the soil, but the soil-inhabiting phase of these organisms was hardly known in pre-modern times. Pre-modern authors had no inkling of microorganisms and nematodes. Only in rare cases could symptom descriptions be linked to soil-borne noxious agents.

Food and feed contain nutrients withdrawn from the soil so that, gradually, the soil is depleted. 'Mining the soil' is the dramatic name for this phenomenon that causes loss of soil fertility. Maintenance of soil fertility was a major concern countered by fallowing, endless ploughing, manuring, and sowing of leguminous crops. Several pre-modern authors had a very detailed knowledge of, or at least opinion about, the various kinds of manure and their application. Unfortunately, there was never enough manure for all arable land. Gardens were well served, and what remained was applied to the nearby fields.

The information available on soils and soil fertility in relation to crop protection is scanty. No systematic treatment is possible here, but relevant items are scattered through the chapters which follow.

3.5.3 The biotic environment – ecosystem services

We may imagine the ecosystem services that the non-farm environment could provide.[92] Water is the prime requisite of agriculture. Forests are the natural reservoirs regulating water supply. They provided fuel and building material, game and fowl, food and fodder, and medicinal plants. Forests were locations for cultural rituals. Hills and forests provided shelter and created favourable meso-climatic niches, protecting buildings and crops from adverse winds. Animal resources were used through domestication and hunting. Plant resources were gradually adapted to human needs for fire, food, feed, fibre, medicine, and ornamental use.

Ecosystem degradation was already known in antiquity (Box 3.3). Forest destruction was due to construction and shipbuilding, the fuel needed for firing the bronze and iron smelters and the pottery kilns, and for making charcoal. In the Middle Ages it was known that forests could retain water and that their destruction caused floods in the lower reaches of the rivers and, during droughts, unusually low water levels.[93]

The Romans captured incredible numbers of wild animals to provision their games for the amusement and appeasement of the populace, under the motto '*panem et circenses*', 'bread and games', far more inimical to nature than present soccer and football. The only advantage of excessive hunting was increased rural safety. Ibn Khaldūn surmised that the (over-)grazing by the herds of the Bedouins in North Africa contributed to desertification.

As to crop protection, ecosystem services may be both positive and negative. Wild land and rough areas are good breeding grounds for insects. Many are the cases where pests hibernate or oversummer in such areas to the detriment of the crops.[94] And many are the cases on record where the beneficials, predators and parasitoids, find refuge in non-crop land and spread to crops. Unfortunately, negative ecosystem effects exist too. Mid-altitude rough areas host various barberry species on which the black stem rust can hibernate and from which it occasionally spreads to the wheat fields.[95] Grasses growing along rivulets may stay green in summer and allow cereal rusts to over-summer.[96]

In pre-modern time agriculture was geographically fragmented with considerable variation in vegetation types in between. The avifauna must have been very rich in comparison with today and insect predation by birds may have been so intense that

Box 3.3 Theophrastus and meso-climatic change

Theophrastus was one of the earliest scientists who jotted down a note on human-induced (meso-)climatic change, with crop protection consequences [CP-5.14.2]. '…: *districts where formerly, when the air was thick, there was no freezing, are now subject to frosts, as in the country Larisa in Thessaly, where formerly, when there was much standing water and the plain was a lake, the air was thick and the country warmer; but now that the water has been drained away and prevented from collecting, the country has become colder and freezing is more common.*'

The evidence is clear [CP-5.14.3]. The fine tall olive trees are gone. Vines never frozen before often freeze now. — Where the air is 'thin' plants run the risk of freezing, where the air is 'thick' these plants are safe. The terms 'thin' and 'thick' are physical terms but with a subjective connotation, pointing toward 'brisk' versus 'oppressive' weather.

Apparently, the area near Larisa was drained, with two consequences. One was that the water masses no longer buffered the temperature in the lower air layers, the other that the lower air layers contained far less water vapour after the drainage, making the air 'thin', whereas before the air contained more moisture, and was 'thick'. One might think of severe night frosts now that the protective nightly fogs have disappeared.

Pliny elaborates the above example, making clear that man-induced changes of meso-climate were understood in antiquity [NH-17.3.30]. '*In the district of Larisa in Thessaly the emptying of a lake has lowered the temperature of the district, and olives which used to grow there before have disappeared, also the vines have begun to be nipped, which did not occur before; while on the other hand the city of Aenos, since the river Maritza was brought near to it, has experienced an increase of warmth and the district round Philippi altered its climate when its land under cultivation was drained*'. ■

serious outbreaks of insect pests were rare.[97] On average the balance of ecosystem services may have been positive, with notable exceptions when extreme weather conditions stimulated outbreaks of migrant pests with long-distance dispersal, such as locusts and cereal rusts.

3.5.4 The phases of the moon

The calendar poses certain problems (Box 3.4). The classic lunar calendar of the Near and Middle East is still the official calendar of the Jewish and Muslim religions. The Muslim agriculturalists were in some difficulty as crops and cropping obey the sun's course. Ibn al-ʿAwwām adjusted to the Syriac-Macedonian solar calendar that had also been in use by the Romans. Following Greek and Roman authors he added a *calendarium* to his book [IA-2.415ff].

In classical agricultural lore the moon played an important part. Waxing and waning of the moon were closely observed. Contradictions occurred as to the right time for sowing pulses: '… *and that the other kinds of seed are not liable to maggots … if sown just before a new moon.*' [NH-18.45.158]. '*Neither are [seeds] eaten when sown at full moon.*' [GE-2.18.13]. The Romans believed 'the more moon the more dew' and dew was considered beneficial to their crops. — The positive opinion of dew may be correct in a dry climate, but dew is also conducive to plant disease.[98]

Tavenner (1918) summarised the Roman view. '… *all planting was to be done just before the moon began to increase, or during the waxing moon. The reason is quite clear; for as the moon increases, so shall the planted crop or orchard increase.*' By the same token the waning moon is good for harvesting, drying, and storing produce. Tavenner quotes Pliny [NH-18.321] '*All kinds of cutting, picking, or shearing are accomplished with less damage during the waning moon than when the moon is on the increase.*' Crescentio explains that the moon is so important '… *because the Moon being so near to the Earth controls and governs all that is on the Earth*' [CR-2.21.].

Ibn al-ʿAwwām recognised 'moon-plants', including melon and flax, that have to be sown at waxing moon.[99] Manure has to be applied at waning moon. De Herrera, discussing the agricultural calendar, followed Palladius but went one step further dividing each month into a waxing and a waning part. De Herrera recommended sowing wheat in the first quarter of the moon and applying manure at waning moon to prevent the appearance of weeds. On pastures, however, fresh manure had to be applied at waxing moon. — The point here is that fresh manure contains many weed seeds which should germinate to replenish the pasture.[100]

Olivier de Serres accepted the effect of the moon's stages. During the first four years a new vineyard should be pruned when the moon is old [i.e. in her last quarter], because the old moon stimulates rooting whereas the new moon encourages branching [OS-153.3.4]. The same author, however, recommended starting the grain harvest as soon as possible without bothering about the phase of the moon, though the old moon is preferable [OS-2.6.116].

Agustín [AG-55] gives by far the most detailed lunar sowing calendar relating crops to phases of the moon. Wheat should be sown at waxing moon [AG-171]; hemp should be sown in March with the new moon ('*en Luna nueva*') and harvested in

Box 3.4 The agricultural calendar

Agricultural calendars were important for performing the necessary agricultural activities at the right time and for observing the appropriate religious obligations and feasts. Agriculture and religion were intimately linked. Greeks and Romans had calendars associated with the signs of the zodiac, and punctuated by religious feasts. Hesiod's peasant farmer lived largely outside, felt the weather, and observed the natural phenomena that served as markers of time, whereas the absentee landowner, who left the management of his property to a hired steward, needed the agricultural calendar as an indispensable management tool.

Most nations used a lunar calendar but crops follow a solar calendar, as Varro [VA-1.27] realized: '*And since we have two measures of time, one annual which the sun bounds by its circuit, the other monthly which the moon embraces as it circles, I shall speak first of the sun*.' He then continues with an agricultural calendar. Columella [CO-11.2] produced a more extensive one, and Palladius organized his book in monthly chapters. As an observant Muslim, Ibn al-ʿAwwām used the lunar calendar and wrestled with the solar calendar needed by agriculture [IA-1.47]. Crescentio's chapter 12 contains an instructive agricultural calendar, solar of course. The lunar calendar, or at least the lunar phases, were respected and used for fine regulation of agricultural activities. De Herrera's calendar splits waxing and waning parts of the month [DH-6.0.350ff].

In the Middle Ages the agricultural calendars were illustrated by sculptural reliefs on churches, wonderful pictorial sources of agricultural activities. Similarly, illuminated manuscripts contained colourful and vivid illustrations of the four seasons, usually characterized by the major agricultural activity of the season, such as ploughing in spring, harvesting in summer, slaughtering in autumn, and hunting in winter. Ms Perrine Mane made a most detailed analysis of these pictorial representations.[101] ■

August when the moon is old ('*en Luna vieja*'). In the same vein he advised cutting graftlings '*en Luna vieja*' and grafting them at waxing moon ('*en Luna cresciente*'). Garden plants were to be sown at waxing moon. Agustín rhymes:

> *'No hinche su troxe,*
> *quien à Luna se acoge'*,

that is '*Who ignores the moon does not fill his granary*'. — I do not know of modern evidence supporting these views.[102]

3.6 Crop management

3.6.1 Soil tillage - Digging

'*The farmer and his sons*' is one Aesop's fables.[103] '*A farmer, being at death's door, and desiring to impart to his Sons a secret of much moment, called them round him and said, 'My sons, I am shortly about to die; I would have you know, therefore, that in my vineyard there lies a hidden treasure. Dig, and you will find it.' As soon as their father was dead, the Sons took spade and fork and turned up the soil of the vineyard over and over again, in their search for the treasure which they supposed to lie buried there. They found none, however: but the vines, after so thorough a digging, produced a crop such as had never before been seen.*' The lesson is clear, 'keep digging'. So recommends Agustín about two millennia later [AG-196].

Deep ploughing was not possible but spitting two spits deep was sometimes recommended, for example to mix different soil layers or to plant special crops, primarily tree crops. Theophrastus: '*Spading [trees] is good for all, since it removes the blockers and interceptors of the supply of food and makes the earth itself damper and lighter, again, air gets mixed in with the earth, as it must when the earth is turned up, and imparts a certain moisture and so provides food. …it dries the wet ground and wets the dry, …*'.[104] Gardens and orchards were hoed.

'*Wounds and blows inflicted by men who dig about the vines render them less able to bear the alternations of heat and cold*;' wrote Theophrastus and he continued '*Indeed, as some think, most diseases may be said to be due to a blow*' [HP-4.14.7]. Sometimes, the hoe wounded the vines; then the soil around the trees had to be dug out and mixed with manure of sheep or goats [CR-4.18].

Vineyards were dug over once a year to control weeds and to prevent shallow rooting. Frequent, early and deep tillage of the vineyard was recommended; but care was to be taken not to wound the tree with the mattock [IA-1.479]. Deep tillage loosens the soil so that roots can grow and breathe easily; it moves the sub-soil up so that the baking sun makes it milder; it removes weeds that take the nutrients

Figure 3.4 Springtime. The soil is opened with a two-pronged hoe to prepare the ground for planting grapevines. On the second level grapevines, not yet budding, each tree supported by a pole. From: Crescentio (1548) p 99 [CR-4.8]. Scale 1:1.

from the grapes; and the soil gets more affinity to the freshness of air and water and better retains the water [IA-1.482].

During World War II food became scarce in the Netherlands and abandoned fields had to be reclaimed. This was tough work as I remember only too well. With two, sometimes three people, weather permitting, we cleaned a sandy field about the size of an acre from couch grass down to a depth of 30 cm. It took six weeks of 'slave' labour.

3.6.2 Soil tillage - Ploughing and harrowing

'Take notice, when you hear the voice of the crane every year calling from above out of the clouds: she brings the sign for ploughing and indicates the season of winter rain, … '. Hesiod [HE-448ff] warns his listeners to start ploughing when the cranes fly south, that is around November 1st. Then, in Asia Minor, the summer heat is over, and the rains soften the hard soil so that ploughing becomes feasible. *'When the ploughing-time first shows itself to mortals, set out for it, both your slaves and yourself, ploughing by dry and by wet in the ploughing season, hastening very early, so that your fields will be filled'.*[HE-458] The message was: hurry up, prepare the soil for the winter crop. Referring to fallow land Hesiod continues *'Turn the soil over in spring; land left fallow in the summer will not disappoint you; sow the fallow land while the field is still brittle'.*[HE-462] Good fallowing is known to be a real life-saver '*Fallow land is an averter of death, a soother of children.*' [HE-464]

Hesiod instructed that there should be two ploughs in the house. If one breaks down another is available; borrowing is out of the question. Acquire two oxen of about nine years old, old enough to avoid *'contending in the furrow'* and young enough to be strong draft animals. The ploughman should be in his forties, a man who cares for his work and drives a straight furrow. The second man, not much younger, should scatter the seeds avoiding over-seeding. A third man is to break the clods and cover the seeds using a mattock.[105]

Tillage was the alpha and omega of pre-modern agriculture (Boxes 3.5, 3.6, 3.7), the very opposite of today's low-till and no-till agriculture in the New World. The Old World had a plough-based agriculture using relatively simple ploughs. Hesiod's plough was a 'scratch plough' or 'ard', a pointed wooden beam drawn horizontally through the soil. The ard had neither coulter nor mouldboard. It was drawn by a span of oxen and kept in position by the ploughman holding a handle (Fig. 3.5). The scratch plough had little depth and did not turn the soil over. The ard left ridges untouched between the furrows. To break the ridges cross-ploughing was necessary. '*Much service, too, does he who turns his plough and again breaks crosswise* [in obliquum] *through the ridges which he raised when first he cut the plain*, …', wrote Virgil [VE-1.97].

Ploughing three times was normal, from Hesiod till Ibn al-ʿAwwām [IA-2.10], and beyond. Cato wrote: '*What is good cultivation? Good ploughing. What next? Ploughing. What third? Manuring*'.[106] Varro prescribed ploughing twice before sowing and once after (to cover the seed). '*When they plough the third time, after the seed has been broadcast, the oxen are said to 'ridge'; that is, with mould boards attached to the ploughshare they both cover the broadcast seed in ridges, and at the same time cut*

Box 3.5 Tillage - the plough

Scratch plough. The oldest plough is the scratch plough, breaking plough, or 'ard'. In essence it is a pointed wooden beam drawn horizontally through the soil. The point of the beam was hardened in the fire or covered by a metal shoe, still to be seen in the archaeological museums of southern Europe.[107] The scratch plough cannot reach deeper than c.10 cm. The implement is symmetrical, throwing the soil to either side of the shallow furrow, so that the farmer can easily move back and forth.[108] The scratch plough only opens the surface, loosens the soil without turning it upside down. Weeds are torn up and left to dry and die. The balks (ridges) between the furrows remain untouched, so that cross-ploughing is imperative. Efficiency required approximately square fields (White, 1962).

The scratch plough is adapted to light, shallow soils, well drained or sloping, as found often in the Mediterranean area. A farmer can repair or even make a scratch plough and, as its structure is light, he can carry it on his shoulder if need be. Before sowing the winter wheat the field has to be ploughed twice at least, cross-wise. This is usually done in October. Before the spring sowing at least one other round of ploughing is needed, usually done in March. Fallow fields are ploughed at least once, in summer.

The scratch plough was the predominant equipment in Western Europe at least until the 12th century. For a long time it remained the major tillage equipment in most of the Mediterranean area.[109] Several types are distinguished according to their construction. The ard is still alive. In Morocco, in 2010, I saw it used for ploughing between the olive trees. In the old city of Fez I even noticed a workshop making new scratch ploughs.

Mouldboard plough. Whereas the scratch plough is symmetrical in build and effect the mouldboard plough (heavy or turning plough) is asymmetrical. With the vertical coulter and the horizontal share a beam of soil (= a strip of sod) is cut loose. By means of the mouldboard this soil beam is thrown to the side and into the furrow. The new furrow is where the last beam of soil has been. Modern ploughs with a curved mouldboard turn the beam of soil upside down, so that the weeds are covered to die and rot. As cross-ploughing is no longer necessary, efficiency dictates long-drawn fields. With the mouldboard plough heavy and marshy soils can be reclaimed. The mouldboard plough reaches deeper than the scratch plough. Fresh soil is brought to the surface. Efficient drainage was possible by alternating furrows and ridges.[110] ■

Box 3.6 Tillage - hoe and spade

Hoe. Medieval illuminations beautifully illustrate the tillage as done in the Middle Ages.[111] The worker using the hoe moves forward and treads the tilled soil. The hoe loosens the soil but does not reach deep, less than 10 cm, unless an extreme effort is made. The hoe is best for light and stony soils. The hoe tears the weeds loose so that they dry and die. With the hoe a man can till 0.03 to 0.05 hectares per day. The blade of the hoe, from rectangular to triangular, is made of iron. The worker has to bend over more or less deeply.[112]

A variant was the two-pronged hoe (L: *bidens*, G: *dikella*, δικελλα), made of iron or, in the north, of a deer antler.[113] It was used to break the clods and to cover the seed. It was also used to lay bare the roots of trees that had to be treated (Fig. 3.4).

The push-hoe is a more recent gardener's tool. The person pushing the hoe can stand upright and move forward, which makes work lighter. The push-hoe can be used only in light or loose soil.[114]

Spade. Digging is done with a spade. The man with the spade moves backward and leaves the tilled soil untouched. The spade easily reaches down to 20 cm. The soil is turned over so that fresh subsoil is moved to the top. When necessary the labourer can even go two spades or about 40 cm deep. The spade is more appropriate for compact and moist soils free of stones. The spade covers the weeds with a layer of soil so that they rot away. The man with the spade can till only 0.02 hectare per day. The blade of the spade, usually rectangular, is often made of wood with an iron rim reinforcing the cutting edge. The worker can stay upright or nearly so.[115] ■

ditches to let the rain water run off….' '*Where the plough makes a hollow or channel with the share, it is called a 'furrow'. The space between two furrows, the raised dirt, is called* porca*, because that part of the field presents the grain; …*'.[116] — Though the grain is broadcast most of the seedlings will appear on the ridges in irregular rows, thus facilitating weeding.

Usually no mouldboard was mentioned. The soil was torn open to a depth of only some 10 cm. This ploughing was not very effective but it was good enough to control weeds. The ard opened the soil, providing aeration to the soil, and preventing drying of the sub-soil. Ibn al-ʿAwwām recommended open furrows so that the heat of the sun could penetrate into the soil and do its salutary work. Crescentio was more explicit: the soil is *1*. opened to water and sunshine, *2*. levelled, *3*. mixed with manure and seeds that are thus protected against drought, frost and birds, and *4*. crumbled. De Herrera added *5*. weed killing, and *6*. 'softening' the soil. I imagine that the strong insolation of the open furrows during the Mediterranean

Box 3.7 Tillage - the importance of frequent ploughing

The importance attached to frequent ploughing cannot be underestimated, at least not in the Mediterranean area. Agustín the Prior wrote: '*If the farmer lets his wheat land rest for two years, it will be better. Others plough their land five or six times before sowing, according to the nature of the soil. Anyhow, the more the soil is moved the better, because the wheat develops better and gains more weight. The Jews had this well experimented, when they were in Spain which now is without them. As they tilled their fields frequently they always produced their wheat at weight, and in the outcome, to obtain that weight more wheat was needed, as it was not thus weighed, and they sold it by volume, and thus made a gain since they would have needed more to get that weight*' [AG-171].

Many Jews in Spain - before their expulsion in 1492 - were farmers, a practically forgotten fact.[117] Apparently they developed a technology to produce wheat with high grain weight, that could get a good price, but with low volume weight. The trick is this: heavy kernels are large so that the empty volume between the kernels is large too. Hence, the total volume of kernels and empty space with large kernels is lighter than with small and more densely packed kernels. This technology had not yet gone into oblivion when Agustín wrote his book, 1617, over a century later.

A crop rotation with a long resting period of the soil was, apparently, part of the game, as was very frequent ploughing. Agustín recommended two ploughings after manuring the field. The frequency of ploughing suggests the use of the scratch plough. I have no information on the draught animals used. Supposedly, the farming Jews manured their fields heavily; perhaps they used night soil or other town refuse.[118] ■

summer kills at least part of the soil-born inoculum of noxious nematodes, fungi, and bacteria, a simple form of modern 'soil solarization'.[119] Exposure to intense insolation in day-time and strong eradiation at night, with daily temperature changes that approach 50 ºC at soil level in the dry Mediterranean summer, was thought to improve fertility.[120]

After ploughing the clods were to be broken. '*Much service does he do the land who with the mattock breaks up the sluggish clods, and drags over it hurdles of osier*.' [VE-1.95]. As a rule the seed was ploughed in, not harrowed. A kind of harrowing could be performed with bundles of willow branches.[121] Pliny knew about a toothed harrow used in the north but stated '*A field that needs harrowing after the crop has been sown is badly ploughed*'.[122] Large fields could be treated with a roller with iron teeth to break the clods and level the field. The Geoponika does not touch upon equipment at all so that we have to rely on the Roman classics and the Moors. The harrow and spiked roller, to break the clods and level the field, are mentioned by

Figure 3.5 Ploughman with scratch plough or 'ard' drawn by a pair of oxen. The ploughman steers with his right hand, holding the stimulus *in his left. A sower has a seed lip in his left hand. The boy with the long stick may be breaking the clods. Also depicted a roe and a locust. Drinking cup (G: kylix, κύλιξ) made by Nikosthenes, Athens, c.520 BCE, c.20 cm ø. From Gerhard (1848) plate I. Scale c.1:1.1.*

Ibn al-ʿAwwām. Crescentio mentions the harrow only in passing, but is firm on clod breaking by hammer, axe, or hoe.[123]

In the Middle Ages both the harness of the draft animals and the plough were improved.[124] Horses replaced oxen to speed up ploughing. Cross ploughing was no longer needed. Fields were gradually transformed from square into elongated to improve the efficiency of tillage.[125] The mouldboard plough came into use, which was a great improvement. The strong emphasis on ploughing in pre-modern agriculture is in stark contrast to the modern tendency toward low-till and no-till. Reduced tillage has its advantages in certain areas but it also has a definite impact on crop protection issues.[126]

3.6.3 Fallowing and crop rotation

In pre-modern agriculture fallowing was imperative for several reasons. (1) Fertilizers did not yet exist and manure was scarce so that a fallow was needed to restore soil fertility. (2) In the Mediterranean area fallowing could help to conserve soil moisture.[127] (3) Weed control by frequent ploughing was effective on fallow land. (4) Stubble grazing could feed animals and the droppings could restore or even improve the nitrogen status of the land. (5) Some degree of soil temperature regulation was indicated.[128] Tillage methods were adapted to these requirements. Superficial ploughing prevented water loss by evaporation. For the same reason Andalusian agronomists wanted fallow land with a carefully crumbled and powdered soil, and a completely flat surface.[129] Frequent ploughing of fallow land with the ard was recommended by all pre-modern authors.

In classical Greece a two-course rotation of cereal and fallow was customary, the fallow being usually 'bare fallow', sometimes 'green fallow'.[130] The bare fallow was intensively tilled for water conservation by avoiding run-off and soil erosion, and for weed control. Green fallow consisted of a leguminous crop, sown if sufficient water was available. The Romans used a crop-fallow rotation where needed but also developed more intensive rotational systems, labour, soil, water and manure permitting. A rotation of fallow – winter cereal – legume – spring cereal allowed three crops and one fallow in three years. Continuous cropping was applied where feasible, that is on fertile and well-watered soils.[131] With their detailed knowledge of soils and crops the Andalusian agronomists were able to refine their rotation systems.

After the fall of the Roman Empire and the reversion from an urban to a more rural civilization most of Western Europe returned to a crop-fallow rotational system. Until the early 19th century France had a two-course rotation south of the river Loire and a three-course rotation north of the river. In some areas, where manure was plentiful, fallow could be skipped, as in Les Landes (SW France) with its abundance of sheep manure.[132] In Flanders (Belgium) and East Norfolk (UK) fallow was replaced by industrial and feed crops.[133] In modern Western Europe, with its intensive land use, a good crop rotation is considered essential to keep soil-borne pests in check, primarily weeds, fungi, and nematodes. — One cannot be certain whether this argument is applicable to pre-modern agriculture.

3.6.4 Sowing and planting

Hesiod had the wheat broadcast so that the seeds could roll into the furrows [HE-463]. A boy following the sower broke the clods with a mattock so that the seeds were covered and (somewhat) protected against birds. The Romans apparently had two ways of sowing grain and covering the seed. On wet soils the seed was broadcast.[134] Then the field was ploughed with ridging boards so that the seeds were raised to the top of the ridges, thus preventing the 'drowning' of seedlings and providing good drainage. On dry soils the seed was sown in the furrows and covered by raking or harrowing. In either case the crop could emerge in irregular broad lines, thus facilitating later weeding. The Romans did not apply row drilling, as far as I could see. De Herrera was explicit about row drilling of faba beans, dibbling them along a string, with adequate space between the rows for weeding the crop [DH-1.18.38].

An illustration from 1511 suggests that the furrows were some 40 to 50 cm apart and that, indeed, most of the seed rolled down into the furrows (Fig. 3.6). In practice a kind of row drilling could result as Crescentio implied [CR-3.18]. Technical and organizational progress is shown by an illumination from c.1530; the horse-drawn harrow, following the broad-casting sower, who follows the horse-drawn plough.[135]

The freshly sown seed had to be protected against insects, voles, and birds. Seed treatment is a classic.[136] Theophrastus and his followers suggested soaking the seed in wine [CP-3.24.4]; alcohol perhaps being considered as a disinfectant? Soaking seed overnight in the sap of '*Sempervivum*' is recommended from Theophrastus to Agustín. Purslane sap was possible too, and also the admixture of soot from the chimney. Agustín's recommendation [AG-60] to macerate the roots of squirting cucumber, add them to water for a full day, and wet the seed frequently with this extract seems quite reasonable; the next day one can sow the mollified seed that germinates faster and is protected against all damage.

Chapter 2.18 of the Geoponika contributes a wealth of seed protection methods. From Pliny to Agustín it was suggested that wheat boiled with alum should be strewn over the crop. Birds eating this would be drugged so that they could be collected manually and killed. Agustín [AG-60] added cooking the seed in wine (instead of alum), soaking the seed in water in which crayfish had been boiled or even more fanciful ideas such as scraped elephant's tusk [GE-2.18.5].[137] — These last two items will not be effective.

De Serres knew that ants, vermin, birds, and other animals took a good share of the seed sown. He observed, however, that wheat tillered so abundantly that the remaining seeds produced a yield ratio of 50:1 to 60:1. He recommended harrowing to distribute the seed regularly and to tear out the weeds. Stony soils should be harrowed twice and cross-wise using a wheeled harrow [OS-1.2.103/4].

3.6.5 Irrigation and drainage

Tapping rivers and streams for irrigation is a time-honoured practice. Mesopotamia reached a high degree of perfection in large-scale irrigation. Elsewhere irrigation systems were more modest. Homer (Iliad 21.257/62) depicts the peasant in action: '*As a man who guides its flow leads from a dusky spring a stream of water among his plants and garden plots, a mattock in his hands, and clears away the dams from the channel, and as it flows all the pebbles beneath are swept along, and it glides swiftly onward with murmuring sound …*'.

The Muslim Andalusians were masters of irrigation, complementing the technical lay-out of the irrigation system by a legal system of water rights and maintenance obligations.[138] They introduced the Persian 'qanāt' system to the West. Water flowing from the mountain side and stored in the rubble at the foot of the mountain is tapped and transported by gravity through underground

Figure 3.6 Ploughing with an 'ard' drawn by a pair of oxen. The ploughman holds a long, pointed goad with a scraper at the lower end. The ridges are indicated by hatching, the furrows by an undulating line. The sower, with seed basket on his left arm, is broadcasting the seed that rolls into the furrows, so that a kind of row drilling is emulated. Sacks with seed corn stand near the house door. Constructions and a garden in the background. From: Crescentio (1511) p 34r. Scale 1:1.

channels to the place of destination. Regularly placed vertical shafts connect the channel (A: qanāt) with the surface for aeration and access.[139] These qanāts can be several kilometres long. They still exist in Iran, Sicily, Spain, and Morocco. Another Persian invention is the water wheel, the nuria, also used in southern Spain. The elevation height was up to about 6 m. In North Africa many small villages were organized around a water source. Hence the Arabic word 'mā' for 'water' also means 'centre'.

For Andalusia Ibn al-ʿAwwām gave clear prescriptions [IA-1.133]. Irrigated fields had to be divided into bunded plots measuring at most 4 x12 ells or c.1.8 x 5.5 metres (Fig. 3.7). If the plot was too shallow the water could not spread evenly, if too steep the seed would be washed away. Ibn Luyūn provided drawings of the equipment needed to construct those plots and instructions about slopes of plots and supply ditches (S: *acequías*). He was explicit about the properties of the irrigation water to be used. Cold river water could be useful to kill the grubs in the soil [IL-12].[140]

Drip irrigation was applied to trees. '*Drip irrigation is applied to the base of the tree by means of two new water jars with a small hole in the bottom. The jars are placed at some distance from the soil to avoid clogging*' [IA-1.196].[141] Seed beds and vegetables were probably watered by means of a watering pot. This was, apparently, an earthenware pot with many small holes in the bottom, to be filled by submersion. A hole in the top allowed the water flow to be regulated by the thumb.[142] Plant decoctions could be added to the water for insect control.

We know that irrigation may drastically change the crop protection needs in fields, orchards, and gardens.[143] I did not find indications for enhanced disease pressure under irrigation in the pre-modern literature other than the obvious fact that several crops could not have been grown (and infected) in the Mediterranean area without irrigation.

Figure 3.7 Bunded garden plots in Moorish style, Madeira, 2010. Plots planted with young banana trees. Narrow water channel between the two pairs of plots.

The Romans were concerned about excess rain water during the winter season. They stressed the importance of draining off the water by means of ditches, open or 'blind', the blind ones being underground drains kept open by stones or faggots.[144] Columella [CO-2.4.8] described the formation of seed beds, '*porcae*', '*when the ground is ploughed in such a way that the earth heaped up between two widely separated furrows affords a dry bed for the grain.*'

'*It is also usual to make intermediate runnels by means of a larger furrow, if the place requires it, for these to draw off the water into the ditches.*' [NH-18.49.179] Pliny's advice was echoed by Crescentio who recommended digging ditches in the field to get rid of excess rain water [CR-2l.17]. In North West Europe excess water was an even greater problem. Walter of Henley recommended making deep furrows at regular intervals in order to drain the field.[145] His instruction suggests clearly that at the time (c.1286) a mouldboard was used, probably a flat one. The curved mouldboard, that turns the soil upside-down, reaches deeper and requires less energy, is an invention of later date. Tusser (1557), an English farmer, rhymed:[146]

'Seede husbandly sowen, water furrow thy ground,
That raine when it commeth may run away round, ...'.

A few technical notes. Grapevines and other trees should be planted in neat rows [VE-2.24; 2.276]. Instead of manure the husks (or straw?) of faba bean and other legumes can be used which not only protect the vines against the frosts but also against damaging insects [GE-5.26.6].

Parks and woods. Parks and gardens already existed in Egyptian and Mesopotamian times, well before 2000 BCE (van Zuylen, 1994). Parks were laid out for leisure and hunting. Woods were planted as windbreaks, for shade, fuel and construction. These parks and woods do not concern us here.

The specialist on trees was Abū 'l-Khayr, the 'tree-planter' or arboriculturist. His book, *Kitāb al-filāḥa* (Book on agriculture), written c.1075, is a general treatise but emphasizes tree planting, maintenance, and treatment. Many of his recommendations are to be found also in Ibn al-ʿAwwām's treatise. De Serres recognized that bees thrived in abundantly flowering orchards but he was clearly not aware of the inverse, that fertilization and fruit set prospered where bees abound [OS-5.14.391].

3.7 Harvesting, storing, processing

3.7.1 The harvest

Timing of the harvest is and was important. Harvesting should not be too late because of the risk of grain shedding and not too early, because the unripe grains may be crushed during threshing. Apparently, grain shattering was more of a problem than today. The method of harvesting is relevant, cutting only the heads with a saw-toothed sickle, mowing with a scythe, or reaping with a small type of scythe called '*zicht*' in Dutch.[147]

As timing is difficult, the choice was between an early or a late harvest. The general preference was for harvesting wheat when not yet fully ripe as it is safer, avoids lodging and grain shedding; the straw is better cattle fodder and the grains produce less bran.[148] '*When some parts of the ripening corn begin to yellow, cut all the corn, before all the barley; but much earlier the pulses must be harvested … do not wait, however, until all is ripe since if you wait that which is dry already will be lost during harvesting*'.[149] When barley is very dry premature grain shedding, a serious risk, could be countered by sprinkling it with water to improve the barley's endurance so that no grain is shed. It is an easy job that a child can do [DH-1.10.30]. Quality-wise, however, a dry product was to be preferred. '*The driest produce is the most resistant, though less in quantity; that which yellows is not only tastier to eat, but also the straw is more pleasant for the animals*'.[150]

De Serres, living in an area where the summer weather was not too reliable, was clear about the risks to the grain crop from '*impetuous winds, violent rains, and other tempestuous thunderstorms, that happen to the ripening of the grain crops, by which they are often thrown down to the soil at very great loss.*' Wheat does not wait. He recommends harvesting when the kernels are firm, but not yet hard, so that the harvest and transport losses are minimal. Only next year's seed should be cut when perfectly ripe, without bothering about losses [OS-2.6.115/6]. Agustín [AG-175] joins the choir: '… *if you wait until it is completely dry, half of it will fall on the ground by shaking, which is much more profitable to the ants than to the owner*;' The nightly moisture was used to harvest seed crops without shedding the seed due to the mechanical effect of reaping.

Harvestibility was discussed by De Serres, without mentioning such a word. No good wheat can grow when it is entangled in weeds and be readily harvested when thistles and similar plants sting the hands of the harvesters. This is another argument forwarded by De Serres for careful tillage of the soil [OS-1.2.112].

Figure 3.8 Threshing. Sheaves are on the floor. Three men thresh with flails while another man arranges the sheaves using a wooden fork. Note the brush on the left, rake to the right. The supervisor, sheltered under a lean-to, takes a drink. Buildings and wattle garden fence in the background. From: Crescentio (1511) p 48 r°. Scale 1:1.

3.7.2 The threshing floor

Threshing of sown crops effectuates the crucial transition from field crop to stored produce (Fig. 3.8). Hence, threshing received much attention from pre-modern authors. Hesiod instructed his hearers to flatten the threshing floor with a roller [HE-599]. The threshing floor, slightly convex so that rain water easily drains away, should be surrounded by a clean area (Box 3.8). A stone floor makes threshing easier and avoids damage by moles, voles and ants. The yield is better and the produce cleaner, without small stones and other impurities [DH-1.10.31].

The threshing floor should not be far from the farm for various reasons such as the avoidance of fraud. Threshing floors are at risk from fire and beasts and thus they should not be too far apart so that people can help each other. At the same

Box 3.8 The threshing floor

In Mediterranean agriculture open-air threshing floors were customary. A solid construction and annual maintenance were imperative. The construction was so good that, when travelling through Southern Spain, in 1958, I saw many deserted threshing floors, still intact, usually at exposed locations.

'The threshing floor should be on the place, in a somewhat elevated spot, so that the wind can sweep over it ; the size should be determined by the size of the harvest. It should preferably be round, with a slight elevation in the centre, so that, if it rains, the water will not stand but be able to run off the floor in the shortest line – and of course in a circle the shortest line is from the centre to its circumference. It should be built from solid dirt, well packed, and especially if it is of clay, so that it may not crack in the heat and allow the grain to hide, or take in water and open the door to mice and ants. For this reason it is customary to coat it with amurca, which is poison to weeds, ants, and moles … ' [VA-1.51.1].

'The threshing floor should be positioned in a high place exposed to the winds from below; be careful to avoid the windward side of houses and parks' and gardens.[151] *The threshing floor must be continuously wetted with amurca and levelled by a roller to keep the ants out; when all has been threshed the threshing floor must also be wetted with amurca so that it remains clean and without ants or plant growth'* [GE-2.26.5].

The threshing floor should be stamped by the men's feet, and a mix of *amurca* and animal droppings should be incorporated into the soil by means of a wooden pounder [IA-2.322]. The threshing floor should be watered and compacted by men or beasts treading it [CR-3.1].

Weeds may spoil the grain and should be controlled. Harvester ants and (field) mice were formidable enemies. Moles and toads were feared, though to the modern eye they are not detrimental to the harvested crops. ■

Figure 3.9 Underside of a tribulum *showing the sharp flint stones some 3 to 5 cm long. The stones shred the straw but also cut the kernels, explaining the excessive kernel loss. Turkey, 2011, karavanserai Sarihan near Avanos.*

time the threshing floors should be far from gardens and vineyards, as the chaff may damage the crops and cause vermin, and should also be far from bad smells. '*Adjoining this [= the threshing floor] there should be a shed (and especially in Italy, because of the changeableness of the weather), in which the half-threshed grain may be stacked under cover if a sudden shower comes up*'.[152]

There were various threshing methods: flailing (Fig. 3.8), treading out by men or animals, or using a special sledge or roller. The *tribulum* was a heavy sledge-like plank with hard and sharp stones inserted on its underside, a kind of large grater, drawn over the straw (Fig. 3.9). The farmer stands on top of the sledge. The *tribulum*, about 150 cm long and half the width, is drawn by a donkey or ox. The straw is shredded and up to 20 per cent of the kernels may get lost.[153]

3.7.3 Storage

After threshing and winnowing, the grain, including cereals and legumes, had to be cooled [CR-3.1] to avoid infestation by seed weevils.[154] A roof or other cover was needed to protect the grain from unexpected rain [CR-3.1]. Adequate storage of commodities during extended periods was essential to the well-being of farm families and city dwellers alike. Good storage contributed enormously to the luxury of the affluent. Dry storage was used for grain, figs, and dates. Vitruvius: '*The granaries are to have a concrete floor, and a north or north-east aspect. In this way the corn will not soon be overheated, but keeps good, being cooled by the draughts. For other aspects produce the weevils and other small creatures, which usually damage the corn*'.[155] Crescentio continues: Grain storage should be on the upper floor of the house in a cool, windy, and dry place, far from stench, manure, and stables. To protect the stored wheat against grain weevils and mice, leaves of wild or domesticated olive trees should be added, or coriander leaves [CR-3.2].

Selected instructions for storage are quoted here, mainly from the Geoponika. Fruit storage tried to prevent dehydration and contamination by contact between individual fruits.

Apples (and other fruits) must be collected and conserved for the winter in sawdust of fragrant wood [GE-3.13.8].

Barley. The storage of barley is not much different from that of wheat (see below). ‘*A few dry leaves of laurel with fruit and whatever type of ash, buried in the grain, keep the barley intact*’ [GE-2.30.1]. ‘*Similarly, the dry ‘house-leek’ mixed together with calamint and gypsum, with the barley*’ [GE-2.30.2]. Beware! Ageing barley becomes bitter [GE-2.30.4].

Faba beans should be harvested when the moon is full, dried on the threshing area following full moon, and stored; if wanted, sea water or salt water could be poured over them [AG-180].

Grapes were stored fresh as in Pliny: ‘…, *and there are some who advise hanging them in a granary, not near any apples, as soon as they are picked, because they say that the dust of the corn dries them best. A protection against wasps for bunches of grapes hung up is to sprinkle them with oil squirted out of the mouth*’.[156] — The mention of apples is intriguing; they produce ethylene that spoils several types of fruit by accelerating their ripening.

Freshly stored grapes gladden the wealthy; hence the extensive discussion in the Geoponika [GE-4.15]. To ensure that all grapes [of a bunch] be healthy the bunches must be cut with a very sharp knife, easily and without force [GE-4.15.2]. Some cut the rotten, dry and green grapes, if any, using scissors so that they do not damage their neighbours [GE-4.15.4]. It is excellent to dip the cut of the peduncle in fire-molten pitch [GE-4.15.4], a good though laborious method for the storage of table grapes to avoid water loss by evaporation and wound infection by fungi.

Bunches are carefully stored in straw and leaves of the plane tree (*Platanus* spp.) dried for that purpose in September [GE-3.12.2]. The bunches should be laid on the floor, separate, without touching each other, on straw, preferably lupine straw, since it is solid and dry and keeps the mice away [GE-4.15.5]. Bunches could be hung in the wheat store as the dust produced in turning over the wheat settles on the bunches and adds to their conservation or they could be treated with purslane sap.[157] Bunches could be placed in chests filled with dry sawdust or millet flour[GE-4.15.9]. Grapes were also conserved in honey [GE-4.15.21], an expensive method.

Agustín contributes a novelty; some let the bunch grow in a pot [AG-199] or place the inflorescence in a glass flask, opening down, shaded by a wooden board to avoid damage by heating. When the grapes are ripe the stalk may be cut and the flask closed [AG-202]. — This expensive storage method could be seen as a primitive way of storage under CO_2.[158]

The storage of fresh grapes boils down to three points, (1) clean the bunches from undesirable grapes to avoid infection [GE-4.15.5], (2) keep the bunches separated so that they cannot infest each other, and (3) keep the bunches dry but protect them against drying out. The same applies to other fruits with high water content.

Lemon. '*The lemon fruit can be stored for a full year when carefully covered with diluted plaster. They do not rot if stored in barley*.' [GE-10.10].

Lentil. Cato [CA-116] '*To preserve the lentils: Infuse asafoetida in vinegar, soak the lentils in the infusion of vinegar and asafoetida, and expose to the sun; then rub the lentils with oil, allow them to dry, and they will keep quite sound*.' Lentil is conserved without rotting if sprinkled with a vinegar that contains latex [GE-2.37.1]. — The origin of the latex is not mentioned, it may be from *Ferula* spp. or (wild) fig.

Pomegranate. Theophrastus on sea squill: '*it is even able to keep other things that are stored, for instance the pomegranate, if the stalk of the fruit is set in it*'.[HP-7.8.4] Fruits can be stored in sawdust of oaks moistened with vinegar [GE-10.38.6]. A dip in hot water with immediate drying also enables good storage [GE-10.38.9]. And so on. — The first two methods seem to be rather expensive though probably effective, at least against insects; the hot water will disinfect.

Wheat. '*Wheat is well protected on lofts that receive light from the east; the place must be well ventilated by north and west winds and be shut off from south and similar winds*' [GE-2.27.1].[159] '*Many roof tiles are needed so that hot air can get out and cool air in, and be protected against humidity, bad smell and noxious vapours. Above all the lofts must be far from the stables and from heat whatever its origin*' [GE-2.27.2]. '*Plaster its walls inside and outside with mud mixed with hair instead of straw and then with the foresaid earth of white clay*' [GE-2.27.3]. '*Then macerate roots and leaves of squirting cucumber for two days, mix the said mortar with that fluid and carefully plaster the inner walls*' [GE-2.27.4]. '*Some also add cattle urine to the lime to create something that kills the vermin, and pour urine over the cover of 'concrete' on the soil*' [GE-2.27.5]. '*However, the best results are obtained by moistening the mortar with* amurca*, because this not only kills all vermin but also makes the wheat more substantial and firm. Thereto some people, reducing the* amurca *by half through boiling, wet the walls with it so that, after letting it dry, they protect the grain*' [GE-2.27.7]. Similar recommendations are given by Ibn Wāfid [IW-12(30)310] and Agustín [AG-176]. — In short, smooth, plastered walls, with a pesticide or at least a pest repellent added to the plaster or whitewash; perfectly reasonable.

Various recipes are given to improve grain conservation in storage. '*Some dust ash of oak branches over the wheat, others dry cow pat, others – finally - add dry twigs of wormwood or great mugwort, or dry leaves of 'house-leek*' [GE-2.27.6].[160] '*Better than all the previous is to prepare dry clayey soil or dry, sifted leaves of pomegranate and to add this to the wheat when being stored in a proportion of about one on fifty*' [GE-2.27.8], a rather high dosage.[161] Wheat in storage can be preserved by '*Taking [wood?] of the cypress tree and leaves of brambles and grinding them and mixing them with the wheat, it will not be damaged …*' [IW-13(31)311]. — Whatever powder is used, storage insects do not like it.[162] To protect grain and especially legumes in storage, dusting and/or adding herbs is still common practice among peasant farmers in the tropics (van Huis, 1991).

'*But the most useful is to place on the soil, under the wheat, a layer of half-dry stinkwort, then a layer of wheat of about 540 litres, another layer of stinkwort, and so on until all is in store; with this storage system the wheat is conserved for many years without rotting and will maintain its weight for bread making*' [GE-2.27.9].[163] The recommendation seems valuable to protect stored grain against insect damage but one wonders whether so much stinkwort would be available for general use. '*Wheat will gain weight when* nitrum *or* afronitrum *mixed with fine soil is thrown over the heaps; this remedy also protects them from insect damage*' [GE-2.28].[164]

From Columella to De Herrera authors warn against moist grain that will engender grain weevils.[165] Columella knew that only the upper 12 cm (a palm's breadth) of the wheat bin is infested by grain weevils; do not disturb the wheat lest the whole amount is at risk [CO-1.6.17]. If the wheat is infested, the larvae should be killed by exposing the wheat to the sun during one or more days, until all animals are dead.[166] Olivier de Serres and Agustín contributed another element. '*Mix two loads of wheat with one of millet which, with its coolness/freshness can provide a defence against every worm, and later that millet will be separated easily from the wheat by means of the sieve*'.[167]

3.7.4 Yields

Agricultural yields were quite low before the period of modern agriculture with its mechanised tillage, irrigation and drainage, fertilizers, improved varieties and, finally, synthetic pesticides. Unfortunately, the old books give little information on yields. The pre-modern situation must have been comparable to that in developing countries during the second half of the twentieth century, where grain yields were in the order of 600 to 800 kg.ha^{-1}, with great variations.[168] Yield stability must have been low by comparison with present-day high-input farming, aimed at high and stable yields.

Let us look at wheat yields. In the rainfed Mediterranean area they used to be less than one tonne.ha^{-1}, a situation lasting until well into the 20th century (Table 3.1). Lack of nutrients, water, and labour were among the yield limiting factors. The 'yield ratio', also called 'seed return factor', the ratio of grain output to seed input, provides some information. This ratio, independent of area, can be given in any measure of weight or volume. Columella mentioned a seed return factor of less than four in the Italian cornlands but White (1963) argued that this yield ratio applied to the wide-spread practice of intercropping olive or grapevine and wheat.[169] White gives credibility to a wheat yield ratio in Roman agriculture of about ten, at least on well-watered fields.

Many pre-modern authors indicate seed rates but yield data are quite rare. The Geoponika specifies yield only once [GE-2.38.2]: the yield of millet may be up to about 2.7 tonnes.ha^{-1}.[170] This yield estimate seems high but not impossible. In the early Middle Ages in Western Europe the yield ratio of cereals was around three. In other words, one third of the grain harvest had to be set aside as seed for the next

Area	Period [a]	hl/ha	Yield kg/ha	x/1 [b]	Source	Comment
Iraq	- 2400		≤ 2000		Jacobsen (1958)	Following fallow
Iraq	- 1200	7	~500		de Vries & G. (2002)	
Attica	- 329/8	8-12	~560		Garnsey T7 p102	
Greece	- 300	17-34	1170-2340		Billiard (1928) p 93 [c]	
Crimea	0		700		Billiard (1928) p 93 [d]	
Crimea	0			≤30[e]		Strabo – Geogr. 7.4.6
Italy	65			<4	Columella [CO-3.3.4]	
Judea	300			5	Krauss (1911) p 189	
France	950			2	Favier (1993) p 148	
France	1150			3-4	Favier (1993) p 148	On good soils 8-14
England	~1300			5.6	Campbell (1983) p 30	E Norfolk, long term, multiple farm average
	1211-1299 1300-1350 1351-1400 1401-1450			3.7 3.9 3.8 3.8	Buisman (1996) p 614, long-term mean values for S England, annual variation from 2 to 5.	
England	1935-1964		3200-2200 2000-1200		Farm yard manure [f] No manure	
Iraq	1960		1000-1600		Wirth (1962)	Varied according to ownership
Jordan	1965		170-1000		Serjeant (1995)	East Bank, according to rainfall

Table 3.1. Some wheat yields in Mediterranean and West European countries from before the Green Revolution, arranged per period.
[a] Approximate times.
[b] Seed return factor. On average this was 3 to 4 with great variation, down to 0 when a calamity happened, up to 10 or more on very privileged soil.
[c] Recalculated by Billiard (1928) from [HP-8.7.4].
[d] Recalculated by Billiard (1928) from Strabo's Geographika 7.4.6 (production without cultural measures).
[e] Top yield in level, fertile land; yield probably exaggerated.
[f] Broadbalk field – 30 years' means, with farm yard manure since 1840, equivalent to ~220 kg.ha^{-1} N, and without any manure. First figure for first year after fallowing, second figure for fourth year after fallowing. Data given for comparison, yields are relatively high due to the modern wheat varieties used.
Source: Rothamsted Experimental Station (1966) p 17, Table 2.

season. The 'Fleta', a commentary on English Common Law from c.1290, states that wheat growing is cost-effective only when the yield ratio is three at least. '… *Moreover, if the produce of the barns does not yield more than three times the seed, the lord will not gain profit therefrom, unless it be by selling corn dear*'.[171]

For Western Europe, in the 9th and 13th century, Slicher van Bath (1963a) quotes yield ratios of wheat varying roughly from two to four.[172] If so, two to three hectares would be needed to feed one person with grain.[173] An estimate of likely consumption is 175 (150-250) kg of grain per person per year, or 0.48 kg per person per day in Attica (Greece) around 320 BCE.[174]

Chapter 4

Harmful agents

Production constraints are of a biotic or abiotic nature. Human constraints have been dealt with separately. Some major abiotic constraints have been indicated in passing only. Biotic constraints were many. Mammals, birds and reptiles, insects and other invertebrates, pathogens and plants that may damage the crops had to be controlled. They are presented in an ordered way to show the great diversity of problems that the pre-modern farmers had to face. Insects were highly visible and could be handled to some extent. Nutritional disorders and plant diseases were known. The symptomatology, as handed down in writing, rarely allows an identification of the harmful agent according to modern standards. Pests and diseases of pre-modern times may not be the same as those of today.

'How many accidents do farmers – or rather all men – fear that crops may suffer from the weather, or the soil, or harmful animals?'

Aurelius Augustinus (354-430 CE) in *De Civitate Dei*.[1]

4.1 Production constraints

4.1.1 Human constraints

Saint Augustine continued '*As a rule, they feel safe when the crops are gathered and stored. Yet, as we know, sudden floods have sometimes put the workmen to flight and swept the finest harvest out of the tarns and destroyed it*', thinking of pre- and post-harvest production constraints. These constraints are of three kinds: abiotic, biotic, and human. Human constraints such as war, political strife, conflicts about land and water rights, and neglect are not discussed here.[2]

Theft is another aspect. Hesiod advised having a sharp-toothed watchdog to protect the harvested crop against thieves: '*And get a jagged-toothed dog – do not be sparing with its food, lest some day-sleeping man [a thief] steal your things from you*'.[HE-604] Varro went into detail '*the enclosures which are constructed for the protection of the farm as a whole, or its divisions*' [VA-1.14.1]. Columella: The kitchen garden plot should be enclosed by walls or thick-set hedges, '*impervious both to cattle and to* *thieves*'.[CO-10.27ff] The Mishnah takes another approach in *Peah* 2.7: '*If a field was reaped by gentiles or by robbers, of if ants nibbled the crop, or if wind or cattle broke it down, it is exempt from Peah*', Peah being a religious tax.[3]

The Salian Law of about 510 describes several forms of theft of agricultural products and the respective punishments, as for example '*He who enters another man's field and in theft takes something away and has been found, shall be liable to pay six hundred denarii … [in addition to returning what he took plus a payment for the time its use was lost].*' [4] Minor problems of a human nature could be settled by mutual agreement among farmers, guided by custom or law. The Byzantine 'Farmer's law', written about 740 CE (Ashburner, 1912), will have been the guideline in the Byzantine realm. How was a conflict about water to be settled? A miller may divert a stream's water needed for irrigation (#83): '*If the water which comes to the mill leaves dry cultivated plots or vineyards, let him make the damage good; if not, let the mill be idle.*'

Theft of seed was feared, too. '*The threshing floor should not be far from the farm, as much for the ease of transportation as to reduce the risk of fraud,…*' [PA-1.36.1]. Emperor Charlemagne warned his stewards in 812 '*Every steward is to take care that dishonest men do not conceal our seed from us, either under the ground or elsewhere, thus making the harvest less plentiful…*'.[5] Walter of Henley wrote c.1286: '*(When corn is issued) of thy barne have thou a faythful man that can charge the reeve in a just manner [measure well] for often tymes a man shal perceave that the barnekeeper and the garneter doe ioyne together to do falslye*'.[6]

The Fleta (ca.1290), commenting on English Common Law, stated: '… *Let the threshers and the winnowers be watched lest they steal any of the corn in their shoes, gloves, wallets, purses or satchels, hidden near the barn*.'[7] — Apparently, medieval personnel could not be trusted in the north western European area. Personal and administrative controls were to be strict.

Somewhat later Ibn Khaldūn, the famous Muslim geographer, wrote '*The farmer is a poor devil*' and '*the peasant is particularly crushed by the taxes*'.[8] He could have added looting and market fees. Two centuries later De Herrera warned of the need to watch the faba bean fields against itinerant workers who stole the beans when they were still green. Agustín provided a remedy: '*To avoid that passers-by and tramps eat the [chickpeas, faba beans] you have to spray them five mornings before sunrise with water in which is soaked the seed of bitter cucumber and wormwood*' which makes them bitter and unpalatable '*but later the bitterness added to them, the dew removes it completely in five other mornings*'.[9] — The persistence of the deterrent is low!

Thieves have always been present. Tusser (1557) rhymed:[10]

'Some pilfering thresher will walke with a staffe,
will carrie home corne as it is in the chaffe,
And some in his bottle of leather so great
will carry home daily both barley and wheat.'

Olivier de Serres wanted to see the grain fields fenced off to protect them against humans and animals [OS-1.2.105]. Long-lived green walls, flowering splendidly in spring, should with their thorns defend the crops against men and animals [OS-6.30.676].

Theft of grapes was a major problem. Crescentio advised planting cultivars with a nasty taste that nonetheless produced an acceptable wine [CR-4.18]. Plant pathologists know that in the Bordeaux area a bluish substance was sprayed on the vines along the roadsides to deter thieves. Millardet (1885) developed the sticky stuff into his famous Bordeaux Mixture that successfully controlled the downy mildews on grapevine and potato — In the 1980s I inspected a potato field in the Netherlands. A suspicious farmer came up to see what I was doing. He told me that people from the city came along by car to collect their winter supply free of charge.

4.1.2 Abiotic constraints

When Saint Augustine expressed his concern, quoted above, he added gloomily: '*… mothers have devoured their own children when driven to such incredible cruelty by the frantic desire for food*'.[11] Among the abiotic constraints are the occasional floods and droughts, severe frosts and excessive heat-waves. The Biblical drought that compelled Jacob to send his sons to Egypt for grain is well known (Genesis 42). The practical answer is risk management but this answer is of no avail in the face of unusual, extreme conditions, among which are thunderstorms and hail.

The abiotic constraints are many, heavy rainfall and hailstorms, floods and droughts, severe frost and excessive heat and, in the Mediterranean area, soil salination. Overviews are found i.a. in Buisman (1995, 1996) and Leguay (2005). Only a few examples touching on plant disease can be presented here.

Salination is a major risk where evapotranspiration exceeds precipitation. A serious problem in Mesopotamia, it is also a concern of the Mediterranean area as Xenophon writes [XE-20.12]: '*And again, all the ways of treating the soil when it is too wet for sowing or too salt for planting are familiar to all men – how the land is drained by ditches, how the salt is corrected by being mixed with saltless substances, liquid or dry*.' Plato knew that salt could cause malformation and disease in plants.[12]

Ibn al-ʿAwwām: '*Saltish soil be tilled in early winter, following the autumn rains, then cover the soil with straw preferably of faba beans.[13] The rotting straw softens the soil so that, toward spring, the moisture loaded with salt does not rise to the surface. Don't touch the soil until next fall. Then apply cattle and horse manure, and sow barley because it does not root deeply*'. And elsewhere '*Barley sown on brackish soil, during several consecutive years, attracts the salt and frees the soil*'. Beets will also desalinate the soil.[14]

A special case of salt damage is seen in the Low Countries, where the dikes could give away during a heavy north western storm. Then, the land was flooded by sea-water which stayed for days to months, soaking the soil with salt. Crops perished in the flood, and they did not grow on the flooded salty soil. It took three to four years with good rains to restore the soil and produce good crops again, as in Friesland after the flood of the year 1234. In 1477, in contrast, the inundation was followed by drought with disastrous consequences for the Frisians.[15]

Fog. In the Cologne area (Germany), in 1438, grain and vine were promising but fogs in July caused disease in the corn, spoiled the wheat and all fruits, and the grapes blackened and dropped off. The word disease was mentioned, but we are left in the dark as to its cause(s).[16] In later literature black stem rust in wheat has been frequently associated with late 'fogs' but in the literature on the Middle Ages examined thus far 'rust' has not been mentioned.

Rain. In North West Europe excess rain was a risk. In the village of Egmond (NL) the continuous rain during the summer and autumn of 1163 caused rotting of grain crops, beans and peas in the field.[17] In France the steady rains in August and September of 1195 caused sprouting in ear and pod.[18] In 1258 the valley of the River Seine (France) experienced excessive summer rains. The grain could not be harvested in time and sprouted in the ear. The soil was so soaked that sowing became impossible.[19] Nothing suggested pathogenic fungi but one can imagine that *Fusarium* and *Septoria* type fungi were rampant.

Hail. Hailstorms were feared because they could be terribly destructive. Hailstones as large as pigeon eggs were mentioned frequently, and occasionally as large as goose eggs. They could also be large and angular, wounding people and killing sheep. On the Saturday following Ascension Day 1308, hail destroyed the standing harvest and the vineyards around Paris.[20] Damaged grapevines would become susceptible to infections but, with the harvest lost, deep pruning may have been the answer.

4.1.3 Biotic constraints

Biotic constraints form the core of this book. Little is known about pest pressures in the pre-modern era. It is likely that pests with high dispersability (rusts) or motility (locusts) were the most damaging but occurred only incidentally. In fact, we hardly know what pests and diseases were common. Correct identification of the pests and diseases based on pre-modern descriptions is a real problem.

The terminology of that era does not satisfy the needs of the modern crop protectionist. Mammals causing damage were known, of course. Locusts and ants were held in awe. Many insects were described as 'fleas' or 'lice', terms that seem to be interchangeable insofar as they attack plants. I consider these terms to refer primarily to aphids, possibly also to flea beetles. Fungal diseases, as we know them today, were indicated as rusts and rots. The term 'rust' was used not only for the rust fungi now known as *Uredinales* but also for red, brown, or yellow flecks of various kinds on different crops.[21] Bacteria and viruses were unknown and the symptoms they caused fell in the categories rust, rot, and jaundice.

Apparently obvious identifications may be questionable. Just one example: a disease on peach and some other tree species called 'curl' is easily identified as leaf curl, caused by a fungus. Indeed, this disease occurs in modern times on peach in the Mediterranean area.[22] However, the most characteristic symptom in Ibn al-ʿAwwām's [IA-1.595/6] description is the association with a small, unpleasant smelling ant. This is probably a 'milking ant' which – in turn – points to aphid-induced leaf curl, a common symptom due to aphids crowding among the leaves that emerge from the bud.

Old descriptions of pests and diseases provide few clues as to the identity of the causal agents. Symptoms, usually non-specific, depend on host species and variety as well as on the species and variety of the noxious agent, on the nutritional status of the host plant, and on weather effects. Symptoms may vary over time and there is little reason to assume they were exactly the same in antiquity and in recent times. Retrospective identification of noxious agents is thus a risky affair. Furthermore, the hypothesis that damaging agents and the damage done were the same, then and now, is attractive but not necessarily correct. Dark & Gent (2001) cautioned: '*Pests and diseases must have been a driving force in agrarian change for several millennia, and cannot be ignored in attempts to understand the history of agriculture*.'

4.2 Mammals

4.2.1 Cattle

Cattle, when in the right place, are a treasure but in the wrong place become a nuisance. '*For certain kinds of animals are the foes of plants, and even poisonous, such as the goats of which you spoke; for they destroy all young plants by their browsing, and especially vines and olives*'[VA-1.2.18]. Costly vineyards must be protected against browsing cattle. '*You must also weave hedges, and keep out all cattle .... wild buffaloes and pestering roes, sheep and greedy heifers*' [VE-2.371]. Virgil recommends willows and Spanish broom for hedges that also provide shade and honey [VE-2433]. The voracious goats were feared. '*For no other crime is it that a goat is slain to Bacchus at every altar, ...*' [VE-2.380].[23] Pliny is more explicit. '*Also to prevent any creature from injuring the foliage by noxious nibbling they recommend sprinkling the leaves with cow-dung mixed with water every time there is a shower of rain, as the rain smears the poison of the mixture over the tree*;' [NH-17.47.267]. — Here, the notion appears of redistribution of a 'chemical' by rain. Foliar fertilization may have been a side effect.

Straying cattle may damage the crop and thus Byzantine law ruled: '*If a man finds an ox doing harm in a vineyard or in a field or in another place, and does not give it back to its owner, on the terms of recovering from him all the destruction of his crops*, ...' .[24] Ibn al-ʿAwwām [IA-1.574] quotes spokesmen explaining how to protect fig trees and other trees against browsing by cattle and camels. A simple means is to pour diluted dog shit over the endangered leaves, though it may cause some bud burning. An alternative is to boil the head of a fat goat and to treat the leaves with the greasy supernatant, or to dip old rags in the supernatant to hang them in the trees. — The dog shit is easily washed off by the rain whereas the goat grease, serving as a sticker, keeps longer.

Grapes can be protected from roaming animals by winding thorny shrubs around the vine trunks, a forerunner of barbed wire to protect the grapes, The vineyard should be protected from browsing animals by ditch and spiny hedge or by dry-stone walls. Gardens have to be fenced off against cattle and other animals, and surrounded by thorn-bushes [AG-46]. Cattle are fond of oats and should be kept out, only lupine needs no guards since lupine plants are too bitter to be eaten by animals.[25] In north western Europe fields were often protected by fences, temporary or permanent, hedges, walls or ditches.[26]

4.2.2 Wild boars and domestic swine

The following description is given of how wild boar can be caught. Near the place where they roam you sow a plot of sorghum, around which you make a high and strong fence of branches. On one side you leave the entrance open and at the opposite side you keep the fence low. Next to the low fence and outside the plot you dig a pit. When the sorghum is ripe many swine will come and enter the plot. Whoever wants to do so comes to the plot, unarmed, positions himself at the entrance, shouts and makes a lot of noise. The frightened swine, who do not see where they can get out unless over the low part of the fence, fall in the pit behind it that they could not see [CR-10.33]. Hunting wild boar was the privilege of nobility throughout the Middle Ages but farmers could trap wild boar by means of concealed pits when the animals damaged the crops. Poaching was common.[27] — In the Netherlands today wild boars can be quite damaging in young forest plantings and in vegetable gardens.

Domestic pigs can be useful in the vineyard during winter time, grubbing up the weeds and trampling noxious animals. They should be kept out of the saffron garden where they are most damaging [OS-6.28.662].

4.2.3 Foxes

'*The foxes often share the harvest with man in such vineyards, and if the land breeds mice the yield is cut short unless you fill the whole vineyard with traps*, …' writes Varro [VA-1.8.5]. He referred explicitly to the vineyards in which the ground serves as a bed for the grapes, then common in parts of Asia. Vineyards could be seriously damaged by foxes, as the Talmud mentions, grapes being a delicacy for foxes.[28] Such vineyards, and the accompanying fox and mice problems, also occurred in medieval Western Europe.[29] — The problem disappeared when, later, all grapevines were supported by tree, stake, or trellis.

4.2.4 Rabbits and hares

'*But there are scarcely any destructive animals, except the burrowing hares [= rabbits], by some called 'peelers'; for they both damage plants and seeds by eating the roots. This pest occurs throughout almost the whole of Iberia*, …' wrote Strabo.[30] Rabbits introduced into the Balearic Islands became a terrible pest. They destroyed the crops and their burrows undermined and damaged the houses. The desperate inhabitants sent an envoy to emperor Augustus (63 BCE – 14 CE) in Rome to ask for assistance from the military. The problem was solved in another way, in Spain and on the islands, by introducing ferrets from Libya. — An early version of biological control.

When rabbits were introduced into England shortly before 1200, farmers protested for some decades.[31] Rabbits became a pest in Belgium in 1398. In 1403 the sea dike at Knokke was so undermined by the rabbits that it succumbed to the pressure of the sea.[32] De Serres warned against the damage done by rabbits nibbling the early shoots of the vines. Burning sulphur is a deterrent. Short sticks are dipped in molten sulphur at one end, like matches, the other end being thrust into the soil. The rabbits disappear immediately. Their return is prevented by fumigating every four days until the branches have become too hard to be palatable [OS-3.5.179].

Hares rarely figure in the old records. Around 1014 CE, during a period of military unrest, gardens north west of Cordoba were devastated by hares. In response a diminution of land rent was awarded to the growers.[33] — Even today rabbits and hares can damage tree nurseries and vegetable gardens.

4.2.5 Voles (field mice)[34]

The Bible mentions an outbreak of voles (1 Sam. 6:4): '*Then said they, What shall be the trespass offering which we shall return to him? They answered, Five golden emerods, and five golden mice, according to the number of the lords of the Philistines: for one plague was on you all, and on your lords*'.[35] The Talmud advises placing traps where voles go.[36] Until the mid 20th century voles were a continuous danger to European agriculture. Dutch records on excessive damage by voles span the period from the Middle Ages until the late 1950s, when I saw old alfalfa fields riddled with holes, as if machine-gunned. — The vole problem came to an end by frequent tillage with heavy machinery, combined with field and farm hygiene.

Aristotle described the excessive reproductive capacity of voles defying all control methods. '*The phenomena of generation of the vole are most astonishing, both for the number of the young and for the rapidity of recurrence in the births. The rate of propagation of voles in the fields and the destruction that they cause, are beyond all telling. In many places their number is so incredible that but very little of the cereal crop is left for the farmer; and so rapid is their proceeding that sometimes a small farmer will one day observe that the time for reaping has come, and on the following morning, taking his reapers afield, he finds his entire crop devoured. Their disappearance is unaccountable: in few days not a mouse will be there to be seen*'.[37] Aristotle suggested several control methods, smoking out, unearthing by men or swine, use of foxes and ferrets.

The Geoponika did not mention the last three methods but it recommended several forms of baiting [GE-13.4/7]. Voles will not touch seeds treated with ox gall [GE-13.5.1], a frequently recommended deterrent. Ash of cork oak placed in the holes will kill the voles [DH-4.7.217] – which seems unlikely.

Crescentio paid considerable attention to saffron, an important crop in his time and area [CR-10.35]. Underground, mice love saffron corms. Traps can be set and the saffron beds should be surrounded by deep ditches filled with water.

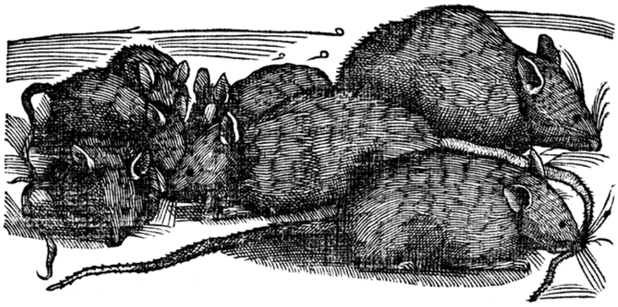

*Figure 4.1 MVRES. Whiskers and long tails characterise the house mouse, a pest of the cheese (S: '*pestilentia del queso*'). Drawn by de Laguna. From: Dioscorides (1566) p 161: Cap LXII De los ratones. Scale 1:1.5.*

4.2.6 Mice

The common house mouse is descended from wild forms living in the Near East (Fig. 4.1).[38] Mice are killed by means of baits consisting of barley meal with lenten rose or seed of squirting cucumber with lenten rose, bitter cucumber and barley flour [GE-13.4.1]. They flee from copper sulphate, oregano, celery seed, and incensed love-in-a-mist [GE-13.4.2]. '*If you want to blind the mice, mash spurges, mix it with barley meal and* mulsum, *place it with them so that they eat it and get blind*' [GE-13.4.4].[39] '*Some prepare a cookie with hellebore, bark of dog's-bane pulverized and sieved, barley meal, egg and milk, and place it in their holes*' [GE-13.4.7]. '*Mice will flee with a censer of haematite stone and burning green tamarisk*' [GE-13.4.8]. Mice do not like lupine straw used in storage of fruits [GE-4.15.5].

4.2.7 Rats

The reference here is to the black rat, a good climber which may cause serious storage losses.[40] The Middle Ages knew professional rat-catchers, of whom the Pied Piper of Hamelin (Germany) still survives in folk tales. He was active during a rat outbreak in 1284. In actual fact the rat-catchers used traps and poisoned baits, not pipes. They carried a long pole, a cage with living rats in the top and dead rats hanging from it. Rat-catchers lived at the seamy side of life, rarely receiving good payment. However, a man who delivered 567 rats caught around the town of Arnhem, Netherlands, was well paid. The Duke of Guelre gave him eleven guilders, a sizeable sum at the time, on Christmas Eve of 1404.[41]

De Serres warns that potatoes should be stored carefully beyond the reach of rats since they are very fond of its 'flesh' and devour everything in a short time [OS-6.10.513]. Wine casks and other winemaking equipment should be kept free of animals because their droppings do great damage. A difficulty is to keep the rats out. If a rat enters a cask it will starve to death as it cannot get out anymore. Therefore, a long stake should be placed diagonally in the barrel so that the rat can climb out [OS-3.6.182].

The brown rat arrived in Europe during the 18th century. Whereas dogs are used to control the brown rat, cats help to control the black rat.[42]

4.2.8 Moles and mole rats

These animals lead a solitary subterranean life. Moles are carnivores and dig with their feet. Mole rats are herbivorous rodents digging with their teeth. Their present-day geographic distribution is mutually exclusive, or nearly so. Both types produce typical 'molehills'. Control methods of moles and mole rats may be the same.

Mole rats live in the Balkans, Asia and Africa, but not in Italy or Spain.[43] The Geoponika mentions the spalax (G: ἀσπάλαξ = σπάλαξ), translated by Dalby as mole rat and by Meana as mole. The Geoponika describes the situation in the Levant and the Byzantine area so that the version mole rat has priority. The genus *Spalax* has many species among which the Balkan mole rat and the lesser mole rat.

'If you want to eliminate mole rats you have to make a cookie with white hellebore, crushed and sieved bark of dog's-bane, flour and eggs, dip it in wine and milk, and place it in their holes' [GE-13.7.1]*. An alternative to baiting is fumigation. 'Make a hole in a narrow jar [a karyíne] or any similar narrow earthen pot, fill it with straw, sufficient cedar resin and sulphur, and in the place where the mole lives, closing the other small openings so that the smoke does not leave there, place the lower part of the jar over the largest opening through which the air enters, and adjusting it somehow to the opening so that all the smell of the cedar resin and the sulphur enters with the smoke and suffocates the mole; and blocking in this way the hole of every mole and repeating the operation eliminates them all'* [GE-13.7.2].

Moles live in the cooler parts of Europe, including northern Italy and northern Spain. Thus, the Roman authors will have concentrated on the European mole. Palladius [PA-4.9.4] advised hunting moles with tamed weasels [ferrets?], but other methods were available: baiting, fumigation, and trapping. Agustín repeated these methods and, referring to Albertus Magnus, added '*place leek or onion in the mole track and the moles will run away from the stench*' [AG-159]. He contributed other novelties '*If you don't want the moles to burrow and dig in your garden, or field, keep there a plant called mole weed* (yerva de los topos) *or, by another name, castor oil plant* (higuera infernal)' [AG-160]. A clarion call in the mole tunnel puts the moles to flight so that they can be caught and killed. Tusser (1557), the English farmer-poet, rhymes for November:[44]

'Cut molehills that stand
so thick vpon land.'

He advocated control by spade, still done but not very effective.

4.2.9 Large red mice (?)

In the autumn of 1410 people from the town of Liège (Belgium) saw that large red mice destroyed the buckwheat and other crops.[45] These 'mice' may have been European water voles that occasionally form locally destructive plagues. Alternatively, they may have been dormice.

4.3 Birds and reptiles

4.3.1 Which birds?

The occurrence of bird species varies with geography and climate, topography and – important here – land use.[46] In the old books the bird names were seldom specific; their use may have been different from ours. Antique illustrations only show game birds and some water fowl in recognizable detail. Medieval pictures often show a flock of birds on or above a field, the birds being uniform in size and relatively large. One might think of pigeons, rooks, or – near the coast – gulls. The type of damage described helps to distinguish birds that eat primarily (grain) seeds, green leaves, insects, or fruits.

Birds are a pest of cereals at two stages. The crop is vulnerable after sowing during germination and emergence, and again during ripening up to harvest. In the first stage pigeons[47] are the main culprits, in the latter sparrows.[48] Starlings are inculpated too.[49] Manuscript illuminations clearly demonstrate the threat of birds.[50]

4.3.2 Bird damage at sowing time

Grain was broadcast. Most kernels rolled down into the broad furrows drawn by the scratch plough (§ 3.6.2). Hesiod: '*Just a little behind [the ploughman], let another man, a slave holding a mattock, make toil for the birds by covering up the seeds*' [HE-470]. The slave had to break the clods and cover the seed. The grain could also be covered by cross-ploughing, the routine until mouldboard and harrow came into use. Medieval artists illustrated the use of harrow and rake.[51] Agustín recommended covering wheat seed by four inches of soil to protect it against birds [AG-174].

Virgil [VE-1.119] complained about damage by geese, who love the young shoots of grasses and cereals, a damage well-known to present-day Dutch farmers.[52] To protect the grain field the Geoponika advises: '*If you sow a bit of wheat mixed with hellebore around the perimeter of the field, the birds will not harm the sown [crop]*'; they will die. Collect the dead birds, hang them on a stick by their feet; no bird will come anymore [GE-2.18.9]. Seed disinfection with 'sempervivum' juice should protect wheat seed [GE-2.18.1] and vegetable seeds [GE-12.7.3] against birds — These are somewhat useless recommendations, but stretching strings between poles in the field or the ploughman's little son making a noise to chase the birds will work.[53]

Ibn al-ʿAwwām lists several recipes to fight off the birds. (1) '*Boil wheat with red arsenic and then throw it to the birds; those who eat it will die without being able to fly away*'.[54] (2) '*Boil lentils in chalk water, let them dry, bring it in reach of the birds, they will be stunned when they eat it*'. (3) '*Soak asafoetida and wheat in water, let the grain dry, feed it to the birds, and those who eat it will go off in a swoon not being able to move*'. (4) '*Soak barley and black hellebore in wine, let the grain dry, throw it to the birds, and those who eat of it will faint*'. (5) *Rub asafoetida with water and honey, soak wheat in it for 24 hours, leave the grain to the birds that will be dizzy without being able to fly again*' [IA-2.338].

Tusser (1557) gives more sensible advice:[55]

'No sooner a sowing, but out by and by,
With mother or boy that Alarum can cry: [Alarum = alarm]
And let them be armed with sling or with bowe,
To skare away piggen, the rooke and the crowe.' [pigeons, rooks, crows]

Scarecrows were mentioned by Abū 'l-Khayr.[56] From about 1300 onwards, records indicate that boys were employed to chase the birds from freshly sown grain fields, and men with dogs or men throwing stones. Threads could be fixed between poles to keep out magpies and crows.[57] In gardens the seeded plots could be covered with thorny brushwood to reduce bird damage.[58]

4.3.3 Bird damage at harvest time

At harvest time bird damage in cereals was reduced in two ways. The early wheat and barley types had covered grains, with glumes adhering to the kernels. Covered grains are less attractive to birds than naked grains. The older naked grain types had awned ears, as is still common in the semi-arid and sub-tropical zones. One advantage of awns is to deter birds, as Cicero knew, '… *and, when it has emerged from the sheath, the ear comes to view with its grain in ordered rows and protected by a palisade of spikes against the attacks of the smaller birds*', or '*a fence of beard*' [NH-18.8.53]. [59] Timely harvesting of grain crops, '*when the crop is even golden yellow*' [CO-2.19], was imperative to avoid excessive drying, grain shedding, and plunder by birds and other creatures. To ward off the flights of starlings or sparrows that harass common and Italian millets bury a plant at the four corners of the field, said Pliny who did not know the name of the plant [NH-18.45.160].[60]

Millets pose a problem, an undesirable form of share-cropping. '*Both millets are accessible also to small birds, in what can only be called joint ownership with the grower, inasmuch as they are contained in thin skins, leaving them unprotected*'[NH-5.18.53]. Millet, very attractive to birds, should be watched after seed set to avoid damage by pigeons, sparrows, and other birds [DH-1.22.41].

The classical way to scare birds at harvest time was to make a lot of noise or just to shout [VE-1.156]. Virgil allowed bird snaring even on festive days [VE-1.269]. Konrad von Megenberg (~1350) complained about the starlings as '*in autumn they cause great damage in the vineyard*'.[61] Crescentio advised protecting the ripening grapes against starlings by a contraption with a tower in the centre of the vineyard and cords to connect the tower with all parts of the vineyard. The tower should be manned by a young boy who pulls the strings [CR-4.18]. In medieval France scarecrows and nettings were used to protect the grapes against bird damage.[62]

To avoid bird damage in fruit trees the Geoponika offered a twofold idea '*Smear garlic onto the pruning knife with which you shorten the branches, and hang garlic in the tree*' [GE-10.80].

Since ancient times, treating the pruning knife has been a kind of panacea protecting trees and vines against many evils including caterpillars and night frost. The Roman agronomists recommended garlic on the pruning knife to deter caterpillars from harming the vines.[63] What else could be applied to the pruning knife? Suggestions include caterpillars boiled in oil, fat of a bear or a billy-goat, frog blood: an incoherent set of items connected only by belief in magic. Matters could be simplified by just treating the whetting stone.

The modern experience in western Europe is that bird damage is no longer serious in large fields but remains a problem when fields are few and small, and when fields are situated near residential areas. My experimental plots at Wageningen University suffered greatly from bird damage unless completely netted. The carbide gun, that replaced Hesiod's boisterous boy, made a tremendous noise to which, unfortunately, the birds got used but not the citizens living nearby.

4.3.4 Reptiles

Snakes have been feared everywhere and at all times. They do not damage the crop but they may hide in the crop and harm the labourers. Plant protection measures and snake deterrents were discussed equally. The recipes are repetitive.[64] Snakes can be chased away by burning evil smelling substances such as *gálbano*, the gum of *Ferula*, sulphur [GE-13.8.2], or the hairs and hoofs of goats. Snakes dislike the smell of garlic [NH-20.18.50]. Snakes and the pomegranate tree have a natural antipathy so that snakes will not sojourn at the foot of this tree [IA-1.255]. '*Snakes can be caught by burying pickling jars around the farmstead, all reptiles will fall in them; you must seal the jars hermetically, and burn them beyond the perimeter*' [GE-13.8.12].

Snakes may endanger resting harvesters and Gargilius Martialis has the answer.[65] '*Burned wild thyme chases snakes and other venomous animals. Therefore it is added to the meals of the harvesters so that they, overcome by sleep when tired, can rest without danger, protected against these animals which at that time turn loose with their poisonous bites*'.[66]

4.4 Insects[67]

4.4.1 Locusts

Today, the best known locust species is the desert locust that ravaged North Africa, the Mediterranean area, and the Near East (Fig. 4.2, 4.3). Anno 2010 it still is a risk. An equally voracious species is the migratory locust, once common in Europe but now nearly extinct. The texts seldom make it possible to choose between the two species.[68]

'*What one locust left, the second has gnawed off, what the second left over, the third has cut away, and what the third left the fourth has devoured completely*' (Joel 1:4).[69] Joel 2:2/11 continues with a highly poetic description of a locust plague that probably took place in Canaan around 400 BCE.[70] Locusts appear at irregular times and unexpected places all around the Mediterranean, deep into Mesopotamia but also in Europe: Hungary, Germany, France, Italy, and the Netherlands.[71] They may destroy all green plant parts. They induce a deadly fear in growers and rulers alike.

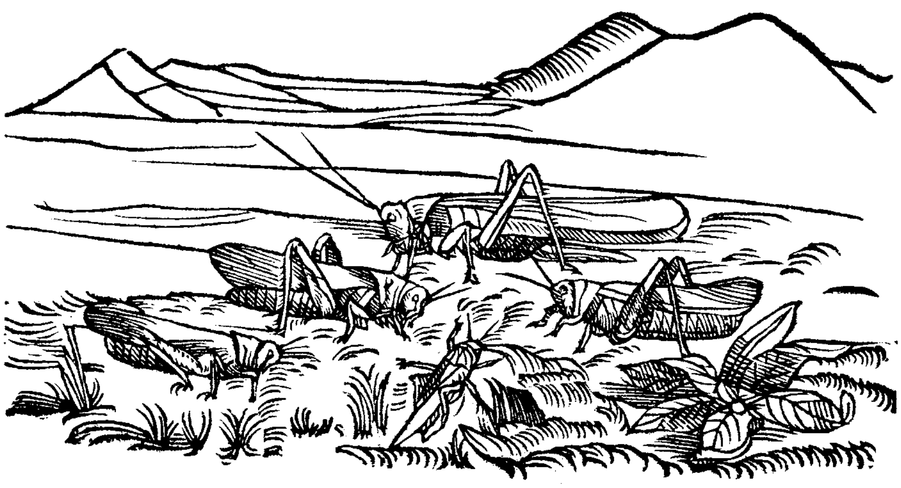

Figure 4.2 Locusts and hoppers eating the last grasses in a desolate landscape. Drawn by A. de Laguna (S: langostas = locusts). From: Dioscorides (1566) p 150. Scale 1:1.

Livy in his history of Rome mentioned several locust outbreaks.[72] Just one example from 125 BCE: '*… locusts appeared in a great swarm in Africa; when hurled into the sea by the wind and cast up by the waves, they produced by their unbearable stench and deadly effluvium a serious plague among livestock at Cyrene, and eight hundred thousand persons are reported to have been carried off by the putrefaction*'. Pausanias knew about three locust (or grasshopper?) invasions on Mount Sipulos in western Turkey; The locusts disappeared once as a result of a strong gust of wind, another time they were killed by a heat wave following rain, and a third time they were destroyed by a sudden cold spell.[73]

The Chronicle of Edessa wrote that in the year 499 CE '*many locusts appeared, but did no great damage that year; but the herbage grew again*'.[74] Apparently the locusts laid their eggs around Edessa. In March of the following year, 500 CE, '*… the locusts came upon us out of the ground, so that, because of their number, we imagined that not only had the eggs that were in the ground been hatched to our harm, but that the very air was vomiting them against us, and that they were descending from the sky upon us*'. About the hopper bands: '*When they were only able to crawl, they devoured and consumed all the Arab territory and all that was of Rasian and Tella and Edessa*'.[75] A terrific famine followed that could not be alleviated by imports because of poor roads and deficient means of transportation. The famine was accompanied by pestilence that killed young and old, poor and rich.

Mass collection of insects by hand is timeless.[76] '*You will chase the locusts if you prepare a* garum *with them, dig holes and soak these with the* garum' [GE-13.1.7].[77] '*When you come before the rise of day, you will find them in the holes plunged in sleep; how to kill them is your business*' [GE-13.1.8]. The situation is clear-cut, at night the locusts rest on the soil, immobile because of the low temperature at soil level. At sunrise they will warm up and start moving. You can collect them when immobilized, if the swarms are not too large.[78] Albertus Magnus: '*When they proceed simultaneously they destroy all the fruits of the earth. In many regions therefore the law requires to go to*

Figure 4.3 Amber knife haft in the shape of a locust, 7 cm long, 2nd century CE, from a grave found in Heerlen (NL). Dutch National Museum of Antiquities at Leyden (NL), inventory number 1 1930/3.20. Scale c.1:1.

the field at certain times and to extirpate the locusts. Benumbed by the nightly cold they remain immobile in the early morning. After sunrise all advance with spread wings, in swarms without leader maintaining a tyrannical community without a law'.[79]

Palladius came up with simple advice: '*If a swarm approaches just hide away within the house and the swarm will pass*' [PA-1.35.12]. Chase away like with like is a typical homeopathic recipe, as in Palladius: '*Burn some conspecifics amidst a swarm of locusts and they will leave*' [PA-1.35.12].[80] A preventive spray had to be applied just in time. *But if they [the locusts] appear suddenly, …, they will touch nothing that is sprayed with bitter lupine or squirting cucumber boiled with brine, because they will die instantly*' [GE-13.1.3].

Several medieval outbreaks of the migratory locust are on record. The extensive reed marshes along the rivers, in present-day Ukraine and along the lower Danube, must have been the main breeding grounds. The swarms roughly followed the valley of the Danube in their westward trek to fan out over southern Germany and northern Italy. In 873 the migratory locust affected large parts of Europe. Flying swarms produced a faint noise. The sky was darkened as during an eclipse. During a two month period, wave after wave passed over western Germany. Swarms advanced at a rate of 10 km per day. They moved westward to reach the ocean near Brittany (France).[81] These locusts, very large, the thickness of a thumb, with six (sic!) wings and stone-hard teeth, devoured everything green, including bark and branches of trees, over fourteen square miles within one hour, according to a Frisian (NL) chronicle.[82] The wind blew them into the North Sea, but the flood washed them ashore, where they spread an unbearable stench that led to fearsome pestilence killing many people.[83] — The chronicler may have read Livy, who told a similar story.[84]

Famous outbreak years were 1337/9. In 1338 the inhabitants of Bolzano (Italian Tirol) declared a War on Locusts according to a contemporaneous chronicler. '*All able bodied men were drafted. All from 10 to 60 years should turn out, curious. In this war especially the women distinguished themselves. The major weapon was the broom; second came sticks, shovels and similar locust killing equipment … Everywhere the European warriors killed the Asiatic foes; people returned home in a flush of victory, the courageous women had reason to take pride*'.[85] Again, the species must have been the migratory locust.

Agustín recommends sprinkling locusts with salt water boiled with bitter lupine, or with wild cucumber [AG-159]. Similarly, they can be killed by nailing bats in the tops of the highest trees. You can also get a similar result by burning the same locusts and with the stench of the burned ones the living ones will flee or die. — Bitter lupine or – better – wild cucumber applied to hopper bands may have an insecticidal effect. The creepy bats were thought to frighten not only people but also locusts.

4.4.2 Grasshoppers

Grasshoppers are usually harmless but some species may become gregarious and damaging under favourable conditions. Megenberg wrote '*About grasshoppers. There were quite many in the period of emperor Louis and they wreaked great damage as I wrote in another part of this book on starlings*'.[86] Megenberg probably referred to the emperor Louis of Bavaria. In that case his 'grasshoppers' will have been migratory locusts that ravaged southern Germany in the period 1337/9, during Louis's reign.

For Mediterranean agriculture the most important grasshoppers are the Italian and Moroccan grasshoppers. The Moroccan grasshopper lives on sunny hillsides at 500 to 1000 m altitude. After two successive dry springs it becomes gregarious and massive swarms of hoppers migrate to the valleys eating nearly everything green on their way, with great damage to agriculture. The action radius of a swarm is 60 km per year at most, and swarming can continue for years. Great damage is recorded from 16th century Spain. The Moroccan grasshopper lays its eggs only in undisturbed soil. After mass egg-laying swarms of sparrows and groups of crows seek out the eggs. To disturb the grasshopper eggs people followed the birds and tilled the field by plough, spade, or hoe.[87]

4.4.3 Mole-cricket

A chapter title of the Geoponika says '*On the locust without wings*' using the word βρούχος [GE-13.2]. This word is usually translated as 'hopper', the apterous stage of the locust. I interpret this apterous 'locust' to be the mole-cricket. Only one line of text is devoted to this rather special insect, occurring in Europe and North Africa, and living mainly underground. It eats invertebrates and plant roots and it can be quite damaging in gardens on light soils. The text indeed suggests an animal living in the soil. '*Around the trunk of the grapevine, next to the root, bury three grains of mustard: when these have been planted, they kill the mole-cricket with their smell*'. Ferrante Imperato (Napels, 1599) wrote that the farmers call the insect '*guoffolo*', much hated by gardeners because of the damage done to plants by eating the roots.[88]

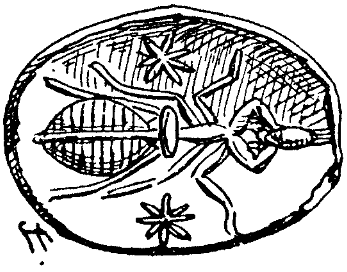

Figure 4.4 Harvester ant carrying a grain of wheat, drawn after a cornelian gem in a collection at Berlin. From: Billiard (1928) p 439 Fig. 59. Scale c.2:1.

4.4.4 Ants

Two kinds of ants are relevant here, 'milking' ants that collect honeydew from phytophagous insects, and 'harvester' ants collecting seeds. The ants in Proverbs are harvester ants (Fig. 4.4). Proverbs 6:6 '*Go to the ant, thou sluggard; consider her ways, and be wise*:' and 6:8 '*Provideth her meat in the summer, and gathereth her food in the Harvest*.'

Harvester ants. In Palestine harvester ants were so important that the Mishna provided rules on the ownership of the content of the 'ant-holes' and on the tithe to be paid on the ants' harvest: '*Produce that ants carry off to ant holes belongs to the farmer. After the harvest, produce at the bottom of ant holes belongs to the farmer and that which is on top belongs to the poor*'. Of course, an alternative opinion existed too, offered by Rabbi Meir: '*All this produce belongs to the poor, for in a case of doubt, produce is deemed gleanings*'.[89]

The zeal of the harvester ants was appreciated: '*If ant-holes have been present throughout a night near a heap of corn that was liable to Tithe, what is found in them is also liable, since it is manifest that the ants dragged away [the corn] throughout the night from produce completely harvested*'.[90] The amounts carried away must have been considerable since they merited religious regulation.[91]

Harvester ants are by far the most damaging ants (Bromiley, 1989). In the Mediterranean area they belong primarily to the genera *Atta* and *Messor.*[92] They collect seeds from grasses, legumes, and cereals, and carry these to their nests as a winter store, covering fair distances with well-marked paths. Some species of *Messor* cast the chaff and bite off the radicle to prevent germination, as was known already in antiquity [NH-11.36.109].[93] Aesop's fable 'The grasshopper and the ants' tells how harvester ants might go out in winter time to dry their store of grain when dampened by a spell of rain.

The Geoponika wanted to keep the ants away from the threshing floor. '*If you pour resin of cedar around the ant hills the ants will not invade the threshing floor*' [GE-13.10.2]. Ants can be killed in or chased from their hills. '*The ants all die if you mix latex from Cyrene with oil and pour it over the ant hill*' [GE-13.10.6].[94] '*… you will make the ants leave their hills by pulverizing brimstone and oregano and scatter it alternately over the ant hills*'.[95] '*If you burn snail shells, or shellfish shells, with styrax [resin], crush it and powder it over the ant nests you will let the ants leave their holes*'.[96] Grain piles can be protected: '*Ants will not touch the grain piles when you surround them by a circle of white earth [chalk or lime] or with wild oregano*' [GE-2.29; 13.10.3]. — Ant respiration may be impaired by the powdered marl or chalk so that the ants avoid passing the circle. These 'magic circles' may hold for several days as long as it does not rain.[97]

Milking ants belong to various genera**.** In fruit trees they are both a symptom and cause of damage. They are a symptom in as far as they prefer to visit trees with many sucking, honeydew producing insects such as aphids, whiteflies, scale insects (Coccidae), and even spider mites. They cause damage as they stimulate the sucking insects to produce more honeydew and interfere with normal parasites and predators of these insects, as for example the black ant.

'*Ants are also pests to trees; these are kept away by smearing the trunks with a mixture of red earth and tar, …*' [NH-17.47.266]. Fruits are protected by treating the trunks of the trees with smears comparable to modern grease bands: '*You will keep the ants away mixing ox bile and pitch with* amurca *and applying it to the trunk. The same result also give ochre and pitch mixed and applied to the trunk*' [GE-13.10.15]. 'T*he ants will not touch the plants if you smear bitter lupine pounded with* amurca *on their trunks, or rather bitumen pounded or boiled with oil*' [GE-13.10.7]. '*Some dissolve latex in vinegar, smear it on the trunks and put it in their holes*' [GE-13.10.9] .[98] Ants can be shaken out of the tree or chased away by placing soot, charcoal, sawdust of oaks, separate or together, at the foot of the tree [OS-6.27.661].

In the Mediterranean area it is still common practice to give the trunks of fruit trees a wash of chalk or ochre to keep the ants off the trees.[99] These white or pink washed trunks have a nice ornamental effect too (Fig. 4.5). To protect trees against ants and to prevent them climbing the fig tree, domesticated or wild, polish part of the stem, a span [23 cm] high, with a polished object or stone, all around the

Figure 4.5 Olive trees with a 'pink-wash' on a farm in Algeria, 1980. The treatment looks nice and it may protect the trees from ants.

tree, until it is very slippery; below it trace a circle with red ochre that the ants do not dare to approach [IA-1.594].

Here are some miscellaneous recipes. The Talmud advises controlling an ant nest by bringing in [conspecific] ants from a nest at least one parasang (> 5 km) away; the populations do not recognize each other and thus will start a fight with mutual killing.[100] The Geoponika makes several suggestions. '*If we tie ivy rich in leaves to the trunks of the grapevine, not only the ants but also the beetles will crowd in its shadow within a short time, and they can easily be collected to be killed*' [GE-13.10.10]. A piece of homeopathic advice: '*When ants are burned the others will flee from the stench*' [GE-13.10.1; 13.10.13]. More questionable is another recommendation. '*Some people hang the fish called 'raven black' on the tree, and eliminate the ants*' [GE-13.10.16]. De Herrera has a fresh idea. In the vineyard ants can be enticed by placing the horn of a very old ram with many convolutions; as the ants will go there they are easy to kill [DH-2.15.75].

Ibn al-ʿAwwām makes several suggestions [IA-1.566]. (1) Plant three or four plants of a herb called *as'samra* near every grapevine and all birds, insects, worms and so on will leave. (2) Take mountain oregano, wild rue, and sulphur, rub them together and powder the mix around the ants' nest, and the ants will leave for ever. The smell of this preparation is fatal to all small animals, ants and insects in general. (3) Take squirting cucumber, bitter cucumber, fresh cow dung, add water, take your time to knead all this together until the mix is fluid as water, and pour the compound over the trunk and branches of vine during three consecutive days, and you will see that all 'green flies' and other insects perish and do not return. — The last suggestion, with the extract of the two cucumbers as the insecticide and the cow dung as the sticker, might be effective. Candidates for the 'green flies' are the greenish weevil and the hazel leafroller.

Probably it is the greenish weevil, which De Serres indicates with the word '*coigniaux*'. His remedy is hand picking of the rolled leaves, which is easiest at sunrise. Even better is to shake the foot of the grapevines and to drown the insects in a bucket with water. The eggs are destroyed by trampling [OS-3.5.179]. The description is not unambiguous so that I hesitate about the identity of the insects. — Apart from insecticides, modern recommendations are pruning the trees up to 60 cm high, cutting branches that contact ground or neighbour trees, applying grease bands, weekly powdering of sulphur on the soil around the trunks, and ploughing the vineyard in summer to kill the queen of the ants' colony. Such measures probably have a long history.[101]

Household ants. The ants meant here are neither typical harvester nor milking ants but rather the 'household' type searching for food in homes and storage areas. '*The ants will not touch the pot with honey, even if open, when you surround it with white wool or draw a circle of white earth or ocre around it*' [GE-13.10.8]. — Magic circles again, but here on a small scale.

4.4.5 'Fleas'

The Greek uses the word ψύλλᾰ (G: psulla = flea), in the English version of Theophrastus translated as 'spider', in the Spanish version of the Geoponika as 'fleas' and 'lice', and in the English version as 'flea beetle'. All these versions, to which I add the translation 'aphid', are probably correct according to the individual case.

Oregano and garden rocket are supposed to keep this vermin away. '*These crops [pumpkins and cucumbers] will not be damaged by aphids if you plant near to them branches of oregano when these are still young, since they destroy the existing aphids and they do not allow the birth of others*' [GE-12.19.9]. And: '*… sown nearby, [garden rocket] is beneficial to all vegetables.*' [GE-12.26.3]. Garden rocket is also mentioned by Agustín [AG-158]. Aphids will not harm the vegetables if you plant garden rocket in their midst. You can also kill them if you take strong vinegar, and henbane, tempered together, and spray the vegetables in which you have the aphids. — Is garden rocket a deterrent or a trap plant? The spray is insecticidal and possibly vinegar is a temporary deterrent.

Vegetables can be protected by fertilizing them with ashes or pigeon manure [GE-12.4.1/2]. — It is not clear whether these are powdered over the plants or added to the soil. In the first case they may be more effective than in the latter.

To avoid aphids the vineyard should be completely free of weeds as they originate there [DH-2.15.74]. Do not plant faba beans in foggy places, says de Herrera [DH-1.18.37], as these generate aphids. — The first statement does not make sense to me. The link in the second statement is probably that such places are foggy because they are shielded from the wind; aphids do not like wind-exposed places. Today, aphids in faba beans still can be a problem.

4.4.6 Grain weevils

Pharaoh's dreams (Genesis 41) were interpreted by Joseph: seven years of plenty will be followed by seven years of famine. During the plenteous years Joseph collected large stocks of wheat which he distributed among the populace of Egypt during the lean years. The story goes that the stocks of the Egyptians were destroyed by worms, whereas Joseph's reserves were saved. Joseph had the wheat stored in the ear, much to the dislike of the weevils.[102] He had treated the bins with the dust from the soil on which they had grown.[103] Partial confirmation of the story is found in the Qur'ān. '*He said "Sow as usual for seven years, and after reaping leave the corn in the ears, except the little you need for food*"'.[104] — Dust of whatever kind damages grain weevils, especially in dry climates. Both methods of wheat preservation are quite effective, dusting, and storage in the ear.

According to the Mishna, dusting the wheat in storage was practiced in Judea during the first centuries CE. It is not clear what material was used, dry soil, sand, or even saltpetre. Dust was added at a rate of 1: c.200 vv. Among the threats were the mealworm and the European grain moth.[105]

The Mediterranean grain harvest took place in a hot season. The threshed and winnowed crop was to be cooled overnight before being brought to the stores in order to avoid seed weevils: in wheat primarily the granary weevil, and in legumes various *Bruchidae*. For long-term storage the grain was to be cleaned once more '*for the better is it scoured the less it is preyed upon by weevils; but if it is intended for immediate use, there is no need for a second cleaning and it is sufficient that it be cooled in the shade and so carried to the granary*'.[106] The idea of overnight cooling is repeated several times.[107]

Columella details the protection of lentils against weevils that may already attack the seed in the pod. Immediately after threshing the seed should be sunk in water. The empty seeds come to the surface. The healthy seeds must be dried in the sun, rubbed with bruised silphium root, dried again, cooled, and stored in sealed bins or pots. The alternative is to mix the seeds with ashes [CO-2.10.16].

'*Some use underground caves as granaries, the so-called* 'sirus' *as in Cappadocia* [VA-1.57.2].[108] Corn can also be stored in pits or trenches, with straw on the bottom. '*Some people recommend building elaborate granaries with brick walls a yard thick, and moreover filling them from above and not letting them admit draughts of air or have any windows;*' '*Many moreover forbid turning over the grain to air it, as the weevil does not penetrate more than four inches down, and beyond that the grain is in no danger*'.[109] De Serres too records deep pits ('*fosses profondes*') accessible by ladder [OS-2. 7.124] — Stored seed produces CO_2 that cannot escape from the pits, and kills the weevils.[110]

4.4.7 Other insects

Columella mentions root cutting pests that kill mature crops [CO-2.9.10]. He recommends seed treatment with sap of 'house leek' or wild cucumber mixed with water. More effective than this preventive measure seems a curative one, to '*sprinkle the furrows with this same liquid or with unsalted lees of oil, when the crop begins to be infested, and so drive off the destructive creatures*.'

Beetles. Many species of beetles are harmful to crops (Fig. 4.6), for example cockchafers that occasionally appear in incredibly large and threatening numbers.[111] '*The beetles will not damage the vines if you moisten the specific beetles and wet with them the stone on which you will sharpen the pruning knives*' [GE-5.49.1; 13.16.1]. '*You will put them [the beetles] to flight if you burn* galbanum *with old cattle manure, and similarly you will chase them by burning the roots of squirting cucumber*' [GE-13.16.2].[112] — The first, homeopathic, recipe will not work, but the second recommendation sounds better. Not all beetles are damaging; beneficial beetles exist too.

Crescentio [CR-4.18] mentioned small green and blue worms that appear with the grapes and bore into the young shoots, which die. They should be collected and trampled underfoot or burned. — The worms are the larvae of the hazel leaf-roller.[113]

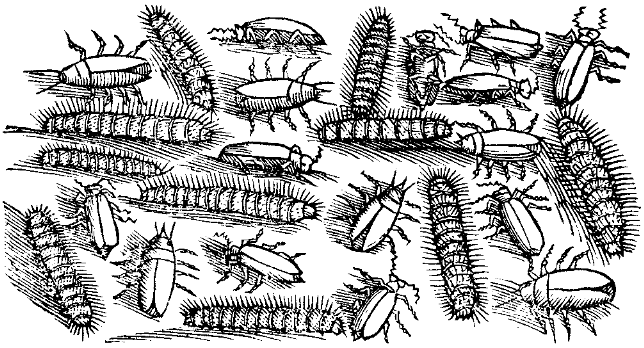

*Figure 4.6 Beetles and caterpillars. Leg numbers are not always accurate. These green beetles are a real pest of the gardens (S: '*verdadera pestilentia de los jardines*'). The caterpillars are of the pine processionary. The combination of these species in one figure is curious. Drawn by A. de Laguna. From: Dioscorides (1566) p 155. Scale 1:1.4.*

Caterpillars. Deuteronomy 28:39 quotes one of Moses' curses for disobedience. '*Thou shalt plant vineyards, and dress them, but shalt neither drink of the wine, nor gather the grapes; for the worms shall eat them.*'. Trees can be grease-banded. Cato gave detailed instructions for making a grease consisting of *amurca*, bitumen and sulphur, heated in a copper vessel. [114] '*Apply this around the trunk and under the branches, and caterpillars will not appear.*' Pliny repeats Cato's recipe: '*In a similar manner to prevent a vine from breeding leaf-rolling caterpillar he advises boiling down two gallons of lees of olive-oil to the thickness of honey, and boiling it again mixed with a third part of bitumen and a fourth part of sulphur, ...this preparation is to be smeared round the bases and under the arms of the vines, and that will prevent caterpillar*' [NH-17.47.264]. — This may refer to the larvae of the hazel leaf-roller or similar beetles. Pliny added another but probably less effective suggestion [NH-17.47.267]: '..., *but as a protection against caterpillars in particular they say that a woman just beginning her monthly courses should walk round each of the trees with bare feet and her girdle undone*'.

The Geoponika does not mention manual collection explicitly. To avoid caterpillars '*put some ash from burning vine stems in water for three days and sprinkle the vegetables with it*' or fumigate with a mixture of bitumen and crude sulphur [GE-12.8.1], and so on.[115] '*Destroy present caterpillars mixing equal parts of urine and amurca, and boil it on the fire, then let it cool down and sprinkle it so over the vegetables*' [GE-12.8.3]. The recommended product might effectively deter or even kill caterpillars but the next product has homeopathic value only, unless the dill decoction has an effect. '*But even if you take caterpillars from another garden, cook them in water with dill, let it cool down and sprinkle it over the vegetables, you will kill the present caterpillars*' [GE-12.8.4].

Cobweb. '*There is in addition a malady peculiar to olives and vines, called cobweb* [L: araneum, G: ἀράχνιον = arachnion], *when the fruit gets wrapped up in a sort of webbing which stifles it.*' [NH-17.37.229]. Cobweb on olive destroys the fruit.[116] — I can see three possible explanations: (1) The web spun by some mite species. (2) The communal web spun by the caterpillars of ermine moths. The nests of these moths are to be hand-cleared during winter by a skilful labourer [OS-6.27.661]. (3) Bodenheimer's observation in Palestine of large spiders covering the olive trees in places by the hundreds.[117] I prefer explanation (2).

'Grubs'. Tree care was important and protection against insect larvae was necessary. Apart from some less interesting remedies two might have been effective. One is the planting of the poisonous sea squill near the roots of a tree, '… *if you lay bare the dry and diseased roots [of olive trees] you should know that those guilty are the grubs living at the base of the roots, that you can eliminate in various ways, but primarily by planting sea squill at their side.*' [GE-9.10.10; 10.90.1]. The other is to lay bare the infested roots and to wet them with pigeon manure [GE-10.90.5]. Agustín echoes these opinions.

Hawk moth. Wood boring caterpillars were a nuisance, '*For these produce their young in timber, as the worm called the 'horned worm' does in trees, having bored and scooped out a sort of mouse-hole by turning round and round*' [HP-5.4.5]. The 'horned worm' clearly is the caterpillar of a hawk moth. Worms in trunks and branches of trees, apple trees foremost, can be recognized by a moist discharge of the bark; they should be cut out and killed, and the wound should be covered with fresh cattle or pig manure, new chalk, and sage, fixed by a rag and willow twigs [OS-6.27.661]. — One of the culprits is the goat moth of which the caterpillars tunnel trees.

Hornets were feared for their aggressiveness. Around 1400 BCE, they assisted Joshua, leader of the Israelites, in conquering Jericho, being feared more than either sword or bow. '*And I sent the hornet before you, which drove them out from before you, even the two kings of the Amorites; but not with thy sword, nor with thy bow.*' (Joshua 24:12). Hornets eat ripening grapes and fruits, causing considerable damage.

The European hornet, an insect predator primarily, can, however, destroy fruits such as apples and grapes.[118] What can be done so that the wasps do not touch the vines, the grapes, and other fruits? '*Take olive oil in your mouth and, by blowing, spit it over the vines, the grapes and other fruits*' [GE-4.10].[119] An original piece of advice is to wrap the bunches in combed wool: the wasps will not come nearby, the vapours of the grapes will be dispersed, and [fresh] air will get to the bunches.[120] Agustín [AG-203] makes a similar suggestion: wrap the grapes in paper or, still better, in linen rags since the paper rains off.[121]

Maggots. Theophrastus mentions fruit fly infestation in many crops. The olive fruit fly is easily recognised. '*Now the worm which infests the olive, if it appears below the skin, destroys the fruit;*' [HP-4.14.9] and '…*the grubs always ruin the fruit; in the olive they ruin the fruit if they get out into the flesh, since the flesh is consumed,*' [CP-5.10.1]. Elsewhere, the reader might think of root maggots.

Scale. A noxious but profitable insect is the kermes scale on oak, used to produce a crimson dye. Theophrastus described a red gall on the kermes oak: '*Besides the acorn it carries kind of scarlet berry*'.[122] No damage is recorded. '*Nevertheless the holm-oak challenges all these products of the hard-oak on the score of its scarlet alone. This is a grain, and looks at first like a roughness on a shrub, which is the small pointed-leaf holm-oak. The grain is called* scolecium, *'little worm'. It furnishes the poor in Spain with the means of paying one out of every two instalments of their tribute*' [NH-16.12.32].[123]

Termites are rarely mentioned. Healthy and fast growing plants are fairly safe but under drought stress plant roots may be attacked. Termites may have been pests sometimes, in some places, mainly in the Near East. To get rid of termites and worms in a tree one has to dig up its roots down to their tip, and wet trunk and roots with pigeon manure dissolved in water [IA-1.545].

Wasps are said to be a problem up until today. Many wasps go for sweet exudates of plants but do not affect undamaged fruits. See also above under hornets.

White grubs are the larvae of cockchafers, living in the soil for some three years and eating plant roots. An apparently soil-borne insect attacking faba bean was tentatively identified as white grub. Dipping the seed for three days in olive oil could prevent the damage due to the *djessem* [IA-2.87]. — The identification is uncertain but not unreasonable. I have seen terrific infestations of sugar beet, not a pre-modern crop, by white grubs in Algeria, 1980 (Fig. 4.7, 4.8).

Figure 4.7 Sugar beet in Algeria. 1980, with white grub damage (the blackish patches where no crop is growing. Note that sugar beet is a 'modern' crop, not yet grown in pre-modern times.

Figure 4.8 White grubs in a field of sugar beet, Algeria, 1980. The grubs, up to 4 cm long, are the larvae of the cockchafer. The grubs live underground for about three years. The damage to the roots is evident.

4.4.8 Other invertebrates

Scorpions do not harm plants but they instil fear among the people. Treatments were usually the same as against snakes. They are chased away by the smell of garlic [NH-20.18.50] (§ 4.3.4).

Slugs. '*Slugs breed among the vetch, and sometimes small snails which are produced from the ground and eat away the vetch in a surprising manner*' [NH-18.44.155]. In the medieval vineyards of France women and children had to hand pick slugs (and snails).[124]

Snails. Hesiod [HE-571] mentioned the appearance of the snails as a signal that spring has set in: '*But when the house-carrier climbs up from the ground on the plants*, …'. These snails can be very damaging to grasses and cereals.[125] Vetch is attractive to slugs and snails, and the snails can be very damaging to vetch [NH-8.44.156]. We jump two millennia and consult with Agustín [AG-159] who recommends avoiding snail damage in the vegetable garden by surrounding the plants with chimney soot or the sediment of fresh olive oil. His alternative is to sow chickpea around the plots. Snails might damage the grapevine buds, especially when a mild winter favoured early hatching of the eggs.[126] — This advice could be effective in the short run.

4.5 Plants

4.5.1 Weeds

'I went by the field of the slothful, and by the vineyard of the man void of understanding; And, lo, it was all grown over with thorns, and nettles had covered the face thereof …' Proverbs 24:30-31.

Cursing himself, Job prayed '*Let thistles grow instead of wheat, and cockle instead of barley*' (Job 31:40). This prayer inversed a reasonable practice. Fields covered by thorny vegetation were considered suitable for wheat, and – when covered by [annual?] weeds – for barley. Syrian farmers thought that 'gold glistens in thorny soil'.[127] In the Near East vegetation run wild could point to good agricultural soil.

Weeds are the number one enemy in organic farming, today as in the early days. Repeated ploughing is the prime remedy (§ 3.6.2). Theophrastus knew why intensive ploughing was needed. Weed seeds germinate earlier and are more powerful than seeds of domesticated crops. But there is hope: '*whereas if the grain comes up first many of the weeds are choked and destroyed, and in general their seeds do less harm*' [CP-3.20.9]. The Parable of the Sower in St. Matthew (13:7) shows resignation: '*And some [seeds] fell among thorns; and the thorns sprung up, and choked them*;'. Virgil lamented '*Soon too, on the corn fell trouble, the baneful mildew feeding on the stems, and the lazy thistle bristling in the fields; the crops die, and instead springs up a prickly growth of burs and caltrops, and amid the smiling corn luckless darnel and barren oats hold sway*'[VE-1.153/6].[128]

Specific data on crop loss due to weeds are difficult to find.[129] An English manager in east Kent complained about losses during the 1360s and 1370s due to '*chronic weediness*' or '*excessive fall of mildew in the summer*'.[130] Child labour is recommended for weeding because boys bend down easily to pull up the weeds [GE-2.2.2]. Repeated ploughing was mentioned explicitly as a form of weed control [VE-1.69]. Crescentio devoted a section [CR-2.20] to weed control. Again, repeated ploughing was crucial. Fields with heavy soil have to be broken when all the weeds have appeared but have not yet set seed. Rushes, grasses, and ferns have to be killed by frequent ploughing.

Tusser (1557) on '*Maies husbandrie*', the field tasks in May:[131]

'In Maie get a weede hooke, a crotch and a gloue,	[crotch = forked tool]
and weed out such weedes as the corne doth not loue:	[loue = love]
For weeding of winter corne now it is best,	
but June is the better for weeding the rest.'	

The farmer-poet continues:[132] [freat = eat away, damage]

'The May weed doth burn and the thistle doth freat,	[mayweed = chamomille]
the fitchis pul downward, both rie and the wheat.	[fitches = vetches]
The brake and the cockle be noisome too much,	[brake = bracken]
yet like vnto boddle no weede there is such.'	[boddle = cornflower?]

On the grain fields of north west Europe the major weeds were thistle, wild oat, wild mustard, field penny-cress, darnel, coltsfoot, and field bindweed, roughly in this order.[133] The thistle was the greatest foe of wheat, a real calamity on the lighter soils, '*pricking the hands of the harvesters*' [OS-2.5.112].

As weeding was so labour-intensive, partial weeding (or relative cleaning) could be practiced in the open fields, sparing the deep-rooting and bushy broom and furze. A secondary benefit may then be the nitrogen fixed by these leguminous plants.[134] De Herrera was not against partial weeding but he advised pulling out the plants which take up too much space, such as thistle, mallow, and chicory.[135]

Bindweed. The term *orobanche* is ambiguous; it might be bindweed, cleavers, or dodder. Here we opt for dodder.

Cleavers. Theophrastus himself indicates the difficulty in sorting out some companion species of cultivated crops. '*Some plants of this character* [= companion species] *evidently attach themselves to more than one kind of crop, but, because they are specially vigorous in some one particular crop, they are thought to be peculiar to that one, as 'vetch-strangler' (dodder) to vetches and bedstraw to lentils. But the former gains the mastery over the vetches especially because of the weakness of that plant; and bedstraw is specially luxuriant among lentils; to some extent it resembles dodder, in that it overspreads the whole plant and holds it fast as it were in coils, for it is thus that dodder strangles the plant, and this is the origin of its name ('vetch-strangler')* [HP-8.8.4]. This bedstraw is cleavers (G: ἀπρίνη, aprinè). Fitzherbert (1534), calling it tare, wrote '*tare is the worst weed, which never appears until June, and especially when there is great wetness, or little before. It grows most in rye, like vetch, but much smaller, and it will grow as high as the corn, and with its weight will pull it down flat to the earth, and devours the ears. …. By early mowing and drying it will make good fodder*'.[136] Here, 'corn' must be read as 'wheat'.

Crown Vetch (Axeweed). '*the weed called crown vetch affects the lentils*' [GE-2.43]. Crown vetch is a very competitive weed that should be eliminated.

Darnel (cockle, tare, or false wheat. Fig. 4.9). Darnel, a cultivation follower that evolved more or less simultaneously with wheat, was already common in the early Bronze Age. In a Phoenician wheat store of ca.1000 BCE darnel was a major impurity (Kislev, 1980). Theophrastus (c. 300 BCE), describing the degeneration of wheat into darnel, knew its poisonous effects [HP- 8.7.1]. The dangerous effects of darnel, a kind of inebriety and finally blindness, were well known in antiquity.[137] Maimonides thought darnel to be a minor wheat type that was called the perfidious

Figure 4.9 Aira (G: Αἶρα) = Lolium temulentum L. = *darnel 'wich growes amongst wheate', a remarkably precise picture. Spikelets edge-on, alternating, correctly arranged in one plane with rachis. Enclosure of stem by leaf auricles sometimes exaggerated. From: Dioscorides (1934) p 133 #122. Scale 1:1.6.*

because of its transmutation in the soil.[138] '*Called darnel, it spoils the wheat, and if mixed in the bread, blinds the consumers*' [GE-2.43]. De Laguna calls darnel, that grows among barleys (!?) and wheats, '*a very serious disease and contagion*'.[139]

Ferns. The Romans, whose ploughs failed to uproot it with their shallow shares, considered bracken a curse.[140] Bracken dies in two years if you do not allow it to produce leaves [NH-18.8]. The Geoponika advises controlling the male fern and other weeds in July: '*Lupine in flower crushed with poison hemlock and applied to the cut roots left over will parch them*' [GE-3.10.7].[141] This is one of the few cases of chemical weed control found in pre-modern agriculture. Ferns can be defeated by frequent ploughing. Also, ferns are suppressed by densely sowing faba beans or lupines and when they appear you cut them with the point of the sickle, they will decay within a short time. Crescentio advises cleaning a heavily weeded field by densely sowing faba bean or lupine to outcompete the weeds, and ploughing the lupines before flowering.[CR-2.20]

Grasses. Several grasses are mentioned, especially *agrostis*, a name that refers to deep-rooting and mat-forming grasses such as dog's-tooth grass and creeping couch grass. '*Barley is affected by bastard wheat*' [GE-2.43], probably goatgrass.

Ivy. 'Overgrowth with ivy' could kill trees [HP-4.16.5]. '*Trees …; they are also killed by ivy binding them round, …*' [NH-17.37.239]. Ivy was sometimes considered a parasite of trees, sucking their sap. The idea was carried forward by Albertus Magnus and Megenberg.[142] — Ivy can damage trees but it is not a parasite.

Mosses. September is the month to clean old pastures from mosses [CR-12.9]. Mosses on trees should be removed patiently with a blunt knife or a piece of wood [OS-6.27.662]. — Today mosses can still be a nuisance in lawns, but is this the case on fruit trees?

Nettles. Tusser (1557) in England:[143]

> *'Where plots full of nettles be noisome to eie,*
> *sowe therevpon hempseed, and nettle will die.'*

Outcompete the nettles by hemp.

Rushes should be '*turned up with a spade after having first been broken with two-pronged forks*' [NH-18.8].

Thistles. One, and only one single crop protection action became so preponderant in people's minds that it was painted on parchment and hewn in stone. Thistle cutting became 'action of the month' for June in English and northern French calendaria of the 11th to 13th century, on an equal footing with grain mowing representing July and hog slaughter depicting December. Calendaria were part of church sculpture to educate the commoner, of manuscript illuminations to edify the elite, and of baptismal fonts to initiate the new-born.[144] The promotion of thistle cutting to one of the twelve major agricultural operations is convincing evidence for the everyday reality of the thistle problem in the early Middle Ages**.** '*The thistyll is an yll wede, roughe and sharpe to handell, and freteth away the cornes*

Figure 4.10 Cutting thistles with 'crotch and hook'. The stem of the thistle, held in place with a metal fork on a stick (left hand), was cut with a curved knife on a stick just under the fork (right hand). The procedure, ergonomically convenient, prevented flowering and subsequent seeding but not continued growth. The flowering thistles are large in comparison with the cereal crop that is summarily indicated. The picture represents July in a Psalter from N France, c.1180, National Library of the Netherlands, The Hague: ms 76 F 13, p 7v. Scale c.1:1.

nygh it, and causeth the sherers or reapers not to shere cleane' wrote Fitzherbert in 1534.[145] — There remains the question of how the problem faded away.

Thistle control was valued at up to two per cent of total harvest costs.[146] One illumination shows a man holding in his left hand a stick with a small fork at its end to fixate the thistle stem, and in his right hand a stick with a small sickle-like knife at its end to cut that stem; a laborious procedure (Fig. 4.10). Fitzherbert described the handling of '*forked stycke and hoke*', crotch and hook.[147] '*And with these two instruments, he shall neuer stoupe to his warke*'; no stooping! Fitzherbert preferred a pair of tongs to uproot the weeds after a rain shower, but warned that the weeder should not tread upon the corn, certainly not after shooting. — When young I participated in thistle control by pulling the plants up with a pair of wooden prongs, about one metre in size, specially designed for the purpose**,** a nasty exercise.

Thistle control should be done late, not before flowering, and according to Walter of Henley after St John (24 June, about the summer solstice), because otherwise every cut stem will grow three new stems.[148] The Fleta writes: '*The bailiff and the reeve should therefore see for themselves, before the time of reaping, that the crops are weeded and that thistles, spurrey, and similar noxious weeds are entirely destroyed. This, moreover, should be done after the feast of the Nativity of Saint John [24 June], for, if anyone should do it before that day, from one stem two or three shoots will spring, and so damage will be doubled*'.[149]

Thistles were a major nuisance on fallow land. Olivier de Serres warns that a good grain harvest is not possible when the crop is choked with weeds since thistles prick the hands of the harvesters. Infestation of next year's crop is to be avoided [OS-1.2.112]. '*To get rid of the weeds, and the roots, and to remove them from the arable land one should plough thoroughly, and very deep, primarily the thistles which have to be controlled before the first rains … since their nature is to start growing promptly when they feel some moisture from the sky*' [AG-168].

4.5.2 Parasitic plants

Chokefitch and dodder are often confused in old texts. Theophrastus' description points to *Orobanche* spp: '*The plant which springs up right from the roots of cumin and the plant called broom-rape which similarly attaches itself to 'ox-horn' (fenugreek) are somewhat more peculiar in their habits. Broom-rape has a single stem, and is not unlike …, but is shorter and has on the top a sort of head, while its root is more or less round; and there is no other plant which it starves except fenugreek. These plants grow in light and not in fat soils*; …' [HP-8.8.5].[150] Dioscorides's description of ὀροβάγχη leaves little doubt: chokefitch.[151] He wrote '*It is used as a vegetable both raw and boiled, being eaten out of a flat dish just like asparagus,* …'. De Laguna called the chokefitch, that lives at the expense of others, '*pestilential*' especially on vetch (Fig. 4.11).[152]

Dodder can still cause problems in the Mediterranean area (Fig. 4.12, 4.13). Pliny: '*There is a weed that kills off chick-pea and bitter vetch by binding itself round them, called orobanche*'.[153] '*Dodder ruins faba bean and chickpea by entangling them*' [GE-

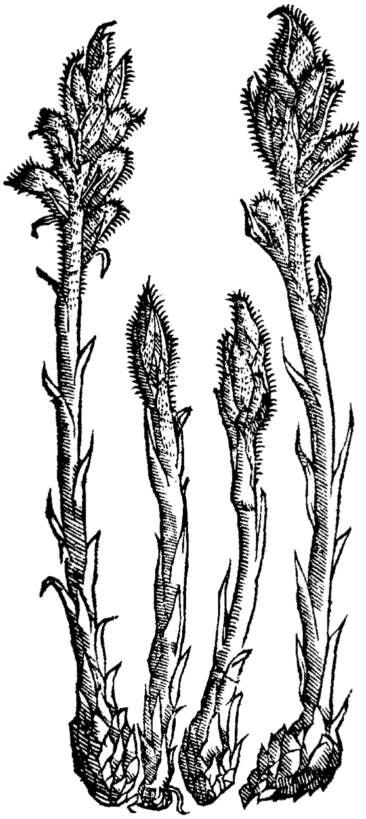

Figure 4.11 Chokefitch = broomrape, as e.g. Orobanche crenata Forskål. This plant parasitizes members of the pea family. The stems with reduced leaves are rendered correctly, the inflorescences, drawn too short, give a fair idea. Drawn by A. de Laguna. From: Dioscorides (1566) p 225. Scale 1:1.

Figure 4.12 Dodder, as e.g. Cuscuta europea L., here parasitizing flax. 'cuscuta vel podagra lini' = dodder or a gout-like affliction of the flax. L: podagra *= G: ποδάγρα = gout. From: Crescentio (1548) p 206 [CR-6]. Scale 1:0.8.*

Figure 4.13 Dodder as it really looks, here on sugar beet, not an ancient crop, Greece, 1989. Dodder appears as white, yellow or red threads with minute flowers and fructifications. Dodder is a harmful parasite of many plant species.

2.42/43]. Dodder was to be controlled by fanciful or magic actions. Dodder in flax should be removed by hand [OS-6.29.668].

In Mesopotamia, another dodder, possibly *C. monogyna* Vahl, grew on thorny bushes such as *Rosa eglanteria* L. and *Rubus sanctus* Schreb. Its capsules were harvested and used to flavour beer and to spice date wine. This dodder used to be cultivated on thorny hedges.[154]

Mistletoe. Theophrastus looked into the biology of mistletoes and described their transmission by birds.[155] He reasoned that they were among plants just like parasitic animals are on host animals. Thus, he recognized mistletoe as a parasitic plant. With the hint of a smile he wrote '*Besides the acorn it [the holm oak] carries a kind of scarlet berry; it also has oak-mistletoe and mistletoe; so that sometimes it happens that it has four fruits on it at once, two which are its own and two others, namely those of the oak-mistletoe and of the mistletoe. It produces the oak-mistletoe on the north side and the mistletoe on the south*'[HP-3.16.1]. Pliny saw the damage done to their hosts. '*Trees …, and mistletoe does them no good, …*' [NH-17.37.239]. Albertus Magnus: '*High up in the branches of old trees originates a plant, which has the same appearance on every tree, it is attached to the plant and it has thick leaves that stay green in winter…*'.[156] — No control of *Viscum album* is indicated.

4.6 Deficiencies and excesses

4.6.1 Deficiencies

Chlorosis due to mineral deficiencies is common in the Mediterranean area, for example in citrus, as I saw in Algeria, Greece, and Sicily. As a general symptom yellowing is non-specific, though many different types of yellowing are known that can indeed be related to specific causes. Various biotic agents cause yellowing, among them viruses, but the more prominent causes are mineral deficiencies. Iron and magnesium deficiencies are frequent, especially on calcareous soils with a high pH. Magnesium and nitrogen deficiency, boron toxicity, and low pH can all cause yellowing in some tree species.[157]

Ibn al-ʿAwwām, quoting from Babylonian sources, describes 'jaundice' of several tree crops, today's 'yellowing' or 'chlorosis' [IA-1.555]. The remedies are several. (1) Make a watery extract of squirting cucumber and calamint and pour it over the vines just before sunrise. (2) Boil ashes of fig or oak in fresh water for one hour, and pour the cooled fluid over the vines. (3) Fumigate [IA-1.556]. (4) Powder ash of figs over the plants. — The ashes may provide minerals, potassium (K) foremost.

Another treatment of jaundiced trees is rather radical. Within a radius of one metre around the trunk the top soil should be removed to expose the root system. The old soil should be replaced by fresh top soil of good quality or be supplemented with manure and returned as loose soil. Sometimes it is recommended that plenty of fresh water should be added. Such treatments, that would be ineffective against virus diseases, apparently remedy whatever mineral deficiency there was. Figure 3.5 shows a man using the *bidens*, the two-pronged hoe, to expose the roots of a tree.

Weakness. The affected leaves begin to bleach; the green tint disappears; the white appears on the reverse side of the leaves; the young twig is of an unusual weakness; it shows a black tint when the weakness is intense. The remedy is suspending the ash of vine twigs in the strongest vinegar, rubbing the stem and the heavier branches with it, and pouring a diluted fluid over the foot of the tree.[158] — The symptoms resemble the yellow mosaic syndrome caused by the grapevine fanleaf virus, known for hundreds of years. The treatment boils down to feed potassium and other minerals to the tree. It could be effective.[159]

4.6.2 Excesses

Theophrastus' discussion on '*Diseases from deficiency of food*' [CP-5.9.8] is followed by that on '*Diseases from over-supply of food*' [CP-5.9.9/10]. [160] '*Also due to excess are the "he-goat" in the vine and all other cases where trees sprout so well that they fail to bear*'.[161] Theophrastus also provides a remedy [CP-5.9.11], reducing the intake of nutrients. Trees are 'castigated' by scarification. '*If a tree does not bear fruit but inclines to a leafy growth, they split that part of the stem which is underground and insert a stone corresponding to the crack thus made, and then, they say, it will bear*' [HP-2.7.6] .[162] At a time, when plant physiology did not yet exist, the idea that excess of nutrients could be damaging was very insightful.

Babylonian Jews treated date palms with over-abundant fruit set and with subsequent fruit drop by heaping up stones around them, so that their fertility was reduced. Division of labour made the alternative treatment less laborious. This was '*to hang a cluster of dates on palms that dropped their fruit as a sign for passers by to offer up prayer for the restoration of their normal fertility*'.[163] — The first treatment has a biological rationale, the tree's root activity will be reduced in soil compacted by the weight of the stones.

Excess manure damages palm trees, they get a yellow tint at the base and the green of the leaves becomes dull [IA-1.555]. De Serres on orchard trees: '*Most often these [the new trees] perish due to too abundant moisture … causing many branches on the trees, reaching upward, which attract to them all the substance of the roots, so that the trunks remain thin and poorly established: not able to carry the weight of the branches and hence the violence of the winds, having a strong grip on them, complete trees are easily knocked down to the ground.*' — The water-sprouts must be controlled by pruning, thinning, and topping [OS-6.27.659].

At times, trees bear fruit in excess. Thinning by hand is the answer. '*Cherries are brought on and made to ripen by applying lime to the roots; but with cherries also, as with all fruit, it is better to thin the crop, in order to make the fruit left on grow bigger*' [NH-17.47.260]. De Serres advice is twofold, avoid breakage of heavy loaded branches by supporting them with stakes, and shake the trees roughly to remove the lesser fruits [OS-6.27.662].

Vines that are growing too lush are stripped, '*pinching off the largest leaves throughout the summer and by thinning the topmost roots*' [HP-2.7.6]. Cutting the roots by spading is an emergency measure. Virgil adds '*The result is similar if one prunes away some of the roots. This is why this is done to the surface roots of the vine when it suffers from luxuriance*' [VE-5.9.11]. The Geoponika advises pruning them seriously, and – if persistent – replacing some of the soil around the roots by river-sand with a bit of ash; the alternative is to place stones near the roots, to cool the grapevines [GE-5.40]. Crescentio treats over-luxurious grapevines to avoid the risk that the grapes will go rotten [CR-4.18]; excess foliage should be trimmed away. — Heavy pruning is an obvious method, but crude. More subtle is the idea of slowing down the growth of the vines by cooling the roots. However the question remains, does it work?

Too lush a grain crop is at risk of lodging, a persistent concern from Theophrastus to De Serres. '*In good soils to prevent the crop running wildly to leaf they graze and cut down the young corn, …*' [HP-8.7.4]. '*Need I tell of him who, lest the stalk droop with overweighted ears, grazes down his luxuriant crop in the young blade as soon as the growing corn is even with the furrow's top …*' [VE-1.111].[164] '*On some soils wheat and barley are sown late to avoid excessive height with lodging and rotting as the outcome. If sown early the evil be remedied by introducing cattle and sheep that nibble the exuberance which induces the fear*' [IA-2.32]. De Herrera gives practical advice, including grazing by cattle and small stock, but this is good only when they are kept on the move. Geese are bad. De Serres wants to admit the animals, preferably small stock, certainly no pigs, only when it is dry, to avoid soil compaction [OS-1.2.114]. — The remedy of winter or spring pasturing was common practice in Europe up to the mid 20th century.[165]

Several authors advised against too dense planting of trees. '*Again trees may destroy one another, by robbing them of nourishment and hindering them in other ways*' [HP-4.16.5]. '*Trees kill one another by their shade or the thickness of their foliage and by robbing each other of nutriment*;' [NH-17.37.239]. Excess density of trees is considered to be harmful. — Several authors specify planting densities.

4.6.3 Patchiness

Columella [CO-2.9.9] describes bare spots in the field that vaguely suggest take-all in wheat due to a fungus, since these spots are low-lying and wet. '*It is best that such bare spots be indicated by the use of markers, so that we may take measures against faults of this kind in due season; for in a place where oozy ground or some other plague kills out the crop it is best that pigeon dung or, failing that, cypress foliage be scattered and ploughed in. But the very first thing to do is to draw off all free water by running a furrow*; *otherwise the aforesaid remedies will be useless*.' This job should be done in September, adds Paladius [PA-10.3.1]. — Plants were probably killed by excess water in the soil leading to oxygen deficiency of the roots. The need to drain the patch is obvious. Pigeon manure may kill pest organisms. The function of cut cypress leaves is not clear.

4.7 Pathogens

De Herrera discussed disease in grapevine [DH-2.15.74]. Following Theophrastus he distinguished external and internal diseases. Among the external diseases were the wounds inflicted by cultivation methods such as hoeing. Internal diseases included premature grape dropping and poor ripening of grapes. In antiquity fungi, bacteria, nematodes, and viruses were, of course, not yet known as distinct classes of pathogens but some of their effects had been recognised.

Cancers of young plants may be cured by sowing pumpkin, melon, beans or purslane between the rows [IA-1.564]. — I do not know what disease is meant here.

Ergot. In the Middle Ages, when rye became an important cereal in continental Europe north of the Alps, poisoning by ergot became a major risk to humans. The 'ergots' are the outsized purple-black grains of rye, the 'cock spurs', in which a fungus largely replaces the grain's tissues. They contain highly poisonous alkaloids. When ergots are milled together with healthy grains the poison will enter porridge and bread, resulting in outbreaks of a human disease called ergotism. Two types of symptoms exist, gangrenous and convulsive.[166] The medieval term for the human disease was *ignis sacer*, the holy fire. The convulsive symptoms contributed to the 'dancing processions', frequent in France and Germany. Participants often died of exhaustion and/or poisoning. The *Annales Xantenses* of the year 857 record: '*a great plague of swollen blisters consume the people by a loathsome rot, so that their limbs were loosened and fell off before death*', the typical symptom of gangrenous ergotism.[167] There were numerous outbreaks of ergotism in France during the 10th to 12th century.[168]

The relation between ergot and human disease or death was clarified gradually from about 1670 onward. Before that time there were at best only guesses. The epidemics of ergotism faded away when the ergots were sifted out of the rye destined for consumption and the ergots from the rye intended for sowing were removed by hand. It remains uncertain if and when this latter action began as an intentional crop protection activity.

Esca. The disease now called 'esca' was known around the Mediterranean in Roman times. Yellowish to reddish patches on the leaves lead to premature leaf fall. Ibn al-ʿAwwām describes a disease that resembles esca. '*The foliage of the grapevine takes a pure, very intense red colour; part of the tendrils and the whole tail of the grape become red also; the stem and the heavy branches are covered by a wrinkled bark; the bunch yellows; it is not so juicy; it remains small*' [IA-1.547]. '*Replacing the diseased trunk using a renewal shoot from the base of the vine has given excellent results*'.[169] Tree renewal is not among Ibn al-ʿAwwām's remedies. — 'Esca' is associated with fungi, including *Stereum hirsutum* and *Phellinus ignarius.*

Fatal disease. Grapes suddenly dry once they have reached the size of a pea. In the French translation this disease is called *accidentelle*, here translated as 'fatal disease'. It is treated by removal of the affected parts in the bunch and the application of the ash of twigs well drenched in strong vinegar [IA-1.550]. — The disease may be due to the gray mold fungus, or possibly to *Phomopsis viticola*.[170]

Fruit rot. Ibn al-ʿAwwām describes fruit rot of grapes [IA-1.558]. Among the diseases of grapevine there is one that causes '*the fruit to rot and decay when it has somewhat ripened, its colour changes to black or to another colour that is not the usual colour of the grape … a kind of sweat appears on the weak and poorly developed parts of the leaves and the branches, about the end of the day, after the ninth hour, (sweat that should not be confounded with) that seen at the onset of the day, which is a remnant of the nightly dew. The remedy is to collect purslane in rather large quantity, press out the juice, and mix that with a bit of condensed barley water, with the mix rub the foot, the root, and all woody parts of the tree. When the bunches begin to decay, rub them with the sap alone. Persist until the problem is over*'.[171] — The condensed barley water will act as a sticker. Treatment of the woody parts may not be effective. An alternative explanation of the untimely 'dew' is honeydew.

'*When the rains of autumn are heavy the grape is exposed to decay …; then the leaves above the bunch must be removed as they might cause rotting and sourness*' [IA-1.500]. — The 'sweat' might be the sporulating mycelium of the gray mold. Purslane sap is often recommended to treat grapes. Removal of top leaves is quite sensible, since it improves the bunch's micro-climate.

Mushrooms were known, of course, but not seen as plant pathogens, with the exception of de Laguna who describes and pictures *Agaricum*, named after a region Agaria, placed in Sarmatia, roughly the present Ukraine. '*Some confirm that the agaric is the root of a certain plant, others that it stems from corruption: as the fungi, on the trunks of trees*'. He depicts a polyporaceous mushroom on trees (Fig. 4.14).[172]

Rugosity of fig trees, mentioned several times, has been attributed to a fungus called *Cladosporium herbarum*.[173] Rugosity was stimulated by light rain in May, but washed off by heavy rain.[174] February is the time to prune the trees and to remove dead and scabby branches [CR-12]. The same or a similar disease of figs, called scab, is ascribed to the fig wax scale[175]. '*Figs extremely liable to this disease, wild fig immune for diseases. Scab* [L: scabies] *is caused by gentle falls of dew after the rising of the Pleiads;' … 'But if there has been excessive rain a fig-tree is liable to another malady due to dampness of the roots*' [NH-17.37.225].

The remedy was to plant sea squill at the roots of the tree or to pour ochre diluted in water around the stem. — The timing is not consistent. If rugosity is caused by an animal and not by a fungus, the treatment with sea squill might be effective.

Rust. Among the fungi the cereal rusts were feared most.[176] Theophrastus writes that '… *countries with a fall of dew and that lie in a hollow and have no wind are especially liable to rust*', a correct statement.[177] Pliny commented on common wheat: '*But it is less exposed to danger in the straw than other cereals, because it always has the ear on a straight stalk and it does not hold dew to cause rust*'[NH-18.20.91]. Nightly dew is indeed needed for the urediniospores of the rust fungi to germinate and penetrate. The straight stalk might have held less dew than the curved one of barley, but usually holds enough to become rusted.

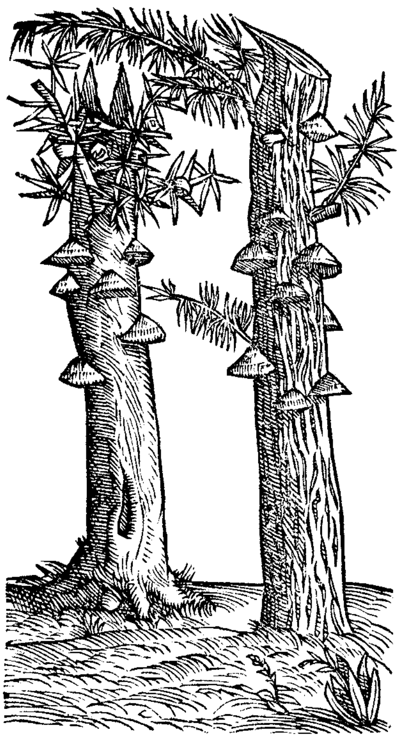

Figure 4.14 Agaricum on larix. The figure shows the stem-less caps of an apparently parasitic mushroom as e.g. Trametes versicolor *(L.) Lloyd, of the family Polyporaceae. The two trees may belong to different species. Drawing by A. de Laguna. From Dioscorides (1566) p 261. Scale 1:1.3.*

Caution is warranted because some of the symptoms described on wheat could have been caused by various other species of foliar fungi. With the Roman authors the term 'rust' had a broader meaning than disease due to rust fungi (*Uredinales*) only. Many red-brown flecks were indicated as 'rust', e.g. in grapevine. Dugan (2008) presented a recent, critical discussion of fungi causing plant diseases in the pre-modern world.

Crescentio mentions three types of wheat [CR-3.7]. One has small awnless ears and yields well due to good tillering, but suffers from '*nebula*'. This generic term points to one or more diseases of the ear with blackening and shrivelling, thought to be due to heavy mists.[178] De Serres blames the drizzle and heavy dews, falling upon well developed cereals that approach ripeness, causing the wheat ears to rot and blacken, so that yields are low and of poor quality, and little more than straw is to be expected. His only remedy is to shake off the dew before the sun can heat it. To do this two men stretch a rope between them, just below the ears, walking with measured steps on either side of the field [OS-1.2.114]. This cord drawing, known in French as '*cordelage du blé*', was recommended until well into the 19th century to control cereal rusts. De Serres gives no specifics of the diseases but we assume that black stem rust ranks first.[179]

Underground pests. '*Certain underground pests also kill out mature crops by cutting off their roots. As a remedy against this they use the juice of a plant which the country folk call* sedum*, mixed with water; for the seeds are sown after they have been soaked in this solution for one night*' [CO-2.9.10]. Juice of wild cucumber and the crushed root thereof is an alternative. Following the prevention comes an intervention. '*Others sprinkle the furrows with this same liquid or with unsalted lees of oil, when the crop begins to be infested, and so drive off the destructive creatures*' [CO-2.9.10]. — What are these creatures? Perhaps insects such as white grubs and wireworms, or fungi such as those causing take-all in wheat.

4.8 Adverse effects of weather

Fear for the adverse effects of weather was universal since little could be done to counteract them. Lucretius: '*and even so at times, these [growths] procured by great labour, when they are already covering the earth with leafage and are all in bloom, are either scorched up in the sun in heaven with too great heat, or cut off by sudden rains and chilly frost, and the blasts of wind batter them with violent storms*'.[180] Farmers looked up at the sky to assess the weather. To them the celestial effects on crops were not yet differentiated into astrological, astronomical, and meteorological effects. The supposed effects of the moon were discussed in § 3.5.4.

Fog. The weather conditions that produced dew and fog were known and something could be done to protect the crop: '; *but that neither phase of the moon is harmful even at night except in fine weather and when there is not a breath of wind, because dews do not fall when it is cloudy or a wind is blowing, and even so there are remedies available. When you have occasion for alarm, make bonfires about the vineyards and fields of trimmings or heaps of chaff and bushes that have been rooted up, and the* *smoke will act as a cure for them; smoke from chaff is also helpful against fogs, in places where fogs do damage* [NH-18.69.292/3]. Dense and continuous fogs can be injurious to grapevine. Make bundles of reed, light them, and let servants carry them at night between the rows. Repeat this several nights [IA-1.554]. — Here I am thinking of dew, fog, and night frost.

Frost. Sowings should be protected against the cold and the rigour of frost by placing sticks or reeds on the soil and covering them with straw, the sticks holding up the straw so that the seedlings will not be choked [AG-60]. Some farmers believed that the tall and robust rye in a wheat-rye mixture protected the low and tender wheat against frost damage.[181] Bananas should be covered at night to protect them against winter damage [IA-1.368].[182]

All fruit trees in Tuscany were frozen in 1594.[183] In Bithynia some growers learned in practice that they, sensing the risk of ice formation, should sift ash over the vineyard, preferably tamarisk ash, since the ash that adheres to the buds will repel the ice fall.[184] — This is a classical recipe, but the question is whether it works, and if so – how. Could the ash lower the freezing point?

Others use faba bean straw to avoid frost damage to the vines [IA-1.481]. When young twigs do freeze they have to be pruned. To avoid frost damage late pruning is an option [IA-1.563]. When vines are damaged by frost deep pruning is needed or the tree has to be cut near the soil in the expectation that a good and early grape harvest will be produced in the next year.[185] Burning dry manure at the windward side of the vineyard protects against frost damage [IA-1.589]. A thick smoke produced with moist straw and half-rotten manure, applied in small heaps and lit immediately when needed, helps to prevent damage [OS-3.5. 178]. — How ashes and faba bean could protect the vines is not clear, but burning manure certainly helps to control night frost.[186]

Hail. See under 'thunderstorm' below.

Heat and drought. Crescentio was concerned about heat and drought damage to the vines [CR-4.8]. Watering was his answer. Droughts were common in the Mediterranean area and usually no water was available. One example is the severe drought that hit Andalusia in 1521 killing wheat and grass, so that people and beasts perished.[187]

Nightly moisture. The coolness and moistness of Mediterranean nights, often with dew formation, were well known and exploited though there was 'a conflict of interests'. Nightly cooling of threshed crops was appreciated because a seed crop stored cool was better preserved. However, the nightly moisture was feared because seed stored moist was sensitive to 'worminess'.

The Geoponika is clear about the cooling of wheat and barley overnight to store it cool for better preservation: '*The winnowed wheat or barley should be left one or two days on the threshing-floor, or at least a whole night, and be collected before sunrise, in order to store it still cold in the granary as this contributes much to its conservation*' [GE-2.25.4] .[188] Similarly, De Herrera recommended leaving threshed faba beans overnight on the threshing floor to cool them and to store them cool in order to avoid storage insects [DH-1.18.38] (§ 3.7.3). '*The grain has to be collected rapidly, when still covered by morning dew*' [GE-2.25.3].[189]

Because dry pods dehisce, lupines should be harvested when wet to avoid seed loss [DH-1.20.40]. The Geoponika even wants rain: '*Lupine flowers three times; it is convenient to harvest after rain, lest the seeds drop from the dry pods and get lost*' [GE-2.39.7].

Rain is usually beneficial in the Mediterranean area but rain at the wrong moment is feared. One such wrong moment is at flowering. '*Worst of all is when rain falls on the olive, vine and the rest when they are in flower, since both flowers and fruit are so weak that they drop off*' [CP-5.10.2]. '*… however it is harmful to wheats and barleys and other cereals when they are actually in flower; for it destroys the flower*' [HP-8.6.5].

Crescentio offers a variant: '*At the time of great heat and fervent sun there often appears a small, venomous, and sparkling rain, that we in Bologna use to call* melume*, burning many grape varieties so that their fruits are reduced to nothing. And where that happens frequently one has to plant those grape varieties that suffer not or little such as malissia, albana, grilla and others*' [CR-4.18]. — Supposedly, the rain drops worked as lenses concentrating the rays of the sun with the effect that holes were burned in the grapes. Apparently, some varieties were more resistant than others.

Torrential rains in early summer do occur sometimes and, when the grain crop is near to ripening, the crop lodges and goes rotten when the wetness continues. Even worse was the situation in Friesland, on 12 July, 1305, and during the following week, when torrential rains washed the standing corn away so that one could hardly see where it had stood.[190] Famine and pestilence followed. Similar summer downpours occurred in Italy in the years 1586 to 1591. In 1590 and 1591 Tuscany lost its wheat crops. In 1591 the wheat crop of Sicily was so bad that there was scarcity and hunger. The situation led to massive grain imports in Livorno, the port of Florence in Tuscany. Dutch grain traders profited.[191]

Residual moisture. In the semi-arid zone it is tempting to exploit whatever residual moisture is left in the soil after the grain harvest. The Geoponika advises ploughing the land in July immediately after the harvest of faba bean or vetch, before it dries out [GR-3.10.5]. In the Mediterranean area residual moisture was often exploited to grow a summer crop.

Shade. Most crops dislike shading. Warnings against too much shade are not infrequent.

Agustín is most explicit. Do not plant trees around arable land, willows excepted. Beware of poplars that give shade, and have many roots that drain the soil [AG-168]. However, vineyards can be surrounded by olive trees as these do not intercept the sun nor obstruct the growth of the vines [AG-194].

Star-blight is the English translation of the Latin word *sideratio* which refers here to weather-induced damage. '*Star-blight depends entirely on the heavens*, …' [NH-17.37.222] . Pliny knew different types of star-blight. '*One kind of star-blight is dew-*

Figure 4.15 Thunderstorm with hail ravaging the ripening grapes, an unusual picture. From: Crescentio (1548) p 96 [CR-4.5]. *Scale 1:1.*

disease, when the grapes shed their blossoms, or when the grapes shrivel up into a hard lump before they grow big.' [NH-17.37.226] . — No specific remedy was indicated. I am not sure about a modern equivalent.

Sunscorch. '*Cuttings and layerings are the main victims of sunscorch because of their weakness. The ailment occurs when the ground is dried up and the plants are unable to attract fluid (which is why most cases occur in the dogdays)…*'. '*Sunscorch, then, is due to these circumstances; it is also due to blows from the outside and the consequent wounding, since wounded trees too become weaker, and forces penetrate them farther*' [CP-5.9.1/2]. [192]

Thunderstorm. In some years there are excessive thunderstorms raging over large areas and causing exceptionally severe damage to trees, vineyards, and field and garden crops (Fig. 4.15). Wind gusts break branches or even uproot whole trees. Hail destroys all fruits and heavy rain lodges the cereal crops. Germany was so hit in 1846.[193] Thunderstorm damage is of all times and all places. Crescentio admonishes that sometimes storms consume the vineyard totally, and nothing can be done against them but to pray piously to God with a pure and clean heart. Against thunderbolt and hail man is defenceless [CR-4.18].

Weighing the adverse effects of abiotic factors against those of biotic factors is a risky affair. Considering the wealth of pre-modern records on damage and crop loss one can hardly escape the impression that, at least in north west Europe, the abiotic risks far outweighed the biotic risks. One reservation should be added: biotic damage is often the sequel of unusual weather. The biotic aspects of damage and loss may not always have been recognized. As to the Mediterranean area, the books consulted so far paid more attention to biotic than to abiotic causes of damage.

Chapter 5

Pre-modern crop protection methods

Sound risk management was mixed with fantastication, magic, and exorcism. Little could be done against abiotic damaging agents such as hail. Mixed cropping was applied for various reasons. Biological control existed in a very limited form. Weed control was of prime importance, with a first indication of herbicidal action. Many treatments were not unlike the modern ones though with very simple technology. Trap crops, grease bands, and baits were recommended frequently. Seed treatment, spraying, dusting, and fumigation were known. Curative action, including scarification, was applied to trees, in a careful but laborious approach.

'I told you a while ago that agriculture is such a humane, gentle art that you have but to see her and listen to her, and she at once makes you understand her. She herself gives you many lessons in the best way of treating her. For instance, the vine climbs the nearest tree, and so teaches you that she wants support. And when her clusters are yet tender, she spreads her leaves about them, and teaches you to shade the exposed parts from the sun's rays during that period. But when it is now time for her grapes to be sweetened by the sun, she sheds her leaves, teaching you to strip her and ripen her fruit.'

Xenophon (c.400 BCE) – Oeconomicus 19.17/9. Translation Todd (2002).

5.1 What is to be expected?

Disease, pest, and weed pressure may have been considerable in antiquity but specific information on crop loss is rare.[1] The fear of insect pests, such as locusts, and plant diseases, including black stem rust of wheat, was all too real as several Biblical passages indicate.[2] Plant pests and diseases were known from antiquity but what about ancient pest and disease control? [3] The medieval Geoponika (c.950 CE), a *vademecum* with recipes, summarized classical agricultural knowledge, with much attention to crop protection issues. The Geoponika refers primarily to the eastern Mediterranean area, semi-arid, sometimes drought-ridden. The Andalusian agronomists echo this knowledge and add their own ideas.

Today's differentiation between methods of cultivation and methods of crop protection would have made little sense to the farmers of the period. The difference reached its peak in the second half of the 20th century and is, in actual fact,

Box 5.1 Ibn Wāfid (Cordoba, 11th century) on cabbage protection

Ibn Wāfid's 'Treatise on agriculture' was probably translated into Spanish in the 13th century. The larger part of this translation survived in a copy of c.1400, published by Millás Vallicrosa (1943).[4] Ibn al-ʿAwwām may have used some elements of the Arabic version [IA-2.156ff] whereas De Herrera consulted a Spanish copy. By way of example I quote the sentences on crop protection of cabbage which, as we know, is quite susceptible to insect damage.

- *'And if at sowing they would add a bit of Ethiopian cumin to [the seed of] the cabbages they will protect the cabbages from caterpillars and from the birds so that they will not damage them. And if at sowing they would add some caraway to the cabbages that will kill all fleas.'*
- *'And he who wants that the birds nor the ants injure the cabbages should moisten the seed at sowing with sap of moorish bramble.'*
- *'And when the moon will be waning no cabbages should be sown.'*
- *'And the ash makes the caterpillars flee from the gardens. And the little of pigeon manure does flee all the bad monsters [the vermin] from there. And if transplanting(?) they would boil the olive leaves in cow urine and would let it cool down and would water the cabbages therewith, these will improve much. And if they would fumigate them with wax and brimstone and with horn of goat or deer, all the caterpillars and the bad monsters will flee from them. And if they would powder ash of fig or olive wood over the cabbages, it will kill the caterpillars.'*

Comments:

1. Whereas the Spanish of De Herrera (1513) reads nearly as modern Spanish, the language of Ibn Wāfid's Spanish version, still undifferentiated, contains elements of modern French, Portuguese and Spanish, interesting but not easy to read.
2. The sentence on the caraway suggests that caraway, and also the Ethiopian cumin, are sown as companion plants to protect the cabbage.
3. Note that caterpillars and birds are to be chased away by the same action, an unusual combination, pointing again to companion plants.
4. 'Fleas' could be flea beetles, aphids, and/or whiteflies. ■

diminishing in modern environmentally friendly agriculture, and nearly vanishing in modern 'organic' agriculture. As to crop protection, pre-modern agriculture may be comparable, in its limitations at least, to modern 'organic' agriculture.[5] Crop protection problems were handled by various ecological, cultural, physical, and chemical practices, which are discussed below. Box 5.1 shows a simple example. Prevention of weeds, pests, and diseases by means of good crop husbandry, the basis of crop protection then and now, was not mentioned explicitly but it is clearly recognizable.

The modern eye sees many of the pre-modern recommendations as being irrational. Recipes such as 'hanging a crayfish in the middle of the garden' to avert caterpillars are too weird to be elaborated upon.[6] Several of the old recommendations were weeded out in the course of time. Other recipes, possibly realistic, are presented here in a modern arrangement. Curiously, a new genre of metaphysical methods was created *de novo* in medieval western Europe, summarized here under the term 'anathema'.

5.2 Irrational and metaphysical methods

5.2.1 Fantastication

Several quotations in the Geoponika belong to the 'fantastic literature'. My favourite among the fantastic recommendations is one to control dodder, a real pest in faba bean and chick pea. '*Let a marriageable virgin, barefooted, nude, without clothes, her hair down, and with a cock in her arms, go in circles around the affected spot, and immediately the dodder will let go and the legumes will be reinforced, maybe because the dodder fears the cock*' [GE-2.42.3].

Ibn al-ʿAwwām quoted the same recommendation in more detail from 'Nabatean Agriculture': '*Why (does the following happen): When the 'grass of the lion' (= dodder) which is harmful to all plants growing near it, grows plentiful, and we want to cut it and root it, this cannot be achieved by plucking it with our hands. If we order a virgin to take in her hands a white cock with a divided comb and she goes with it around the place where this grass is growing, shaking the bird so that it flaps its wings and she repeats this several times, this grass will wither and some of it will die that day, the rest after two or three days, not more than that. From what action does this occur? Do you not think that the grass was frightened by the cock and withered and stopped growing because of this, and is it the action of special properties?*' [7]

Two traditions merge here, one concerning the power of a nude woman, the other about the antagonism between lion and cock (Box 5.2). The link is the Arabic name of dodder, 'lion's weed'. White cocks played a role in magic and were thought to be antagonistic to lions.[8]

5.2.2 Magic, contract, intimidation

In magic a one-to-one relationship is expected between cause and effect, between the action taken and the expected result. Some magical recommendations have a homeopathic tinge, in the sense of 'like cures like'.[9] '*But even if you collect caterpillars*

Box 5.2 The lion and the cock

Bolos Demokritos of Mendes (Egypt), c.200 BCE, is considered to be an originator of paradoxographical literature (Wellmann, 1921). He was a physician and scientists who wrote several books including one on agriculture. In an original way he brought together Egyptian sorcery, Iranian magic, and Phoenician superstition. Demokritos developed a theory on the 'sympathetic element'. He argued that interactions existed between different realms of nature, interactions mysteriously embedded in the nature of things, and manifesting themselves as sympathy and antipathy.

One example was the belief that the lion fears the cock, an old idea possibly of Persian origin. This long-lived idea appears frequently and in different ways. One example is in Pliny: '*this animal [the lion] is frightened by … and even more by the crested combs and the crowing of cocks, …*'[NH-8.19.52]. The Geoponika repeats the story, attributing it to Demokritos [GE-2.42.3]. It also contains a paragraph entitled '*On the natural compatibilities and incompatibilities. From Zoroaster.*' [GE-15.1], a title pointing to an Iranian source. '*A lion walking over the leaflets of a Holm Oak stiffens, and he also fears the cock and its crow, and if he sees one he runs away*' [GE-15.1.9]. This belief was still alive in the Middle Ages as seen in a pseudo-albertine script.[10]

The fear of the lion is projected onto the 'lion's weed' (G: osproleon, ὄσπρολέων), a then current name of dodder, that could be removed by exposing it to a cock. ■

from another garden, cook them in water with dill, let it cool down and sprinkle it over the vegetables, it will kill the caterpillars present' [GE-12.8.4]. Similarly: '*Also, if you catch part of the locusts and burn them they are blinded by the stench, and some die and others, wings folded, wait to be caught and die under the effects of the sun*' [GE-13.1.5].[11] And another one, '*It is a natural remedy: since if you catch a scorpion and burn it, you will capture or chase more of them; the same with ants, as experience shows, and maybe the same succeeds also with other similar animals*' [GE-13.1.6].[12]

A contract could be written on paper with the promise to provide living space to the voles. '*Let the voles that meet here swear that you do not damage me nor permit that another does: then I give you this field. But when I come to surprise you to be still here, taking the mother of the gods as witness I will cut you in seven pieces*' [GE-13.5.4]. Did Cassianus Bassus himself or the editor of the Geoponika believe in these fanciful recommendations? As to this 'contract' with the voles he wrote: '*I referred to this to avoid the impression of excluding something, but I don't believe that any of this will work. I recommend everybody the same, that they don't concern themselves with these laughable things*' [GE-13.5.6].

Intimidation is another procedure, recorded by the Geoponika, Abū ’l-Khayr, and Ibn al-ʿAwwām, of possibly Mesopotamian origin.[13] When a tree does not produce fruits the tree should be intimidated and threatened with felling. One person should lightly tap the tree addressing it with the words ‘*Sure, I will cut you if you will not yield*’. At the same time another person should intervene and say ‘*Leave it for the time being, as she will produce fruits next year (I promise you on her behalf)*’. And so it happens, *deo volente*. — The comment ‘*This procedure, according to Abū ’l-Khayr, is based on experience*’ might be interpreted as the insight that several tree species bear fruit in alternate years mainly, as does the olive tree.[14]

A comparable procedure, with a discussion between plaintiff and defendant, is found in one of Christ’s parables (St Luke 13.6/9): ‘*A certain man had a fig tree planted in his vineyard; and he came and sought fruit thereon, and found none. Then said he unto the dresser of his vineyard, Behold, these three years I come seeking fruit on this fig tree, and find none: cut it down; why cumbereth it the ground? And he answering said unto him, Lord, let it alone this year also, till I shall dig about it, and dung it: And if it bear fruit, well: and if not, then after that thou shalt cut it down*’.[15] St Luke joined a Near-Eastern tradition.

5.2.3 Anathema

Successive agronomists gradually eliminated fantastication and magic due to growing scientific insight, religious considerations, or both. This was progress. But there was also regress. The Church – today we would say the Roman Catholic Church - fell back on a mix of the two, and took to outlawry. The new weapons were law suit, prayer and procession, excommunication, and anathema.[16] In retrospect, the mix was beautiful theatre at best, straightforward fraud at worst, destined to keep the common folk quiet.

In several cases, thoroughly analysed and humorously described by Evans (1906), locusts and cockchafers, when appearing in damaging swarms, were summoned in court. A public prosecutor would lodge a complaint, a lawyer would serve as counsel for the defence, the ecclesiastical court would hear both sides, and the presiding prelate would pronounce a verdict. Most often the sentences included a ban into exile. And as for the locusts, the swarms behaved as usual, they went on or perished. Either way, the locusts complied, thus consolidating the honour and trustworthiness of the Church and her dignitaries.

The first known case is from 824 CE, the last took place in 1866, with a peak in the 14th and 15th centuries. Among those prosecuted were caterpillars, cockchafers, grasshoppers, moles, locusts, rats, snails, vermin, voles, weevils, worms, a long list with locusts ranking high. The first documented legal case before an ecclesiastical court was in Avignon, 1320. Two priests in full regalia summoned the cockchafers to appear before court under penalty of a ban. They received notification in writing that counsel for the defence would be available. Counsel argued that the cockchafers did not appear before court because they had not received a letter of safe-conduct. He stressed their right to search for food. The court passed sentence that the defendants should move within three days to an indicated field with ample food. Those who did not comply were outlawed and could be exterminated.[17] — The outcome of several such trials gave the animals time to get away and thus to confirm the power of the Church.

5.2.4 Prayer

When nothing material can be done, prayer is the last resort. King Solomon's prayer at the dedication of the temple is magisterial. '*If there be in the land famine, if there be pestilence, blasting, mildew, locust, or if there be caterpillar, …*' '*What prayer and supplication be made by any man, …*' (1 Kings 8:37/8). Disaster was often seen as an expression of the wrath of God. Whatever the calamity, religious leaders always and everywhere jumped at the occasion to lead their flocks back to the right path.

Matter-of-fact Crescentio gave sound technical advice to avoid damage to the grapes by summer storms and continued '*against which nothing else will be of value than the pious prayers to the Majesty of God made with a pure and clean heart*' [CR-4.18]. Prayer, at any rate, may give peace of mind in the face of disaster. To this very day, the litanies sung in the Roman Catholic Church during the Rogation Days contain prayers on behalf of crops, prayers reaching back over at least two millennia.[18]

5.3 Cultural methods

5.3.1 Risk management

Cultural methods are the alpha and omega of old crop protection.[19] They begin with the pre-planting decisions to avoid unnecessary risk. Spreading the risk across places, planting times, and varieties was and still is a standard method. Many are the do's-and-don'ts and only a few can be cited here.

Authors from Cato to Ibn Luyūn hammered home the importance of the appropriate location for an estate and its buildings.[20] Fresh air, clean water, and protection from the intemperances of the climate are pertinent. The location of fields, gardens, and orchards is considered too. The location of new plantings should be chosen carefully, a recommendation valid at all times. '*Some do not want to plant grapevine near rivers and marshes with cold and stinking vapours that lead to worminess*' [IA-1.338].

'*The majority prefers not to plant near a river, the less so when it is marshy, because of the fog and the cold air that emanate from it without interruption; and with them appear rusts that damage the vines and the sown crops and make the air harmful; therefore the marshes must be eliminated carefully from the neighbourhood*' [GE-5.5.2].[21] The 'rust' on the leaves of the grapevine refers to brown flecks that may have been induced, among other causes, by under-cooling.[22] If the vines are growing along trees they will not be damaged [GE-5.5.3].[23] De Herrera warns that aphids and other vermin on grapevine are more frequent in valleys and other adverse locations with little wind than in wind-exposed higher places [DH-2.15.74]. At the time it was well-known that rust on cereals appears preferentially in low lying areas protected from the wind.[24]

Sowing time. Book 3 of the Geoponika contains an agricultural calendar arranging activities by month, primarily sowing and planting. '*Of the sowing times [of wheat and barley] the best of all is the earliest; one must select deep soil if for the time being there was little rain*' [GE-2.14.1]. Barley should be sown somewhat earlier than wheat [GE-2.14.3]. '*Until six days before the first of October it is risky to sow because the seed will perish if a drought would come*' [GE-3.12.4]. Lupine is the exception because it does not require rain [GE-3.12.5].[25] Staggered planting is recommended, two to four sowing times being safer than a single one.[26] De Serres, however, whose estate could sometimes be influenced by weather coming from the Atlantic, stressed early sowing of wheat since the favourable period was short, from 20 September to 10 October [OS-2.4.103].

Multiple varieties. Up to this very day risk in orchards is spread across multiple varieties, which differ somewhat in bloom and harvest times, and in their reactions to adverse conditions. From Palladius to de Serres the agronomists recommended planting at least three grapevine varieties per vineyard.[27] The varieties should be planted in separate plots so that the ignorant harvesters cannot mix them up**.** '*As for trees, it is our wish that they shall have various kinds of apple, pear, …*' ordered Charlemagne in 812.[28]

Other risks. The risk of theft was discussed in § 4.1.1. For the risk of cattle and fire on the threshing floor and for the risk of threshing to gardens and vineyards see § 3.7.2. The risk of an adverse effect of stench on stored crops leads to careful location of stables and stores in relation to each other. De Serres, however, rejects this idea in favour of short transportation lines [OS-2.6.119].

5.3.2 Prevention

When pest and disease control in the modern sense was not yet available the emphasis in crop protection was on prevention. Many of the ancient comments were just common sense. One example is the sowing of faba beans in wet soil that helps to avoid insect damage during germination and emergence [GE-2.13.3; 2.35.1]. In olden times, with 'organic' agriculture and relatively modest yields, the distinction between crop husbandry and crop protection was less relevant than today with 'industrial' agriculture, high yields, and advanced crop protection technology.[29] Most items refer to avoidance of damage rather than to cure. Some advice touching on crop protection is described here.

Ploughing. Hesiod [HE-458-461] already recommended ploughing fallow land three times a year, in spring, summer, and autumn. The Geoponika paid much attention to tillage in relation to the season before sowing [GE-2.23]. In hot and dry areas ploughing is a means of conserving water in the soil and controlling the soil temperature. Deep soils and mountain soils should be tilled with the two-pronged hoe unless the field is too large [GE-2.23.13].[30] Summer ploughing should be done at night, before sunrise, to conserve soil moisture [GE-2.23.13]. '*To plough for the second and third time, use a heavier plough, so that in this way the substance of the soil be ploughed in depth and the clods be turned around*' [GE-2.23.14].

Soil depth. '*Wheat can be sown best in deep flat soil, barley in a soil of medium depth and pulses in a more shallow soil*' [GE-2.12.1]. — Relating to the depth of soil, these were reasonable recommendations, well over one thousand years old.

Soil moisture. '*Barley should be sown when the soil is not moist but well dried*' [GE-2.13.1]. '*In contrast wheat has to be sown in muddy and very wet soil, as it will grow better therein; wheat seeding should not be delayed*' [GE-2.13.2]. '*Faba beans and peas have to be sown in muddy soil, as in very dry soil they will be wormy before germination and get lost, and those that are not wormy emerge poorly*' [GE-2.13.3], a recommendation repeated in the chapter on faba beans [GE-2.35.1]. '*The other legumes will hold on also if sown in a very dry soil, but appear more luxuriant and better developed if sown in moist soil*' [GE-2.13.4].

Seed quality. Virgil warned: '*I have seen seeds, though picked long and tested with much pains, yet degenerate, if human toil, year after year, culled not the largest by hand. Thus by law of fate all things speed towards the worst, and slipping away fall back; …*' [VE-1.197]. The Geoponika is clear: '*It is imperative that one who wants to plant vegetables provides for good seed, appropriate land, water and manure*' [GE-12.2.3]. '*Some select the heaviest [wheat] ears, those that carry full and ripe seeds, extract from them the best fruit and set it aside for sowing*' [GE-2.16.3].[31] '*The best seed is that of one year [old], that of two years is less and that of three years is worst; older seed is sterile*' [GE-2.16.4]. See also § 3.4.3.

Avoidance of infestation. Donkey manure is better for gardens than horse manure because donkeys eat more slowly, chew better, and hence crush the weed seeds more than horses. The order is donkey, goat and sheep, horse and mule. Inversely, because of the many seeds, horse manure is excellent for pastures [DH-4.5.213]. Fresh manure is to be avoided because it contains many weed seeds that germinate readily. Two dung hills are recommended to be used alternately. Manure has to ripen for at least one year [AG-170].

Avoidance of contamination. Vines should be bound to stakes. '*A stake without bark is better, since in a stake with bark beetles and other insects enter and hide that use to ruin the vine*' [GE-5.22.3]. Grape bunches are cleaned from rotten, dry, and green grapes to avoid decay of the adjoining, good grapes. See also § 3.7.3.

As to grain storage Olivier de Serres is explicit. Different grain lots should be kept separate '*Because, by contagion, only a little poorly qualified wheat suffices to infest much [wheat]*' [OS-2. 7.123].

5.3.3 Abiotic damaging agents

Hail is a permanent threat to agriculture, also in Mediterranean areas, against which neither precaution nor remedy is effective. Hence, people have recourse to magic.

'*Also the following treatment which I am about to describe has been experimented on, namely that a tortoise which is found in the marshes is taken and someone takes it in his right hand, turned on its back. Then he goes around the whole vineyard. When he has accomplished this, he puts it upside down in the middle of the vineyard* *while it is still alive. Then he digs around it a little so that it cannot turn over and start crawling. Hence, if the ground under its feet is deeper than elsewhere, it cannot turn over because it cannot then find any support. If we do this, no hail will fall on that vineyard. If this is done to sown fields or any other place, no hail will fall on that place*'.[32] A more animal-friendly variant ends with: '*When the sky is (again) cloudless, one should hurry to turn the tortoise on its legs so that it can crawl away*'.[33] The tortoise magic with the legs turned upward, moving continuously toward the sky, may be seen as apotropaic, averting evil.[34]

Ibn Waḥshiyya also renders a more scabrous version: '*When we see a cloud which seems to bring a hailstorm, or the hailstorm has already started to fall on a field and we order a menstruating woman to take off her clothes and she lies down on her back showing her pudenda towards the clouds, this will stop the hailstorm at that place and there will be no more hailstorms on that place where she has lain down doing this up to 100 or 200 or (even) 300 cubits (dhirāʿ) from here. What else could this curious thing be and what could its material cause be except the effect of a special property*?'[35]

The tortoise recipe was rendered in brief by Palladius [PA-1.35.14] and in the Geoponika [GE-1.14.8]. Palladius offered two simple recommendations, one: '*Avoid hail by carrying the skin of a crocodile around your property*' [PA-1.35.14], and the other: If a hail-bringing cloud could see her own ugly face in a mirror she might refrain from pouring hail forth to a field. Thus, in that field a mirror was aimed at hail clouds [PA-1.35.15]. The Geoponika is rich in hail averting magic that does not need to be repeated here [GE-1.14.1/12].

Heat and drought are best avoided by choosing the right crop, sowing time, and manure. The sowing calendar is important. '*The experience teaches that in very dry places only the pomegranates and the olives grow well*' [GE-2.8.3]. Note that pigeon manure, added to the seed for a good harvest, is to be avoided in dry localities [GE-2.19.3]. Nothing helps against scorching winds, as Ibn Waḥshiyya describes for Babylon: '*People fell down like locusts and their own health diverted them from caring about their fields. That year a very severe famine befell the people and fruits were few in number because of the bad effect of the wind on the trees causing diseases*'.[36]

Frost and night frost should be avoided, again selecting appropriate locations, crops, and seeding times. Sensitive trees can be protected: '*In the same month [October] we shall protect the lemon trees that we keep in sites with rigorous winters; we shall cover the trunks with pumpkin leaves and apply to the roots around [them] the ash obtained from pumpkin*' [GE-3.13.6]. — One wonders why pumpkin ash is chosen.

'*People in Bithynia, who learned from practice, assure that if night frost is expected it is fitting to sieve ash over the vineyard, preferably of tamarisk, but if not available of any wood, since in this way the ash, sticking to the buds, repels the falling night frost*' [GE-5.32.2].[37] Pliny mentioned dusting ashes to control night frost in vineyards.[38] The recommendation is repeated elsewhere [IA-1.563]. — Sieving ashes over the vines is obviously meant as a preventive measure. It is, however, difficult to image that ash particles on buds, small twigs or flowers could affect their temperature and save them.[39]

'*Others sow faba beans in the vineyard and believe that thus the grapevine will not be seen affected by the night frost*' [GE-5.31.4]. Some add to the young transplants the straw of legumes, especially that of faba beans, because it gives warmth during the winter and prevents the damage caused by the vermin; others add urine [GE-5.9.4]. Dug-in pods of faba beans will protect the vines against ice and frost [IA-1.481].[40] — These recommendations are not very trustworthy.

'*Place dry manure in the vineyard at varying intervals according to the direction of the wind in the vineyard, and when you see the hoar frost appearing, put the manure to fire; then the smoke, dragged along, will disperse the frost*' [GE-5.31.1]. — This recommendation, then already a thousand years old, was and is common practice. It is not so much the smoke that chases the night frost as the heat of the fires that increases the temperature within the orchard and causes turbulence mixing the colder lowest air layer with the warmer air layers above, so that the air temperature at bud or flower level exceeds the critical value.

Young vine trees can be protected against the winter cold by placing pigeon manure around the trunk in October [CR-12.10], by digging around them and covering them in November [CR-12.11]. Pigeon manure is highly concentrated, hence 'sharp', 'burning', or 'hot', but is it also 'heating'? De Herrera confirms that frost damage in vineyards can be prevented by good digging. Clean vineyards suffer less frost damage than weedy ones full of thistles and thorns. On poorly tilled soil the grapevines suffer more frost damage than on well tilled soil [DH-2.15.75]. — The digging recommendation is counter-intuitive because a loose surface soil conducts the heat from subsoil to crop far less than a compacted surface soil.[41] A weed cover, however, would impede heat exchange from soil to crop, here flower buds.

When it is obvious that the fruit is lost, cut the plants back so that the vines keep their strength and produce a double harvest the next year [GE-5.32.1], a consolation offered by the Geoponika. Crescentio agrees: cut them down and they will bud forth again [CR-4.18]. When only the young shoots are frozen good pruning will suffice. To avoid damage by hoar-frost, Crescentio calls it white frost, plant late varieties of grapevine [CR-4.18].

Salt. Soil salinity is a constant threat in semi-arid areas, especially in irrigated areas, when evapotranspiration exceeds precipitation and irrigation. The ancients, apparently aware of this danger, applied straw as a remedy. '*Turn up the salty soil with small ploughs and spread straw of faba beans, since that is the best straw; second in quality is that of barley and wheat*' [GE-2.23.9; 3.1.10]. — This practice will improve crop growth by the nitrogen in the bean straw, and possibly by improved soil aeration; the straw will improve the structure of the soil and the percolation of rain water, and so help to reduce the salt content of the top soil.

Sun-burn. Cicero warned against sun-burn of grapes: [42] '... *and, enwrapped in foliage, it has no lack of tempered warmth and turns aside the more ardent glances of the sun*'; a plea for the arbour or pergola to produce grapes? Vines may suffer from sun-burn, with reddish leaves as a symptom [GE-5.36.1]. The Geoponika's remedies are bizarre: scarification, sea-water, urine, or a concoction of olive oil and pitch [GE-5.36.1/2].

Threshing dust. '*[The garden] should not be located down-wind of the threshing floor, so that the plants will not be destroyed by the chaff*' [GE-12.2.2]. — This often repeated admonition not to position a threshing floor near to and upwind of the living quarters and gardens is justified. The wind-born dust irritates the eyes, respiratory tract and skin of people and animals, and it spoils the vegetables reducing their photosynthesis, appearance, taste, and digestibility.

5.3.4 Weed control

Chemical control. Varro noticed that, whenever *amurca* flowed from olive oil presses, the ground became barren. '*The olive yields two products: oil, well known to all, and amurca. As most people are ignorant of the value of the latter, you may see it flowing out from the olive presses on to the fields, and not only blackening the ground but rendering it barren when there is a large quantity of it; whereas, in moderate quantities, this fluid is not only extremely valuable for many purposes, but is especially valuable in agriculture, as it is usually poured around the roots of trees, chiefly olive trees, and wherever noxious weeds grow in the fields*'. Hence he regarded *amurca* as a herbicide, the first herbicide ever on record [VA-1.51.1, 1.55.7].

Clearing forest land is cumbersome so that a herbicide is welcome. '*Democritus has put forward a method of clearing away forest by soaking lupine-flower for one day in hemlock juice and sprinkling it on the roots of the trees*' [NH-18.8.47]. Pliny and the Geoponika probably had the same source, Demokritos. '*Crush lupines in flower with* konion *and apply it to the place of the roots that remained in the soil, it will dry them*' [male fern and other weeds] [GE-3.10.7]. — *Konion* (G: κόνιον) has two meanings, one being 'poison hemlock', the other 'caustic substance' (NaOH, CaO). Either way, here is the second oldest herbicide.

Competition. Chickpea destroys weeds [HP-8.7.2]. '*If the land is pervaded by roots you can sow lupines therein, cut them when they are in flower and plough it in so that the cut parts are turned under, and leave it after applying a thin layer of manure to it*' [GE-3.10.8]. Crescentio [CR-2.20] advises dense sowing of faba bean or lupine, and cutting them [the weeds?] with the point of the sickle when they appear. In the advanced agriculture of eastern Norfolk (UK) around 1300 oats were sown at the high seed rates of 200-300 kg.ha^{-1}, obviously as a smother crop.[43] The Englishman Tusser recommended choking the nettles with hemp.[44] — The basic principle is that a densely sown crop outcompetes the weeds. In addition, lupine serves as a green manure. Apparently it is thought that the ploughed-in lupine adds to the killing of undesirable root masses of weeds.

Crop rotation would improve preventive weed control, certainly in combination with intensive tillage. Crop rotation as such is not a special item in the old books, Pliny excepted.[45] Information on rotation is rather scattered. Alternation of cereal crops with pulses is mentioned frequently. The Geoponika's sentence '*Sow the barley called* leptitis *where wheat was grown last year. Sow sesame, einkorn wheat, emmer wheat, millet, and hemp in the appropriate places*' [GE-3.3.12] is at best a minor reference to crop rotation. Following the wheat harvest, legumes can be sown on deep and flat land, as they allow the soil to rest [GE-2.12.2]. The beneficial effect of legumes, chickpea excepted, on soil fertility was well known in antiquity but it was not mentioned in relation to weed control. The Moors in Andalusia applied many types of rotation not necessarily dictated by weed control.[46]

Indirect weed control occurred in two ways. Raised bed cultivation of winter cereals, common in Flanders and adjoining areas, provided drainage and created a top soil favourable for cereal seedlings but relatively unfavourable to grassy weeds, especially common windgrass.[47] Marl was applied regularly in areas at risk of soil acidification, thus preventing the establishment of some persistent weeds preferring a more acid soil.[48]

Livestock. Grasses could be controlled by grazing cattle (§ 4.2.1). '*Before flowering the cattle can be let into the [lupine] field, because they will eat the remainder of the weeds without touching them [the bitter lupines] which they know to be bitter*' [GE-2.39.2]. — Weeding by cattle on crop land during the off-season and on fallow land was a normal procedure in W Europe but weeding by cattle during the vegetation season was unusual and feasible only when the crop itself is unpalatable, as with lupines.

Sheep produced wool, meat, and milk. Shepherding was described by Jean de Brie in his 1379 treatise, written in French and referring to northern France. He was an experienced man who started as a shepherd at the age of eleven. He gave sheep an explicit function in weed control. In June the shepherd should pasture his sheep in high places where the thistles grow. In July they should go to fallow lands, in August to stubble fields, in September to the recently harvested wheat and oats fields, and in October to the fallows again to graze the weed regrowth. Sheep that refused to eat thistles (because of dental problems) had to be culled.[49]

Pigs were led into the vineyards during winter time, after harvest, to eat the weeds, pull out the grasses, and trample the hiding places of moles and ants [DH-2.16.76]. In Spain, pigs were used to root the fields where crickets had laid massive quantities of eggs, and to eat and trample the egg packets.[50]

Manure always contains weed seeds (§ 5.3.2). The Geoponika thoroughly discusses the merits and risks of various kinds of manure [GE-2.21/22]. Manure of the current year should not be used [GE-2.21.10], one reason being – of course - that the weed seeds in the manure have not yet died. Another reason is given, 'creatures': '*Because it is not useful, may damage some crops, and produces very much vermin. In turn that of three to four years old is excellent, as in the course of time all odour is dissipated and the hardness is softened*' [GE-2.11.11]. Bird manure is recommended except that of water fowl; '*pigeon manure is much better since it is very hot. Some stray it thinly with the seed without treating it [the manure], but applying it as it is, as it is useful for soil without force, feeding it and making it stronger for the germination and nutrition of the crops, and adequately controls grasses*'. Next best is human manure that 'eliminates' all weeds.[51]

Tillage. Weeds were discussed in § 4.5.1. Here we mention some general weed control measures. Frequent ploughing ranks first in preventive weed control (§ 3.6.2). Xenophon was clear about weed control by ploughing or digging in his interview with questions (Q) and answers (A). Q. '*do you think that there is any better way of securing that than by turning the land over as often as possible in summer*?' A. '*Nay, I know for certain that if you want the weeds to lie on the surface and wither in the heat, and the land be baked by the sun, the surest way is to plough it up at midday in midsummer.*' Q. '*And if men prepare the fallow by digging, is it not obvious that they too must separate the weeds from the soil*?' A. '*Yes, and they must throw the weeds on the surface to wither, and turn up the ground so that the lower spit may be baked*.'[52]

The Geoponika contains several admonitions. '*It is also important to those who prepare the land for sowing to plough and turn it over, because when it is turned at that time [March] it will not produce many weeds and it will be more spongy; but it is not sufficient to do the operation once, but two or better three times*' [GE-3.3.10]. '*And in the same month [of May] we will also turn over the soil burdened by an excess of [Bermuda and couch] grass and we will leave it so that all the grass torn from the root will dry …* ' [GE-3.5.8]. '*If rains come unexpectedly after mid-September, plough immediately, before manuring, the soil of poorly developed land plagued by roots and bushy weeds, and manure without delay*' [GE-3.12.6].

Weeding. As to weeding after sowing '*the sown field is best turned over by men, but lacking people, weeding can be done with oxen*'. '*When the emerging crop begins to cover the clods it has to be weeded to remove the wild vegetation … ; and if weeding occurs twice, that will be double nice*'.[53] Whereas the oxen suggest mechanical weeding the other comments refer to hand weeding.

'*In this month [July] it is appropriate to pull off all wild weeds and shrubs*' [GE-3.10.3]. '*And about the middle of the same month one will have to pull off from the root the common male-fern, the flowering rush, the spiny rush, and the giant cane*' [GE-3.10.7].[54] '*In the month of July the soil of the grapevines has to be turned over until the second hour and until nightfall, but not in depth, and the weeds should be pulled off, above all the [Bermuda and couch] grass*' [GE-3.10.1].

Crescentio wanted the wheat growers to weed their fields in March, when the wheat was in the four-leaf stage[55], with a small hoe or by hand [CR-3.7]. Visiting southern Spain in 1953, well before herbicides became popular, I saw long rows of women on their knees weeding the immense wheat fields, the wheat being at about the same stage. They put the weeds in sacks dragged with them, probably to feed the goat at home. Such a scene was not found in the books that I consulted but I surmise that it existed in pre-modern times too. This type of hand-weeding was temporarily rejuvenated in modern organic agriculture when groups of school children were hired to clean up the fields, as I saw in the 1970s and 80s in the Netherlands.

The Geoponika recommends a round of weeding when wheat begins to ear, the Roman *runcatio*, '*because so the fruits will ripen without impurities and will be more beneficial, the soil being loosened to feed them well*' [GE-2.24.3].[56] The wording suggests hoeing. In contrast, Ibn al-ʿAwwām, who wants to begin with clean fields free from weeds, advises a round of hand weeding when wheat begins to ear [IA-2.52]. The yield will be better because more nutritious saps will be available to the wheat plants.

Box 5.3 Seven modes of combination cultivation

In combination cultivation the advantages should outweigh the disadvantages. The advantages are efficient use of available space, optimal use of light, efficient use of the soil profile as to nutrients and water, mutual protection against pathogens and insects, and partial mutuality, one crop providing nitrogen to the other. The disadvantages are complications in crop husbandry, especially at harvest time. I distinguish seven modes.

Mode 1. Sown crop, one species, multiple varieties. The varieties must have about the same stature and ripening date. Averaged over the years such mixtures can out-yield each of the composing varieties grown separately. In the western agriculture of today, varietal mixtures are not in favour for commercial reasons, except when grown for feed.[57]

Mode 2. Sown crop, multiple species, sown and harvested as mixture. Until the 1970s barley-oats mixtures were grown on the drought-sensitive sandy soils in the Netherlands. From the Middle Ages until far into the 19th century wheat-rye mixtures, known as maslin (L: *mixtilio*, E: *mestlen*, F: *méteil, seiglus*, NL: *masteluin*), were popular. Other mixtures were used too. Risk management was a major argument for these mixtures, but in retrospect I believe that they were also effective in reducing the load of foliar pathogens. In a cereal-legume mixture we expect, in addition, a positive effect of the legume's nitrogen fixation on the cereal.

Mode 3. Sown crop, multiple species, sown simultaneously but in alternating rows, harvested separately, and not necessarily at the same date. This intercropping is the modern version of combination cultivation as propagated by e.g. ICRISAT for Sahelian farming. In Venezuela, 1974, ►

Agustín, also timing the second weeding '*when the wheats begin to forward their ears*', warns not to damage the roots [AG-174].

De Herrera has a detailed chapter on weeding [DH-1.9.26]. On some soils, and under specific conditions, weeding of wheat and barley crops can be done by ploughing, apparently with the ard. The text implies, but does not say so, that these crops were sown in widely spaced rows. The author added that the recommendation does not apply to rye because rye outgrows and chokes the weeds anyway.

In eastern Norfolk, around 1300 hand weeding was intensive and expensive, at least 60 % of the crops being weeded.[58] Strong leather gloves could be used for weeding, as shown in the famous Luttrell Psalter dating from c.1340 and in Tusser's rhyme of § 4.5.1.[59] — At the time crop density was low, probably up to 100 stems per m^2 instead of the 400+ stems per m^2 in modern West European wheat crops, so that damage by trampling was negligible.

I saw vast stretches planted with alternating rows of maize and pigeon pea, the two crops tapping the soil water at different levels and times.

Mode 4. Sown crop, multiple species, sown at different dates in alternating rows. The species are sown as in mode 3 but with an intentional delay between their sowing dates. They are harvested separately and not necessarily at the same date. As the crops were harvested by hand separate harvesting was not a problem. Interestingly.

Mode 5. Relay cropping by undersowing cereals with clover or vetch was common in medieval Flanders.[60]

Mode 6. Sown crop and planted crop combined. Several authors thought that in young vineyards the sowing of an annual crop, such as millet, between the rows was profitable. Tree crops with limited root systems, such as apples, were acceptable too. In that case a larger distance between the rows of grapevine had to planned. Wheat sown among the olive trees was of common occurrence from antiquity until recently.[61] In the 1950s I saw many such fields in S Spain. There, mulberry trees (to feed the silk worms) were planted in rows bordering the wheat fields.

A special form of mode 6 is the old Italian '*coltura promiscua*' (= mixed cropping) with crops at two different levels, a herbaceous crop and a tree crop, thus using vertical space efficiently. To harvest the fruits of the tree crop a ladder is needed (Fig. 3.2).[62]

Mode 7. Different perennial species planted simultaneously providing ecosystem services, such as elm trees for the support of grapevine, a classical system. Trees planted as wind shields around orchards, and hedgerows to keep cattle out are still common. As with the mulberry trees there is a clear spatial separation between the different species.[63] ■

5.3.5 Mixed cropping

In developing countries peasant farmers often grow mixtures of crops in, at first sight, random arrangements. Closer inspection usually reveals that there is 'method in the madness'. In recent times many mixed cropping systems have been analysed. Their advantages are several, risk spreading, physical support or protection, better use of water and minerals in the soil, and mutual protection against pests and diseases.[64] I distinguish two main types of mixed cropping, combination cultivation and companion cropping. In combination cultivation different varieties or species are grown together on about an equal footing (weight or area).

Box 5.3 shows seven different modes of combination cultivation relevant to our purpose. In companion cropping the companion crop has a minority position relative to the other crop(s), and yield of the companion crop is not an issue. The disadvantage of mixed cropping is the difficulty of mechanical harvesting, a point irrelevant to pre-modern farmers.[65]

Pre-modern farmers must have seen or at least suspected some of these advantages and weighed them against the disadvantage, a difference in ripening time, a few days usually. Mixtures must have been common in antiquity. Biblical sources, however, were opposed to mixed cropping. '*Thou shalt not sow thy field with mingled seed*' (Leviticus 19.19).[66] The argument: '*… since God created all things with an inherent potential for perfection, mingling of diverse kinds patently interferes with this potential and thus impugns the perfection of God's work*'.[67]

In companion cropping the companion crop is sown as a (minor) admixture to another crop. The reason is not always clear. The Geoponika states that, when a field is cleared from roots with the help of lupines, '*Twelve days later the field should be ploughed again and a crop should be sown that is beneficial to the land, adding a small amount of lentil to the seed*' [GE-3.10.9]. ' *… that you have to mix with the [vetch] seed some lentil because they naturally resist strong winds*' [GE-2.18.15]. '*Fodder vetch once sown will not be eaten when you admix a bit of fenugreek seed at sowing*' [GE-2.18.11]. — In some cases the companion crop, e.g. fenugreek, may have been either a trap crop or a repellent crop. Why lentils? What is protected, seed, seedlings, young plants? Is protection against strong wind by lentil effective? A gardener may plant common rue to keep cats (and witches) out of his garden.[68] In modern times companion cropping as a means of crop protection has surfaced again (Picket *et al.*, 2010).

Modern combination cultivation is seen in the tropics, with two crops in alternating rows, usually one cereal crop and one leguminous crop, each of a pure variety.[69] The cereal crop is maize, sorghum or millet, and among the pulses are pigeon pea and peanut. One advantage of combination cropping is its efficient water use, the crops rooting at different depths. The leguminous crop provides some nitrogen to the cereal and it may reduce aerial dispersal of cereal pathogens. The cereal crop may give the legume some protection against sunburn, wind damage, pathogens and pests.

Sown crops. Hand-sown, broadcasted combination crops have a long tradition. Columella recommended a barley-oat mixture as cattle fodder, without mentioning whether he meant green plants, straw, or grain as fodder [CO-2.10.24]. The barley-oats mixture was a popular combination on the high sandy soils of the Netherlands until the 1960s. Its merit was water use efficiency and risk spreading, the oats doing better in drier years and the barley in wetter years. — In-depth analyses of the merits of these mixtures on the high and dry sandy soils were made in the Netherlands.[70]

It is a fair guess that mixtures of various kinds were grown, except maybe on the large estates producing grain for the market. During the Middle Ages single-species crops in W Europe were partly replaced by multiple-species crops.[71] One record from England anno 1371 is on corn [probably wheat] mixed with vetch.[72] Mane (2005 p 94) mentions the rye-wheat combination. Tusser rhymes:[73]

If soile doe desire to haue rie with the wheat, [to have rye with wheat]
By growing togither, for safetie more great, …

During a severe stem rust epidemic in Tuscany, 1766, Tozetti noticed that wheat in wheat-rye (I: *segalati*) and wheat-vetch (I: *vecciati*) mixtures remained free of rust.[74] — Around 1960 I saw the last rye-wheat-barley combinations in Westphalia, Germany.

Crescentio introduced an innovation, two species in alternating rows. Between the rows of faba beans, and in places were the stand was thin, sorghum could be intersown.[75] The timing was indicated clearly, after the second weeding of the beans. De Herrera picked up the idea of alternated row drilling but he stated that Spain was too dry for this technique. However, millet could be sown in the vineyard between rows of grapevine.[76]

Bordering on mixed cultivation is the protective ring around the field, probably a magical act. '*When some wheat mixed with hellebore is sown around the field the birds will not destroy the sown crop*' [GE-2.18.2]. Then a homeopathic notion sneaks in: The birds that try it will die; make sure to collect them, hang them on a stick by their feet, and no bird will come [GE-2.18.9]. — Are birds really scared away by their conspecifics hanging upside down?

De Herrera reports a curious case of companion cropping, the intentional sowing of some rye in the wheat field. The rye straw, long and supple, can be used to bind the wheat sheaves. He doesn't think this a good idea because at threshing time some rye seed will be mixed with the wheat as an impurity.[77]

Garden crops. Theophrastus observed that some plants collaborate, '*... or sow bitter vetch among the radishes to save them from being devoured*' [CP-3.10.3}. And on 'pot herbs': '*To protect radishes against spiders* [G: ψύλλαι = aphids, flea beetles?] *it is of use to sow vetch among the crop; to prevent the spiders from being engendered they say there is no specific*' [HP-7.5.4]. The Geoponika reiterates '*Vegetables are not eaten by flea beetles*[78] *if at sowing they are mixed with a certain amount of vetch; that method is indicated especially for radish and turnip*' [GE-12.7.1].[79] '*Others, following a more natural remedy, plant garden rocket in stead, especially with cabbages, as they suffer more from fleas*' [GE-12.7.2; 12.10]. — The passages vaguely suggest the use of admixtures as trap plants.

Is this companion crop a trap or a deterrent? Ibn Wāfid: '*If one adds a bit of Ethiopian cumin to the cabbage at sowing the cabbages will keep free from caterpillars and birds that will not damage them. And if you add some caraway to the cabbages at sowing time it will kill all aphids [or flea beetles]*' [IW-75(36)316]. The Andalusian authors expect gardeners to plant vegetables in neat rows. Ibn Baṣṣāl explicitly tells gardeners to plant faba beans in rows and to interplant (onion) bulbs with basil to exploit all available space.[80] De Herrera recommends sowing mint between the vegetables, especially cabbage, using the term '*yerba buena*'.[81] — Possibly the strong smell of certain umbelliferous plants and mint types were thought to have an insect repellent effect.

Planted crops. Theophrastus writes that '*... growers sow barley ... among vine slips to reduce their wetness*' [CP-3.10.3]. Combination cropping of grapevine and fig, or of grapevine and annuals, is described by Ibn al-ʿAwwām [IA-1.331/2]. He thought it advisable to protect tree sprigs in cutting beds by interplanting them with crops that need much water, as e.g. eggplant, to protect them against the heat of the sun [IA-1.177].[82] Coriander could protect walnut cuttings. Similarly, cypress can be undersown with barley; the cypress reaches the height of barley when the barley ripens [IA-1.267].

Fig. '*If you dig in fig plantlets with their roots you have to add sea squill*' [GE-10.45.6]. '*The fig trees will not produce caterpillars when at planting you insert the sprig in sea squill; and those that are inside will go out when you stray caustic soda on the roots and in the cavities of the trunk*' [GE-10.46].[83] — Sea squill with its toxic substances appears frequently in the pre-modern treatises as a remedial companion. Its use may be characterized as a preventive, seldom curative, living insecticide.

Grapevine. Here we do not cover the system in which elm trees were used as a support for vines, common in classical and medieval times.[84] Row alternation was applied in vineyards. '*The trellises offer more advantages in all respects: because, on the one hand, they produce a better wine, more stable and sweeter, on the other hand, if they are placed at intervals they allow the area between them to be sown every two years*'. '*Between the rows [of trellises] one may also admit fruit trees with small rooting system such as pomegranate, apple and quince*' and, when space permits, olive trees but not figs.[85]

One section of the Geoponika deals with this row alternation [GE-5.11]. Faba bean and bitter vetch, pumpkin and cucumber can be sown in the vineyards without damage [GE-5.11.1]. Then comes the warning: '*But the experience teaches that it is positive to plant nothing in the vineyards, because what is sown snatches food from the grapevines and its shadow harms them*' [GE-5.11.2]. Agustín is more constructive [AG-197]. When the soil in the vineyard is too rich, corrupting grapes and wine, it should be reduced by intersowing barley, faba bean, or chickpea. A poor soil can be enriched by sowing lupines, ploughing them in after the second flowering.

Olive. It was and is customary to sow cereals between the olive trees.[86] 'The plant holes of the trees should be at a distance of 23 m so that the winds can blow between the trees and the area between them can also be sown' [GE-9.6.6]. Cárdenas *et al*. (2007) stressed the importance of cereal cover for the abundance and diversity of spiders in olive groves. — In the old days intercropping of olives with corn was common so that biocontrol may have been stimulated unknowingly.

'***Pomegranate*** *likes a warm climate and is planted in dry areas but you have to put them in together with sea squill*' [GE-10.29.1]. — Perhaps intended to protect the plantlets against insect damage.

5.3.6 Antagonism and mutualism

Plants of different species growing together may positively influence each other, the idea behind combination cultivation, or they may negatively affect each other. Allelopathy is any (negative) effect of one plant on another by way of chemical compounds escaping into the environment. The term 'allelopathy', coined in 1937, was defined with reference to chemical interactions between plants (Willis, 1985).

The phenomenon of allelopathy was known in antiquity but seen in a different light, as in an Egyptian doctrine on sympathies and antipathies elaborated by Bolos Demokritos.[87] Cabbage (and bay) were thought to have an antipathy toward grapevine. Antipathy, one plant damaging the other, was recognized. '*Again trees may destroy one another, by robbing them of nourishment and hindering them in other ways. Again an overgrowth of ivy is dangerous, and so is tree-medick, for this destroys almost anything.*' [HP-4.16.5].[88]

Theophrastus states '*Indeed a few plants are even injured by odours, as the vine by the odours of bay and cabbage, and it shows that this is so from the moment it sends out shoots. For when the vine is near cabbage or bay its shoot curves its tip and (as it were) turns back because of the pungency of the odour*' [CP-18.4]. Pliny adds '*Some call this variety rock-cabbage; it is strongly antipathetic to vine, so that the vine tries very hard to avoid it, or, if it cannot do so, dies*' [NH-20.36.92]. Cato explains '*If you wish to drink deep at a banquet and to enjoy your dinner, eat as much raw cabbage as you wish … it will make you feel as if you had not dined, and you can drink as much as you please.*' [CA-156] — Apparently, eating fresh cabbage protected against inebriety.[89] The argument was repeated over more than a thousand years. The cabbage-grapevine antipathy covered the complete trajectory from vineyard to brains.

The Geoponika emphasizes '… *and those who want to drink much wine without getting drunk eat raw cabbage in advance*' [GE-5.11.3]. '*And if it happens that grapevine and cabbage have been planted near to each other, when the vine grows and approaches the cabbage it does not advance easily and even retreats because of being incompatible with the cabbage*' [GE-5.11.4]. '*In effect, if once or twice the cabbage approaches the grapevine in the crops the first dries up immediately or it dries out the vine*' [GE-12.17.18]. The 'explanation' is given in somewhat cryptic terms. '*Due to the hostility existing between them, it follows that by a flow of humours from the head the uvula descends down the gullet, the sap of the raw cabbage spread by the head attracts it to the palate*', and so on [GE-12.17.19/20]. Crescentio extended the range of plants inimical to grapevine: cabbage, hazel, laurel, and common maple [CR-4.18]. — In reality no allelopathy exists between cabbage and grapevine.[90]

Sympathy, one plant helping the other, is recognised by Theophrastus: '*That among plants too some collaborate to preserve and propagate others can be seen from the following*: … *and the plants sown among the vegetables either to do this [reduce excess of fluid] or to keep them free of the pests that arise, as bitter vetch is sown among radish to help against the flea-spider*, …' [CP-1.2.18.1]. Theophrastus again: '*This is why both pomegranates and myrtles are each planted in close formation, so that the trees can shelter one another and be screened from the sun.*' Myrtle and olive '*entwine their roots*' [CP-3.10.4].[91] The point is taken up by the Geoponika: '*Democrites confirms that pomegranate and myrtle like each other, and when one is planted together with the other they will give a good yield and their roots will interlace, even if they have not been planted close together*' [GE-10.29.5].

Ibn al-῾Awwām, drawing from 'Nabatean Agriculture', has a lengthy paragraph on sympathy and antipathy among trees. The sympathy between grapevine and jujube is like that which a man feels for a beautiful woman. Olive and grapevine profit from each other, though some distance be respected.[92] The elm tree and the grapevine show affection and in association the grapevine produces more. All plants near a walnut tree show their antipathy to it, the fig excepted. The lemon citron and orange trees suffer from pungent odours as exhaled by rue, plantain, lemon balm, and spurge.[93] — In antiquity elm trees were a usual support for the grapevine. As to the walnut canopy, heavy shading will reduce plant growth in the under-storey, as does the dripping of noxious substances exuded by the leaves.[94]

Neutral neighbourhood was recognized early, with good botanical reasoning. '*The pine too is held to be friendly to all because it has a single root and the root goes deep*.' No root competition, myrtle and bay grow well under pine. '*And it is clear that roots interfere more than shade, since the pine casts a large shadow*' [CP-3.10.5]. Apple and pomegranate are easy and harmless neighbours [CP-3.10.7]. Melon profits from the proximity of aubergine [IA-2.220]. — One wonders why.

Plant-animal antagonism exists too. The pomegranate and the walnut tree are antagonistic to snakes and vipers and do not allow them to stay under these trees. The hazel is antipathetic to venomous animals such as snakes and scorpions.[95]

5.3.7 Soil fatigue

Soil impoverishment by depletion of minerals did occur in late antiquity.[96] 'Mining the soil' is the name of the process in which the field's export of minerals, packed in the commercial product, exceeds the sum of the field's import, packed in manure, and the field's natural renewal by mineralisation. Records of exhausted soils are not infrequent. In medieval France, an inadequate supply of manure caused the farmers to replace wheat by rye, as possibly also in southern England. For the same reason rye had to be replaced by buckwheat in part of the Netherlands around 1450.[97]

'Baking the soil' was advocated in the Mediterranean area. When spring arrived the soil should be opened with wide furrows so that the heat of the sun can exert its beneficial effect, admitting air to the soil, softening the soil particles, and killing the weeds [IA-1.484]. This southern solar treatment of the soil is more or less equivalent to the northern freezing-and-thawing of the soil. Another method to rejuvenate the soil is by a parallel of 'deep ploughing'. '*The soil must be dug in such a manner that [soil] from above comes under and that from below comes on top, so that what is dry acquires the superficial moisture whereas the moist and compressed gets the warmth and the looseness of the surface*' [GE-5.19.3].

Did Columella describe what is now called 'replant disease'?[98] '*As to vineyards which have become worthless through long neglect, it is agreed by all authorities that they are worst of all if we wish to replant them, because the lower soil is imprisoned in a tangle of many roots, as if caught in a net, and has not yet lost that infection and rottenness of old age by which the earth is deadened and numbed as if by some poison or other*' [CO-3.11.1/2]. — Columella's solution is to give the soil a rest of ten years, a sensible piece of advice.

Soil sickness, due to depletion of minerals, nematodes, soil-borne fungi, and insects, will have occurred in pre-modern times but the evidence is thin at best. It was widely known that chickpea exhausts the soil, a point repeated from

Theophrastus [HP-8.7.2] to de Serres [OS-2.4.110]. Before planting new trees a 'tired soil' could be cured by repeated ploughing in winter time, removing all weeds.

5.3.8 Biological control

Whereas old Chinese sources recount specific biocontrol methods, little of this sort is found in pre-modern sources, the use of livestock excepted.[99] I mentioned the control of ants by conspecific ants (§ 4.4.4). In comparison with the situation of today I suppose that in olden times the extent of agriculture was more limited, the geographic fragmentation higher, and the forests, bushes and rough areas more abundant. Supposedly, the wilderness supported a diversified bird life with short routes between nesting areas and crop lands. This situation may have led on the one hand to greater damage by seed eating birds, on the other hand to high predation by birds (§ 3.5.3). The books render an unbalanced view because seed loss by birds was obvious whereas insect predation is not easily observed.

This will certainly be true in the case of insectivorous birds. Only in an emergency, as during the caterpillar plague of 1829 in Groningen (Box 8.2), the birds will be too late. In a more regular situation birds play their part in the food web, eating insects and mice. White storks, abundant in Morocco and lost but reappearing in the Netherlands, are not averse to mice and other small mammals. Grey herons occasionally snatch a small mammal or even may get used to mouse hunting.[100] The many white stork nests that once embellished Alsace may have been of practical use too. In the eastern Netherlands it was common usage to accommodate the barn owl that helped to control mice. Owls were not mentioned in the pre-modern books consulted so far.

The simplest biocontrol agent of mice and other rodents, and even of small snakes, in and around the house is the cat. In the literature references to cats were few, but this does not necessarily imply that no cats were employed. During the early centuries CE Babylonian Jews attached economic value to cats, kept to chase mice and snakes.[101] A millennium later Crescentio provided a variety of ways to control mice, the simplest being to house a cat [CR-10.35]. De Laguna: '*House mice multiply so fast that we would be no more on this world without cats*.[102] Biocontrol was not the hot topic it is today but some notion of biocontrol existed. On December 15th, 1571, Duke Albert V of Bavaria (1528-1579) prohibited fox-hunting because of a vole problem.[103]

Harvested grain used to be stored on the farm. Cats and owls helped to keep mice in check. What about the vermin? In stored grain it can be controlled by chickens, according to de Serres [OS-2. 7.123]. — I doubt whether this applies to grain weevils that pass most of their time inside the grains. The chicken droppings may have been a nuisance.

5.4 Traps and baits

5.4.1 Trap crops (companion plants)

Trap crops and trap plants are used to lure insects away from their target crop (see also § 5.3.5).[104] The insects are left to feed happily on the trap plants, where they can be killed or removed with ease. Some bitter vetch seed added to seed of garden crucifers would protect the latter against aphids. Garden rocket should be planted in the vegetable garden to protect cabbage from aphids. Chickpea sown among the vegetables attracts snails and/or slugs that can be removed by hand.[105]

5.4.2 Traps

An insect trap was made by binding an ivy branch with many leaves around the trunk of a grapevine; it provides shade and shelter for insects that can be collected and killed [GE-13.10.10]. Charming medieval illustrations of mouse traps have been published. Dug-in ceramic pots, usually glazed inside, caught the voles, sometimes hundreds per night. The record was a catch of 2300 animals in one night, in and around a single hay stack near Rotterdam, the Netherlands, 1665.[106] Moles were trapped in jars placed vertically in the soil with their opening at surface level; they will enter but cannot leave [DH-4.7.216].

5.4.3 Plasters and grease bands

In antiquity grease-banding was used to protect trees against insects crawling up the trunks, caterpillars and ants. '*Ants also are pests to trees; these are kept away by smearing the trunks with a mixture of red earth and tar ….*' [NH-17.47]. '*In a similar manner to prevent vine from leaf-rolling caterpillar he advises boiling down two gallons of lees of olive-oil to the thickness of honey, and boiling it again mixed with a third part of bitumen and a fourth part of sulphur, this second boiling being done in the open air because the mixture may catch fire indoors; and he says this preparation is to be smeared round the bases and under the arms of the vines, and that will prevent caterpillar*'.[107] Columella [CO-12.14]: '*Crush lupines and mix them with the dregs of oil and smear the lowest part of the vines with this; or else boil bitumen with oil and touch the lowest parts of the vines with this; then ants will not crawl beyond.*'

Bolens found a common denominator among the recipes given by Andalusian agronomists:[108]

1. A simple bitter substance such as bitter cucumber and squirting cucumber.
2. A slow drying, not abrupt, in the sunshine.
3. A re-humidification with water.
4. The establishment of rotting after careful mixing of the elements.
5. A second round of drying of the new mix.
6. The pulverisation of the dried material.
7. The addition of ashes.
8. The result was made into a plaster by adding sticky substance, olive oil or fresh cow dung.

If we associate 'bitter' with 'alkaloids', 'ashes' with 'high pH', 'rotting' with 'fermentation', and 'oil' or 'dung' with 'sticker', the logic of a phytopharmaceutical formulation begins to appear.

Bands of pitch mixed with manure were used to stop ants from climbing trees [IA-1.594]. Crescentio recommended smearing the sticky juice of mistletoe or applying strands of silk dipped in oil.[109] — In modern times grease banding is still in use.

5.4.4 Baits

Theophrastus: '*As for pests, radish is attacked by spiders [ψύλλαι], cabbage by caterpillars and grubs, while in lettuce, leek, and many other herbs occur 'leek-cutters' [πρασοκουρίδες = ?leaf-maggots]. These are destroyed by collecting green fodder, or when they have been caught somewhere in a mass of dung, the pest being fond of dung emerges, and, having entered the heap, remains dormant there; wherefore it is then easy to catch, which otherwise it is not*' [HP-7.5.4].

The Geoponika is rich in baits [GE-13.4,5,7]. '*But its is better to crush all together, in the Dog Days, seed of poison hemlock with lenten rose and barley flour, or squirting cucumber, stinking nightshade or bitter almonds and lenten rose and mix it with equal parts of barley flour, dilute it in olive oil and place it near the holes of the voles, then trying it they will die*' [GE-13.5.2]. '*If you mix filings of iron with yeast and you place it where mice abound, by tasting it they will die*' [GE-13.4.3]. Next to baiting is the following practice: '*Experienced people from Bithynia fill the holes [of the field mice] with oleander leaves so that the voles leaving in haste touch them with their teeth, then touching them they will perish*' [GE-13.5.3]. Similarly, baits of flour or grated cheese with oleander, bitter cucumber, *adelpho negro*, or bitter apple will work [AG-161].

De Herrera echoed Theophrastus, holding that aphids were brought forth by vegetables. He stated that they will perish after good rainfall. If not, small heaps of fresh manure will lure them. The aphids hiding there can be trampled to death [DH-4.7.216]. — When it rains aphids and other insects will hide and disappear from sight, but it is doubtful whether they will all perish. Trampling aphids will not be easy.

Bury the entrails of a ram in the centre of your vineyard and all vermin, aphids, locusts, and small beetles that eat the twigs of the grapevines will go there so that you can kill them. Elsewhere the entrails of a male calf are recommended, a cure that can be repeated several times until the garden is free from vermin.[110] — We can be sure that much vermin will develop in this type of bait, primarily scavengers but probably no insects noxious to plants.

Not baiting in the strict sense is Varro's suggestion: '*Grain which the weevil has begun to infest should be brought out for protection. When it is brought out, bowls of water should be placed around in the sun; the weevils will congregate at these and drown themselves*' [VA-1.63]. — They may come out, but it is questionable whether they will drown themselves.

5.5 Treatments

5.5.1 Kinds of treatments

The kinds of treatment recommended in pre-modern writings were nearly as diverse as today. To control weeds ploughing and spitting (or rather hoeing?) were mentioned regularly, hand weeding was suggested rather than mentioned explicitly. In the following I have classified treatments in a modern way, according to method of application: hand picking, seed treatment, disinfection, and so on. Details on the recommended crop protection substances are given in Chapter 6.

Botanicals excepted, the number of materials available for crop protection was quite limited. Materials with a smell disagreeable to humans were often used, with the idea that pest animals might also dislike the stench and abstain from eating crop or produce. Easily accessible materials were mentioned frequently, such as olive lees, ash, and urine. In addition a wealth of botanicals was quoted.

5.5.2 Hand picking

Any modern gardener will pick off a discoloured leaf or flower, almost without thinking. Hand weeding of gardens was and is common practice. Hand picking of insects and diseased leaves is timeless, from the beginning of agriculture until today and tomorrow. Sometimes caterpillars enter the vineyard that eat everything green, green worms and small '*acuti*' that perforate and shrivel up grapes and twigs. One has to interfere by hand to collect them, trample them, or kill them by fire [CR-4.18]. Hand picking in medieval vineyards was routinely done by women and children.[111]

De Herrera is explicit. When aphids or caterpillars are on the buds of the grapevines pick them by hand and burn them; don't bury them as they may multiply due to the warmth of the soil. Snails can be hand-picked from chickpea sown as trap plants. Aphids and caterpillars, appearing more among trees than in open spaces, can be hand-picked and burnt. The alternative is to shake the plants in the morning, when it is still cool, so that the insects fall on the ground and crawl away. More efficacious is shaking aphids and other small insects from the twigs into bags, wide open at the top and narrow at the bottom; this should be done before they lay eggs.[112]

'*The most secure way to protect the [fruit] trees from damage by caterpillars is to search diligently for the brood during winter, to get rid of it. An easy thing to do, as it is a matter of taking and breaking the eggs. One finds them grouped in packets wrapped in dry leaves, bound together by the spinnings of those animals, as the spider's work, and those packets hanging from the branches of the trees*' [OS-6.27.661].[113]

These instructions refer to the careful regular work as opposed to the occasional mass destruction. Locusts had to be collected with bare hands, and burned or trampled. Livy described the events in 173 BCE (box 8.1).[114] Albertus Magnus wrote: '*They sometimes move together in such numbers that they destroy all the fruits of the earth. It is held, therefore, as a law in many lands that at such a time the people are to go out in the fields and exterminate them. In the morning they sit unmoving,*

Box 5.4 Grasshoppers on Cyprus

During the Venetian reign of Cyprus, 1473 to 1570, 'locusts' were a serious problem, primarily Moroccan grasshoppers. Their menace was particularly strong during the first quarter of the 16th century. In 'normal' years wheat suffered an average loss of over six per cent due to the grasshoppers, not to mention the loss of sugar cane and cotton. Control measures were of two kinds, one of religious magic and the other of applied ecology. The first kind was of little avail but it pleased the farmers who believed that one cricket killed engendered another 100 animals, a belief that suited their indolence. The second kind was reaping the eggs, a method enforced upon the populace by the matter-of-fact Venetian authorities.

Pietro Lion, captain of Famagusta, reported that 1510 was a bad year, with local famine and loss of next year's seed. Reaping the eggs became obligatory. An amount of 75,000 litres of grasshopper eggs was thrown into the sea. To impress the authorities in the capital, Nicosia, he sent them a cart-load of eggs. In 1516 over 2.4 million litres of eggs were collected, a terrific amount requiring a high level of organisation and logistics.[115]

The control measure was enforced with carrot and stick, payments and fines. Recalcitrants were punished, one punishment being shaving beard and hair, a fearsome humiliation. After 1550 the threat decreased for reasons unknown. Farmers coped with the problem by changing from wheat to barley, which could be harvested one to two months earlier, reducing the risk at the cost of a less valuable crop. Barley remained the dominant grain crop of Cyprus well into the 19th century (After Arbel & Barnavi, 1989).

paralyzed by the night's chill. When the sun has arisen, however, they stretch their wings and all go forth in crowds with no king and no law to watch over their tyrannical government, …'.[116]

The 'Calendar of Cordova', dated 916, advises the destruction of the hopper bands that appear in March.[117] The advice may refer to locusts but more probably to grasshoppers that at times become gregarious. In 1574 a grasshopper plague ravaged parts of Spain. In one place the grasshoppers were caught by chasing them to cloth walls and traps. Over a period of six weeks up to a hundred men collected some 90 cubic meters of grasshoppers, probably Moroccan grasshoppers.[118] On Cyprus, grasshopper eggs had to be collected (Box 5.4).

5.5.3 Seed treatment

Theophrastus mentioned seed treatment with wine, because its pungency prevents disease [CP-3.24.4]. The ethanol may have a disinfecting effect, though the concentration is a bit low. The idea is repeated frequently, e.g. by the Geoponika [GE-2.18.6]. Virgil recommended treating the seed with herbs, *nitrum* (native soda, KNO_3), and dregs from the oil-press (*amurca*) [VE-1.193/4]. Both recommendations were repeated by Pliny, who added two more. Seed is to be ... '*kneaded in a mixture of urine and water three days before sowing*;' and seed is '*... not liable to maggots if [seed] mixed with crushed cypress leaves*.' [NH-18.45.158]. There are many recommendations on seed treatment, but they are not always simple to execute. Among the materials to be applied were various botanicals (Chapter 6) but also ox bile. — Presumably, seed treatment was applicable to garden crops but not to sown crops on large estates. *Nitrum* works as fertilizer and disinfectant; it may protect wheat against fungal disease such as covered smut.[119] The highly valued seed treatment with 'house-leek' [GE-12.7.3, 12.20.4] demands special attention (§ 5.7).

Cereals. Seed treatment with either the sap of 'house-leek', extract of the root of squirting cucumber, or *amurca* is recommended.[120] These substances supposedly make the seed less palatable to birds and ants, but what about the flies? '*Sow the grain after having moistened it with the sap of the 'house-leek', since in that way it will not be damaged by birds, flies or ants, but the plants will develop much nicer*' [GE-2.18.1]. Pliny's cypress leaves appear again: '*And if you snip cypress leaves and mix them with the seed these will not be eaten and will be conserved*' [GE-2.18.4]. It was thought that cypress leaves stimulate the germination. '*Grind the root of squirting cucumber, soak it a day and a night, sprinkle the fluid over the seed, cover it with a mantle, sow it the next day, the sowings will not be damaged, it will even gain in quality*' [GE-2.18.10]. '*But the best preservation is by splattering water with* amurca *over the seed*' [GE-2.18.7]. Soot from the chimney suspended in water can also be used to treat seeds [DH-4.7.216]. — The use of *amurca* and squirting cucumber seems quite reasonable as a protection against insects. On the effects of cypress and soot I found no further information. They may protect the germinating seed against insects.

Faba beans. '*They [= faba beans] are saved from becoming wormy when wetted with sea water, and also with softened* magodaris' [GE-2.35.9]. *Magodaris* remains unidentified, possibly the gum of a *Ferula* species. The text does not clarify whether it refers to seed protection in storage or to seed protection in the field after sowing, probably the latter. De Herrera has several recommendations such as soaking the seed for one day, treating it with *amurca*, and sowing when the moon is full.[121]

Lentils. '*... and there are others who sprinkle lentils with vinegar mixed with silphium, and when they are dry give them a dressing of oil*.' Cow dung is recommended for lentils: '*Lentils emerge much nicer and earlier if before sowing they are covered with dry manure, such as cow dung*'.[122]

Vegetables. To protect them from birds and other animals, treat the seed with 'house-leek' before sowing [GE-12.7.3]. The advice is repeated: '*If you moisten the seeds of the cucumber seed beds with sap of 'house-leek', you keep them intact*' [GE-12.20.4]. '*All seeds, the garden-grown as well as the wild, are protected against whatever parasite if you sow them after soaking them in the sap of mashed squirting cucumber*' [GE-12.7.4]. — Sap of the squirting cucumber may have had an effect, but what is to be made of the next recommendation? '*The vegetables will survive without being eaten if sown in a tortoise shell*' [GE-12.7.5].[123]

The function of the recommended seed treatments is not always clear. Some may be insect repellent (soot, ox bile), some insecticidal (squirting cucumber), others disinfectant (wine). Soaking the seed may speed up germination and emergence, and thus reduce the period of exposure to soil-borne agents. Treatment with biologicals, especially powdered or diluted manure, might be seen as a form of bioprotective seed coating stimulating microbial life in the rhizosphere (Nene, 1999).

5.5.4 Disinfection

Pruning knife. Several recommendations refer to treating the pruning knife. '*...; or rub the pruning knives with garlic crushed in olive oil.*' [GE-5.30.1] '*But if you rub the pruning knife with oil containing boiled caterpillars taken from roses, the vine will remain unaffected by any other animal or by night frost*' [GE-5.30.2]. Elsewhere the rubbing is with fat from a small billy goat, or with frog blood. Sometimes treating the whetting stone is thought to be enough. — The caterpillar recipe is homeopathic. The best to be expected from such practices may be some protection against the transfer of fungal, bacterial, or viral inoculum. The belief in garlic as a cure of whatever ailment is ineradicable.[124]

Wounds. Man-made wounds cause disease. '*Moreover, the wounds and blows inflicted by men who dig about the vines render them less able to bear the alternations of heat and cold; for then the tree is weak owing to the wounding and to the strain put upon it, and falls an easy prey to excess of heat and cold. Indeed, as some think, most diseases may be said to be due to a blow; for that even the diseases known as 'sun-scorch' and 'rot' occur because the roots have suffered in this way. In fact they think that there are only these two diseases; but there is not general agreement on this point.*' [HP-4.14.7].

Wounds made by grafting needed special care to let the graft succeed. Cato recommended covering wounds due to grafting with a sticky mass, a smear consisting of clay or chalk, a little sand, and cattle dung, thoroughly kneaded [CA-40.2/4]. A similar mix, always with some kind of dung, could be applied to large wounds. To keep the mix in place it should be covered with a rag bound to the stem by means of willow sprigs (Fig.5.1).[125]

Man-made wounds in the bark of trees should be treated with dung.[126] Powdered soil mixed with powdered goat droppings, prepared with olive oil and fresh water, can be smeared on the wounds [IA-1.562]. Dry lesions on grapevines and spots that are infested by worms or ants should be cut away down to the living flesh so that new flesh can be formed. Then treat the wounds with olive lees mixed with mud. Wounds caused by plough or hoe can be treated with condensed olive lees without salt, then smeared with dung of sheep or heifers, and carefully covered with soil.[127] These are sound recommendations; olive lees has biocidal properties.

De Serres noted that apple trees were often attacked by grubs, probably of the goat moth. Excision wounds should be treated carefully. '*Recognizing the trouble by the bulge of the bark, and a certain liquid oozing from such a spot, one shall there make an incision in the bark and remove all rotten material found, cutting to the life wood; and after having killed the animal and removed its venom; to consolidate the wound it*

Figure 5.1. Graftings. The woodcut shows branches of cultivated trees grafted onto wild stocks, with grafted branches coming into leaf. The wound care is remarkable. Wounds are covered by some mixture, wrapped in rags, and bound with willow sprigs [CR-2.22]. From: Crescentio (1548) p 58. Scale 1:1.

should be covered by a plaster consisting of fresh dung, from cattle or swine, fresh chalk, and sage, fixing it with linen and willow bindings, to leave it there as long as it will hold and until the incision is healed'.[128]

5.5.5 Sprays

'Spraying' is the anachronistic term used here to indicate the pouring, sprinkling, or spattering of a fluid over the crop. Most of the substances recommended for spraying can be seen as repellents. Some notion existed of the limited persistence of a sprayed substance. Chickpea during ripening had to be treated every five days by water with powdered seeds of squirting cucumber and wormwood since dew washed away the bitterness of that solution within five days [GE-2.36.4].

The Geoponika is not clear about the preparation of the various sprays. Recommendations are limited to remarks such as 'the herb is dissolved, macerated, mashed in water'. Urine, vinegar or *amurca* may be added. In some cases it is obvious that the mix must have had a foul smell. '*Destroy the existing caterpillars by mixing equal parts of urine and amurca, boil it on the fire, then let it cool down and spray it so over the vegetables*' [GE-12.8.3]. Strong vinegar with henbane heated all together kills aphids in the vegetable garden [AG-158] — Caterpillars cooked with dill will not scent as perfume [GE-12.8.4], but the dill might have some effect. Henbane could be effective.

We may wonder about the application methods. The Roman watering pot or can was mentioned in § 3.6.5. Snails can be prevented by sprinkling water with soot or with *alpechín* over the vegetables using a *hisopo* or (holy water) brush [DH-4.7.217]. A variant is the use of a rag (S: *hisopillo*), dipped in a mix of the sap of mashed black henbane and strong vinegar, to treat the vegetables [DH-4.7.216]. Were the rags just placed among the plants, used to dab the leaves, or used to spatter? Take asafoetida, bind it in a rag, wet it in water, then spray them [the plants] with it, it will kill all the caterpillars, writes Ibn Wāfid [IW-(42)322].

Pliny provided a special version of spraying: '*A protection against wasps for bunches of grapes hung up is to sprinkle them with oil squirted out of the mouth*', a version echoed in the Geoponika and by Agustín.[129] Pouring boiling water in ant holes is a good way to chase ants [DH-4.7.216].

5.5.6 Repellents

Various substances were recommended as repellents, probably because of their bad smell and/or taste.[130] Among them oregano was popular. Young pumpkin and cucumber plants are protected against aphids when you place oregano branches among them, aphids die, and no new aphids appear [GE-12.19.9]. To protect trees and vines against caterpillars and other parasites '*Pulverise Lemnian red lead and oregano in water, pour this on the roots and plant sea squill around*' [GE-10.90.1].[131] Agustín: '*You can defend the melons against caterpillars, and other small animals, by sowing oregano around them, or by placing oregano branches among them …*' [AG-74]. Garden rocket comes next in popularity. It should be planted in the vegetable garden to repel (or to trap?) aphids [AG-158]. '*… Sown nearby, it [garden rocket] is beneficial to all vegetables*' [GE-12.26.3]. When seed is impregnated with ox bile voles will not touch it [GE-13.5.1]. — The effect of ox bile seems credible.

'*A locust will touch nothing if wormwood, leek or cornflower is dissolved in water and sprayed*' [GE-13.1.9]. '*But if they [the locusts] appear suddenly, before that precaution is taken, they will touch nothing when sprinkled with bitter lupine or squirting cucumber boiled with brine, as they will die instantly*' [GE-13.1.3]. '*Similarly they [the locusts] will pass by to the leeward land if you catch bats and hang them on the trees above the place*' [GE-13.1.4]. — The effectiveness of the last counsel is questionable, but wormwood, bitter lupine and squirting cucumber may have had some effect as deterrent or poison.

5.5.7 Dusts

Dusting is recommended repeatedly and for different purposes. The 'dust line' begins with Theophrastus and continues for 1800 years at least. Unfortunately, Theophrastus' comments are not unambiguous, as in: '*Dust too is considered to be nutritious to certain plants and to make them flourish, as it does to the grape-cluster, and growers therefore dust it frequently, some also hoe the fig-trees where this is needed.*' [HP-2.7.5]. What is dusted and how?[132] '*As to dusting the fruit [i.e. the grapes], we got one good piece of advice and one bad. The good advice is not to neglect it at first, when the clusters are beginning to turn dark, and wait until they are ripe … The bad advice is to dismiss dusting as quite useless and in fact harmful, since its usefulness is attested by growers' resorting to it and by results in other plants*' [CP-3.16.3]. Theophrastus states that dust is food and also functions as a screen against the sun. '*The covering of cucumbers with dust is not unreasonable. For the sun dries them out and so makes them hard, which is why growers also hide them under the leaves. So there are two ways for them to become plump and tender: or cover them [with dust] or water them*' [CP-3.16.4].

When the grapes reach the adolescent stage, Columella writes [CO-4.28.1], '… *it is proper to bind it and strip it of all leaves, and also to make it plump by frequent diggings; for fruit is made more plentiful by pulverizing the soil.*' With pulverizing he '*meant the working of the ground about the vine when it was dry, reducing it to powder, and raising clouds of dust to settle on the leaves and fruit as a protection against sun and fog*'.[133] Pliny explains the objective of the pulverization (L: *pulveratio*) for grapes in August; it helps the grapes to mature.[134]

Columella is echoed by the Geoponica: '*Break the clogs in August so that the dust is blown up, that then settles on the [grape and olive] fruits and lets them ripen faster*', [GE-3.11.1]. Those growing along the roads are more fleshy, because of the dust that travellers stir up [GE-3.11.2]. The dust at this time [July] favours the grapes, making them bigger and ripening them earlier, wrote Ibn Wāfid.[135] De Herrera qualified the third, superficial tillage that stirs up the dust. In humid places the dusted grapes will grow better, become juicer, ripen sweeter, and rot less, in dry places dusting may damage the twigs [DH-2.16.77]. The rationale of the dust idea is quite complex (see Box 6.1).

Dusts were used to protect grain and pulses in storage, but there are other uses. '*Often the lice attack the upper parts of the cauliflowers; they are delivered thereof by spreading sieved ashes; it is a proven method*', says Ibn al-ʿAwwām [IA-1.593]. Sulphur, found in quantities near the Etna volcano on Sicily, was dusted. '… *you will make the ants leave their hills by pulverizing sulphur and oregano and scatter it alternately over the ant hills*'.[137] If the ants enter the vegetable garden from outside strew ashes or chalk where they enter [DH-4.7.216]. — Sulphur may irritate, deter, or even kill the ants.

To improve the vines Ibn al-ʿAwwām describes a dust made of ash of willow branches burned with grape leaves, thoroughly mixed with dried cow dung or the ash thereof. This powdery mix should be thrown over the foliage. The dust stimulates growth, removes rats (or dormice?), and kills the worm [= white grub] formed at the root [IA-1.513]. Among the scores of vegetables and flowering plants two are said to react to dust. Aubergines profit from the dust stirred up by weeding [IA-2.238] and violets suffer from it [IA-2.273]. Ibn al-ʿAwwām's texts are often repetitive but the dust example shows that it is also rich in unexpected detail.

5.5.8 Fumigation

Fumigation to chase away the insects is a classic means of control. Many substances were recommended to be burnt as incense, such as deer antler, goat nail, powdered ivory, or women's hair. These items all produce stinking fumes. What humans experience as a nasty stench is, apparently, thought to chase the vermin but this supposition is questionable. However, particulate smoke may impede the respiration of insects and induce them to move away. Some of the fumes may have contained elements that are toxic or deterrent to some insect species.[138]

'*The caterpillars that damage the vines or nest in part of the vineyard will die when cattle manure is burnt in the direction of the wind*' [GE-5.48.1]. '*Others drive the vermin away from there by burning the resinous sap of fennel, deer antler, goat nails, sawdust of ivory, or root of Madonna lily in the vineyard*' [GE-5.48.2]. As to vermin on the vines:

'*Others put the vermin to flight by burning or planting common peony near to the grapevine, and others what is called greater burdock*' [GE-5.48.4].

If locusts are fumigated in a locust-infested place all other locusts will flee, and the same with ants [IA-1.595], a homeopathic advice encountered in many variations. Mice are chased away by burning incense of green tamarisk [GE-13.4.8]. Moles are killed in their holes, or smoked out, by apparently toxic fumes (§ 4.2.8). The following fumigations may be less effective to control caterpillars. '*You will also kill them by burning the mushrooms that grow under the walnut tree*' [GE-12.8.7]. '*Or burn bat excrements and the cloves of the garlic without the tops, so that the smoke spreads all over the garden*' [CR-12.8.8]. Burning garlic straw or sulphur in the vegetable garden repels the caterpillars [DH-4.7.216].

More promising is burning sulphur in whatever mixture. As to [garden] trees, '*… fumigate the trees with bitumen and crude sulphur*' [GE-12.8.1]. To protect the cabbage plots against flies and aphids one places a censer with pitch and sulphur in the middle of the cabbage plot.[139] A particularly damaging caterpillar with many feet eats the leaves, shoots, and fruits of the grapevine. To kill them take olive lees boiled until it has the consistency of honey, mix it with an equal amount of sulphur, cook the mixture and burn it for two or three days at the windward side of the vineyard when there is a little breeze; the caterpillars will die everywhere [DH-2.15.74]. Burning bitumen and sulphur will do indeed, writes Agustín [AG-157], and he adds burning bats. — Sulphur vapour is commonly used in greenhouses to control mildew, spider mites, and thrips. Sulphur burning, I suppose, has a certain effect as it produces a nasty fume (SO_2); if converted to sulphuric acid (H_2SO_4) it might really harm the insects.

Reed, grown to produce supports for the vines [GE-5.53], has to be cured by smoke. '*They say that the reed stems placed over smoke do not produce the vermin called woodworm, which are those that most affect the grapevine, as they assure that this vermin appears at the vines from the reed that rots away*' [GE-5.53.6]. — This sounds reasonable, though migration of insects from reeds to vines is questionable.

5.5.9 Fire and heat treatment

Homer (c.800 BCE) depicted a swarm of terrified locusts fleeing a bush fire as a metaphor for soldiers running away in panic.[140] '*And as before the onrush of fire locusts take wing to flee to a river, and the unwearied fire burns them as it comes on suddenly, and they cower down into the water; ….*'. — Was such a fire lit intentionally? Homer leaves the reader with a shadow of doubt. Using fire to chase away or control locusts seems a crude though plausible method.

Firing old pasture to rejuvenate the vegetation was and is a world-wide practice. Virgil warned '*For oft from thoughtless shepherds falls a spark*' that may lead to a blazing forest fire [VE-2.303]. '*Brushwood is best removed by setting fire to it*' [NH-18.8.47].

'*I imagine that the stubble may be burnt with advantage to the land, or thrown on the manure heap to increase its bulk*', wrote Xenophon about 400 BCE. Virgil mentioned stubble burning. This measure, still common in many countries, contributes to the control of weeds (plants and seeds), insects, and straw-borne diseases (Fig. 5.2). In Roman agriculture stubble burning was common practice.[141]

Figure 5.2. Modern stubble burning near Arles in S France, 9 October 2012. Here, the swaths of straw, deposited by the combine harvester, are burning but the stubble itself not (yet). In several European countries stubble burning is forbidden.

De Herrera recommended burning the stubbles to control weeds, down to the roots [DH-1.5.15] . He rightly believed the ashes to be good fertilizers for cereals [DH-4.5.214]. Indeed, the use of fire for recycling of nutrients and thermosanitation continued far into the 20th century.[142]

Heat treatment was known but not frequently recommended. Wormy seed of leguminous crops could be spread out in the sunshine to cure the seeds [OS-2. 7.123]. '*To keep onions free from rotting, dip them in hot water and dry them in the sun, and when dry place them in barley straw so that they do not touch each other*' [GE-12.31.4]. A heat dip helps to preserve pomegranates [GE-10.38.9]. Grapes in storage keep a full year if picked early and dipped in hot water with alum, and removed immediately [GE-4.15.20]. — Early picking of the grapes reduces the period of exposure to infection. Alum is an excellent means of conservation but it has to be washed off before consuming the grapes, all-in-all an expensive procedure.

The noxious effects of night frosts and cold mists in vineyards were controlled by torches of reed and fires of dried manure (§ 4.8).

5.6 Curative action

5.6.1 Scarification

Scarification is the term used here for wounding plants or trees with the intention of healing them. To the modern eye this treatment is of little avail, comparable to the age-old practice of bloodletting of humans. The reasoning behind this treatment goes back to the classical Greek humoral theory, stating that disease is due to the imbalance between the four body humours (black bile, yellow bile, phlegm, blood). The theory, a leading theme in early Greek, Muslim and West European medicine, was applied somehow to trees.[143] If grapevines weep or drip at pruning time you have to uncover the roots and stab the thickest one with a knife [DH-2.15.74].

Digging up the main roots of trees or grapevines and driving nails or wooden pegs through them is a frequent recommendation. '*Into the almond tree they drive an iron peg, and, having thus made a hole, insert in its place a peg of oak-wood and bury it in the earth, and some call this "punishing the tree,"* …' [CP-2.7.6]. '*When the roots of old trees are split and stones are driven into the fissure the trees will better attract nutriments and become fertile when sterility befell the aged plants* …' [CR-11.19]. Grapevines showing prematurely discoloured leaves as a sign of weakness or indigestion can be helped by pegging of a root [DH-2.15.74], with brackish water added regularly. Scarification of main roots is suggested by Agustín to treat unproductive fruit trees such as peach or apricot [AG-116] and grapevine [AG-200].

Spitting the vineyard was a routine measure (§ 3.6.1). The roots in the upper soil layer were cut off intentionally. When the vines do not thrive, one-sided deep digging will help [HP-4.13.6], the other side can be done later. — I did not see an explanation; one may think of a parallel with regular pruning. The practice stimulates deep rooting, a good protection against prolonged drought. In France, ploughing the vineyard is still practiced by some organic farmers.[144]

5.6.2 Cures

Curative action is seldom mentioned and, if so, the action seems of little avail to the modern eye. A rare case of cure is this one: '*A scabby fig tree presumably affected by the fig wax scale is cured by planting sea squill near the roots or by pouring water with ochre around the trunk*'.[145] Trees lagging behind in growth or production received special treatment. The root system, laid bare by chopping with hoe or two-pronged fork, was treated when deemed necessary.[146] Manure, sometimes specified in detail, was added and the roots were covered with soil again. Ibn al-ʿAwwām is fond of this treatment, apparently of Mesopotamian origin.[147] Agustín briefly mentioned the treatment in passing, with little emphasis [AG-114].

Some of the following wound treatments may be effective: '*But if the said flow [of sap] damages it [the bud or shoot of grapevine] wet the bark with olive lees boiled without salt*' [GE-5.21.2]. Wounds of olive trees should be covered by clay kneaded with straw [IA-1.214]. Sap of purslane is said to cure rotting twigs of grapevine [GE-5.41.1] and rotting bunches [IA-1.559]. The extract of purslane might give some relief, but this can hardly be thought of purslane smear. '*Others, mixing barley meal with the purslane, smear it around the trunk*'.[148] — One wonders why purslane is proposed.

Grapevine. '*You will cure the diseased grapevine by sprinkling ash of old vine trunks or oak mixed with vinegar, though human urine poured over the roots also helps much*' [GE-5.37.1]. And another piece of advice: '*But if it happens that the grapevines are already affected by rust you can repair the damage in this way: puncture roots or leaves of squirting cucumber or bitter cucumber, soak them in water, and spray the vines* *affected by the rust before sunrise; the same result also gives ash of fig or oak, similarly wetted and sprayed*' [GE-5.33.3]. — The remedy may work against insects if these are the cause of the rust flecks. The timing, before sunrise, suggests an awareness of radiation damage when spray droplets work as lenses, condensing the sunlight and burning the leaves.

'*Others, when the grapevine is diseased cut it at soil level, cover the stump lightly by soil mixed with manure, and when it sprouts again, cut the weakest sprouts and keep the best ones, and do this every year until they are cured*' [AG-201]. '*When the grapevine produces many tears, and water, you shall cut the bark in the lower part of the trunk, and water will come out of the cuts and the bleeding at the tips will stop; if that is not enough you shall make open wounds in the trunk and the thickest roots, covering the wounds with the dregs of boiled olive oil …*' [AG-201]. — In fact, only the site of the 'bleeding' is changed.

Olive. Some curious treatments are recommended for olive trees that do not produce enough fruit or of which the fruits do not ripen properly [GE-9.10]. For the control of vermin the text [GE-9.10.9] refers to the chapter on grapevine where fumigation comes first [GE-5.48]. Sea squill is recommended to control caterpillars growing at the roots [GE-9.10.10].

Other tree crops. '*Every tree deserves its own and specific treatment; …*' [GE-10.84.1] without neglecting the general treatment which is good for all trees. To keep all trees healthy and strong dig around the roots and wet roots and trunks with rancid urine of men and animals [GE-10.84.2]. At planting some pour ox bile over the roots and the plantlings will remain free of damage [GE-10.84.4], as recommended for keeping apple trees free of caterpillars [GE-10.18.9]. '*The caterpillars damaging the apple tree should be extracted with a bronze nail, lifting the bark to find the insect, and the affected area should be wetted with manure*' [GE-10.18.10]. — As to urine, the ammonia may kill insects and fungi, and the nitrogen will stimulate plant growth. The caterpillars are probably wood boring caterpillars of some hawk moth.

'*Take the precaution to place faba bean seeds near the root of a tree, so that the tree does not dry out…*' [GE-2.35.1]. Faba beans are credited with unusual powers. Faba bean straw is recommended to remedy unproductiveness of trees [GE-10.83.3]. Whatever the tree, straw of faba beans or other leguminous plants is good for trees [GE-10.84.6].[149] And again: '*All the trees that lose their leaves or flowers treat them thus: dig up the soil around the roots and pour some 26 litres of faba bean straw mixed with water at a large tree, and not less than seven litres at a small one; because in this way the diseased ones will be cured and stay healthy thereafter*' [GE-10.88]. — The ailment is not clear but the remedy may just be nitrogen fertiliser.

Diseases of the fruits of orange trees could be treated by laying bare the roots of the trees, adding black ash or ash from the baths to the roots, and filling the hole again.[150] The orange trees will be restored to their original state, green and tender.[151] The alternatives are the blood of a billy goat or, if not available, human blood from a bloodletting treatment.

Ibn al-ʿAwwām cites a certain Sidagos of Ispahan [IA-1.543]. Weakened trees, characterized by low production, loss of fruits, and wormy fruits, over a period of some years, show a languor coming from the soil where the roots find their nutrition, or due to the weakness of the roots themselves. Dig a ditch around the tree 1.85 m wide and uncover the roots with care. Check whether the dug-out soil is too dry or too hard? If so, take fresh surface soil, press the soil with a piece of wood so that the wind does not blow down the tree, add water. Do this in autumn. If you find rot in the roots, remove it carefully, apply well-seasoned old manure, and water. New roots will appear and the tree will regain its old strength. — The treatment supplies nutrients, air, and water to the roots and removes rots and insects (larvae).

If worms or termites attack the roots of fig and apple: bare the roots, apply a smear of pigeon manure diluted with water to the trunk and the roots. To free the apple tree from worms you dig down to the roots, lift the bark, and find the worm and other gnawing creatures; apply fresh cow dung or, in the case of the fig tree, ashes, and return the soil [IA-1.545]. And so on. — I went into some detail here because Bolens (1981 p 8) writes that the Spanish Meseta was colonized by islamized Maghrebians, mainly Berbers from present Morocco, who were sedentary orchardmen.[152] I surmise that some of these Berber skills had Punic or Babylonian roots.

5.7 The 'House-leek' riddle

The problem of interpretation can be illustrated by the 'house-leek' riddle. House-leek was originally a plant of the mountains, growing on more or less bare rock. Its cultivation is centuries if not millennia old. By order of Emperor Charlemagne (742-814 CE) every house should carry house-leek to avert a stroke of lightning, a reference to its upright flower stalk. [153] One of the Dutch names is 'thunder leaf'. By the way, house-leek was part of a witches'-salve, applied to the thinner parts of the skin (armpit, chin), used to get 'high' with a feeling of flying on a broomstick as witches are supposed to do.[154] Two points have to be considered, a linguistic and a biological one.

The linguistic problem is the correct translation of the Greek ἀείζωος βοτάνη, literally 'the everliving plant'. Meana *et al.* (1989) translate it as house-leek (*Sempervivum tectorum*), as does the authoritative dictionary by Liddell & Scott (1961), but the latter add αειζωον λεπτόφυλλον (the thin-leaved ever-living) as stonecrop (*Sedum stellatum*). Theophrastus mentioned ἀειζοον, translated by Hort (1961) as house-leek and by Amigues (2006) as stonecrop. In view of Theophrastus' habitat description I opt for Amigues.[155] Mayer (1959) and Dark & Gent (2001) also opted for *Sedum*. Several species of *Sedum* naturally grow at sea level, on road sides, walls, and roofs.

The biological problem is a matter of quantity. House-leek was and is grown as an ornamental and not as the mass-cultivated crop that would be needed if seed treatment with house-leek were applied to food crops. Even if only applied to vegetables in gardens the supply of the slow-growing house-leek would rapidly

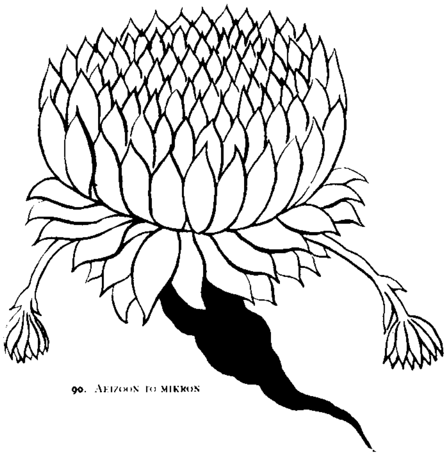

Figure 5.3. Houseleek. Aeizoon to mikron = Sedum ochroleucum or Sempervivum parvum. The Greek name in Latin script means 'the small everliving'. From: Dioscorides (1934) p 487 #90. Scale 1:1.5.

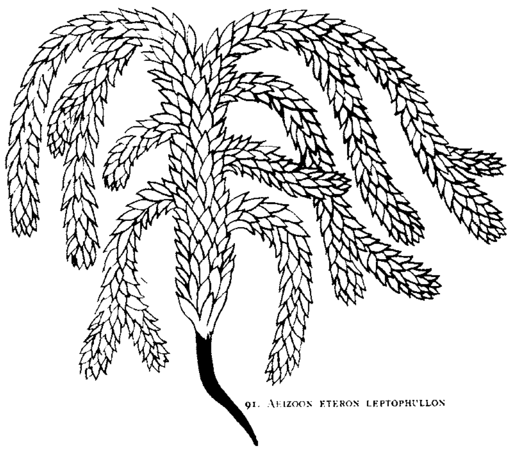

Figure 5.4. Stonecrop. Aeizoon eteron leptophullon = Sedum stellatum. The Greek name in Latin script means 'the other small-leaved everliving'. From: Dioscorides (1934) p 488 #91. Scale 1:1.64.

exceed the demand. This consideration is less valid for stonecrop. Columella, aware of the quantitative problem '*since there is not a large quantity of this plant available*', recommended chimney soot [CO-11.3.61].

The *Sempervivum*/*Sedum* confusion is at least as old as the book written by the Byzantine physician Dioscorides (~65 CE) 'On medical matters'.[156] Goodyer's unpublished English Dioscorides translation from 1655, printed in 1934, illustrated after Diocorides saw the difference between *Sempervivum* and *Sedum* but called both Aeizoon (Fig. 5.3, 5.4). In the revision by Mattioli *et al.* (1598) *S. tectorum* and *Sedum* are well-drawn and clearly recognisable, but *Sempervivum tectorum* is also called *Sedum magnum* or *majus*, the large S*edum*, whereas our *Sedum* is also indicated as *Sempervivum parvum* or *minus*, the small *Sempervivum*. The House-leek riddle entrapped the Geoponika (at least five mentions), de Herrera [DH-4.7.216], and Agustín [AG-60], but de Herrera played safe and mentioned both '*sedo*' and '*siempreviva*'.

To solve the riddle we can choose from several options:

1. Erroneous identification – see above.
2. House-leek / stonecrop was cultivated for the purpose – hardly feasible and no indication whatsoever.
3. House-leek / stonecrop collected in the wild for the purpose – not sustainable and no indication whatsoever.
4. The recommendation of treating the seed was followed rarely at best, maybe not at all.
5. The recommendation is not based on any observed effect but on the magical association of the plant name with a long life and the health of the crop.

At present I hesitate to choose between options 4 and 5, maybe both are correct.

Chapter 6

Natural products for pre-modern crop protection

Numerous pesticides were recommended, all natural products. Much attention was given to 'botanicals'. Some 60 plant species were mentioned for crop protection purposes. Their histories, uses, and – if known – active ingredients are indicated. Several natural, non-plant pesticides are on record including sulphur and arsenic, but also ox bile, dog shit, and dust. Petroleum products were known and applied. Pigeon manure and wood ash were frequently mentioned in a crop protection context. Olive lees, *amurca*, was used for many purposes, a panacea generally available in the Mediterranean area.

'Agriculture is the oldest of all crafts, in as much as it provides the food that is the main factor in perfecting human life, since a man can exist without anything else but not without food.'

Ibn Khaldūn (1377) – The muquddimah.[1]

6.1 Natural products

All substances used in pre-modern crop protection were, by necessity, natural products of either abiotic or biotic origin, non-plant substances and plant substances. Plant substances are placed in one of two categories, 'botanicals' and 'other plant substances'. The first category covers products that are meant to be pesticides prepared from plants, comparable to modern 'botanicals'. The second category, less clearly delineated, includes materials of plant origin that have also been used in a crop protection context. The distinction between the two categories is not always cristal clear.

The botanicals recommended by the pre-modern authors were crude preparations, usually crushed plant parts, or their watery extracts or, more rarely, heated extracts. Processing of natural products was common. Purification methods were not yet applied but concentration by boiling or heating was mentioned repeatedly. Mixtures of substances from different origins were common. Sometimes salt was added intentionally, sometimes omitted explicitly. Stickiness was obtained by adding latex or pitch. Urine was added frequently, and so was vinegar.

6.2 Non-plant substances

The number of non-plant products used in crop protection is relatively low. Several mineral products were readily available and easily commercialised. Some animal products were decidedly useful, but recommendations about decoctions of caterpillars, locusts, or bats cannot be taken seriously. The non-plant products reviewed here are placed in alphabetical order.

Alum. Early harvested grapes are dipped in hot water with alum, removed immediately, and placed in storage [GE-4.15.20]. Alum, used in the Middle Ages to conserve wood, has insect deterring and, to some degree, fire protecting properties.[2] Agustín recommended scattering seed cooked with alum to drug birds foraging on freshly sown fields. The drowsy birds can be collected and hung on a stick to impress and deter the newly arriving birds [AG-60]. — Alum will protect the stored grapes against bacteria, fungi and insects, but one wonders about their taste.

Arsenic. Sandarach (L: *sandaracum*), a natural product consisting of arsenic sulphide (AsS), was burnt to chase away snakes and scorpions, actually not plant pests, but always mentioned in the same breath.[3] The 'red earth' mentioned by Columella and Pliny as a component of grease bands may have been sandarach.[4] Sandarach was part of bird baits [IA-2.338].

Bats are animals of the night, mistrusted and even feared. Catch bats and fix them to the high trees of the location, and the locusts will pass by.[5] To kill caterpillars: '*Or by burning the excrements of bats and the cloves of garlic without the heads, so that the fume is dispersed all over the garden*' [GE-12.8.8].

Bile. '*At planting some people wet the roots [of fruit tree plantlets] with ox gall and that which is planted thus remains undamaged*' [GE-10.84.4]. Bile was used against voles by impregnating seeds [GE-13.5.1]. — Ox bile occurs in many magical recipes, maybe because it is a disgusting but easily accessible material.[6] It is a complex mixture with a disagreeable, bitter effect, probably a good repellent or antifeedant (§ 5.5.6).

Bitumen, see pitch.

Brine. '*But if they [the locusts] appear suddenly, …, they will touch nothing that is sprayed with bitter lupine or squirting cucumber boiled with brine, because they will die instantly*' [GE-13.1.3]. — Admixture, solvent, or active ingredient? An effect as active ingredient seems improbable.[7]

Clay, see dust.

Copper sulphate. House mice will flee from vitriol [GE-13.4.2], probably blue vitriol (copper sulphate, $CuSO_4$).

Dogshit. Unpleasant stuff, diluted in water and applied to foliage to repel browsing cattle and camels, and to prevent damage to whatever crops [GE-2.18.16]. — The persistence of diluted dogshit will have been low, a few days without rain.[8]

Dust (field application). '*That dust, which is dry, should feed a plant is wondered at. … The covering of cucumbers with dust is not unreasonable. For the sun dries them out … which is why growers also hide them under the leaves. So there are two ways for them to become plump and tender: you cover them or water them*' [CP-3.16.4]. Theophrastus' '*dusting the fruit*' refers to the third spading of the vineyard '*when the clusters are beginning to turn dark*'.[9] The Romans called this tillage of the vineyard *pulveratio*; the clods were broken and the dust was stirred up to settle on the leaves and fruits.[10] Pulverization was done late in the season, when the grapes began to ripen. '*This is the best way of protecting the grapes both from sun and from fog*'.[11] See also § 5.5.7.

Olives and grapes growing besides the roads are more fleshy and ripen faster due to the dust stirred up by the travellers [GE-3.11.2]. Ibn al-ʿAwwām [IA-1-483] too praises the dust of the roads, stirred up frequently and well-baked by the sun, enriched by the droppings of the passing animals. Road dust gives the soil softness and fineness. Dust is often mentioned as a kind of manure and also as a protection against night frost, and even against fruit rot (Box 6.1). — We need not doubt the basic observation, better fruit along the road side. Stouter plants along the border of the wheat field are still a common sight.

Spreading ashes over the plants as a protection against night frost has been mentioned frequently. How ash particles on buds, small twigs or flowers could affect their temperature and save them is difficult to imagine.

Dust (in storage) was described in § 4.4.6. Stored wheat can be preserved by an admixture of sieved clayey soil [GE-2.27.8]. — Adding whatever kind of powder or dust is a time-honoured method to deter storage insects.[12] The composition of the dust seems less relevant than its mere presence.

Dust also protects grapes in storage. '*Grapes will also be kept during a very long time when suspended in the wheat stores, foremost when the wheat is turned over; as the dust which is stirred up settles on them, it contributes considerably to their conservation*.' [GE-4.15.12]. This advice echoes Pliny and Columella.[13] — The dust here may form a protective layer reducing evaporation and preventing fungal infection.

Fat. Animal fat appears regularly in recipes as an admixture. Rarely it is recommended as a stand-alone. '*The grapevines and its branches will not produce aphids when the bark of the trunk is smeared with ox fat*' [AG-200]. — Probable ineffective against aphids but possibly with grease-banding effective on some other insects.

Fish. Fish and other animals were used as baits for ants [NH-17.47.266], obviously with the idea of destroying the ant-infested baits by fire or water.

Gold. If the citron tree, or the pear tree, does not set fruit or drops its fruits early fertilizing with gold serves as a measure of last resort. The pure gold should be placed in boreholes low in the trunk – '*I did the experiment … and obtained a satisfactory result*' [IA-1.522]. In the same vein wrote Ibn Luyūn [IL-90]. — One wonders what to make of the experiment.

Box 6.1 A rationale of dust application

'*It's to the fruit that this curious treatment is aimed, a treatment unknown in our days. The dust is supposed to facilitate the ripening of the grape. False idea probably, but universally popular in antiquity*', wrote Billiard.[14] He may have been mistaken. The pre-modern authors emphasized the grapes, ignoring the fact that the foliage is dusted at the same time. The rationale of dust application is complex, with many possible effects (§ 5.5.7). If kaolin coating is a fair proxy of classical dusting, we may use some modern studies to answer questions on the effect of dusts applied to plants.

Nutritional effects. Two 'border effects' have been noted time and again by travellers and farmers. (1) Road dust, and certainly dust from the pre-modern dirt roads, contains many minerals. Crops along a road side often show a band of flourishing plants, that receive extra nutrients – including nitrogen from animal droppings – with the dust stirred up by the passers-by. Ibn Wāfid: '*And due to the dust the olives near the road are better than the others that away from the road*' [IW-(44)324]. (2) A lack of interplant competition alongside the road occurs, so that the roots of road-side plants have access to comparatively more soil water and minerals.

Physiological effects. (3) Abou-Khaled *et al.* (1970) applied a film of kaolin(ite) as a kind of white-wash to individual leaves, and studied their responses. The kaolin reflected incoming radiation and hence leaf temperatures were lower than in the untreated control. Evapotranspiration and photosynthesis were affected. The water use efficiency of the leaves increased, especially at higher radiation levels.The dust might protect ►

Gypsum was used to seal storage vessels filled with lentils, a good protection against weevils [CO-2.10.16]. '*Stored barley will be protected from whatever damage by sieving pulverised gypsum over the storage room and the grain so that a trace of white can be seen*' [IA-2.324]. — Gypsum in old texts may refer to gypsum as we know it today or to quicklime.[15]

Iron filings added to baits were expected to kill voles and mice. '*If you mix filings of iron with yeast and you place it where mice abound, by tasting it they will die*'.[16] — Do iron filings cause internal bleeding, comparable to modern coumarin? Possibly, an iron salt (ferrous sulphate) was formed but iron salts are not effective.[17]

Konion. The word κόνιον (also κονία) is used in the Geoponika for either caustic soda (NaOH) or quicklime (CaO). Unfortunately the word is similar to that for hemlock, κώνειον. This similarity leads to much confusion. Konion is part of a herbicide (§ 5.3.4).

the ripening grapes against extreme temperatures. '*A screen against the sun*', suggested Theophrastus [CP-3.16.3]. It is difficult to image that ash particles on buds, small twigs or flowers could affect their temperature and save them, but the 'saltiness' of the ashes might prevent the formation of damaging ice cristals. Two very different options are offered, (4) one being the lowering of the freezing-point at the plant surface, (5) the other being the resistance-inducing action of potassium. [18]

Ecological effects. (6) Dust changes the ecosystem of the plant's surface. '*Road dust drifting into orchards and fields can upset the balance of insect pests and their natural enemies*'.[19] Pascual *et al.* (2010) sprayed kaolin in an olive grove and studied the effect on harmful and beneficial insects.[20] Kaolin density on the leaves was far lower than in the foregoing experiment. The main pest target, the olive fly, and another pest, the olive black scale, could be controlled, but not the olive psyllid, a third pest. The abundance and diversity of non-target arthropods, beneficial insects included, was seriously reduced. Apparently, the kaolin particle film served as a deterrent, but with undesirable side effects.

Biocidal effects. (7) Various dusts, even inert dusts, may upset the water balance of insects so that they die. (8) Dusts of whatever kind may change the plant (and grape!) surface so that it is less supportive to fungi and bacteria causing decay. (9) Rain may remove much of the dust, but dew deposited on a dusted plant surface may produce a chemically active film of water. Plant ashes will lead to an alkaline solution (high pH) and powder of sulphur might produce sulphuric acid (low pH), extremes that may prevent infection by fungi and bacteria. ■

Lead. To control caterpillars in trees and vines pulverize Lemnian red lead in water and pour that on the roots and plant sea squill around them [GE-10.90.1]. Ibn al-ʿAwwām quoted a recipe from 'Nabatean Agriculture'. '*To remove rats from the harvest take burned lead, that is to say litharge[= lead monoxide] and cerose [=white lead], knead it with one sixth of flour, weight for weight, adding some olive oil. Make little balls the size of peas, cover them with cheese with a strong smell, and place these on the trail of the rats, that die immediately upon eating them*' [IA-2.335].

Lime. Probably ground limestone ($CaCO_3$) is meant. Smith & Secoy (1976) reported that lime (slaked lime, $Ca(OH)_2$) came into use in the late 16th century to kill insects, slugs, and snails.

Lodestone. Place a lodestone (a magnetic stone) at the entry of an ant nest and the ants will not leave but dig in. A lodestone in the middle of a heap of wheat will keep away the ants and kill the bats [IA-1.597]. — Recommended because of its scarcity? Bats will not be killed but ant species which have a magnetic sensitivity might be diverted.[21]

Manure. Various kinds of manure and their respective merits were amply discussed by most pre-modern authors. Here, we only consider crop protection effects. Pigeon manure was seen as 'hot', which is justified, though today we say, rather,'sharp' or – more technically – 'concentrated'. [22] Manure from water fowl was seen as poor in quality or even damaging for reasons unknown but possibly correct. Fresh cattle manure was often used for treatment of wounds in trees, until well into the 19th century.[23] — Many recipes were very specific. I suspect that these particularities were meant to impress the reader without being based on experiment or experience.

Pigeon manure is the second best manure to kill the vermin, the first being ash [GE-12.4.2]. Smeared on the bare roots of trees pigeon manure protects against caterpillars [GE-10.90.5]. It kills locusts; second best is human manure that has a weed destroying property [IA-1.83]. '*Pigeon and swine manure are also used for dressing wounds in trees*' [NH-17.47.259]. — Fresh human manure may singe some weeds, but its major merit is probably its freedom from weed seeds. Pigeon manure might kill the egg masses of locusts. Pigeon manure has a high status in the Geoponika and in other writings, possibly because dovecotes were among the privileges of the gentry who sold pigeon manure at a good price.

Whatever other manure is used, it should not be recent - because that produces vermin – but it must be kept for one year and turned many times by hoe [GE-12.4.5]. Donkey manure contains fewer weed seeds than horse manure, and human manure even less. — Donkeys chew better than horses and thus kill more seeds. The risk of recycling human pathogens, when applying human excrements, was not yet recognized.

Other uses of manure were to protect seed in storage and after sowing. Dry cow dung dusted over grain in storage was thought to protect against vermin [GE-2.27.6]. Seed coating with dry manure (powder?) or cow dung (slurry?) was recommended for lentils [GE-2.37.1].

Mud. Plastering wounds of trees with mud helps to cure them [HP-4.15.2]. Smearing mud on wounds of the bark was common usage, the mud often mixed with cow dung.

Nitrum is native sodium carbonate (Na_2CO_3), primarily used as an antifeedant, though other effects are ascribed to it. *Nitrum* was applied to wheat in storage. '*Virgil recommends wetting the seed with nitrum and water*' in order to protect the seed after sowing.[24] *Nitrum* was imported from Egypt.

Pitch and bitumen.[25] To cure vines burned by the sun, '*Others irrigate these grapevines with seawater; others … pour around them a concoction of olive oil and bitumen*' [GE-5.36.2]. '*The ants will not touch the plants [grapevines?] if you rub bitter lupine pounded with amurca on their trunks, or bitumen pounded or boiled with [olive] oil*' [GE-13.10.7].[26] Wounds of trees are to be treated with a mix of pitch and powdered droppings that facilitates the formation of scar tissue [IA-1.595], or a mix of pitch and asphalt [IA-1.597]. Pitch was applied in grease bands and burned in censors to chase away the vermin. Dried figs could be preserved in a vessel when a few figs dipped in liquid pitch were added [GE-10.54.1]. — These recommendations were probably effective.

Salt appears regularly in recipes but I could not detect a system in them. Sometime salt should be added, at other times it should be avoided. One example, '*when the whitebeams, pistache trees, azaroles, cherry trees, olive trees and laurels produce too little fruit, bare the roots and place fine salt around them, proportional to the volume of the tree, …, then cover them with soil and leave them alone*'.[27] — Maybe this provides the necessary micronutrients.

Sea water. Sea water is mentioned several times, sometimes as favourable, sometimes unfavourable. If leaves of grapevine colour red, pour salted water or sea water over the soil.[28] '*Some people apply sea water to the roots [of weakened grapevines]*; …' [GE-5.39.3]. Faba beans moistened with sea water will not be punctured [by insects] [GE-2.35.9]. If you sprinkle salt water over the locusts they will do no damage [AG-159]. — Unconvincing statements. The effect, if real, is difficult to understand. Few growers will have had sea water at their disposal.

Shells. Ants leave their holes if you burn shells of snails, or of shellfish, with styrax resin, then crush the stuff and powder it over the ants' nests [GE-13.10.4]. — The styrax may be effective, but what about the calcium carbonate (and/or CaO?) or the chitine?

Soap. '*Put wine soap in water for three days and spray the vegetables therewith*, … to control caterpillars [GE-12.8.1]. — Apparently an alkaline fluid is to be administered to the plants. It may help to drive out and kill insect larvae. In recent times various soaps have been used as broad-spectrum insecticides working fast against soft-bodied insects, without residual effects.[29]

Soot from the chimney is often recommended, usually to control insects, either as a powder or suspended in water. This soot, stemming from burning wood, must contain many unhealthy oxydized carbohydrates. Agustín recommends seed treatment with soot [AG-60]; vetch plants can be protected by pouring soot around them [AG-159].

Sulphur. Sulphur is much used in modern organic agriculture. In ancient times it was readily available from the volcano Etna on Sicily though transportation costs may have been high. The purging effect of burning sulphur was known to Homer (c. 800 BCE) already: '*Odysseus said to the staunch nurse Eurycleia: 'Bring sulphur, old woman, to cleanse from pollution, and bring me fire, that I may purge the hall*'.[30]

Treatment by sulphur is mentioned frequently, as for example burning sulphur to control caterpillars by fumigation [GE-12.8.1], usually in combination with asphalt. Agustín recommends fumigating vegetables with pitch and sulphur [AG-157], though bats or garlic will do too. Powdered brimstone is recommended to control [harvester] ants [GE-13.10.5]. — The burning sulphur will produce a pungent smell that may deter the ants; if turned into sulphuric acid the ants might really dislike it. Fine powder injures insects.

Sulphur and pitch burned together on a *brasero* in the middle of a cauliflower plot deters all insects and the lizards [IA-1.591/2], in the middle of vegetables all aphids [AG-158].

Tar can be of mineral or vegetable origin. Tar added to irrigation water kills worms and caterpillars in vegetable gardens [IA-2.139].

Urine of unspecified source is a frequently mentioned liquid, usually applied in mixtures.

Urine with *amurca* works against caterpillars [GE-12.8.3]. '*Wetting fruits, trees and grapevines with rancid urine and dissolved dog shit will preserve them all without damage*' [GE-2.18.16]. To protect the vines against beetles and larger animals: '*Others, to keep the larger animals away, moisten dog shit in rancid urine and pour it all around [the trunks]*'.[31] If there are too many insects they can be killed by sprinkling a mixture of cattle urine and *amurca*, in equal amounts, boiled on a mild fire. Worms will die [IA-2.139]. — The common denominator may be the unpleasant smell of stale urine and, possibly, the temporarily repellent effect of ammonia. At the time nobody could image that the insect world of odours differed so much from the human world of smells (Newland *et al.*, 2009).

Mixtures with urine were applied in the vineyard. '*You will cure the diseased vine by sprinkling on the trunk ash of vine branches or oak mixed with vinegar, while it also helps much to pour human urine over the roots*' [GE-5.37.1]. '..... *Others apply human urine to the trunk and the roots [of grapevines burned by the sun]*' [GE-5.36.3]. — These and other paragraphs suggest a fertilizer effect rather than a direct cure.

White earth, chalk. '*The ants do not touch the pile of grain if you draw a circle around it with chalk or place wild oregano around*' [GE-2.29]. — The circle is not necessarily a magic circle. It could work, the chalk may have a caustic effect, and the finely powdered chalk or marl may damage the insects.

6.3 Botanicals - generalities

Nowadays, analytical chemistry has become so effective that large numbers of chemical compounds can be found for each plant species. The actual number on record depends on the importance attached to the species for human nutrition and medicine. For a well researched species such as the olive over 270 compounds are on record (Ross, 2001/5). The concentration of individual compounds will vary according to species and sub-species, degree of domestication,[32] cultivar, habitat, (time of the) year, plant part, extraction method, target organism, method of testing, and method of application. In some cases (as in *Allium* spp) the active ingredients are formed by human intervention (crushing) only, in other cases active ingredients get lost over time.

At least a hundred thousand 'secondary plant metabolites' exist, relatively complex molecules not needed in the maintenance metabolism.[33] Many serve to defend the host plant against noxious agents, be they insects, nematodes, fungi, bacteria, or viruses, and/or as chemical signals to other organisms. Insects live in and react to a complex chemical world. An insect has thousands of sensory cells that monitor its highly diverse chemical environment continuously. Insects are attracted by some and repelled by other substances. Another set of compounds is used in chemical plant-to-plant 'talk' or plant-to-animal 'talk', the molecular signalling function. The compounds listed below, known because they have a very specific effect or are available in sufficient quantity, need not necessarily be instrumental in the effect attributed to the species. That effect could also be due to molecules not yet considered.

Some 'botanicals' are straightforward toxins, others are non-toxic 'antifeedants' (Schoonhoven, 1982), substances that prevent damage by insects feeding on crops in field or storage. Some antifeedants are 'repellents' that induce the insect to move away from the potential food. Others are 'deterrents' that deter from further feeding after a first bite. Note that 'antifeedant' does not equal 'poisonous'. Feeding, necessary to ingest the poison, may do some damage to the host plant though further damage will be prevented by the death of the insect. The antibacterial, antifungal,[34] antiviral, and anthelminthic properties mentioned below are a selection only.

Treatments were applied in several forms, sap, tea, smear, and slurry. When plant parts were crushed to obtain the sap, to which water and other substances could be added, we call the resulting juice a herb sap, 'sap' for short. When a decoction of plant parts was made with hot or even boiling water we call it a herb tea, 'tea' for short. Botanicals were also applied as 'smears', often using the milk sap of plants such as fig or spurge as a 'sticker'. The plant parts to be used have not always been indicated clearly, either leaves, whole shoots, fruits, roots, bulbs, or bark. Supposedly, tea and sap were diluted with water without losing the characteristic taste or smell of the product.

Pre-modern texts often combine remarks that today belong to different categories, phytopharmaceutical, pharmacological, and dietary. Many botanicals contain allergenic compounds, but I did not see allergy being mentioned. Frequent allusions are made to effects on human fecundity, both fertility improvement and birth control. The latter was common in antiquity, using contraceptives and abortifacients, as illustrated by Juvenal's satires: '*These poor women, however, endure the perils of child-birth, and all the troubles of nursing to which their lot condemns them; but how often does a gilded bed contain a woman that is lying in?*' and '*So great is the skill, so powerful the drugs, of the abortionist, paid to murder mankind within the womb*'.[35]

Christianity with its adage '*Be fruitful, and multiply, and replenish the earth, and subdue it*' (Genesis 1.28) changed the attitude towards birth control. '*There were many towns where commerce and industry promoted a large population, and the Christian tradition of marriage stopped the voluntary restriction of births previously obtaining in Greece and Italy*'.[36] In the Middle Ages medicine became an academic study, for males only. The medical guilds excluded the herbalists, midwives and wise women, who were the guardians of the knowledge on fertility and its prevention. Medieval herbals are very secretive on birth control.[37]

Let me stress our ignorance about (1) the amount or concentration of any compound in the recommended plant species, (2) the extraction method applied, (3) the fate of any chemical during preparation of the phyto-medicine, (4) dosages applied,[38] and (5) the combination effect of the various bio-active chemicals. Linking modern biochemistry to pre-modern crop protection is a highly speculative activity.

6.4 Botanicals - specifics

6.4.1 Sources of information

The plant species are arranged according to their Latin name. Many Greek names of the Geoponika can be linked directly to modern binary Latin names, but not all. Sometimes, the identifications by Meana *et al*. (1998) and Dalby (2011) differ. As to modern English plant names I follow Dalby. A few elementary *Botanical* [39] and *Historical* [40] data are given as a general orientation. Under the heading *Use* [41] some pre-modern applications are quoted. Under *Comment*[42] some modern aspects are mentioned.

Wikipedia served as an invaluable guide toward more specialized literature. Medical uses of botanicals are summarily indicated only since they are abundantly documented elsewhere.[43] For several plant products the toxicity classes of the World Health Organisation are mentioned (Watson & Preedy, 2008), expressed in terms of oral LD_{50} in rats:

Ia	extremely hazardous	(≤ 5 mg/kg)
Ib	highly hazardous	(5-50 mg/kg)
II	moderately hazardous	(50-500 mg/kg)
III	slightly hazardous	(>500 mg/kg)

Modern equivalents of and improvements on pre-modern botanicals are to be found on several web sites, many of which are commercial.[44]

Pre-modern books discussed the utilisation of plants without a sharp distinction between human medicine and plant medicine. The knowledge of drugs in human medicine was impressive. The dietary aspects of foodstuffs received much attention (Dioscorides and others). The preparation of the drugs, including the phytopharmaceutical ones, was rarely indicated and – as with modern botanicals – their chemical composition was not known in detail. I did not find any information about dosages applied in pre-modern times.

6.4.2 Botanicals by species

Allium porrum L. = *Allium ampeloprasum* var. *porrum* (L.) Cav., leek.
Botanical: Biannual stalk-forming plant from Asia Minor, domesticated form of *A. ampeloprasum* L.
Historical: Leek was consumed in Egypt and probably in Mesopotamia in the 2nd millenium BCE. Common vegetable.
Use: Leek dissolved in water and sprinkled averts locusts [GE-13.1.9].

Comment: It has its characteristic odour from allicin with bactericidal and fungicidal effects.

Allium sativum L., garlic.
Botanical: Biannual corm with several cloves, vegetatively propagated. From Central Asia.
Historical: Used in Egypt and Mesopotamia in 2nd millennium BCE. Garlic, το σκόροδον, was used for flavouring, but also to strengthen pyramid building slaves and Roman soldiers. Probably introduced into western Europe by the Crusaders. Compound of witches' salve ('flying ointment').[45]
Use: Garlic is mentioned several times. '*To avoid caterpillar damage to vines, mash garlic and wet the pruning knives*' [GE-5.48.6]. This recipe should also work against bird damage in trees [GE-10.80]. '*To frighten the wasps garlic grated in olive oil should be burned. This is a proven method*' [IL-61].[46]
Comment: Garlic contains organo-sulphur compounds toxic to several mammals.[47] Among the active ingredients are allicin, allistatin and ajoene, that appear under the influence of alliinase after crushing the corms. Allicin has interesting antibacterial, antifungal, molluscidal, and even antiviral activity (Cutler & Wilson, 2004; Hanson, 2007). Allistatin is a broad-spectrum fungicide and bactericide. Ajoene has antimicrobial and miticidal effects (van den Berg, 1996). Essential oil impregnated on absorbent granules repels small animals such as moles and starlings (Hanson, 2007).
Late 20th century organic horticulture uses garlic as an extract, rarely as a powder, to deter game, birds, moles, and insects. Garlic tea is said to enhance plant resistance and to prevent fungal diseases (e.g. cucumber mildew). It is also applied as a seed protectant. Garlic is planted in companion cultivation as an insect deterrent. Garlic has the reputation of being a panacea but in fact its products are expensive broad-spectrum pesticides at best. Interesting evidence for effectiveness of garlic products in crop protection is given by Block (2010 pp 300-323). Perhaps garlic on the pruning knife could reduce the transfer of bacterial and fungal, maybe even viral inoculum from one pruning wound to the next.

Anethum graveolens L., dill.
Botanical: Annual or biannual erect plant, about 0.6 m high. Native to Eurasia. Common weed in the grain fields of south eastern Europe, widely cultivated.
Historical: Cultivation indicated in the Neolithic lake side settlements of Switzerland. Used in Greece in 7th century BCE. Seeds and leaves, fresh and dry, used as herbs and spices.
Use: A decoction of caterpillars boiled with dill and sprayed over the vegetables supposedly kills the caterpillars present [GE-12.8.4]. Perhaps a homeopathic recipe?
Comment: Dill essential oil has genotoxic (Lazutka *et al.*, 2001), anti-fungal and anti-bacterial properties (Singh *et al.*, 2006). Its rosmarinic acid is said to be antimicrobial toward plant pathogens. Dill oil contains i.a. odourous carvone (Hanson, 2007), a bioactive substance used for example to prevent sprouting of seed potatoes in storage.[48]

Arctium lappa L., greater burdock.
Botanical: Eurasian biannual plant of disturbed habitats high in nitrogen, up to 2 m tall.
Historical: Used to be widely cultivated for its edible inulin-rich roots, young sprouts used as vegetable, also medical use. Supposedly keeps rats away.
Use: Planted among the vines as a companion crop to deter 'fleas' [GE-5.48.4].
Comment: Roots diuretic, blood purifying, diaphoretic. No indications found for phytopharmaceutical effects.

Artemisia absinthium L.*,* common wormwood.
Botanical: Robust perennial herb, up to 1 m high. Eurasian. Cultivated in S Europe.
Historical: Used in Egypt c.3500 BCE. The bitterness and the inebriating qualities of *Artemisia* spp were known in biblical times. '*He hath filled me with bitterness, he hath made me drunken with wormwood*' (Lamentations of Jeremiah 3: 15). Since antiquity used as spice, pest control agent, and abortive. Dioscorides (ca. 65 CE) advised putting wormwood in clothes' drawers to keep out moths and mice.[49]
Use: Dry branches added to wheat in storage [GE-2.27.6]. If regularly sprayed it protects chickpeas during ripening [GE-2.36.4]. Dissolved in water and sprayed it keeps locusts away [GE-13.1.9]. Good in baits against mice [GE-13.4.1]. Planted around the farm it keeps the snakes out [GE-13.8.1]. Wormwood wetted in seawater and sprayed kills insects of the living quarters [GE-13.15.1]. Macerate wormwood in water for 24 hours and pour it over the tree suffering from ants [IA-1.595].
Comment. Neurotoxic, class II-III. Produces absinthin and other sesquiterpene lactones, essential oil with α- and β-thujone (a neurotoxic monoterpene), and chrysanthenyl-acetate. The latter substance is used in organic insecticidal sprays as a moth repellent. Absinthin and thujone have anthelmintic properties. Wormwood is thought to have a broad-spectrum insecticidal and deterrent effect but it is detrimental to earthworms.
Wormwood also produces volatile methyl-jasmonate, probably responsible for its allelopathic effect. Several *Artemisias* produce phytotoxic (Rimando & Duke, 2006), insecticidal (Godfrey, 1995), insect repellent, and antifeedant terpenoids (Cutler, 1988). Thujone affects the autonomous nervous system, leading to hallucinations, delirium and seizures. Several *Artemisia's* are said to be abortifacient

Artemisia arborescens L., great mugwort.
Botanical: Evergreen Mediterranean shrub. Grown in S Europe.
Historical: Leaves, fresh and dry, used as condiment.
Use: More or less as wormwood. Recommended for granaries [GE-2.27.6], apparently to deter insects. If planted around the farm it keeps the snakes out [GE-13.8.1].
Comment: Its strong lemon smell may deter noxious animals. Its essential oil, insecticidal but instable, might be delivered in Solid Lipid Nanoparticles (SLNs; Lai *et al.*, 2006).

Artemisia vulgaris L., mugwort.
Botanical: Perennial from temperate northern hemisphere, 0.5 – 1.5 m high.

Historical: Mugwort was used in the Middle Ages as an insect repellent in gardens, especially against moths. Young leaves, fresh and dry, used as (slightly bitter) spice.
Use: Dissolved in water and sprayed over the plants it deters locusts [GE-13.1.9] (and/or grasshoppers?) If planted around the farm it keeps the snakes out [GE-13.8.1].
Comment. Mugwort contains thujone, a neurotoxic monoterpene, and essential oils, see under *A. absinthium*. Plants and especially seeds poisonous, abortifacient.

Azadirachta indica A. Juss., neem tree, Indian lilac.
Botanical: Tall evergreen drought-tolerant tree from India.
Historical: Medical and cosmetic usage in India for thousands of years.
Use: Ibn al-ʿAwwām recommends the tree as a shade tree for cattle and farm implements, also to keep surface water fresh [IA-1.312/3]. In India traditional and actual use of (powdered) leaves in grain storage pots.
Comment: The recommendation is from 'Nabatean Agriculture'; I doubt whether the tree was grown in Spain. Extracts contain azadirachtin, di- and triterpenoids, fatty acids and S-containers, that have pesticidal, sedative and contraceptive (spermicidal) effects. The fruits mainly contain azadirachtin, now applied as a non-synthetic pesticide.[50]

Capparis spinosa L., caper bush.
Botanical: Branched, spreading, spiny shrub, up to 150 cm high, large pinkish flowers, fleshy leaves, Mediterranean. Grows on poor, often rocky soils.
Historical: Found in classic Greek remains, then used in medicine.
Use: Protect vegetable seeds against insects by soaking them 24 hours in watery extract of Capparis seeds [IA-2.139]. Flower buds and berries used for seasoning and garnishing, usually pickled.
Comment: Contains flavonoids among which rutin and quercetin. High selenium content. Possibly anticarcinogenic.

Cedrus spp. – cedar.
Botanical: Large coniferous trees with scented wood. Lebanon (*C. libani* A.Rich.), Cyprus, Atlas Mountains (Atlas cedar = *C. atlantica* Manetti). The Geoponika writes κεδρία, which also may refer to Syrian cedar = Greek juniper. Seeds contain blisters with resin of unpleasant taste.
Historical: Used for timber (as in the Temple of Solomon).
Use: Resin mentioned as part of a mix to smoke mole rats and/or moles out of their holes [GE-13.7.2]. When poured around their nests the harvester ants will not enter the threshing area [GE-13.10.2].
Comment: The resin probably contains various terpenoids functioning as deterrents.

Centaurea cyanus L., cornflower.
Botanical: Annual, up to 0.6 m high. The Near East hosts many thistles of the genus.
Historical: The blue flowers crushed with sugar were used in confectionary.

Use: A watery extract sprayed over the plants deters locusts [GE-13.1.9]. Root of cornflower deters snakes, mixed with other compounds and incensed it chases snakes [GE-13.8.8].
Comment: No indications found on phytopharmaceutical effects of cornflower. However, some *Centaurea* species show allelopathy and antimicrobial activity ascribed to catechine (Rimando & Duke, 2006).

Citrullus colocynthis (L.) Schrad., bitter apple (colocynth, bitter cucumber, Fig. 6.1).
Botanical: Perennial creeping vine growing in the Mediterranean area, Near East, and India. Domesticated as water melon (*C. vulgaris* Schrad.), from sub-Saharan Africa, of which fruits are consumed fresh, seeds roasted; cultivated in Mediterranean and tropical areas.
Historical: Bitter apple has very bitter fruits and seeds rich in fat and protein. Grown in Egypt c.3500 BCE. The name 'Vine of Sodom' may be due to its use as an abortive as described in Egypt (1550 BCE). The 'wild gourd' of 2 Kings 4:39/40 is probably bitter apple. In Rome used for rodent control. The powdered fruit flesh is used in lozenges named 'troches of alhandal'.
Use: An infusion of roots and leaves is to be sprayed on wine leaves with 'rust', before sun rise [GE-5.33.3]. Colocynth is used as a constituent of baits to poison mice [GE-13.4.1]. Ripening chickpea can be protected with a spray containing among other things an extract of colocynth seeds [GE-2.36.4].
Comment. Cell toxin, class Ib. Contains cucurbitacines (tetracyclic triterpenoids, up to 3%), partly present as glucosides, that are bitter and have various pharmacological effects. They are poisonous to mice and large herbivores. Cucurbitacin E (= α-

Figure 6.1. Colocynthis. *Bitter apple,* Citrullus colocynthis *(L.) Schrad. Perennial creeping vine of the cucumber family. Drawn by A. de Laguna. Dioscorides (1566) p 489. Scale 1:1.3.*

elaterin) is a feeding deterrent of insects. The extreme bitterness protects the plant against large herbivores and many, but not all, insects. Root extracts used as an abortifacient.

Clinopodium menthifolium (Host) Stace (*Calamintha sylvatica* Bromf.) - common calamint.
Botanical: Low perennial, up to 0.4 m high.
Historical: Fresh leaves of some *Clinopodium* spp used as spice and for teas.
Use: Indicative for presence of ground water [GE-2.5.4]. Added to barley in storage [GE-2.30.2].
Comment: High content of essential oils, mostly monoterpenes. *Calamintha ashei* (USA) produces phytotoxic terpenoids (Cutler, 1988).

Conium maculatum L., poison hemlock.
Botanical: Biennial herb, up to 2 m high, in wet and ruderal areas of Eurasia, North and East Africa.
Historical: The large scale intoxication of the Jews after eating quails during the exodus was, possibly, due to the quails having eaten hemlock seeds (Numbers 11:33). Used in classical Greece and Rome for murder and suicide.
Use: Recommended to control male fern and other weeds [GE-3.10.7]. Poison hemlock was a component of poisonous baits placed in the holes of voles [GE-13.5.2].
Comment: Neurotoxin, class Ia. Contains the highly toxic piperidine alkaloids coniine and γ-coniceine (in fruits up to 3.5%). Its furanocoumarins protect the plant against insects. Psoralen and its derivatives are phototoxic to micro-organisms, insects and mammals. Coniine causes ascending paralysis of motor nerve endings starting at the tip of arms and legs and ending with respiratory failure and death. The poisonous drink given to Socrates (399 BCE) was a hemlock extract.

Coriandrum sativum L., coriander.
Botanical: Self-pollinating annual from Near East in wild rocky open areas in oak park-forests.
Historical: Found in Israel's pre-pottery neolithicum, cultivated in Syria 2nd mil BCE.
Use: All plant parts used as spice. Added to stored wheat against weevils and mice [CR-3.2]. In some folk medicine considered a mild tranquillizer.
Comment: Strong smell. Contains anti-oxidants, surfactant compounds are also anti-bacterial.

Crocus sativus L., saffron crocus.
Botanical: Native to Greece and Asia Minor. The triploid saffron crocus has flowers with three stamens of which the stamens were and are harvested.[51] Saffron crocus is vegetatively multiplied by means of its small corms.
Historical: A yellow dye and food colorant was extracted from the stamens. These were also used as a (slightly bitter) spice, in perfume, to fortify wine and *laudanum* (an opium cocktail), as an aphrodisiac, and in medicine (abortion in high dosages). In western Europe saffron crocus was grown as a crop in the 18th century (Zadoks, 1981).

Use: The stamens of saffron crocus were used to dye cloths, to season dishes, and to cure various ailments of men and horses.[52]
Comment: Neurotoxic, mind altering, class II. Crocetine is a yellow diterpene. Picrocrocin is a bitter glucoside. The aroma of dried stigmata is due to safranal, the aglycone of picrocrocin. No alkaloids.

Cuminum cyminum L., cumin.
Botanical: Low annual herb from Central Asia or Mediterranean area. Odorous seed.
Historical: Cultivated from eastern Mediterranean area to China, seeds used as a condiment.
Use: '*Some grind cumin and salt in equal amounts and prepare dry cookies that they put in the flour [for its conservation]*' [GE-2.31.2].
Comment: Why the salt? A strong smell (mainly cuminaldehyd) emanating from ground seed might deter storage insects, at least temporarily. Essential oil contains antibacterial substances (Iacobellis *et al.*, 2005). *p*-cymene is toxic, β-pinene is used to manufacture insecticides.

Cupressus sempervirens L., Mediterranean cypress.
Botanical: Tree from eastern Mediterranean area, up to 35 m high. Durable, scented wood.
Historical: From ancient times planted as an ornamental.
Use: Wood chips added to grain in storage. Drained bare spots in the field could be treated by ploughing in cypress leaves [CO-2.9.9]. Crushed cypress leaves mixed with the wheat seed protects them against being eaten [NH-18.45.158], [GE-2.18.4]. Cypress leaves are thought to stimulate seed germination.[53] Leaves and seeds are vermifugal in children [AG-110].
Comment: No information found on phytopharmaceutical effects. Cypress contains pharmacologically active coumarins with antibacterial, anthelminthic properties.

Cynanchum acutum L., swallowwort, dog-strangling vine, dog's-bane.
Botanical: Perennial climber, native to Palestine.
Historical: No information found.
Use: Cortex was used as a component of baits to poison mice [GE-13.4.7] and moles [GE-13.7.1].
Comment: Its tylophorine is highly toxic to frogs, slightly toxic to mice, and has antifeedant properties.[54] Possibly confounded with *Strychnos nux-vomica* L., producing strychnine.

Ecballium elaterium (L.) A. Rich., squirting cucumber, wild gourd (Fig. 6.2).
Botanical: Perennial creeping herb in Mediterranean area and W Asia.
Historical: Common in the Near East. *Ecballium* is Latinized Greek meaning abortion, *elaterium* refers to the drug prepared from the sap.[55]
Use: Treatment of seeds [GE-2.18.10], walls of storage rooms [GE-2.27.4], and chickpea crops [GE-2.36.4]. Grapevines are treated with extracts of squirting cucumber to treat chlorosis [IA-1.555], various insects [IA-1.564], and green beetles (probably *Rynchites auratus*) [IA-1.566].

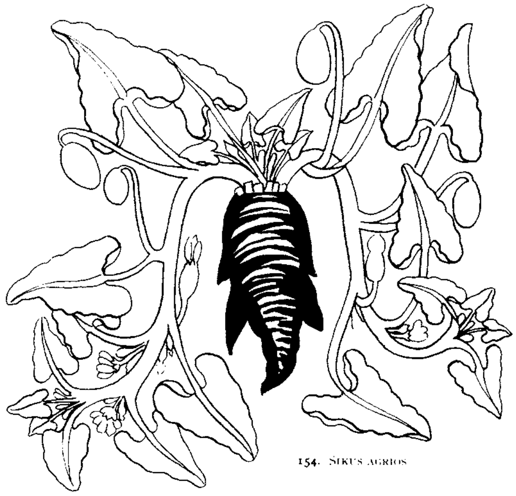

Figure 6.2. Sikus agrios *(G: Σίκυος ἄγριος)* = Ecballium elaterium *(L.) A. Rich. = squirting cucumber. Young fruits shown, no flowers. 'It grows in ye rubbish of houses, & and sandy places, but ye shrub is bitter'. From: Dioscorides (1934) p 546 #154. Scale 1:2.*

Comment. Cell toxin, class Ib. Contains a mixture of bitter triterpenoids (>2.2%FW), especially cucurbitacins E and I, elaterine, ecballin, ecballin cid, prophetine, elaterid. Used in medicine. Skin contact causes blisters and inflammation. Abortifacient.[56]

Eruca sativa Mill., garden rocket, rocket lettuce.
Botanical: Mediterranean annual herb, branched from the base, up to 1 m high. On dry, disturbed ground. Pungent, bitter taste, strong flavour.
Historical: Cultivated since ancient times as a salad plant. Fresh herb with peppery taste and strong flavour in salads.
Use: Sown as a companion crop among the vegetables, and cabbage especially, it is beneficial, supposedly as a trap crop [GE-12.7.2], or as a repellent [GE-12.7.2, 12.10].
Comment: Erucic acid, a bitter and pungent unsaturated fatty acid, has some medical applications. *E. sativa* and other cruciferous plants contain glucosinolates that protect against many phytophagous insects.

Euphorbia spp., spurge.
Three species are mentioned here. The Geoponika mentions spurge without any indication of species. Ibn al-ʿAwwām's spurge was translated as '*réveille-matin*' or sun spurge.

Euphorbia cyparissias L., cypress spurge, perennial milkweed.
Botanical: Perennial, up to 0.5 m high, grows from Europe to Central Asia in arid places, dry meadows, and track sides. Creeping rhizome.
Historical: No information.
Use: To improve the yield of pomegranate and other trees smear crushed spurge and purslane around the tree base [GE-10.35, 10.82.1]. Recommended for baits to blind mice [GE-13.4.4].
Comment: Cell poison, class Ib. In latex carcinogenic phorbol esters. *Euphorbia* spp. produce a latex irritating to mucous membranes and skin. Sap contains 5-deoxy ingenol (a toxic diterpene), triterpenes and their esters, sometimes poisonous esters of polyhydroxy-diterpenes. Poisonous to herbivores, goat excepted.

Euphorbia helioscopia L., sun spurge.
Botanical: Annual, 10-40 cm, companion weed of field crops, on disturbed ground.
Historical: No information.
Use: '*But the most effective thing for killing ants is the heliotrope plant*' [NH-19.58.17]. Extract kills caterpillars on grapevine [IA-1.564]. A decoction added to irrigation water kills lizards, large worms (earthworms?, caterpillars?), and others [IA-1.593].
Comment: Highly poisonous. Contains i.a. euphorbon and 1.2-deoxyphorbol.

Euphorbia lathyrus L., caper spurge, mole plant.
Botanical: biennial, up to 1.5 m high. Eurasia.
Historical: No data found.
Use: The mole plant was placed in mole tracks to chase away moles.
Comment: see above.

Ferula spp., fennel.
Botanical: Herbaceous perennials with long stems (1-3 m, L: *ferula* = rod), often growing under dry conditions in the Mediterranean area and eastwards to Central Asia. The taxonomy of the genus Ferula is not yet clear.[57]
Historical: The sap was used to produce a gum/resin of medical and culinary interest. The Greeks and Romans were keen on *silphium* (σίλφιον) = *laser* or *laserpicium*, the gum from a *Ferula* species,[58] now extinct, that grew in Cyrenaica, a coastal area of present Libya, called after the classical Greek town of Cyrene (G: Κυρήνη). It did not grow on arable land, leaves were fed to sheep, stems were edible, and roots were harvested. The harvest was regulated by the authorities [HP-6.3.2]. Silphium was so important commercially that *Ferula* stems were depicted on the obverse of coins minted in Cyrene (Figure 6.3).

Figure 6.3. Sylphium *on a tetradrachme. This silver coin was minted in Cyrene, a Greek settlement in the East of present Lybia, between 435 and 331 BCE. Diameter 25.8 mm, weight 13.2 g. We see a fennel-like plant, with leaf sheaths clasping the stem and small umbels sprouting from the leaf axils. Central terminal umbel not shown. Scale 1:0.32.*

Use: Its sap, used as condiment and medicine, had contraceptive and abortive properties.[59] This may have been a major reason for its high price and its extinction. Pliny considered *silphium* to be exterminated because it '.. *is sold for its weight in silver denarii*.' '*Only a single stalk has been found there within our memory, which was sent to the emperor Nero*' [NH-19.15.38ff].
Comment: Possibly too expensive to be used in crop protection.

Ferula asafoetida L. also written *F. assa-foetida*, devil's dung, asafoetida.
Botanical: Herbaceous perennial with flowering stems up to 3 m high and 10 cm thick. Schizogenic ducts in the cortex contain resinous gum. The sap has a pungent odour.
Historical: Brought from Iran by the army of Alexander the Great. The resin-like gum was used in cooking and medical practice. Lentils were treated with an infusion of asafoetida in vinegar for storage.
Use: Asafoetida was used as a spice. It was also recommended to kill caterpillars on vegetables [IW-(42)322]. An infusion of asafoetida watered over pumpkins kills 'worms' [IA-2.139].
Comment: Contains much essential oil with an insect repellent effect. The gum has contraceptive and abortive properties.

F. gumosa Boiss.= *Ferula galbaniflua* Boiss. & Buhse, giant fennel.
Botanical: Native to Iran. It produces a resinous gum, *galbanum*. Up to 4 m high.
Historical: Burned separately, it has a pungent, disagreeable smell. Imported, it was part of the holy perfume for the tabernacle (Exodus 30:34 ff).
Use: Galbanum was burnt as incense to chase away the vermin from the vineyard [GE-5.48.2]. Extracts from roots or branches protected faba beans [GE-2.35.9] and lentils [GE-2.37.1] in storage.
Comment: The gum has a high terpene content (c. 8 %). Its high sulphur content causes the pungent smell.

Ferula tingitana L., another 'giant fennel'.
Botanical: Produces African *ammoniacum*, a gum-resin.
History: The mysterious *magodaris* (G: μαγύδαρις) is quoted as protecting seed against seed insects [GE-2.35.9]. This substance is probably the gum of another *Ferula* species.
Use: Latex in vinegar was spattered over lentils for conservation [GE-2.37.1].[60]
Comment: For comparison we consider another Ferula. Extracts from *Ferula leiophylla* Korovin inhibit growth of *Gloeosporium* phytopathogens (Rimando & Duke, 2006). Isopimpinellin has molluscicidal, piscicidal, and antifungal properties. Umbelliferone with antifungal and antibacterial properties is photomutagenic. Ferulic acid has allelopathic, antifungal and antibacterial effects.

Ficus carica L., fig tree.
Botanical: Wild forms along the Mediterranean in rock crevices and such primary habitats with male caprifigs and female true figs in equal numbers. Dioecious, cross pollinating. Many feral types. Wild type seed-propagated, cultivated type vegetatively propagated by rooting twigs.

Historical: Grown c.7000 BCE in present Syria and Israel. Third classical fruit associated with the beginning of horticulture in Mediterranean area. Fruit-bearing clones propagated. Modern types parthenocarpic, by single dominant mutation. Smyrna type pollinated (caprification), a technique already applied in Greek and Roman times.
Use: Fruits eaten fresh and dried. Milky sap or latex was used as sticker in grease banding, and added to pulses for conservation.
Comment: The latex in this plant and others is considered to be a means of defence against herbivorous insects.

Hedera helix L., common ivy.
Botanical: Woody climber with aerial climbing roots. Western Asia, Europe, also ornamental.
Historical: Ivy was used in religious rites such as the Bacchus feasts in Greece and the Saturnalia in Rome.
Use: Incensed ivy kills bats [GE-13.13; AG-162]. Branches rich in leaves are wound around the bottom of grapevine stems so that ants and beetles hiding in its cool shade can be gathered and killed [GE-13.10.10, 13.16.4].
Comment: Cell poison, class II. Causes nausea, vomiting, shock, even death. Up to 8% bidesmosidic saponins with oleanolic acid, phenolics, polyacetylenes (i.a. falcarinol that causes dermatitis). Its antifungal (falcarinol), antiparasitic, and molluscicidal properties were not used in the Geoponika.

Helleborus niger L., black hellebore, christmas rose.
Botanical: Low herbaceous perennial, up to 0.3 m. Alpine species not growing naturally in the Mediterranean. As *H. niger* rather is an indicative name for various *Helleborus* species including *H. orientalis*, lenten rose, I use 'black hellebore' as a neutral term.
Historical: Burning taste. Hellebores were used in classical medicine. Used in Central Europe as sneezing powder, now obsolete.
Use: A mixture of wheat and hellebore sown around a grain field prevents bird damage [GE-2.18.2; 2.18.9]. Black hellebore was a component of baits to control mice and voles [GE-13.4.1; 13.5.2].
Comment. Heart poison, class Ia. Cardiac symptoms, unrest, death. Hellebores contain saponines, poisonous bufadiënolides (helleborine), C24-steroids, alkaloids, and irritating ranunculin. The saponines may be antifeedants, antimicrobial and antifungal. Used against intestinal worms. Abortifacient.

Hyoscyamus niger L., henbane, stinking nightshade.
Botanical: Mediterranean annual or biennial herb p to 0.8 m high. Bad smell.
Historical: Since antiquity used in pain relief. Narcotic, inebriating, used in witchcraft as a component of nine-herbs witches' salve.[61] Bitter tropane alkaloids substituted hop in beer and enhanced alcohol effect. In antiquity and Middle Ages used for murder and suicide. Component of 'dream tea'.
Use: Component of poisonous baits placed in the holes of voles [GE-13.5.2].

Comment: Neurotoxin, mind-altering, class Ia. Among the active ingredients are tropane-alkaloids such as atropine and scopolamine. Atropine, hallucinant, sedative, depressant, and toxic, is produced in the roots and transported upward.

Inula viscosa (L.) Aiton (*Diittrichia viscosa* (L.) Greuter), stinkwort, woody fleabane.
Botanical: Ruderal species.
Historical: Widely cultivated for its roots.
Use: Recommended for preserving wheat in storage placing it half-dry on the floor [GE-2.27.9].

Comment: Contains the sesquiterpene-lacton alantolactone with insecticidal, anthelminthic and fungistatic effects. The 'meal worm' *Tribolium effusum* does not tolerate flour with over 2 per cent alantolactone.

Iris germanica L., German iris.
Botanical: Numerous species of iris grow in natural meadows. Garden plants; many 'botanical species' commercialized as minor crops in the bulb trade.
Historical: Rhizomes use to produce perfumes, medicine, and flavours.
Use: Fumigation with iris roots protects garden plants against insects [IA-2.139].
Comment: Rhizomes contain terpenes and organic acids (i.a. ascorbic, myristic, undecylenic acids). Some species and hybrids contain iridine, a toxic glycoside.

Lagoecia cuminoides L., wild cumin.
Botanical: E Mediterranean herb, up to 0.5 m high.
Historical: No information.
Geoponika: Mashed in water applied in living quarters to keep the vermin out [GE-13.15.5].

Comment: No information, compare *Cuminum cyminum*.

Laurus nobilis L., bay laurel, bay.
Botanical: Mediterranean tree, up to ~15 m high.
Historical: Dried leaves used as condiment. Cultivated.
Use: '*Apuleios says that if you place laurel branches in the field the rust damage [of the grapevines] passes to them*' [GE-5.33.4], as in Pliny [NH-18.161].
Comment: It was suggested that the clause refers to the barberry, the alternate host of black stem rust of wheat. I tend to believe that the passage is a magical recipe. Essential oil bactericidal.

Lilium candidum L., madonna lily.
Botanical: Bulbous plant, stem 1.2 (up to 2) m high, from Balkans and SW Asia, fragrant.
Historical: Possibly the lily of Solomon's Song 2:1/2. Oldest garden lily, cultivated for thousands of years. Symbol of purity.
Use: Roots are used in an incense to chase away the vermin from the grapevine [GE-5.48.2].

Comment: The alkaloid narciclasine has cytotoxic properties (Hanson, 2007). Many lilies are very poisonous to cats. Poisonous principle unknown.

Box 6.2 *Amurca*, a pesticide prepared from olives

Olive cultivation in antiquity was described in detail by Smith (1875). Noteworthy is the care for intercropping with wheat or barley. Olive trees produce in alternative years, and so the cereal was sown every second year when olive production was low. Manuring the cereals and the trees were quite different operations. Olive groves were ploughed annually and the soil around the trees was loosened every year by *bidens*. Olives had to be picked, usually by hand, before they fell naturally.

Olive oil was an essential commodity in antiquity, and olives were grown all over the Mediterranean area. To obtain the oil the harvested olives were crushed and pressed. The first and slight pressing produced a dark, foul smelling and bitter tasting watery substance, called ἀμόργη in Greek, *amurca* in Latin. The second pressing produced the oil. In English we see the – not fully appropriate - terms olive lees or olive dregs.[62]

Evidently, *amurca* was amply available and usually home-made. In antiquity it was used as a panacea, expected to control ants, voles, and weeds, and to preserve seed in storage. *Amurca* contains phenolic compounds among which oleuropein, a glycoside, that makes food unpalatable. Sometimes salt was added before pressing making the *amurca* salty. Alternatively, salt was added to the *amurca* itself. *Amurca* was often condensed by boiling in copper vessels.[63] Salt and copper ions may have added to the antifungal effects of *amurca*.

Over 270 chemical compounds derived from olive trees are listed.[64] Several compounds have at least some biocidal or biostatic activity. ►

Liquidambar orientalis L., oriental or Turkish sweetgum.
Botanical: Deciduous tree forming relict forests in south western Turkey.
Historical: Resin used in medicine.
Use: Used in incense mixture to control ants [GE-13.10.4].
Comment: Sweetgum oil, made from the sap, has antibiotic effects on skin afflictions.

Lupinus albus L., white lupine.[65]
*Botanical:*Erect herbaceous annual, up to 1.2 m high, Mediterranean, N-fixing.
Historical: Selected c.2000 BCE. Protein crop for food, feed, and green manure. In antiquity the toxicity of the seeds was known; the seeds were debittered by cooking and leaching. Lupine extracts were used as insecticides (Hanson, 2007).
Use: Component of sprays to avert locusts [GE-13.1.3] and of smears to repel ants.[66]
Comment: Neurotoxin, class II. Contains bitter, poisonous quinolizidine-alkaloids up to 3%, such as lupanine and sparteine, both toxic to livestock. Sparteine is toxic to insects. Quinolizidine alkaloids are abortifacient. Luteone and wighteone are prenylated isoflavones with antifungal properties.

Oleuropein inhibited some strains of bacteria. Hydroxytyrosol has some antibacterial effect and an ethanol extract of dried leaf may inhibit the phytopathogenic gray mold fungus. This result is meagre in view of the status of *amurca* as a panacea. Possibly, the combination of many compounds with limited effect each has an additive effect explaining the evident enthusiasm for *amurca*. The bottom line is that it is easily available in large quantities. Its foul smell and bitterness certainly help to make people believe that *amurca* works as a biocide, or at least as a deterrent, and as manure.

Theophrastus wrote about *amurca* but not in a crop protection context. Virgil recommended treating the seed with herbs, native soda (*nitrum*), and dregs from oil-presses (*amurca*) [VE-1.193/4]. Both recommendations were repeated by Pliny [NH-18.45.158], who added kneading the seed in a mixture of urine and water three days before sowing.

De Herrera discussed olive lees in detail [DH-3.34.182]. He distinguished *alpechín* (= olive lees, *amurca*) from green and dark olives, without or with salt, fresh or boiled. Fresh and without salt, mixed with water, it can be added to the bared roots of trees, especially olive trees. In winter time the dosage could be lowered as an overdose may damage the plants. Where weeds are not acceptable salted alpechín can be applied; it sterilizes the soil but damages the trees. Where *alpechín* was poured over the soil there will be no fleas, voles, ants, or caterpillars. Hence, threshing places should be treated with *alpechín*, and also storage jugs. Condensed to a honey-like substance it was applied to mouse holes, the mice get stuck and die. Mud mixed with *alpechín* was applied to the wall of grain stores to deter mice and vermin.

Columella advised salt-free amurca as fertilizer for olive trees [CO-11.2.29]. ■

Marrubium vulgare L., white or common horehound.
Botanical: Perennial herb, up to 40 cm high. Grows on wild, neglected rough areas.
Historical: No information found.
Use: Recommended for seed treatment [CO-10.357]. Said to be a grasshopper repellent. Folk medicine; in cough lozenges[67], possibly abortifacient.[68]
Comment: Many flavonoids, essential oil, diterpenes (marrubiin).[69]

Momordica charantia L., bitter melon, bitter gourd.
Botanical: Tropical annual climbing-plant (5 m), very bitter. Origin unknown.
Historical: No information found.
Use: Seed of vegetables dipped in decoction of bitter melon is protected against insects [IA-2.134]. Leaves used as vegetable, fruits cooked. Widely used in folk medicine.
Comment: Antiviral, anthelminthic, antimalarial, bioactive compounds. Glycosides, terpenoids. Momordin is a cytotoxic protein, inactivates ribosomes.

Nerium oleander L., oleander.
Botanical: Multi-stemmed woody shrub up to 6 m high, from Mediterranean to western China.
Historical: Originally from the Indies? Became widespread in the Jordan valley. Poisonings occurred as a result of eating meat skewered on the stems, or inhaling smoke from burning leaves or wood. Cultivated as an ornamental. Used in suicides.
Use: The entrances of the holes of voles were filled with oleander leaves [GE-13.5.3].
Comment: Heart poison, class Ia. Contains cardenolids up to 22% DW. Oleandrin and neriine are potent cardiac glucosides (cardenolids) affecting the Na-K equilibrium in the nervous system. Cortex contains rosagenin. Oleandrin pollutes honey by way of pollen. Adynerin is toxic to vertebrates. Abortifacient.

Nigella damascena L., love-in-a-mist.
Botanical: Circum-Mediterranean annual, up to 0.5 m high, on moist patches.
Historical: No data found, but *N. sativa* L. (nutmeg flower, black caraway) grown for seed (black cumin) to be used as spice. Found in Tutankhamun's tomb (Egypt, ~1335 BCE).
Use: Incense of *Nigella* repels mice [GE-13.4.2], snakes [GE-13.8.2], and mosquitoes [GE-13.11.1]. A watery spray eliminates vermin in the house [GE-13.15.2].
Comment: The species *N. sativa* contains nigellone and anti-tumor compounds beta-sitosterol and thymoquinone. Seeds with 10 % essential oil of which 1 % damascenine (alkaloid).

Olea europea L., olive tree.
Most important classical fruit tree of the Mediterranean area since the Bronze Age. For details see § 3.3.2 and box 6.2.

Origanum vulgare L., oregano.[70]
Botanical: Mediterranean perennial, up to 0.6 m high.
Historical: Fresh and dry leaves used as spice, seeds in sausages, essential oil in soap and perfume, dried leaves in *bouquet garni*.
Use: To protect trees and vines against caterpillars pour water with ochre and oregano over the roots [GE-10.90.1]. Repellent, used to protect grain piles against ants.[71] Aphids are repelled or even killed when young shoots are planted among the vegetables [GE-12.19.9]. Powder used to chase ants from their nests [IA-1.566]. Agustín [AG-74] protected melons against vermin by using oregano.
Comment. This species contains, as so many of its family, essential oils with a high content of monoterpenes and diterpenes that deter insects. Contains antioxydants (phenolic acids and flavonoids) such as thymol and carvacrol. Thymol, a monoterpene phenole, is a strong antiseptic. Carvacrol has antibacterial, antifungal and anthelmintic properties. Cattle and horses do not eat wild oregano. Essential oil protects courgette seedlings against some pathogenic fungi (Yang Bi *et al.*, 2012).

Paeonia officinalis L., common peony.
Botanical: Perennial herb, up to 1 m high. Mediterranean and northward to Central Europe. In mountainous areas, bushes, meadows.
Historical: At least 500 years in culture as an ornamental.
Use: Fumigated or planted in vineyards to chase away the vermin [GE-5.48.4].
Comment: No phytopharmaceutical information found. Peonidin has some cancerostatic effects in vitro.

Pistaccia lentiscus L., mastic, lentisk.
Botanical: Mediterranean shrub up to 4 m high, growing on dry and rocky soils. When the bark is cut it produces 'tears' of aromatic resin that harden in the sunshine.
Historical: Used as chewing gum and as spice, applied in cosmetics and medicine.
Use: '*In order that the caterpillar may not damage fig-tree seedlings, put in the bottom of the trench a slip from a mastic-tree with its top inverted*' [CO-5.10.9].
Comment: Mastic oil has some antibacterial and antifungal effects, mainly ascribed to isomasticadienoleic acid. The deterrent effect possibly ascribed to the aroma.

Portulaca oleracea L., common purslane.
Botanical: Annual therophytic plant with succulent leaves and deep roots. From the Old World tropics. Small prostrate weedy form is ssp *oleracea* L., cultivated form ssp *sativa* (Haw.) Celak. Now a common weed. Small black edible seeds. Plants harvestable when 5-8 cm high.
Historical: Grown in Greece 7th century BCE. Leaves used as vegetable.
Use: Sap cures rotting twigs of grapevine [GE-5.41.1,2] and moulding grapes in the bunch [IA-1.558]. Grape bunches are conserved by treatment with purslane sap before hanging them [GE-4.15.19]. To improve the yield of pomegranate and other trees pour crushed spurge and purslane around the tree base [GE-10.35, 10.82.1].
Comment: Produces latex. Extracts with antibacterial properties. Vermifuge. Purslane, with up to 9 per cent oxalate, may lead to acute oxalate poisoning.

Punica granatum L., pomegranate.
Botanical: Spiny, deciduous shrub or tree, up to 8 m high, drought tolerant, bushy. Native to northeast and Central Asia (Iran).
Historical: Pomegranate was grown extensively in and around the Holy Land, in the early bronze age already at Jericho. Grown in the hanging gardens of Babylon. Traded by Phoenicians (*malum punicum*). Dedicated to Astarte. Symbol of fertility and life. The rind of the fruit produces a red dye and a medicine. Fruit sap used in soft drinks.
Use: Add dried and powdered leaves (~2% v/v) to preserve wheat in storage [GE-2.27.8]. A pomegranate branch beside the straw mattress chases vermin [GE-10.32] and snakes [GE-13.8.3].
Comment: Neurotoxic, class II. Bark contains antioxidant phenols, piperidine alkaloids (such as (-)-pelletierine, anthelmintic, highly toxic to tapeworm). Fruit rind with up to 28% tannins (punicaline, punicalagin). Antibacterial, antifungal, antiviral, and anthelminthic properties according to plant part, extraction method and target organism.

Quercus spp L., Q. *robur* L. and *Q. petraea* (Matts.) Liebl., holly oak and sessile oak.
Botanical: The genus *Quercus* has around 400 species, spread over the northern hemisphere. Big trees.
Historical: Oak forests were widespread on the north side of the Mediterranean, until cut for building houses and ships, for firing the kilns to make bricks and pottery, and to feed the furnaces for the production of bronze and iron. Men ate acorns before grain was grown. Symbol of strength and endurance.
Use: Oak forest needs sufficient rain to establish [GE-2.8.4]. Strew acorn pieces, the size of faba beans, over planted cuttings of grapevine; mix with them bitter vetch [seeds], crushed and ground once, so that they just split and open, and strew them over the area of plantlings [GE-5.9.2, 5.24.1]. Mice in contact with oak-cured ham will get mange and die [GE-13.4.2]. Pomegranates can be stored in sawdust of oak wetted with vinegar [GE-10.38.6].
Comment: Obviously, the acorns and bitter vetch seeds strewn in the young vineyard should not germinate but leach substances such as tannins. The bark of young trees, but also green acorns, have a high tannin content (up to 16 %), leaves up to 5 % DW. Many tannins are feeding deterrents. Tannins probably protect against fungi and bacteria (ellagic acid: Hanson, 2007), may avert insects, and could have some allelopathic affect. Death of horses and cattle by tannin intoxication is known.

Ricinus communis L., castor bean.
Botanical: Suckering perennial shrub, up to 12 m, not cold hardy. Mediterranean area, East Africa, India.
Historical: Grown in Egypt, 4000 BCE, for its oil, used as lamp oil, body ointment, and hair growth stimulant.
Use: Only in Agustín, keeps moles away [AG-160].
Comment: Castor bean, with 40-60% castor oil, contains triglycerids (mainly ricinolein), undecylenic acid (a natural fungicide, laxative, purgative, and cathartic), and ricin (plant lectin, protein, poison). Seeds highly poisonous; 4-8 seeds suffice to kill a person. Poisons provide natural protection against insects (aphids).

Rubus spp. – bramble, primarily *Rubus fruticosus* L.
Botanical: Bramble occurs nearly everywhere as a perennial shrub. Here *R. ulmifolius* Schott?
Historical: One of the shrubs used in fencing.
Use: House mice will die if they eat bramble root mixed with butter, bread, and cheese [GE-13.4.6]. '*And who wants that the birds nor the ants injure the cabbages should moisten the seed at sowing with the sap of Moorish bramble*' [IW-75(35)315].[72]
Comment: Plant parts contain casuarictin and peduculagine, tannins poisonous to cattle.

Ruta graveolens L., common rue.
Botanical: Perennial, up to 0.7 m high, heat and drought tolerant, producing a strong odour. Native of and commonly cultivated in southern Europe.

Historical: Dedicated to Hecate, daughter of the night and brewer of toxins. The ancients believed that this plant could prevent contagion and heal various ailments, hence 'herb-of-grace'. Used to improve and stabilize poor quality wine. Aromatic leaves used as spice. Tea medicinal. Planted in gardens to repel cats. Component of grappa (Italian brandy).
Use: Added to wine for field labourers at lunch [GE-2.47.5]. Part of powder used to chase ants from their nests [IA-1.566]. Seeds abortive [GE-12.25.6].
Comment: Cell poison, mutagen, class II. Hallucinogenic. Contains essential oils, coumarins, furanocoumarins, furanoquinoline alkaloids (active against various phytopathogens (Rimando & Duke, 2006)), bitter pilocarpine, and the flavonoid rutin (up to 5%). Alkaloids mainly in roots. Rutacridone epoxide has antibacterial and rutarin has antifungal properties, causes itching (photodermatitis), and abortion.

Sedum acre L., biting stonecrop, wall-pepper (§ 5.7).
Botanical: S. acre is but one example of the genus *Sedum*, with tens of species. It grows in Europe and western Asia on sandy soils, walls and roofs, well adapted to drought.
Historical: Some *Sedum* species were used in salads.
Use: May have been confused with *Sempervivum tectorum*, that also grows on roofs.
Comment: S. acre contains piperidine alkaloids that give it a sharp peppery taste, insecticidal nicotine, and anthelmintic pelletierine. *Sedum* species can be poisonous.

Sempervivum tectorum L., common houseleek (§ 5.7).
Botanical: Sempervivum, a genus of mountain dwellers in Europe and Anatolia, prefers an open rock habitat between 1000 and 2000 m altitude. *Sempervivum* is not a typical Mediterranean genus. As the name suggests the plants are long-lived. *S. tectorum* grows in the mountains of the central Pyrenees, the south eastern Alps and the southern Apennines. Frequently cultivated, it is naturalized all over Europe and Iran (Eggli, 2003). Plants grow slowly, forming clusters by clonal reproduction.
Historical: In north western Europe often grown on roofs. Component of witches' salve.
Use: Dry leaves recommended for the preservation of grain in storage [GE-2.27.6, 2.30.2], juice advised for seed treatment [GE-2.18.1, 12.7.3, 12.20.4].
Comment: No phytopharmaceutical information was found. Many crassulaceous plants contain bufadienolides (toxic glycosides).

Solanum nigrum L., garden nightshade, hound's berry.
Botanical: Europe, disturbed soils. Successful weed, annual, branched, < 80cm.
Historical: Medical and culinary uses; recommended as an insecticide.
Use: Soak garden nightshade in water for a day and a night, add strong vinegar. Water this mix over everything where the presence of insects [aphids on fruits and vegetables] is feared; they will die [IA-1.594].

Comment: Steroidal alkaloids inhibit acetylcholinesterase. Contains solanine with solasodine as aglycone, solaceïne, solaneïne, solamargine and degalactotigonin, irritant saponins, and toxic levels of nitrate. All plant parts are poisonous, green berries foremost. Humans may die by cardiac or respiratory failure.

Strychnos nux-vomica L., strychnine tree.
Botanical: Evergreen tree from India and SE Asia.
Historical: If used probably imported into Mediterranean area.
Use: Confusion with *Cynanchum acutum* is possible; translation of Geoponika questionable.
Comment: Contains many alkaloids, such as strychnine (seed) and brucine (bark). Very poisonous, 1 gram per kg can be lethal. Strychnine is too toxic to be of general use as a rodenticide (Godfrey, 1995).

Styrax officinalis L., snowdrop bush.
Botanical: Small deciduous trees 2-14 m high, SE Europe and SW Asia. Resin produced from pierced bark.
Historical: Resin used in medicine, perfumes, and incense (frankincense, Exodus 30:34).
Use: Used to control ants [GE-13.10.4]. Mixed with other substances and burned as incense it repels snakes [GE-13.8.8] and mosquitos [GE-13.11.7].
Comment: Used as incense it produces benzene and formaldehyde, but are the amounts adequate?

Tamarix africana Poir., tamarisk, salt cedar.
Botanical: Shrub up to 3 m high, growing in damp places. Moldenke (1952) mentions other *Tamarix* species.
Historical: Indicates humid patches in dry areas.
Use: Ash of tamarisk strewn over the shoots in the vineyard protects against frost [GE-5.32.2]. Mice will be repelled by burning green tamarisk in a censer of haematite stone [GE-13.4.8].[73]
Comment: Tamarisk is allelopathic through salt excretion by its foliage. *T. arceuthoides* Bunge shows differential allelopathy (Rimando & Duke, 2006).

Thymelaea hirsuta (L.) Endl. – thymelaea.
Botanical: Shrub, up to 1 m high, dry, coastal Mediterranean habitat.
Historical: Leaves found regularly in grain storage vessels, Santorini, ca.1500 BCE (Panagiotakopulu *et al.*, 1995), apparently to protect grain against insects.
Use: No recent use found.
Comment: Produces daphnane diterpenoids, with antioxidant and antitumor properties, flavonoids, and various volatile compounds. Flowers and shoots contain water-soluble phytotoxic compounds (Ladhari *et al.*, 2011).

Thymus serpyllum L., wild or creeping thyme.
Botanical: Creeping shrub a few cm high, Europe and North Africa, prefers dry rocky soil. Strongly scented flowers. Honey plant.
Historical: Herbal tea. Source of 'oil of serpolet' used in herbal medicine.
Use: If burnt it repels snakes; used to protect resting harvesters (§ 4.3.4).

Comment: Essential oil contains thymol and carvacrol, when fumigated toxic to storage insects (Isman, 2000); antibacterial.

Trigonella foenum-graecum L., fenugreek.
Botanical: From south western Asia. Seeds with soft bitter aroma.
Historical: Grown already 4000 BCE in Near East. Seeds eaten in India. Used mainly as cattle fodder. Leaves used as herbs, seeds as spice. In pickles, curries, tea, and confectionery.
Use: Some fenugreek seed mixed with vetch seed is said to protect the vetch from being eaten [GE-2.18.11]. Gardens flower better when watered with crushed fenugreek [GE-12.6].
Comment: The strong scent emitted by the plants probably explains the recommendation to mix with vetch seeds, an inefficient measure [GE-2*92]. Rich in polysaccharide (galactomannan) and saponines. Contains alkaloids such as trigonelline, and volatile oil.

Urginca maritima (L.) Baker, sea squill, sea onion (Fig. 6.4).
Botanical: Bulbous perennial. Sea squill grows in the Mediterranean sands and forms large bulbs.[74] At the end of the summer it produces a leafless inflorescence over 1 m high. The curious growth rhythm of sea squill, growing amidst the sands, gave it a kind of magic aura.
Historical: The use of sea squill goes back to antiquity.[75] It was used in purificatory rites and in classical medicine. At New Year the Greeks used to hang the bulbs in their houses as a fertility rite. The bulbs unearthed by the plough are sometimes used to mark field boundaries (Polunin & Huxley, 1967). Until recently rat poison

Figure 6.4. Scilla (G: Σκίλλα) = Urginea maritima *(L.) Baker = sea squill. The bulb is not readily recognizable. The plant, over 1 m tall, is rendered in starkly shortened form. It is also used as an 'Alexipharmacon, being hanged vp whole before the doores'. An alexipharmacon is an antidote, here meant to avert evil from the household. Drawn by A. de Laguna. Dioscorides (1566) p 247. Scale 1:1.25.*

was made from the bulbs with red tunics (*U. sanguinea*) of certain North African sub-species. — I doubt whether a market supply of sea squill bulbs was extant.
Use: sea squill is mentioned frequently. '*…it is even able to keep other things that are stored, for instance the pomegranate, if the stalk of the fruit is set in it; and it is said that, if planted before the entrance door of house, it wards off mischief which threatens it*' [HP-7.13.4]. The latter function, as described by Dioscorides: '*It is also an Alexipharmacon, being hanged vp whole before the doores.*'[76] Planted as a protectant together with pomegranate [GE-10.29.1], fig [GE-10.45.6], and other trees [NH-17.16.87]. '*Some say that, if you plant a bulb of sea squill at the foot of a tree, it will be protected against all accidents that could affect it*' [IA-1.574].
Comment: Heart poison, class Ib. Contains many poisonous substances among which scilliroside (rodenticidal), glucoscillaren A, and scillaren A (very toxic), and toxic bufadienolides up to 1.8 %. Rodenticide and insecticide. The sap, causing blisters, was used for wound disinfection. The pre-modern information suggests that the bulb exudes some bio-active substances as it was planted near other plants to keep the vermin away [GE-10.90.1].

Veratrum album L., white hellebore.
Botanical: Robust perennial herb up to 1.75 m high. Europe. Root highly poisonous.
Historical: Medicinal use in antiquity. Used to produce sneezing powder. Source of insecticides, now obsolete.
Use: In baits to poison mice [GE-13.4.7] and moles [GE-13.7.1].
Comment: Cell toxin, neurotoxin, class Ia. Contains steroid alkaloids (protoveratrine A, B) up to 1.3% in all parts, and glyco-alkaloids among which haemolytic saponins. Rhizome and seed very poisonous because of veratridine and cevadine, neurotoxins that affect sodium ion channels in excitable membranes, and antibacterial jervine; 'hellebore', the dried rhizomes of *V. album*, contain highly insecticidal proto-veratrine A (Godfrey, 1995). Used as a rodent poison, and against ectoparasites (lice). Abortifacient.

Vicia ervilla (L.)Willd, bitter vetch, ervil.
Botanical: Low annual herb from Anatolia and Near East.
Historical: Cultivated in Turkey before 6000 BCE, in Greece before 5000 BCE. Grown for forage and grain. Mentioned already by Theophrastus to deter aphids from radish.[77]
Use: Some bitter vetch sown among the vegetables, especially radish and turnip, protects them against fleas, lice, and birds [GE-12.7.1]. Strew over planted cuttings of grapevine acorn pieces, the size of faba beans; mix with them bitter vetch [seeds], crushed and ground once, so that they only split and open, and strew them over the area of plantlings [GE-5.9.2, 5.24.1].
Comment: Obviously, the acorns and bitter vetch seeds should not germinate but leach substances such as tannins. Contains non-protein amino acids that may be toxic.

Vicia faba L., broad bean, horse bean, etc.; here called faba bean.
Botanical, Historical: § 3.3.4.

Use: The Geoponika sees faba bean straw as a panacea, beneficial to the soil, diminishing salt damage, protecting grapevine against frost, curing ailing trees, and so on. Where straw is written the dried pods or shucks may be read.
Comment: It is hard to believe that such a firm conviction is based on imaginary effects only. Straw and pods may add organic matter, nitrogen, and some minerals among which K.

6.4.3 Botanicals disregarded

Curiously, the pre-modern authors did not mention several plant species producing potent botanicals, though they were known at the time. Four species, described in § 6.4.2, deserve mention. Old books gave little attention to the Brassicaceae of which interesting effects are known now. Only the garden rocket was given due attention.

Castor bean was grown early in Egypt and, later, probably elsewehere in the Mediterranean area.

Common tansy with its vermifuge and abortifacient properties must have been generally available, mainly somewhat north of the Mediterranean Sea.

Deadly nightshade was popular as an arrow poison but I did not see it used in crop protection. The Romans used it to poison humans.

Neem tree was mentioned by Ibn al-ʿAwwām, probably only for completeness sake; I doubt whether it was ever grown in Spain. Neem tree, from India, probably had been planted in Mesopotamia.

6.4.4 Some classes of bio-active molecules

The enumeration of chemicals in § 6.4.2 is rather confusing. An attempt at classification might be helpful. The countless molecules of living beings are conveniently separated into 'household molecules' and 'secondary metabolites'. Household molecules, indispensable to life, are common to most or many organisms. Secondary metabolites, evolved differently in different groups of plants (family, genus, species), have various functions among which defence and signalling. The variety of secondary metabolites is great and their grouping awkward. Some groups are briefly indicated here.

Some plant species produce complex bio-active molecules that are difficult to classify. Such stand-alones are e.g. azadirachtin (*Azadirachta indica*) and scilliroside (*Urginea maritima*).

In living plant cells many of the above mentioned molecules occur in a bound form, e.g. as glucosides coupled with sugar-like molecules, as with the saponines in cucurbits (*Citrullus colocynthis*). These complex molecules are hydrolysed during the preparation of the various extracts, teas, and other concoctions used in crop protection.

Aliphatic compounds. Some plants produce a relatively simple aliphatic fatty acid such as erucic acid (*Eruca sativa*). Falcarinol (*Hedera helix*) is a polyacetylene chain containing double and triple bonds.

Alkaloids are a heterogeneous group of heterocyclic and usually basic molecules with often specific physiological effects on target organisms that ingest them.[78] Some are highly poisonous such as coniin (*Conium maculatum*) and atropine (*Atropa belladonna*). By the same token, they may be used as medicines if applied at the right dosage, or as spices and perfumes. An active group of molecules consists of tropane alkaloids, that have tropane – a heterocyclic double ring structure – as the common element; atropine is one of them.

Coumarin, a dicyclic compound with oxygen in one ring, is part of several bio-active substances (*Ruta graveolens*). Umbelliferone (*Ferula* spp.) is a hydroxycoumarine.

Essential oils are hydrophobic concentrates of plant oils, usually obtained by distillation. The term does not refer to any class of chemicals; the word essential refers to a smell or taste characterising a plant species. In recent times several essential oils have been found effective against some insect, fungus, bacterial and nematode species, as deterrent, antifeedant, growth inhibitor, or toxicant.[79] Now that synthetic pesticides are falling out of favour, essential oils are tested for commercial purposes. One example: fumigated essential oil of wild thyme (*Thymus serpyllum*), rich in thymol and carvacrol, is highly toxic to certain storage insects.[80]

Proteins are typical household chemicals but, as an exception, poisonous proteins exist such as momordin (*Momordica charantia*).

Saponines consist of two parts, a triterpene and a glycoside. They protect plants against insects, fungi and bacteria. Solanine (*Solanum nigrum*) is a saponine.

Terpenes are a class of hydrocarbons consisting of concatenated isoprene molecules. Many terpenes are signalling molecules active in the interaction between widely different species; among them are many fragrant molecules. Several molecules are bio-active such as thujon (common wormwood), limonene (*Citrus* spp, *Apium graveolens*), camphor (*Ocimum basilicum*), thymol (*Origanum vulgare*), carvon (*Anethum graveolens*), and myrcene (*Laurus nobilis*). Carotene is an important molecule in human nutrition. Phorbol (*Euphorbia* spp) is a terpene with many hydroxyl groups.

6.5 Other plant substances

Algae have been used as fertilizers by farmers living at the coast**.** Sea slime, here interpreted as the remnants of algae found on the beach, can be used to control ants '*… stop up the mouths of ant-holes with sea-slime or ashes*' [NH-19.58.17].[81] Biofertilizers containing algae may strengthen the resistance of plants against fungi.[82]

Ashes – abiotic damage. Ashes were used to protect vines from night frost and common rue from winter cold [GE-12.25.1]. '*You will cure them [grapevines weakened by low night temperature] by smearing the trunks with ash diluted in a strong vinegar and pouring it above all around the stem, spraying also the own vines with the moistened ashes*' [GE-5.39.2]. — The cold dew and the berry drop it causes are both called *roratio* in Latin. The action leads to a supply of minerals, of potassium first of all. The effect may be enhanced when the vinegar neutralizes the alkalinity and dissolves the nutrients.

We see different applications of ashes, as a dry powder or in watery suspension (Box 6.1). Ashes are good fertilizers, indeed in part because of the potassium they contain. The dusting of the plants and/or of the dry soil surface with ashes may have an insect-repellent effect. The protection of plants against low temperatures by ashes has been claimed repeatedly.[83]

Ashes – biotic damage. '*Ashes also have the effect of salt, but it acts more gently; consequently they are sprinkled on figs and on rue, to prevent their getting maggoty or rotting at the roots.*' [NH-17.47.261] '*For the vegetables the best fertilizer of all is the ash, because by being fine and hot by nature, it will kill the aphids, caterpillars and vermin of that class*' [GE-12.4.1]. A watery suspension of ashes from old vines poured over the garden protects all garden plants against caterpillars [IA-2.138; AG-157]. Ash of fig wood strewn over the vegetable plants averts insects [IA-2.139, 2-159]. Ashes were applied to protect wheat in storage from insects.

Ashes can be used to control voles: '*If you put ash of holm oak in their holes, you will see something wonderful; all voles leave their holes full of mange, and they will die*' writes Agustín cheerfully [AG-161]. Ashes of willow branches with grape leaves, mixed with cattle dung, dry or fresh, and powdered onto the leaves of the grapevine improve quantity and quality of grapes, keep rats (or dormice?) away, and destroy worms in the roots [IA-1.513]. — The belief in a beneficial effect of ashes was widespread, but this enumeration sounds too good to be true.

Ibn Baṣṣāl offered a drastic solution to avoid unidentified soil-borne vermin in vegetable beds. Spread ash from the baths over the surface of the soil in a layer one inch thick; cover it with manure and sow the beds.[84] '*In this way the indicated animal when it leaves the soil in search of the plant will encounter the ashes and will flee defeated. So that the ash will be as a protection placed between the plants and the noxious animals.*' — I wonder what will happen when the roots of the germlings have penetrated the ash layer and enter the soil.

Carbon dioxide. In modern times vegetables in the food store are often sold in hermetically sealed packages filled with CO_2 to prolong shelf-life. Some old uses had a comparable effect, though the users did not know about CO_2. I think of grape (§ 3.7.3) and grain storage (§ 4.4.6). On the island of Santorini airtight ceramic containers with grain and pulses were found, sealed with stone cover and clay, probably internally coated with oil, dating from c.1500 BCE (Panagiotakopulu *et al.*, 1995).

Honey is frequently recommended to trap ants. The bone of a wood pigeon thickly covered with honey can be used to trap ants damaging a peach tree; when you see them caught you throw them in the water far from the tree; repeat this until the tree is free from ants [IA-1.595].

Latex is a milky sap produced by various plants. The texts refer to *silphium*, to the milk sap of other *Ferula* species, or to the latex of (wild) fig [GE-2*155] and spurge. When exposed to the air the latex becomes sticky, so it may function as an adhesive or sticker. Latex may also contain various toxic chemicals. To cure trees from whatever damage: '*Others, rub the trunks of the plants [trees] with the latex from the plant called polypremnos [an unidentified plant with many trunks], conserve them without damages and harvest very much fruit*' [GE-10.84.5].

Resin is mentioned several times but not always with the source plant. The smell could be repellent and in some cases its stickiness may be effective. '*Sociόn recommends to smear the base of the plantlet [grapevine] with a minimal quantity of cedar resin so that it will not rot and will prevent that insects, smelling it, will come near*' [GE-5.9.9]. '*If you smear cedar resin around an ant nest the ants will not invade the threshing floor*'.[85] '*The flour remains intact for a long time if resinous chips are cut and added to it*' [GE-2.31.1]. — Resin from hardwoods contains many phenolic compounds and terpenoid substances which protect resinous trees against most insects.

Seaweed. If trees yield many fruits that do not ripen, or lose their blossom, they can be cured by digging around the crown and adding a certain amount of sea weed [GE-9.10.8]. — Perhaps providing minerals and nitrogen.[86]

Vinegar, always made from wine, is mentioned regularly, usually as a carrier of something else. Sometimes it seems to be a solvent as when ashes in vinegar are applied to 'cure' grapevine trees. '… *and they [lentils] are conserved without rotting if they are sprayed with a vinegar containing latex*' [GE-2.37.1]. — Whether vinegar functions as a solvent of latex I do not know.[87] Vinegar may have been used because of its nasty smell but then it is at best a short-lived deterrent.

Wine is frequently recommended for seed treatment from ca.300 BCE onward [CP-3.24.4]. Soaking the seed in wine may have two functions, a pre-germination treatment and a disinfection treatment. The seed can absorb water so that germlings emerge faster with shortened period of exposure to soil-borne pests. The ethanol content of wine (up to ~14 %) is not good enough for complete external disinfection but it may help. '*Apuleius states that seeds treated with wine will have less diseases*' [GE-2.18.6].

6.6 A personal evaluation

How should one evaluate pre-modern plant protection compounds in the light of modern knowledge? *Amurca* must have been locally available and plentiful. Sulphur and pitch were trade commodities available at a certain price. Several botanicals that might have been available locally were not suitable for trading and at best could be used in gardens. We should, however, not underestimate the herbal knowledge of some individuals in pre-modern times about medicine, human reproduction, and – why not – agriculture.[88]

Published reports on phytopharmacological tests of botanicals often show an unsatisfactory methodology, leading to disappointing results, as extraction methods are not clearly specified and quantitative data (amount applied per unit area of crop) are not provided. Bloksma's (1987) analysis of botanicals used in the Netherlands does not give much hope. At the time, none of these botanicals, pyrethrum and rotenone excepted, had been decently tested. Some were definitely harmful to non-target organisms.

Most of the pesticides mentioned were broad-spectrum insecticides, a few were typically rodenticides. Fungal and bacterial diseases were not known as such; hence typical fungicides and bactericides were not used. However, some rots were treated with *amurca*, pitch, or sulphur with at least some fungicidal and bactericidal effects. Wounds were often treated with manure which can provide bio-protection. Nematodes were not known but some treatments may have been nematicidal, i.c. root treatments with – again - *amurca*.

To date, plant brews for crop protection are still home-made, foremost in the tropics. The PAN organization[89] provides extensive recipes for many plant species, among which some mentioned above: basil, coriander, garlic, mint, neem, and onion. Note that PAN writes about non-chemical pest management. As shown above it is all about chemicals but PAN intends to communicate the idea that the chemical industry, producing synthetic pesticides, is not involved in these brews prepared in the scullery.

Chapter 7

Pre-modern crop protection lore

Plant disease is an old concept mentioned in the Bible and in Greek writings from Plato onward. Crop protection as known today, a separate discipline, did not exist in pre-modern times but many authors devoted a section to typical crop protection issues. The pre-modern 'crop portfolio' is indicated. The 'pest portfolio' lacks differentiation. The 'control portfolio' was well-filled but low-tech. Thought is given to experience, experiment, and scientific writing on agriculture. Some aspects of human behaviour are considered. The question of evolution versus revolution in agricultural knowledge is discussed. Some practices and beliefs persisted for over two millennia.

'I come now to the pleasures of agriculture in which I find incredible delight; they are not one whit checked by old age, and are, it seems to me, in the highest degree suited to the life of the wise man.'

Words attributed to Cato by Cicero in *De senectute* (= On old age), 15.51.

7.1 Pre-modern agriculture and crop protection

7.1.1 Plant health

Plant health was an accepted concept in former times.[1] It was threatened by pests, diseases, and physical factors of both natural and man-made origin. These threats were not always observed and categorized as we do now. Physical damage was often seen as disease; today we would be more likely to say injury. Weeds were seen as noxious organisms. Insect pests have been recognized from the very beginning of agriculture, but is it the same for plant disease? The Old Testament did not use the concept *in abstracto* but it mentioned several plant diseases (and pests) by name. Greek and Roman authors were more specific.

Plato (424/3-348/7 BCE) recognized that plants could be diseased. In his 'The Symposium' the physician Eryximachus (G: Ἐρυξίμαχος) takes the floor and, comparing heavenly with popular love, says: '*Note how even the system of the yearly seasons is full of these two forces; how the qualities I mentioned just now, heat and cold, drought and moisture, when brought together by the orderly Love, and taking* *on a temperate harmony as they mingle, become bearers of ripe fertility and health to men and animals and plants, and are guilty of no wrong. But when the wanton-spirited Love gains the ascendant in the seasons of the year, great destruction and wrong does he wreak. For at these junctures are wont to arise pestilences and many other varieties of disease in beasts and herbs; likewise hoar-frosts, hails, and mildews, which spring from mutual encroachments and disturbances in such love-connexions as are studied in relation to the motions of the stars and the yearly seasons by what we term astronomy*'.[2]

Xenophon (c.300 BCE) mentioned blight in a context of (un)predictability. '*But in husbandry a man can rely very little on forecast. For hailstorms and frosts sometimes, and droughts and rains and blight ruin schemes well planned and well carried out; …*'[XE-5.18]. It took well over two millennia to improve the situation by means of need-based treatments following sophisticated warning systems.

Theophrastus (c.371- c.287 BCE) distinguished internal and external causes of disease [HP-4.14.7]. Indeed, he used the common Greek words for disease. [3] '*Diseases (as in animals) have their origins either in the individual itself or outside it, …*' Among the external causes are hail (see Plato), rain, drought, and excess temperature, and '*There are moreover the results of a blow or wound inflicted by hoeing or pruning or thinning or some other causation of the sort (indeed some causes such as hail-stroke are an act of God)*' [CP-5.8.2]. Many followers made the same distinction between external and internal diseases. De Herrera applied it to grapevine [DH-2.15.74]. Among the external diseases are the wounds due to various cultivation measures, and among the internal diseases are, for example, premature grape dropping and poor ripening of the grapes. Darwin Senior repeated the basic distinction , still valid today.[4]

Theophrastus mentioned disease of plants frequently, his 'disease' including damage by insects, frost, wind, and equipment. '*As to diseases - they say that wild trees are not liable to diseases which destroy them … Cultivated kinds however, they say, are subject to various diseases …*' [HP-4.14.1]. This basic comment still holds true. Domesticated plants, and not only trees, are more susceptible to damage by more harmful agents than their wild progenitors. The reasons are threefold, (1) genetic - selection for yield with neglect of resistance, (2) physiological – improved plant nutrition, and (3) epidemiological –crowding of identical genotypes.

Varro (1st century BCE), writing about the olive harvest, warned '*Those [fruits] which cannot be reached with the hand should be beaten down; but a reed should be used rather than a pole, as the heavier blow renders necessary the work of a tree-doctor*'. He used the word *medicus*, meaning physician, to cure the injured trees.[5] Pliny acknowledged '*For even trees are liable to attacks of disease*' [NH-17.37.216]. Trees were a legitimate subject of concern since they represent a long-term investment.

7.1.2 Crop protection singled out

This book focuses on medieval crop protection and thus disregards earlier Chinese, Indian, Egyptian, and Mesopotamian material. The book begins with the European Classics on agriculture because several of the Ancients were well read and much quoted in the Middle Ages. Homage must be paid to the Islamic scientists who contributed so much to agricultural science by transmitting and expanding classical knowledge on plants, agriculture, and crop protection.

Whereas crop protection as a discipline is a product of the late 19th century, crop protection as an activity is nearly as old as agriculture itself. In the pre-modern writings crop protection is firmly embedded in crop husbandry. Crop protection was often implicit except – maybe – weed control. Many remarks on pest control, in other words on crop protection, are scattered throughout the old texts. Successive authors devoted increasing space to pests and diseases, sometimes under separate headings. At the time it was customary to discuss afflictions of humans and plants in combination, discussions often interspersed with dietary comments.

Several pre-modern authors had their reasons to single out crop protection as a topic on its own. Theophrastus had a paragraph '*On diseases and injuries done by weather conditions*'.[6] The foregoing chapters contained several striking examples taken from Columella. Palladius had a chapter on crop protection called '*Recipes to protect the garden or the field crop*' (De remediis horti vel agri) [PA-1.35]. The Geoponika devoted book 13 specifically to all kinds of nuisances, with the opening words '*On the measures against locusts, locusts without wings, scorpions, snakes, and poisonous animals, and so on; and also on the treatment against fleas, bugs, mosquitos, and other similar noxious vermin*'.

Abū 'l-Khayr (1070/5) in Seville developed a beginning of crop protection theory (Box 7.1). In his wake, Ibn al-ʿAwwām (c.1200) produced a Chapter 14 called '*Curative measures for diseases of trees, some plants and vegetables*' [IA-1.534]. For many crops he mentioned specific crop protection recipes but he concentrated several crop protection techniques in dedicated 'articles' such as on fumigation and on wild animals.[7] Just over a century later, Crescentio included chapters such as '*On the harms that affect the grapevines …*' (Fig. 7.1) and '*On the medical treatment of trees*'.[8] Besides the numerous crop protection recommendations mentioned under the individual crops, de Herrera (1513) devoted two chapters specifically to crop protection problems, '*On some diseases of grapevines and their cures*' and '*In which we speak in general on some diseases of vegetables and other particularities*'.[9]

Wisely, Pliny (1st Century CE) warned readers not to overdo their efforts in correcting plant disease, giving the example of excessive pruning: '*But it is of the first importance to avoid allowing our remedies to produce other defects, which results*

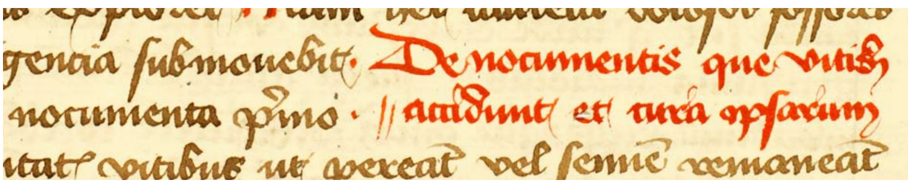

*Figure 7.1. Fragment from a Crescentio manuscript in Latin, dated c.1440, detail from Fig. 2.2. The text in red is the heading of chapter 4.18. '*De nocumentis que vitis accidunt et cura ipsarum*' ('On the harms that affect the grapevines and their cure'). Scale c.1:1.*

Box 7.1 A lesson in theory by Abū ’l-Khayr, c.1075 CE

The author summarizes eighteen pages on crop protection, primarily of planted crops:

‘In summary, most of the plant diseases are due to the influence of the four elements: water, air, manure, and soil. What is appropriate is the agreement of one element with the other and even with a third. To improve the state of all trees and to free them of noxious substances, the soil of their roots be removed, unsalted amurca mixed with fresh water be applied to them [= the roots], and the soil be returned. If the straw of faba beans is applied to the said roots its fruit is multiplied and its condition improved. Experienced persons agree that faba beans are good for all fruit trees because, strewn over their roots, they serve them as antidotes against various diseases’.[10]

Comments:

1. The theoretical basis is Empedocles’ theory of the four elements, water, air, fire, and earth, but with an agricultural twist.[11] The earth becomes the soil in which plants grow. Fire is replaced by manure, that – left on the pile – produces heat all by itself.
2. The humoral theory of health implies a good balance between four elements, blood, phlegm, yellow bile, and black bile. This Hippocratic theory, with Mesopotamian or Egyptian roots, is linked to the theory of the four elements.
3. Humoralism is in the back of the mind of most pre-modern authors. ‘Bleeding’ has been recommended to restore the balance between the four elements, also in plants.
4. It remains unexplained how amurca restores the balance; application of *amurca* seems to be a *non sequitur*. Apparently, people had seen the practical effects of *amurca*, amply available in the Mediterranean area. The procedure loosened the soil around the main roots, with improved access or air and water to the root system. The *amurca* possibly contributed some antibiotic effects and some micronutrients. I look to ancient Greece for the source of this firm belief in *amurca*.
5. Olives after harvest were often salted and set aside for some time before being pressed, hence the warning ‘unsalted’.
6. Another belief is made explicit here, the favourable effect of faba bean straw. The procedure loosened the soil and contributes nitrogen to the root system, but it is difficult to see that these improvements are sufficient to support such a firm belief, shared by so many experienced people. I suppose that a magical element contributed to the belief, which possibly originated in North Africa and was transmitted by way of the Near East. ■

from using remedial processes to excess or at the wrong time' [NH-17.45.257]. This is an early version of the 17th century dictum '*Primum non nocere*', that is 'First, do no harm', a leading principle in medical and veterinary teaching up to this very day.[12]

7.1.3 The Crop Portfolio

The Crop Portfolio contains the total array of crops covered by a person or period. Among the ancients Columella mentioned about 400 species. The *Capitulare de villis* contained only 89 plant species. 'Nabatean Agriculture' mentions over 360 plant types, the Geoponika about 270 plant species, and Abū 'l-Khayr about 240.[13] Ibn al-ʿAwwām peaked with over 580 different plant types. In his time agriculture, arboriculture, and horticulture were highly sophisticated. Crescentio discussed over 210 and Ibn Luyūn just over 200 plant species.

The various authors had different interests. The classical authors emphasized food crops, grapevines, and olive trees, but did not omit vegetables. The Andalusians added many medicinal plants, herbs, and ornamentals. Crescentio, de Serres, and Agustín showed a clear interest in food plants, though giving ample space to vine and wine. In this book my major interest is in food crops though at times I touch on other crops.

7.1.4 The Pest Portfolio

In this book the word 'pest' is used in its most general meaning, any living entity that impairs plant production. The pest portfolio comprises the full range of pests within a certain agricultural environment, as far as seen and understood by the growers in that environment. The pest portfolio of the tropical lowlands differs widely from that of the Nordic plains, though they are all at roughly the same altitude above sea level. The pest portfolios of the Mediterranean area and of north western Europe differed due to differences in climate, soils, and crops.

Looking back at the pest portfolio of pre-modern agriculture, primarily in the Mediterranean area, what did it contain? The number of crops was lower (medieval Andalusia excepted), cropping areas were smaller and more fragmented than today, and the nutritional status of the crops was poorer than today. Due to this low nutritional status the pre-modern pest portfolio should contain more 'poor man's pests', differing from today's portfolio with more 'rich man's pests'.[14] Locusts are a poor man's pest since they prefer plants with a low nitrogen level.[15] Rusts and mildews are rich man's diseases flourishing at high nitrogen levels whereas glume blotch of wheat is rather a poor man's disease preferring wheat with nutritional deficiencies.[16] The fragmented agro-ecosystems may have favoured polyphagous pests and pests with good survival ability over the years.[17]

Diseases caused by fungi, bacteria, viruses, or nematodes were not known as such but – if present – fell under the headings of rotting, wilting, and jaundice. Mineral deficiencies, as we recognize them now, were seen as jaundice too. The consequences of lack and excess of water were recognized, and these problem could be handled. What we see now mainly as deficiency or excess of nitrogen was known as jaundice and luxuriance, respectively, and could be treated in principle.

The 19th century brought an increase of the pest portfolio because so many harmful organisms became known. Late in that century the discovery of bacteria and viruses as plant pathogens drastically enlarged the pest portfolio. In the 20th century the shipments of pest organisms all over the world in the wake of globalizing commerce enlarged the pest portfolios in many different agricultural environments. Plant breeding, fertilizer applications, water management, and chemical control constantly modulated the regional pest portfolios. In pre-modern times less drastic changes must also have had effects on the pest portfolio, but with what result?[18]

The notion of 'contagion' existed in pre-modern times but was it applied to plants and their diseases? The evidence is slight. Fruits were to be stored without touching each other, hence the notion of contagion was there but the concept had no name. Black stem rust of wheat was said to spread like fire, hence the contagion was seen, again without naming it. The technical means to recognize infectious agents (hand-lens, microscope, Petri-dish, DNA-analysis) were not yet available. In contrast, insects had good visibility. The distinction between harmful and beneficial was not yet made, most insects being considered harmful.

The phenomenon of 'host specialization' was seen and described, but not yet named. Theophrastus was well aware of differences between insect species: '*As for the grubs, the shapes too differ in many trees and fruits, but the greatest difference is this: the grubs from one tree or fruit cannot be transferred to another kind and survive*' [CP-5.10.5]. He knew that phytophagous insects were specialised but he was in the dark as to the origin of the grubs. '*The grubs produced by a plant feed on the corruption that produced them*'.[19] The life cycles of insects became known only in the 17th century, which is beyond the scope of this book.

7.1.5 The Control Portfolio

The control portfolio is the full complement of pest control methods within a certain agricultural environment, as far as seen and understood by the growers in that environment. Although chapters 5 and 6 are lengthy, the control portfolio is restricted. Typically, it is a poor man's Portfolio, comparable to that of today's self-help farmers in many tropical countries.[20] Only weed control was brought to perfection by preventive tillage and curative elimination, especially in the Mediterranean area. Chemical control, so often recommended, must have been limited in its application. The rich man's synthetic pesticides were not available, then and there.[21] In medieval times, many of the modern pest control methods were applied in principle, but to what extent is not known.

A long list of botanicals was available for 'chemical control'. Most of these were broad-spectrum pesticides. Much control was manual, such as hand-weeding and hand-picking of insects. 'Fumigation', with questionable effectiveness, was popular. Seed treatments were recommended and some treatments may have been effective, but quantitative considerations suggest that they could be applied only in gardens and small field plots (§ 5.7). Seed treatment was applied primarily against insects damaging seeds and seedlings, but implausible effects on storage (and on cooking and consumption qualities, not discussed in this book) were mentioned.

We may distinguish renewable and non-renewable materials. Typical renewables were ashes and manures. Squirting cucumber is a renewable too. Silphium was a non-renewable; it was eradicated (§ 6.5). Several other botanical products, as e.g. the juice of 'house leek', must be ranked among the non-renewables (§ 5.7) because the 'house leek' grows too slowly to match the quantities needed.

Tree care was remarkably detailed. 'Grease banding' and 'chalking' to protect trees against insects were apparently common. Many problems were met by digging and laying bare the crown and the root system, or at least the main roots (Fig. 3.4). Trees were subjected to surgical interventions as grubs and rots could be excised and the wounds treated. Manure and/or surface dust was added to the soil used to fill the dug-out hole. These measures are laborious but perfectly reasonable. Air and water could reach the roots, minerals were supplied to the tree, and excess water was drained off.

Two major problems were birds and voles. Though they could be handled in principle, these animals were a constant threat, and – even when met with chasing and baiting – caused frequent and serious losses. Against migratory pests, such as locusts or black stem rust, farmers were utterly helpless; the only thing they could do was to tighten their belts.

Prevention rather than intervention was emphasized, and this prevention was completely embedded in crop husbandry. Tillage was extremely important in weed control though its primary purpose was to maintain soil fertility. We might call the medieval approach to pest control a prophylactic or precautionary control. The grower took his precautions and then he had to sit, wait, and pray.

7.2 Revelation, experience, experiment

7.2.1 Revelation

In ancient times truth was thought to be revealed to people by divine inspiration. This is the Near-Eastern tradition as expressed in Bible and Qur'ān. Revelation is mentioned in 'Nabatean Agriculture': '*Some of these things we have learned through experimentation, some through revelation given by the gods to our forefathers, …*'.[22] The distinction between the so-called revelation and the experience handed-down from generation to generation may have been less sharp than the words suggest. The Greeks had their mysteries but at the same time they tackled the natural phenomena by description, analysis, and reason.

7.2.2 Experience

'*Gaius Furius Chresimus, a liberated slave, was extremely unpopular because he got much larger returns from a rather small farm than the neighbourhood obtained from very large estates, and he was supposed to be using magic spells to entice away other people's crops. He was consequently indicted by the curule aedile Spurius Albinus; and as he was afraid he would be found guilty, when the time came for the tribes to vote their verdict, he brought all his agricultural implements into court and produced his farm servants, sturdy people and also according to Piso's description well looked after* *and well clad, his iron tools of excellent make, heavy mattocks, ponderous ploughshares, and well-fed oxen. Then he said: 'These are my magic spells, citizens, and I am not able to exhibit to you or to produce in court my midnight labours and early risings and my sweat and toil.'* This defence procured his acquittal by unanimous verdict [NH-18.8.41ff]. The pride of Chresimus in his experience and inventiveness is nearly palpable.

Experience was handed down by example and by word of mouth. Hesiod's poem 'Works and days' must have been repeated a thousand times wherever farmers sat together in the ancient Greek world. Similarly, Aesop's fables, didactical short stories, must have been repeated in Greek and – translated into Latin – in Roman gatherings time and again. Here we have an oral peasant tradition.

The leading classes, at ease with reading and writing, had their books: Xenophon, Aristotle, Theophrastus, on the Greek side, and Cato, Varro, Virgil, Columella, Pliny, and Palladius on the Roman side. The Roman authors were estate owners who gave due attention to estate management. Many educated Romans were fluent in Greek and they may have read Greek agronomy books now lost. Somehow they picked up bits and pieces from the near-eastern tradition as several fantasticated stories suggest. The experience from the Roman estates, laid down in writing, persisted for a long time, as exemplified by Ibn al-ʿAwwām quoting Columella. Ibn al-ʿAwwām wrote repeatedly: '*This procedure is confirmed and supported by experience*.'[23] We are left in doubt about the kind of experience, observational or experimental.

Theophrastus' botanical observations, made with a clearly scientific mind-set, remained unsurpassed for at least fifteen centuries. I quoted his observation on the absence of true breeding in olives, repeated in the Geoponika (§ 3.4.5). Botanical observation combined with scientific doubt were clearly expressed by Ibn al-ʿAwwām. On a mountain slope with cultivated olives he observed numerous self-sown olive trees of which most belonged to the wild type (§ 3.4.5), but he did not pretend that all wild olives there sprouted from [cultivated] olive seeds [IA-1.215/6]. This is science as it should be done, but it is still observational science.

Ibn al-ʿAwwām wanted to convince the reader of his personal experience. '*According to my observation …*' [IA-2.160]. '*I have seen, says the Author, the thing with my own eyes*' [IA-1.202]. '*With our own eyes we have seen the antipathy of those reptiles [snakes] for the pomegranate*' [IA-1.255]. '*I have … used this procedure in a moist pasture on the Asharf mountain, and I got a good result*' [IA-2.214]. Here, experimental science complements observational science.

Estate owners such as Varro, Columella, and Palladius must have talked with and listened to their colleagues. What about peasant farmers? We do not know. Did Ibn al-ʿAwwām listen to farmers? Probably, yes. Certainly Ibn Luyūn did so (§ 2.8). Crescentio, himself an estate owner, is explicit: '*And I have read and studied many books of classical and recent authors: And diverse and various operations of farmers have I seen and known*'.[24] De Herrera, who learned the tricks of the trade from his farming father, spent several years as an estate manager in the *vega* of Granada.

He learned many new things from surrounding Andalusian Muslim growers since these were far more advanced than their colleagues elsewhere in Spain.[25]

Frayn (1979 p 148) described the interplay between the villa farming and peasant farming in Italy, 200 BCE to 300 CE. '*…it should be observed that in the Roman period the type of husbandry practiced on the large farm and the smallholding had much in common.*' '*The owner of the villa was drawing upon a fund of knowledge and practice built up by generations of small farmers. Some of this tradition was mediated to him through his family, his workers or his neighbours: some he may have learnt from the written sources which have come down to us*'.[26]

7.2.3 Experiment

The notion of experimentation existed in antiquity. Theophrastus may have derived some of his insights from small experiments in his botanical garden. He knew about seed testing. Pliny wrote '*Consequently the best course is to rely on experiment*' [NH-17.2.24]. We should not, however, confound these notions with modern experimentation.

Farmers experiment all the time, not by means of replicated trials ready for statistical analysis, but by trying 'something different' in a small corner, and looking intently at the result.[27] If satisfactory, the 'new something' will be tried again on a somewhat larger scale.[28] In the long run the 'new something' becomes a promising innovation copied by neighbours, friends, and relations. Estate owners, less vulnerable because of the size of their enterprise, may have been bolder in testing fresh ideas. The borderline between experience and experiment is fuzzy.

The botanical gardens of the medieval Muslim rulers were centres of innovation where scientists could perform trials without risking disaster, as they stood under the protection of the ruler. The Muslim agronomists experimented, practised various methods of grafting, acclimatized introduced species, and created or selected new varieties.[29] '*I have done the experiment myself, says the Author; the result has confirmed the instructions.*' [IA-1.195], the Author being Ibn al-ʿAwwām himself writing on transplanting trees. Elsewhere: '*this procedure is confirmed*' [IA-1.546]. He experimented in the royal gardens on mount ash-<u>Sh</u>araf near Seville. '*As to myself, I planted saffron on the Asharf mountain in an irrigated field; it was a success*' [IA-2.117]. Ibn al-ʿAwwām recommended his readers to test the seed quality of wheat and barley: '*Soak seed in water for 24 hours, sow counted number of seeds in a good soil well fertilized and watered, and count what emerges*' [IA-2.19].

Later in the Middle Ages and further north, the many monasteries of western Europe were repositories of knowledge and centres of innovation but – as far as I could see – Muslim knowledge on agriculture did not cross the Pyrenees. Monks, especially Cistercians, became the new ag-entrepreneurs, reclaiming virgin lands and initiating agriculture in many places all over western Europe.[30] They usually chose rather inaccessible sites and they must have experimented a lot, starting from scratch at every new settlement. De Serres undoubtedly experimented during the twenty years before he published his book but he did not say so.

7.2.4 Scientific writing

Pre-modern authors thought it appropriate to repeat their predecessors.[31] Repetition without criticism demonstrated the deference of an author to his predecessors, the classic masters. Such repetition was an essential part of scientific writing in pre-modern times, as written in the introduction of the Geoponika's Chapter 1. In the same vein Ibn al-ʿAwwām stated '*I report the opinions of these authors textually, as they have consigned them in their works, without ever seeking to modify their expression*' [IA-1.9]. His counsel: '*Compare and study what has been said before and judge*' [IA-2.12]. Approvingly, Ibn al-ʿAwwām quoted a certain Kastos: '*I kept to, he says, reproducing both [theories] because this repetition of opinions must make it more familiar, and let it better know to the readers, what is stable and fixed in these theories, as follows from the concordance and the concourse of the testimonies. This is what I have done several times in my book, since I have wanted to present that which is most certain and best verified*' [IA-1.390].

Early scientific writing made no distinction between the natural and the supernatural. Ideas from both spheres were recorded on an equal basis, and they were felt to be equivalent. The 'Nabatean Agriculture' contains an equal mix of the perfectly reasonable and the irrational. The Geoponika, with its melange of natural and supernatural, clearly leans towards the near-eastern tradition. But did its compiler believe everything he wrote down? Definitely not! '*This is what the ancients have said, but some things they said I consider extremely inconvenient and objectionable, and I recommend everybody to give them no attention whatsoever; as I quoted them to avoid the impression that I omitted anything from what the ancients said*' [GE-1.14.11]. The compiler even ridiculed the 'contract with the voles' (§ 5.2.2).

Roman agronomists, among them Virgil and Pliny, could not resist the temptation to interlace rational and irrational, but they tended heavily towards the rational. Pliny, a matter-of-fact military man and administrator, did not believe all fantastication or magic: '*… inasmuch as most people believe that hailstorms can be averted by means of a charm, the words of which I would not for my own part venture to seriously introduce in my book,…*' [NH-17.47.267]. Dutifully, Ibn al-ʿAwwām cited a fantastication from the 'Nabatean Agriculture' on the grafting of a tree (Box 2.1) without believing it. Ibn al-ʿAwwām took care to quote his predecessors in detail.

The passages expressing disbelief nevertheless show the respectful attitude of the medieval scientist toward his predecessors, whose ideas should be rendered carefully. Desirous to present a broad overview, extensive (Ibn al-ʿAwwām, De Herrera) or concise (Geoponika, Crescentio, Ibn Luyūn), they did not hesitate to add new information. '*In Bithynia …*' says the Geoponika's compiler.[32] Ibn al-ʿAwwām took care to quote Christian sources but without mentioning names. '*I have also introduced the opinions of men foreign to Islamism: I don't name them, but I indicate them in an indirect way by letting the quoted passages precede, as a shortcut, by the words: Another has said that.*' [IA-1.9].

Fantastication, sorcery, and magic gradually disappear from later texts. Ibn Khaldūn commented: '*The Muslims who studied the contents of the work [noticed that it belonged to] sorcery, which is barred [by the religious law] and the study of which is forbidden. Therefore, they restricted themselves to the part of the book dealing* *with plants from the point of view of their planting and treatment and the things connected with that. They completely banished all discussion of the other part of the book. Ibn al'Awwâm abridged the* Kitāb al-filāḥa al-nabaṭiyya *(Book on Nabatean Agriculture) in this sense*' [IK-3.151/2].[33] Crescentio, a matter-of-fact observer who possibly tested various ideas on his own estate, is also free from irrational methods. His near-contemporary in Andalusia, Ibn Luyūn, the Qur'ān teacher, is free from superstition. De Herrera, the Spanish priest, hardly mentions irrationalities. The Catalan Prior Agustín, however, still reflects some superstitious ideas from the Geoponika.

7.2.5 Herb knowledge

Herb knowledge of the classical and early medieval writers was impressive, as shown in Chapter 6. It was applied to medicine, diet, fertility regulation in women and men, family planning, lactation, plant protection, vermin control, murder, warfare, and so on. The famous herbal of Dioscorides abounds with medical data but contains no crop protection information.[34]

Among the affluent of the classical period, family planning was more or less routine. When Christianity became the dominant religion, and its dictum 'be fruitful, and multiply' (Genesis 9:1) was implemented, the knowledge on fertility regulation went underground, was hinted at in indirect phraseology, or got lost. The herb knowledge used to be shared among men and women, with differences in emphasis. The sexes drifted apart when medicine became a university study. Males acquired the formal herb knowledge. The women became the owners of much informal herb knowledge. They were pushed into the position of midwifes, wise women, even witches.[35] Apparently, much useful information was lost.

Herb knowledge was applied in crop protection too. The Geoponika, and several of its medieval successors are the repository of this herb lore (Chapter 6). It would be interesting to compare the pre-modern situation with the present condition in the tropics, where many small farmers still rely on herb knowledge.[36]

7.2.6 The rationality of pre-modern crop protection

In the old days people in distress turned to Higher Powers to beg protection against or delivery from disaster, real or feared. Collective rituals came into being such as the Robigalia, the Roman ritual to invoke protection of the wheat crops against rust. Individuals took to prayer, as Crescentio advised, when no other means would be of help. The relation between the act of piety and the safety of the crop was felt to be a reality. In view of the limited means to avert a calamity these uses can be considered rational within the preconditions of the time. Today we see, maybe, peace of mind in the face of calamity as the major result of a ritual but not crop protection in the modern sense.

Self-appointed mediators between humans and Higher Powers, prophets and priests of whatever denomination, made use of the people's anxiety to improve their moral behaviour with the promise that the desired improvement would change the situation to the better. In line with the foregoing are the Church's court cases against animals, envisaged as effective since the animals went away.[37] Anxious people were quieted because everything had been done which could reasonably have been expected. The modern reader may see such mediation as rational since the public unrest was addressed.

The foregoing actions were verbal actions, speech acts, on behalf of a collective. Verbal actions at the individual level existed too, e.g. the threat spoken to a fig tree (§ 5.2.2). A verbal action in writing was the contract with the voles (§ 5.2.2). The alternative of a speech act is a mechanical act. Most treatments of Chapter 5 must be seen as rational, according to the standards of the times, even if today we think that they are (next to) ineffective.

Sometimes, an imminent calamity was personalized. If an approaching hail storm can see its own ugly face in a mirror it may pass by in shame (§ 5.3.3). The act of holding up a mirror has a logic of its own, once the premise is accepted. Hailstorms follow, usually, a long but narrow path. Hence, the act of defence can be considered effective if the hailstorm's path does not cover the mirror and its surrounding fields. People were so helpless against the disastrous effects of a severe hail storm that any means of defence was acceptable. If the diversion of the hail was not successful, the actor may at least feel satisfied that he did his utmost to avert the hail. This behaviour is not unreasonable, though miles away from modern rationality.

In the course of time individuals were advised to take individual action. Burying the entrails of an animal to attract the vermin so that it cannot damage the plants is such an individual action. As these entrails, offered as a bait, will rapidly be colonized by all kinds of organisms, among which the insects have most visibility, the act has the logic of association. Similarly, 'bleeding' the vines is associated with the supposed healing effect of the bleeding of persons.

Association was the dominant way of reasoning in the Middle Ages. Astrology, describing the association between phenomena in the skies and their parallels on earth, was basic knowledge applied in explanation and prediction.[38] The association between phases of the moon and agricultural actions, handed down from early times, was a certainty to be taken into account. Astrology in the service of agriculture was recommended by both de Herrera and Agustín, but rejected by Olivier de Serres. However, the latter, balancing tradition against practicality, was not completely unambiguous about the influence of the moon.

In pre-modern times, beliefs and acts seen today as superstitions had a logic of their own. In the course of time the actors changed from collective to individual, and the acts changed from ritual to situational. The chains of cause and effect as demonstrated by modern experimental science were not yet available to pre-modern agronomists. Being no fools they applied the knowledge and the ways of reasoning of their time. The implicit knowledge of growing and protecting plants may have been considerable but remains inaccessible. The explicit knowledge laid down in the available books shows only flashes of understanding in the modern sense.

7.2.7 Agriculture, craft or science?

Columella complained about the lack of education in agriculture [CO-11.1.10]. Writing about seed treatment he used the word *medicare*, to be translated as doctoring. '*Some ancient authorities, Democritus for example, advise that all seeds be doctored with the juice of the herb which is called houseleek …*' [CO-11.3.61]. Columella considered agriculture to be a craft supported by science. '*It is practice and experience that hold supremacy in the crafts, and there is no branch of learning in which one is not taught by his own mistakes. …*' [CO-1.1.16]. '*Hence these precepts of ours promise, not to bring the science to perfection, but to lend a helping hand. And no man will immediately become a master of agriculture by the reading of these doctrines, unless he has the will and the resources to put them into practice*'.[39]

Agriculture progressed step-wise and patch-wise, and innovations spread slowly. Thus, agriculture never had a genius who changed the world with a master equation like $E = mc^2$. Instead, thousands of farmers experimented during thousands of years. They rejected and selected, communicated, and improved. To these many minor contributions a few individuals could make a larger contribution, for example by introducing new crop species. These individuals are largely unknown. Generations will have passed before a new introduction was adapted to its new environment, including soil type, day-length, and temperature regime.

Old agricultural knowledge was rather like a network originating from many sources with countless deletions and additions. Sometimes the network condenses into nodes such as our three pivotal books, the *Geoponika*, the *Kitāb al-filāḥa*, and the *Ruralium Commodorum*. Policy considerations stimulated the initiator of the Geoponika, scientific interest inspired Ibn al-'Awwām, and social change motivated Crescentio.[40] A keen interest in agriculture was certainly the mainspring for the writing of these books. All three authors had at least some experience in agriculture and they were fully aware of its importance to society. At the same time, a wide social gap separated the – supposedly illiterate – peasant farmers from the affluent estate owners at whom the books were aimed. The toil and anxiety of the small peasant are depicted in the probing poem '*Moretum*', written by an unknown poet in the first century CE.[41] No books for him, but only a chat in the town's market place.

Agricultural knowledge was largely implicit, taught by example and learned by doing.[42] Sometimes such implicit insights surfaced, as in the words of the aristocrat, warrior, and historian Xenophon about ploughing in the spring: '*Yes, and the grass turned up is long enough at that season to serve as manure, but, not having shed seed, it will not grow*' [XE-16.12]. In fact, some notions were made implicit on purpose, such as Aesop's incentive to dig the vineyard intensively (§ 3.6.1). Explicit ideas, trying to answer the 'why' question, were scarse. Progress was limited, being restricted mainly to new crops and varieties and to elimination of obvious nonsense. The art of grafting trees was greatly advanced by the experiments of the Moors, including Ibn al-'Awwām.

7.2.8 The scientific status of pre-modern knowledge

Knowledge becomes science when explanations can be given, explanations that also remain valid in future cases. The source books provided few explanations. Some of these explanations, rendered in this book, although simple, are quite reasonable to the modern eye. Bolens commented on the Andalusian Muslim agronomists: '*The empiricism, though based on the renewal of observation, places the agronomic thinking of this Andalusian school, at the level of a pre-science*'.[43] Her comment, I think, applies also to those parts of de Herrera's work that show a high level of pre-scientific agronomy, with some attempts at explanation.

Such a positive opinion is not applicable to the crop protection lore presented in this book. The interventive side of crop protection abounded with superstition, magic, and false concepts. In crop protection matters even de Herrera, with his rambling reproduction of all the recommendations of his predecessors, was decidedly medieval, as was his advocacy of astrology, which he called a divine science.[44] Admittedly, pre-modern weed control was as good as it could be within the technical limits of the period. As to the preventive side of crop protection the precautionary (prophylactic) methods indicated by the pre-modern authors were perfectly reasonable. Several interventive recipes are quite sensible from a present-day viewpoint, including the use of sulphur and pitch, fumigation, and grease banding. Some of the botanicals must have been effective if properly applied.

On the esoteric side both Crescentio and Ibn Luyūn showed far more reservation than de Herrera. Our last author, Agustín, even took one step backwards. From a present-day viewpoint the scientific status of pre-modern crop protection is modest at best, but this judgement does not imply that pre-modern crop protection was without a logic of its own.

7.3 Behaviour

7.3.1 Money, the bottom line

The Romans Cato and Varro stressed the money. Cato [CA-39] on work for the slaves when the weather was bad: '*Remember that even though work stops, expenses run on none the less.*' Varro, considering whether gleaning would be worthwhile, noted: '*For the thing to be kept in view in this matter is that the expense shall not exceed the profit*' [VA-1.53]. The same Cato [CA-134] gave extensive religious prescriptions.

Seventeen centuries later, in another part of Europe, the protestant Olivier de Serres, another pious man, produced an awkward paragraph in which he tried to combine recommendations for obtaining the best price for wheat with admonitions to support the distressed [OS-2.7.124]. De Serres made a point of paying workers adequately, on time, and without discount [OS-1.6.36]. He often struck a moralistic note but his opinion on the tenant farmers was harsh. '*To sum up, all their husbandry is done by fraud, grumbling, with regard for profit only, without a thought to honour*' [OS-1.8.48].

Farm management was the affair of males. However, Varro, 80 years old, wrote his book to instruct his wife Fundania, who had just bought her own estate.[45] What about other women? We may wish to believe that women were – usually - decision makers on an equal footing with men inside the house, but custom would not allow this to be shown to the outside world. This is still true in many developing countries, and often in advanced countries too. Nonetheless, I have encountered very decided, able, and outspoken women farmers. Women and children often did the unpleasant work, such as weeding and hand-picking insects. Pictures show women binding sheaves, raking hay, carrying loads of grapes, in cooperation with men but not necessarily performing the same tasks (Mane, 2006). But there is another twist to the stories about women.

7.3.2 Mulier menstrualis[46] *- The power of women*

Of old, the fertility of the earth and the fertility of women were seen as analogues. Man is the only species in which females show the phenomenon of menstruation. This led not only to wonder but also to various stories that in the modern eye are curious, funny, even pornographic, and always useless. Dark powers were attributed to menstruating women, powers that could be brought into action against noxious agents. During their period women could kill plants, spoil cabbage, protect against caterpillars, avert hail storms, and remove dodder.[47]

'*All plants indeed turn yellow when a woman comes near them at her monthly period*'. Whereas Pliny makes this general statement Columella is specific: '*A shrub of rue lasts for many years without deteriorating, unless a woman, who is in her menstrual period, touches it; in which case it dries up*'. Ibn Wāfid picked up the message '*A woman who is not clean should not approach rue to avoid damaging it*'. The Geoponika, Ibn al-'Awwām, and Agustín repeated the comment stating that cucumbers are at risk. '*If a menstruating woman passes among the melon or cucumber plants she will kill them, and the fruit will turn bitter*', reprinted in 1762! Ibn al-'Awwām referred i.a. to cabbage, cucurbits and to the wallflower, an ornamental.[48] The incomprehension and anxiety expressed here, phrased by several Roman authors, was repeated by others during a millennium and a half.[49]

To protect vegetables and trees against caterpillars the Geoponika advises: '*When a large number of caterpillars damages the vegetables and the trees a menstruating woman*[50] *should be led into the garden, barefoot, hair loose, wearing one wide dress and nothing else, neither girdle nor other garment. When she, in this state, circles the garden three times, goes through it and leaves, the caterpillars will disappear immediately*.'[51] De Herrera, repeating this method to control caterpillars in the garden, adds that then a woman's destructive force is such that it taints the mirror in which she looks and often breaks it, '*as experience shows*'. No wonder then that it kills the aphids.[52]

Chaplain de Herrera echoes the Geoponika, with the reservation *dicen* (= they say) [DH-4.7.217]. Religious reasons or a sense of decency may have induced Ibn al-'Awwām to tone down the now familiar prescription. Introduce into the garden a fasting woman, bare-footed, hair loose, covered by one garment only, without waistband, walking silently in the middle (of the garden), repeating her walk three times, and all worms and caterpillars will die instantly [IA-2.140]. Agustín, the Prior, dropped the recommendation as indecent, useless, or both.

The common element in these tales is the idea that menstrual blood kills, physically or at least magically. It is difficult to imagine that serious men such as Pliny the Elder, a high-placed civil servant and military leader, or Columella, an agricultural entrepreneur and a soldier, really believed this nonsense. Pliny, the encyclopaedist, who skipped quite a bit of meaningless information, must have felt compelled to mention the recipe several times, even quoting the source.[53] So did de Herrera, the priest. Did these authors think that they should not omit such a widespread belief?

Contemplating such typical men's stories we may consider two points. First, we should not think that these stories were the hot fantasies of sexually deprived male farmers. Belonging to the category 'to-be-told' rather than to the 'to-be-done', such stories, having the 'thousand-and-one-night' tinge of palace tales, must have been told at the level of farmers' gossip. Second, comparable stories existed among women. Women collected the first menstrual blood of their daughters to make a talisman assuring conjugal fidelity of their husband *in spe*, as in the village Montaillou (southern France) around 1300, or to prepare a love potion for luring a promising male.[54]

7.3.3 Religion

In past times religion and agriculture were closely linked, religious celebrations being agricultural feasts, or *vice versa*. Biblical Easter observed the end of Lent by sacrificing firstlings of the herds; it also marked the beginning of the grain (barley) harvest.[55] Pentecost marked the end of the grain (wheat) harvest with offerings of grain. The Jewish Sukkot was an autumn festival celebrating the grape harvest. In the course of time these feasts were given a spiritual meaning hardly remembering their agricultural origin.

Greece and Rome had their own agriculture-related religious ceremonies. The Greek bacchanalia celebrated the grape harvest. During the Roman Robigalia a field procession was held to avert evil from the crops, a custom continued well into the 20th century.[56] The Greek God Apollo was implored to keep the locusts away. We have seen that in the Middle Ages the Church stepped in to 'control' insect outbreaks. In the western world, a 'prayer day' to implore the blessing of the crops and a 'thanksgiving day' to celebrate a good harvest are part of religious customs up to this very day.[57]

7.3.4 'Thou shalt not kill'

The Bible texts of Exodus 21:13 and Deuteronomy 5:17 are identical: '*Thou shalt not kill*'. This commandment was limited, of course, to the specific clan of believers. The 'others' could be slain whenever opportune. In the course of history the not-to-be-killed target group was gradually extended to all human beings, notwithstanding the many cases of mass killing of the 'unbelievers', in past and present. In recent times, the commandment is also applied to animals, higher animals first. But what about the lower animals that damage our crops?

Saint Augustine, the patriarch, had his doubts.[58] '*What then will you answer about the useless thorn-bushes and weeds? Farmers exterminate them by pulling them up when weeding the fields and they cannot at all produce food thereof.*' '*What to do when locusts or rats or voles destroy the fields, as evidently happens so often.*' So far, I have not read an answer, but 'spiritual control' is at least one response (§ 5.2.3). Sceptical Evans quoted a query by Thomas Aquinas '*whether it is permissible to curse irrational creatures*' since '*no animal devoid of understanding can commit a fault*'.[59] Much depended on the viewpoint taken. Were these noxious creatures employed by God for the execution of His judgements or were they satellites of Satan proper, to be cursed?

Evans described a well-documented case from the French town of St. Julien, 1545, where insects ravaged some vineyards, possibly greenish weevils.[60] Having heard the prosecutor and the defendants, the Chair issued a Proclamation on May 8th with the preamble: '*Inasmuch as God, the supreme author of all that exists, has ordained that the earth should bring forth fruits and herbs, not solely for the sustenance of rational human beings, but likewise for the preservation and support of insects, which fly about on the surface of the soil, therefore it would be unbecoming to proceed with rashness and precipitance against the animals now actually accused and indicted; on the contrary, it would be more fitting for us to have recourse to the mercy of heaven and to implore pardon for our sins.*' He concluded that processions be held within a fortnight. The insects went away; they would have gone anyhow. Evans commented gloomily: '*It [= the law case] was the product of a social state, in which dense ignorance was governed by brute force, …*'.

Modern organic agriculture offers biological control as a solution. Let noxious organisms be killed by those organisms whose nature it is to parasitize, predate, and kill. The motive is environmental rather than religious-ethical. Pesticides are considered undesirable as they kill non-target organisms, pollute food and environment, and endanger the health of men and animals.[61] Buddhist farmers in Sri Lanka, 1986, told me that they welcomed the concept of Integrated Pest Management (IPM) in rice because it relieved them largely from the obligation to kill the vermin artificially.[62] Natural killers were acceptable because parasitizing or predating was their inherent nature. In China, 1987, a keen old Buddhist priest, who survived the Mao-terror as a handyman doing odd jobs in town, confirmed the point when I consulted with him.[63]

7.3.5 Good conduct

Moral considerations are rarely stated *expressis verbis* in agricultural writings. Hesiod, with a decidedly moralistic undertone, is the exception. Relevant comments used to be more down-to-earth. Pliny the Elder quoted Mago the Carthaginian [NH-18.7.35]. '*Mago's opinion that a landlord after buying a farm ought to sell his town house – that being the opening with which he begins the exposition of his instructions – was too rigorous, and not to the advantage of public affairs, though nevertheless it has the effect of showing that he laid stress on the need for constant oversight.*' Pliny added '*… on the farm the best fertilizer is the master's eye.*' [NH-18.8.43].

Ibn al-ʿAwwām too addressed the master: '*The Nabatean Agriculture also wants that the master of the property himself has the supervision to be sure of the diligence of the industrious workers, to reward them stimulating them even more, to know of the negligence of the less industrious ones and to replace these.*' [IA-1.498] The author recited the proverb: '*The field tells its master: Show me your shadow and till*' [IA-1.4]. Agustín implores the master of the house: '... *in the way that the eye of the master fattens the horse, so the diligence and the presence of the master fattens the field and makes it fertile; ...*' [AG-192].

Ibn al-ʿAwwām linked morale and temper to success in planting and harvesting. '*One should confide the planting of an olive tree, its tillage and its maintenance, only to a man of good morals, free of sin, and of a regular conduct ...*' [IA-1.224]. '*The [wheat] reapers should always be cheerful and in a good mood*' [IA-1.34]. Ibn al-ʿAwwām also listened to the common people with their traditional stories. One tells '*that it is very profitable to play the flute, to beat the drum, and to sing amidst the melon crops; the vegetation is richer, the fruit more tasty, and all nasty events are remote*' [IA-2.221]. The Fleta (c.1290) writes about the ox-drivers: '... *They should not be mournful men or wrathful, but cheerful, singing and joyous, so that by their tunes and songs the oxen may in some measure be heartened in their work.*'[64]

We find scattered notes such as '*The vine will be very productive if the person who prunes it wears a crown of ivy*' [GE-5.24.1]. A more comical note was struck, unintentionally, by Ibn al-ʿAwwām: '*.. the onion should be sown only when the stomach is empty and never when one has to satisfy a natural urge; one has to deal with it before even touching the onion seed; when pure one can sow the grains at will. But if one goes on tormented by one or the other of the two natural needs the onion will decay and doesn't profit*' [IA-2.190].

Let us remember that Columella's admonition is still true: '... *But any who combines painstaking care with scientific knowledge ...*' could easily obtain far more yield from his vineyard than a conservative person [CO-3.3.7].

7.4 Developments

7.4.1 The Greek heritage

The Greek heritage must have been impressive but, as stated before, most documents were lost. The classical Greeks are still revered as original thinkers, philosophers and theoreticians. Theophrastus gave us a glimpse of a theory on agriculture (Box 7.2). He accepted differences of opinion (§ 5.5.4, wounds). His advice not to rely on the calendar but to observe the plants and to act on the basis of need is noteworthy. This warning sounds very modern, at the end of the 20th century.

Box 7.2 Theophrastus – Agriculture: 'theories and disputes', c.300 BCE

'About each procedure [of agriculture] there is the account that gives its reason, and the reason must not escape us. For the man who carries out the procedure in ignorance of the reason, guided by habit and by the event, may perhaps succeed, but he does not know (just as in medicine), and complete possession of the art comes from both. As for those who have a greater love for understanding, this very thing, understanding, comes only when we have the account and the reason (G: λόγος καὶ αἰτία, logos kai aitia)' [CP-3.2.3].

'Many matters are in dispute; in some the dispute is a simple question of yes or no, in others it is a question of better or worse, just as in the other arts. But in agriculture something rather special also occurs: some experts have their view fixed on their own country and often state as a general rule what is successful there. Sometimes moreover both rules work and there is no deciding which is the better, since the outcome of the agricultural measures depends on accidents of weather' [CP-3.2.4].

'For one should not in fact be governed by the celestial conditions and revolution [i.e. the farmers' calendars] rather than by the trees and slips and seeds, since owing to good tempering contributed by these conditions and to their own power they often either resist mistaken measures or in some cases recuperate, just as a human constitution does with the mistakes of medicine. And so disputes in addition to those common to the other arts arise in agriculture for these reasons' [CP-3.2.5].[65] ■

7.4.2 The Roman heritage

The Romans developed large estates, enterprises comparable to modern 'industrial agriculture', based on slave labour, with good management and administration. They further developed irrigation and drainage systems, expanded knowledge on soil and tillage, tested new crops and varieties, and extended the reach of agriculture with dry-land farming. A technical innovation such as the 'Gaelic harvester', invented in the north eastern part of the empire, say between present Paris and Trier, was known but not used in Mediterranean agriculture.[66]

Roman farming attained a high degree of sophistication but went for moderation rather than for top yields [NH-18.38]. In his book on Roman agriculture White's (1970, p 454) final sentence reads: '*Roman farmers could, and did, increase their production by the use of improved methods, such as legume-rotations, or by the introduction of improved varieties of plants. But the development of economic rationalism, enabling them to increase their income by forward planning, as distinct from the prevailing empiric methods, lay far ahead in the future.*'[67]

Subsistence farming existed in Italy before, during, and after the Roman period.[68] In fact, there was a great deal of continuity temporally and socially. '… *we cannot and should not make a sharp division between Roman farm life and those agricultural practices existing in Italy before or after the Roman period*.' '… *it should be observed that in the Roman period the type of husbandry practiced on the large farm and the smallholding had much in common*'.[69] As to the poor peasants farming marginal land, tenants of smallholdings, tillers of garden plots, and seasonal labourers, Frayn stated '*It is substantially this group, however, the least well provided, whose continuance as a section of the rural population can be most clearly discerned during the later years of the Roman empire and the subsequent history of European agriculture*'.[70]

The large estates, the *latifundia*, appeared in the last centuries BCE, '*But in the basic operations undertaken from day to day by the farm-worker, the methods, and most of the tools, were those of the 'small man*'.[71] Some authors thought little of estate farming. Virgil repeated an adage of Cato: '*Give praise to large estates, farm a small one*' [VE-2.412], implying that it is more profitable to till a small farm well than a large one badly.

During the late imperial period neglect slipped in. Little pressure was felt to innovate because the *latifundia*, where funds for innovation would have been available, were sufficiently profitable. Neither absentee owners nor their staff, with many slaves and few free-men, had an interest in innovation. Unrest in peripheral and once profitable parts of the large Roman empire did not contribute to the zest to innovate.

In many respects the Byzantine empire was the successor of the Roman Empire. The Geoponika was written for an estate-owning elite interested in agriculture as its primary source of wealth. It seems improbable that the peasant community read the book, but we may imagine that many of its well-known recommendations were transferred by word of mouth, repeated over and over again when socializing at the fire place, adding another link to a long 'chain of knowledge'.[72] The Theophrastine tradition, complemented with near-eastern knowledge and superstition, possibly of Mesopotamian roots, spread all along the Mediterranean. '*Popular beliefs presented a notable degree of complicity among quite distant cultures*'.[73]

7.4.3 The Muslim heritage

Mediterranean agriculture changed drastically between the 8th and 13th century CE with an increase in knowledge, improvement of cultivation methods, and introduction of new crops from Africa and Asia by Muslim agriculturalists. A wave of globalisation went through that part of the world recently conquered by Islamic forces. Commercial networks were established, spanning an area from the Atlantic to the Pacific, and maintained by regimes imposing a period of relative peace, the *pax islamica*.

Developments peaked in Andalusia, southern Spain. Agriculture became market oriented, producing two, and sometimes even more, crops per year. This was made possible by new crops, among which rice and cotton, adapted varieties, irrigation, improved crop husbandry, a keen interest in soils, and better insight into the effects of various types of manure. Classical Roman irrigation systems were complemented by Persian hydraulic technology. Processing of agricultural produce was industrialised. Commercialisation led to an ample supply of old and new plant products. Better nutrition improved human health and contributed to an economic upturn.

Contributing elements were: (1) Good governance. (2) Sophisticated irrigation systems with noria (a kind of water wheel), hydraulic mill, wind mill, and hydraulic press, allowing double cropping, a rain-fed crop and an irrigated crop. (3) Scientific description of agricultural methodologies from all over the known world. (4) Proprietary rights on land and workers' rights on part of the produce were recognised in principle. (5) Subsistence agriculture was transformed into market agriculture.

Conditions for these developments were peace and free trade, a city population with purchasing power, and a relatively independent and innovative rural population, supported by the development of science and technology. Rulers hired the services of scientists to establish botanical gardens, for pleasure and for experimentation. The affluent had their country houses and estates. '*As we know, the (people of Spain) of all civilized people, are the ones most devoted to agriculture. It rarely happens among them that a man in authority or an ordinary person has no tract of land or field, or does not do some farming*' wrote Ibn Khaldūn [IK-2.279]. Such was the situation in southern Spain for some two centuries.[74] Around 1300 the political system in Muslim Spain was past its peak.

Ibn Khaldūn had a low opinion of North African agriculture, once so productive. Around 1360 he wrote: '*Agriculture is a way of making a living for weak people and Bedouins in search of subsistence*' [IK-2.335]. '*This is because agriculture is a natural and simple procedure*' [IK-2.335]. About estates: '*… estates and farms to provide for the education of the orphans of the land-owners. Children weak of body or mind were sent to the estate*'.[75]

7.4.4 Evolution or revolution?

If we characterize a 'Green Revolution' as a sudden and rapid development in agriculture due to the introduction of new crops and varieties and new technology,[76] we witness a 'Muslim Green Revolution' in Andalusia and some other areas of the western Mediterranean basin (Watson (1974, 1983). In the area of crop protection the assortment of herbal methods was extended, tillage methods and crop rotations were refined, and – in rare cases – even irrigation was exploited in crop protection. The herbal knowledge from east and west was combined, and some nonsensical ideas were filtered out.

Decker (2009) argued that some major crops, possibly new to Spain, were certainly not new to the Mediterranean area. He clearly refuted the 'new crops' argument and – in passing - partly invalidated the 'irrigation' argument.[77] Butzer *et al.* (1985) agreed that Muslim agriculture had a solid base in Roman agriculture, with incremental intensification but no revolution. Thus, the choice between revolution and evolution becomes irrelevant, a matter of taste rather than of principle. In view of 'socio-economic' arguments, such as political stability, government incentives, switch to market economy, (semi-)industrial processing, I still prefer to think of a Muslim Green Revolution, at least in Andalusia.

The 15th century conquest of Muslim Spain by the Christians from northern Spain under the guidance of the royal couple Ferdinand and Isabella, the '*Reyes catolicos*', called '*reconquista*' was completed in 1492, destroying the complex and vulnerable Muslim production system of Andalusia. The Muslim Green Revolution was largely undone. De Herrera, arriving in Granada in the year 1492, came just in time to pick some flowers of Muslim wisdom.

7.4.5 The North-West European development

The fall of the Roman Empire was followed by turbulent times but life in north west Europe, north of the Pyrenees and Alps, gradually stabilized. Europe's economic 'centre of gravity' shifted from the Mediterranean area to the North, beyond Pyrenees and Alps (White, 1962). The 13th century was a period of rapid population growth. The 14th century was a tormented era accentuated by the Black Death of 1346/50, that killed about one third of the population.[78] One effect was the scarcity of labour that necessitated innovation in agriculture. New methods of tillage, new rotation schemes, and new social relationships were developed. The transition was gradual with different speeds at different locations.

In western Europe an important development occurred due to two inventions, the horse's harness and the heavy mouldboard plough. Thanks to the harness, ploughing with horses became more efficient than with oxen. Due to the mouldboard plough cross-ploughing was no longer necessary. Fields gradually changed in shape, from squarish to longish. A three-course system replaced the older two-course system. Rye became the major cereal on the relatively poor soils. Food production became more efficient. 'Crescentio' became the common textbook.

The plough with the curved mouldboard, turning the soil beam upside down, will have considerably improved weed control. Weeds were turned into green manure. Stubble could be ploughed under and, if infected by pathogens, these were buried. Other information on innovation in crop protection was not found except, maybe, the method to prevent thistles from flowering and setting seed (§ 4.5.1).

7.5 Change and continuity

7.5.1 Change

An important change was the gradual elimination of fantastical and magical recommendations. Ibn al-ʿAwwām dutifully recorded much fantastication but at the same time he tried to distance himself from it. Crescentio and Ibn Luyūn, a good century later, were free from any superstition whatever. Thus progress was made, but some regress also occurred as in 'The book of the Prior'.

In north western Europe the slow replacement of the ox-drawn scratch plough by the horse-drawn mouldboard plough was a major change, that made the heavy soils productive in the Atlantic climate zone with its summer rains, a situation radically different from that in the Mediterranean area. The summer wetness and the three-course system will have affected the year-to-year transmission of soil-borne and stubble-associated pests and diseases, but no particulars are available. Weed control was certainly affected as evidenced by north western European problems with the highly invasive creeping thistle.[79]

Much of the herbal lore and knowledge in crop protection was gradually forgotten, as it was in medicine, either by ignorance or because crop protection problems in north western Europe, with its temperate Atlantic climate, differed from those experienced in the Mediterranean climate zone. Progress in crop protection was slow. Bolens gave a numerical example.[80] Practical Palladius provided 59 recipes for crop protection, 26 of which she traced down in Andalusian writings. A modern man like Olivier de Serres rejected many of the classical recipes.

7.5.2 Continuity

The historical continuity in good ideas as well as in misconceptions is impressive. One such misconception is about the 'the lion and the cock' (Box 5.2). Another item is the transmutation of wheat into darnel, a misconception alive during two millennia at least, from Theophrastus (c.300 BCE) to Agustín (1762 edition).[81] A trivial example of continuity, just one out of several, is the recommendation to protect cruciferous vegetables by sowing vetch as a companion plant (§ 5.3.5). The recommendation to treat the seed with sap of house-leek is equally persistent and the 'house-leek' riddle (§ 5.7) bewitched the authors from Theophrastus to Agustín. Such ideas, right or wrong, were remarkably tenacious.

Fortunately, sensible ideas were also repeated constantly, such as the recommendation to use manure that had ripened for one year [AG-170]. All authors rightly stressed the importance of good tillage, to maintain soil fertility and to control weeds. De Serres rendered his own experience in the form of rhymed folk wisdom [OS-2.7.124]:

Le labourer & l'espargner,
Est ce que rempli le grenier.
'Ploughing and saving is what fills the grain store'.

Another example of continuity is the companion cultivation of vegetables with some vetch to avoid damage by flea beetles (§ 5.3.5). The line of descent contains Theophrastus, Pliny, Palladius, Geoponica, Ibn al-ʿAwwām, and Agustín.

As a final illustration of continuity I mention the threshing floor (Boxes 7.3 and 3.8). Over 2500 years the threshing floor was considered of utmost importance. Among the reasons were safety of the harvested crop, efficiency in threshing, and cleanliness of the threshed product. That view came to an end with the introduction of mechanical threshers and combine harvesters.

Box 7.3 Continuity – the threshing floor

Hesiod: '*Urge your slaves to winnow Demeter's holy grain when Orion's strength first shows itself [about 20 June], in a well-aired place and on a well-rolled threshing floor*' [HE-597/599].

Cato is more explicit. '*To make a threshing floor: Turn the soil for the floor and pour* amurca *over it thickly, letting it soak in. Then break up the clods carefully, level the ground, and pack it with rammers; then cover again with* amurca *and let it dry. If you build in this way the ants will not injure it, and weeds will not grow*'. [CA-91] He continues: '*To make a floor for threshing grain: Break the ground fine, soak thoroughly with* amurca *and let it absorb as much as possible; then pulverize the dirt and level with a roller or a rammer. When it is levelled the ants will not be troublesome, and there will be no mud when it rains*'[CA-129].

Columella provides similar detail, warning about ants and mice, but he describes also how meadowland can be readied for threshing [CO-2.19.1].

Ibn al-ʿAwwām repeats all the instructions on preparing the threshing floor, exaggerating somewhat on two points. The fragments of chaff and straw blown forth he calls 'deadly poison' for all useful plants; the threshing floor should be far from the graveyards [IA-2.323]. — Why that?

Crescentio keeps it simple: '*In the month of June the threshing floor should be readied and cleaned from straw, manure and dust to the utmost.*' [CR-12.6]

Ibn Luyūn: '*The essence of threshing floors is their location in high and level places, avoiding shadowy sites, allowing the wind to blow without hindrance. One should take into account that the dust from the threshing place is injurious to the cucumber plots and that they [the threshing floors] should be situated far from whatever type of [cultivated] plants. The access of ants is hampered by strewing gypsum and ashes around them*' [IL-116].

De Herrera repeats most points and adds a few new ones [DH-1.10.29]. The various threshing grounds should not be far from each other so that mutual assistance is possible when fire breaks out or undesirable animals appear. The threshing floor should be placed on a large stone to facilitate the threshing and to avoid moles, mice, and ants. The kernel yield will be higher, the grain will be cleaner, without small stones and other pollutants. The cleaner the wheat, the better its keeping quality.

Agustín repeats most of these detailed instructions for constructing and maintaining the threshing floor [AG-175]. ■

Chapter 8

Once upon a time - organic agriculture

This chapter aims at real life of real people in medieval times and before. How real were, in pre-modern times, the abiotic mishaps, the pest outbreaks, and their control? What about the frequency, intensity, and extent of outbreaks? An attempt at reality assessment is preceded by some theoretical considerations. Risk reduction, then considered of paramount significance, was mainly by preventive measures applied to field and store. Very little is known about pesticide application in real life, the use of botanicals especially. What was the effectiveness of the methods applied? Is a comparison of medieval agriculture and crop protection with their modern organic counterparts sensible? Around 1600 modernity sets in.

Since the Earth is the common mother and nurse of the human race, and every Human being wants to be able to live there at ease: Likewise, it seems that Nature has placed in us an inclination to honour and value Agriculture, because she lavishly brings us abundance of all that we need for our nutrition and maintenance.

Preface in Olivier de Serres (1608): Le Theatre d'Agricvltvre & Mesnage des Champs.

8.1 'All that we need'

Olivier de Serres wrote optimistically: agriculture brings us an abundance of 'all that we need'. Really? What happened in real life? In medieval reality, abundance happened to be scarce as comes forward from the chronicles of the period. From primary sources Buisman collated a wealth of data on weather and a lot of information on harvests.[1] The result is an endless litany of misfortunes. Old chronicles seldom described the normal situation since, if the situation was normal, the medieval chronicler had nothing special to communicate.

In this chapter, medieval agriculture and crop protection will be compared with their recent counterparts by placing them in a modern theoretical framework. I will try to sketch the realities of injury, damage, and loss.[2] What were their frequency, intensity, and extent? Discussing the reality value of pest control I tread on slippery ground. Much information may lie hidden in local chronicles and estate account books, letters and personal diaries, but at this moment in time the information on the practice of crop protection, on what farmers really did, is scanty at best.

8.2 Crop protection at a distance

8.2.1 The pest tetrahedron

Crop protection, seen from a distance, is the struggle of man to manipulate the agro-ecosystem in favour of his crop. A metaphor for the interactions ruling crop protection is the 'pest tetrahedron' (Fig. 8.1). The bottom is formed by the 'pest triangle' which symbolizes the mutual interactions of host, pathogen, and environment.[3] The manifold mutual interactions within the pest triangle have been sufficiently illustrated in the preceding chapters. Here, the position of 'man' is of interest. The original tetrahedron was published in 1979. The design is characteristic for the optimism of the last quarter of the 20th century, an outcrop of the positivist tradition of the 19th century: man on top of everything. It represents man as the great maker, able to solve any problem. In retrospect the figure is emblematic for the 'makeable society', the idea of 'engineering the society', an idea which, in a way, led to the disaster denounced in Rachel Carson's 'Silent Spring'. A medieval thinker would never have placed man on top in this way, considering it totally unacceptable hubris.

The pest tetrahedron has another implication: man as the source of problems, also in crop protection. A few modern examples follow (1) Extensive monocultures offer easy food for pests with high motility. (2) Rotations of profitable crops become so short that soil-borne pests can feast on the crop. (3) Chemical treatment becomes so intensive that beneficials are eliminated and secondary pests emerge. (4) International trade creates new problems by shipping pests from one continent to the other. Modern man has indeed created tremendous problems. At the same time he has solved many old problems for example by building dikes to control floods and irrigation works to mitigate the effect of droughts. To what degree medieval man was a source of problems in crop protection has yet to be determined.

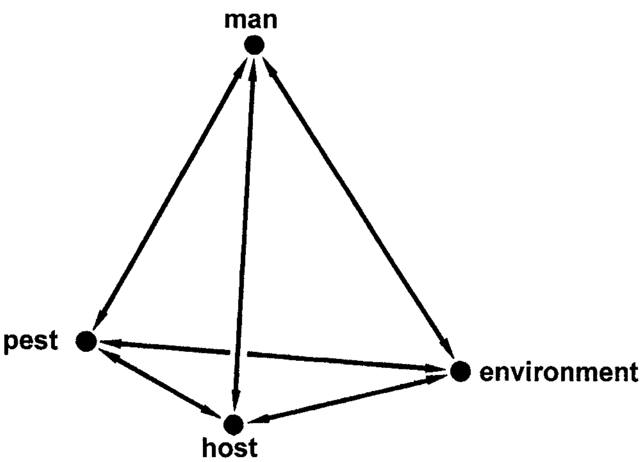

Figure 8.1. The 'pest tetrahedron'. The base represents the 'pest triangle'. All three elements are affected by man. Modified after Zadoks & Schein (1979) p 5.

8.2.2 Matters of scale[4]

The pest tetrahedron is a concept independent of scale in time and space. Two examples must suffice. (1) The abiotic environment stands for the macro-, meso-, and micro-climates. 'Weather' determines crop and pest development and therewith human welfare and wellbeing. Variation may be considered over hours, days, years, or centuries. (2) The local climate largely selects the dominant pest species: indirectly by determining the crops to be grown, and directly because different pest organisms have different environmental requirements. Most interactions are local, but the interactions of migratory pests are stretched out in time and space. A few years of drought along the Black Sea sufficed to create locust swarms that ultimately drowned in the Atlantic Sea, well over 2000 km west (§ 4.4.1).

'Man' may stand for the farmer or his farm hand, the Secretary of Agriculture or his administrator, the pesticides manufacturer or his local salesman. In this way, the term 'man' is scale-independent too. Today, as in former times, agriculture is not only a private but also a state affair. The great difference is today's state regulation which is very intensive in the area of crop protection, with its quarantine laws, pesticides regulations, rules on genetic modification, and food quality control. None of this existed in the Middle Ages, but food security was not only a matter of public concern but also every single peasant's worry. Modern concerns on food safety or nutritional security have no parallel in the books consulted so far.[5]

8.2.3 Man and his interactions

Environment-man interactions. Climate and soil determine where and what man can grow. Production and storage of food are deeply affected by the environment. From the viewpoint of crop protection, cattle raising is part of the environment. In modern industrialised agriculture cattle and crops are far more separate than in pre-modern times. My favourite interaction between cattle and crops is exemplified by a demesne in medieval northern France. Weeds, among which the highly dispersive thistle, were a nuisance to crops and people. Weeds were grazed, and thus controlled, by sheep. The droppings of the sheep fertilized the land so that a better crop could grow, damaged again by weeds. The major external inputs to this particular agro-ecosystem were solar and human energy, and the major outputs were grain and ovine products such as milk, mutton, and wool (§ 5.3.4).

Host-man interactions. Man makes a choice from the crop portfolio and thus, unconsciously, he makes his own pick from the pest portfolio. All the portfolio's pest species have ancestors that lived in nature, untouched by man, doing little harm. Bringing genetically similar plants together in groves and fields, man offered pest organisms a great opportunity to multiply and disperse, with crop loss as the unwanted consequence.

Today, genetic uniformity of crops is far more advanced than in medieval times. Production efficiency and trade rules dictate uniformity of the produce. Thus, a crop should be grown in large groves and fields, far greater in size than ever before. For the time being, modern organic farming often escapes this dictate. Unfortunately, I found very little about genetic uniformity and the heterogeneity in pre-modern times, certainly in relation to crop protection. Mixed cropping was common but the literature examined so far is not explicit on its crop protection effects (§ 5.3.5).

Pest-man interactions form the body of this book. Direct interaction takes place where pests challenge man to take action in order to avoid or reduce damage. Direct interaction usually operates on short time and distance scales. Indirect interaction, such as the experience or even fear of frequent losses, reduces man's food base in the long run. In reaction, man may change his behaviour, in the worst case even his domicile.[6] Such an indirect interaction may have long term effects, and sometimes also long distance effects.

Epidemics are certainly not scale-independent. The larger the size of the fields, the greater the aggregation of the fields and the uniformity of the crops, and the higher their plant density, the more the crops become epidemic-prone. This is the 'crowding effect' of the host which in the past was far less intense than it is today. In the old days, furthermore, the proportion of crop land relative to non-cropped land was far lower than today, thus providing an element of epidemiological security.

The direction of the arrows. The modern idea of a socially engineered society, where everything is 'doable', applying sophisticated technology, leads to arrows pointing down from man to the pest triangle: man as the master of the agro-ecosystem. This is largely true in modern industrial agriculture, some climatic mishaps excepted. In medieval times the arrows should rather point upward. Man had to undergo the circumstances he could not master, and to suffer the consequences. A serious mishap was considered an 'Act of God'. Here we touch upon an essential difference between modern and pre-modern agriculture.

8.3 Theoretical considerations

8.3.1 A 'theory of yield'

In 1979, a 'theory of yield' was proposed with four non-quantified yield levels named primitive, actual, attainable and theoretical yield, respectively.[7] The 'primitive yield' was defined as the yield obtained with practically no inputs, as often encountered in developing countries. The 'theoretical yield' was the calculated maximum yield with all imaginable inputs and the most favourable environmental conditions. The 'actual yield' was what the farmer actually harvested, whereas the 'attainable yield' could be obtained under the given environmental conditions with the best available technology, including crop protection. To illustrate the theory in concrete terms approximate wheat yields in western Europe are indicated here. Primitive wheat yields were of the order of 0.6 to 1 tonne.ha^{-1} dry matter (Fig. 8.2).

Theoretical wheat yields are of the order of 10 to 20 tonnes.ha^{-1} dry matter. Actual and attainable yields are in between, say 6 and 10 tonnes.ha^{-1}.

Figure 8.2. Wheat in Bhutan with an open stand, a recent example of a crop with a 'primitive yield'.

The theory received new input in 1982 by the distinction between 'production situations'.[8] Here we use the revised terminology of 1989.[9] The best production situation is the one without limiting factors. The next lower production situation experiences water limitations. The third production situation has water and nitrogen limitations, whereas the fourth is also limited in phosphorus. Production situation 1 produces the attainable yield and, ultimately, the theoretical yield. Production situation 4 corresponds roughly to 'primitive yield'.

The 'theory of yield', seen as a unifying concept, was enriched by the introduction of new terminology.[10] 'Yield determining factors' include incoming radiation, water, nitrogen, and phosphorus. 'Yield limiting factors' are any of the foregoing if limiting. 'Yield reducing factors' are those factors of abiotic and biotic nature that reduce the expected yield. Crop protection is about the control of yield reducing factors.[11]

In two respects the theory is deficient. First, the most important input, healthy seed of an appropriate crop genotype, fully adapted to the environment chosen, the inputs available, and the produce wanted, is overlooked.[12] Commercial varieties, developed for conventional farming, are not always adapted to the requirements of organic farming.[13] Second, the theory of yield usually expresses the desired output as kg.ha^{-1} dry matter but neither product quality nor by-products are considered.

8.3.2 A 'theory of loss'

The 'theory of yield' is complemented by a 'theory of loss'. Loss assessment methodology was systematically developed in the United Kingdom.[14] A typology of losses was proposed in 1976.[15] The yield gap between attainable and actual yield was called 'avoidable loss', that is loss avoidable by means of available crop protection methods. Conceptual and physiological views on crop loss were published and the methodology of crop loss assessment was further developed.[16] Thus, a more or less abstract theory, without mention of specific crops and specific causes of loss, came into being.

Generally speaking, medieval agriculture had quite limited external inputs, production situations 4 and 3. Pests, and the losses they cause, are closely linked to production situations, as evidenced by the existence of 'poor man's' and 'rich man's' pests (§ 7.4.1).[17] One example is the response of wheat pests to modern high input crop management, especially high nitrogen input. Rusts, mildew, and aphids increase due to a twofold mechanism, (1) a higher nitrogen content of the leaves, and (2) a more favourable microclimate due to the denser canopy.[18]

The contrast of poor versus rich does not imply that the two extreme production situations, 1 and 4, produce very different pests and diseases but rather cause a shift of emphasis. On the poor man's side the typically biotrophic diseases, such as rusts and mildews, may have been less important in the past whereas the perthotrophic diseases may have been more prominent.[19] Locusts may have liked the medieval N-poor crops better than modern N-rich crops, whereas aphids, feasting on modern high-N grain crops, would be disgusted by medieval low-N crops. Aphid plagues in cereals are a fairly recent development, related to nitrogen top dressing. This physiological explanation of the recent aphid plagues is complemented by an ecological explanation. The modern reduction in the frequency of hedges, bushes, and waste lands drastically reduced survival opportunities of natural enemies including predatory insects.[20]

Apart from yield level we need to consider yield stability, the key issue in subsistence agriculture, then and now. In High External Input Agriculture the inputs not only serve to maximise yield but also to stabilise yield at a high level. Yield instability can be measured as the coefficient of variation of yield over a set of years. Yield on modern organic farms seems to be somewhat less stable than on conventional farms, at least for the time being.[21] The high content of organic matter in the soil, sought for in organic farming, will certainly contribute to yield stability in the long run. In medieval farming yield stability was low.

8.3.3 Pre-modern farming reconstructed?

Aficionados have attempted to emulate pre-modern farms and farming.[22] These attempts have answered several technical questions of the type 'how to'. But is it possible to reconstruct a medieval soil? Old varieties or land races may be used, but such genotypes which are one or at best two centuries old can hardly stand model for genotypes one or two millennia old. The reconstructed pre-modern farms are inevitably placed in a modern agricultural environment, so that the reconstruction does not apply to the influx and outflow of harmful and beneficial agents (landscape buffering).[23] I fear that, with respect to crop protection issues, little can be learned from modern attempts to reconstruct ancient farming systems.

8.3.4 Old and modern organic agriculture – a comparison

It is tempting to compare modern organic agriculture not only with modern conventional farming but also with pre-modern organic agriculture. The differences between modern and medieval organic agriculture are considerable since western organic agriculture has been tremendously successful. In the best cases the yields of modern organic and conventional farming systems are nearly equal.[24] Where organic farms have low yields the major culprit is nitrogen deficiency, the next one being phosphorus deficiency. Both deficiencies can be remedied within the framework of organic farming so that further improvement is to be expected.

Yields. In medieval crops, organic by necessity, the yield determining factors were deficient, sometimes even increasingly deficient as expressed by the term 'mining the soil' (§ 3.5.2). Most of these medieval crops yielded little more than a 'primitive yield', production situation 4, or 3 at best. Pests and diseases must have responded but the details remain unknown. Modern organic farms are in production situation 1 or 2, with yields incomparably higher than those of medieval farms. Therefore, a backward projection of modern organic agriculture onto medieval agriculture is not warranted, certainly not with regard to crop protection.

Thumbing through the records one impression is inescapable: the abiotic factors seem to outweigh the biotic factors by far. A reservation has to be made here: the chroniclers could not record things they did not know about, such as plant pathogens. Whereas biotic factors, pests, may have been the proximate causes of yield reduction the abiotic factors were often the ultimate causes. The abiotic factors seriously reduced yield stability.

Medieval farming lacked many stabilising inputs, and this posed serious problems. Buying food when yields were deficient was nearly as difficult as selling produce when it was abundant because the market system did not function well, mainly due to the awkward overland transportation facilities.[25]

By-products have already been mentioned. Modern commercial farming aims at a single use product. In cereals only the grain is valued, the straw is more of a nuisance. In medieval farming multiple-use crops were appreciated. In cereals, for example, grain was the primary product, but straw and chaff were valuable commodities with several applications including bedding, litter, manure, feed, fuel, and temper in mud bricks or walls.[26]

Crop protection. Whereas conventional farms have unintentionally but drastically reduced the array of beneficials by using synthetic pesticides, many organic farms have been able to (partly) restore that array over the years, thus profiting from available ecosystem services.[27] Unfortunately, the modern non-agricultural environment of crops is much smaller than in medieval times. I see no way to compare the interchange of beneficial and harmful agents between crop and non-crop areas in former and modern times.

Nowadays, biological control agents are produced for sale by the bio-industry.[28] Large areas can be treated, whereas medieval crop protection was a small scale operation. Some crop protection materials legally acceptable in modern organic agriculture have undesirable side effects, including sulphur and copper preparations, and even such a seemingly neutral substance as suspended kaolin clay (§ 6.2). The ashes of medieval agriculture, being far from neutral, probably destroyed most of the local beneficials. The natural products and botanicals recommended in pre-modern times, being broad-spectrum pesticides (Chapter 6), supposedly had the same deleterious effects on beneficials as their modern synthetic counterparts. Here, medieval and modern organic crop protection show some uncanny similarities.

The essential difference in organic farming between 'now' and 'then' is the production situation. The second difference is the extent of agricultural operations as expressed in the proportion of crop land to non-crop land. Most of the other differences are derived from these two major ones. The conclusion seems inescapable: a comparison of medieval agriculture and modern, western organic agriculture is not sensible. This conclusion applies *a fortiori* to the comparison of organic crop protection then and now.[29]

Habitat fragmentation. Modern ecologists complain about habitat fragmentation of natural flora and fauna, detrimental to the maintenance of biodiversity, by human activity including agriculture. A mental U-turn is needed to envisage the medieval situation, at least for large parts of western Europe. Habitat fragmentation of agro-ecosystems, detrimental to the spread of crop pests, was the rule as human settlements were scattered in a still relatively undisturbed natural environment. The landscape-epidemiological consequences of this inverted relation between agriculture and nature cannot yet be fathomed.[30]

8.4 Real-life experiences

8.4.1 Reality of abiotic hazards

Sudden floods and extended droughts, killing frosts and sweltering heat, torrential rains and hail storms with stones as large as pigeon eggs, once even goose eggs, followed each other in motley succession. The major difference with today is that medieval agriculture had but little technology available. A few examples suffice. Some degree of water management existed but, certainly in north western Europe, irrigation and drainage systems were not yet well developed. Farm mechanisation was non-existent so that soils were either too wet or too dry and could not be tilled. If the land was defended against floods by dikes these dikes were weak and easily broken. Sometimes, the top soil was washed away by heavy rains. The question arises as to the frequency, intensity, and extent of crop losses due to abiotic hazards.

Frequency. Mishaps due to abiotic causes were certainly quite frequent though no figures can be quoted. The consequences depended on their intensity and extent. The chronicles and their summaries abound with losses due to abiotic causes.

Usually they record the negative deviations from 'normal' without, however, specifying the norm. Obviously, crop loss was frequent and variability of yield was high, much higher than today.[31]

Intensity. Many of the misfortunes in the records were fatal, that is they caused total crop loss or nearly so. Fatal describes a loss so large that not enough seed is left for the next season. Intermediate intensity with partial losses appears from the records in terms of poor harvest (grain, grapes) or poor quality of the product (wine).

Extent. The extent of abiotic damages varied greatly as the following examples, somewhat haphazardly chosen, show. Near Louvain (Belgium), a hailstorm destroyed all rye and other standing grain crop in the year 1310. Between the mid-afternoon prayer (L: *none*) and vespers, that is between 3 and 6 in the afternoon, big hailstones poured down over an area of one by three miles, wrote the chronicler in verse, with amazing precision.[32] In contrast with this local event is the night frost of 25 and 26 April, 1422, that killed all the very promising grapevines of 'France', that is to say a regional event affecting the northern part of present day France.[33]

If the extent was local, a farming community could survive, supported by mutual assistance and charity. If the extent of the mishap exceeded the local level, scarcity or even famine were the fate of the victimized communities.

Connectivity is a modern technical concept, also applied to crop protection issues. 'Structural connectivity' of a landscape refers to the abundance and configuration of habitats in that landscape. Here, pest habitats are the fields of a particular crop susceptible to a given pest. If fields are highly scattered within patches and patches are far from each other, pests will have difficulty in spreading from patch to patch and from field to field. This difficulty is called landscape resistance. Landscape characteristics do matter, even in modern times.[34] In former times the connectivity of the European agricultural landscape was low or, in other words, landscape resistance to the spread of pests was high, relative to the situation of today.

'Functional connectivity' is the ability of organisms to access suitable habitats. The migratory locust happened to be a pest with very high functional connectivity. This functional connectivity did not change over time.

So far we have discussed spatial connectivity but there is also temporal connectivity. Temporal connectivity depends on location and weather. Soil-borne pests show a high functional connectivity since it is not easy to get rid of them once they are established in habitats that suit them. The structural aspect of temporal connectivity comes to the fore in a sequence of bad years, years favourable to a particular pest, the knock-on effect of mishaps with carry-over of losses.

Carry-over of losses. The unusual sequence of rainy years, from 1315 to 1321, which affected most of north western Europe was very serious. In the Atlantic climate continuous rains during the summer do sometimes occur. They may cause lodging of the grain crops, moulding and rotting of foliage (think of *Fusarium-* and *Septoria*-like fungi) and heads, and sprouting in the ear. The lodging and moulding reduce grain filling, so that the yield is low, and the sprouting reduces the quality of the produce including the seed to be used for the next season. This seed will be infected by various pathogens as for example *Fusarium*-type fungi. Thus, the loss in one season sows the seed – literally - of the loss in the next season, the carry-over or knock-on effect (§ 3.5.1).

If the rains continue and tillage is next to impossible, the seed bed will not be crumbly and well aerated but compacted and water-saturated. Inevitable late sowing on an inhospitable seed bed will make the next crop, already weak because of the poor seed, susceptible to winter frost. When the crop freezes out, recourse has to be taken to spring-sown crops, if seed is available. If not frozen, the crop may yield modestly only, unless boosted by a very nice spring and summer. Another wet season will cause the carry-over of inoculum of fungal pathogens from the second crop to the third. Such a concatenation of mishaps contributed to the sequence of crop failures in the years 1315-1321.[35] This event of (sub-)continental extent caused a serious and prolonged famine aptly described as 'The Great Famine' (Jordan, 1996).

8.4.2 Reality of pest outbreaks in pre-modern times

A reality check of events distant in time is difficult because of the paucity of records.

An outbreak may be considered to be 'real' when mentioned by two or more independent sources. One example is an outbreak of rodents, rats and mice according to the sources, but voles I surmise, on the clay soils of the Netherlands during the dry summer of 1596. The records come from the province of Friesland and the towns of Hoorn and Amersfoort, some 60 to 100 km apart.[36] In places, the damage to the grain crops in the field and in storage must have been great, but the intensity and extent of the plague cannot be assessed with any accuracy.

Little doubt exists about the reality of plant pests in pre-modern times but we are ill informed about the intensity, extent, and frequency of pest outbreaks. Biblical texts suggest that outbreaks were so infrequent that the priests could interpret them as the wrath of God toward the disobedient flock, a view expressed up to recent times. However, outbreaks were sufficiently frequent to create rituals for averting them, as exemplified by the payment of tithes in Biblical times,[37] the Robigalia in Roman times,[38] and the legal cases brought against animals in the Middle Ages (§ 5.2.3).[39]

Frequency. Livy (59 BCE – 17CE), describing the history of Rome, mentioned locust outbreaks repeatedly. Most probably this was the desert locust devastating crops on either side of the Mediterranean. The infestation could be so severe that the locals had to be mobilised, under state supervision, to fight the plague. Between the years 803 and 1694 some twenty Germany-wide locust plagues are on record.[40] Medieval records of cases brought against animals give an impression (Table 8.1) of real problems. It was not a light-hearted decision to initiate a legal case before an

Box 8.1 Two examples of locust outbreaks in Roman times

173 BCE. '*Such great clouds of locusts from the sea suddenly appeared over Apulia that they covered the fields far and wide with their swarms. To destroy this pest, so fatal to crops, Gnaeus Sicinius, praetor-elect, was invested with the* imperium *and sent to Apulia, and assembling a vast crowd of men to collect the locusts, spent a certain amount of time in this way*'.[41] — A top official was sent down to Apulia, the 'heel of Italy', to be in command of the eradication campaign, using the bare hands of a crowd of men as the eradication tool. We may think of the desert locust having crossed the Mediterranean, or – possibly – the Moroccan grasshopper.

125 BCE. '*At Arpi there was a rain of stones for three days …locusts appeared in a great swarm in Africa; when hurled into the sea by the wind and cast up by the waves, they produced by their unbearable stench and deadly effluvium a serious plague among livestock at Cyrene, and eight hundred thousand persons are reported to have been carried off by the putrefaction*'.[42] Happily, the wind drove the swarm to the sea where it perished. — Livy rendered the miasmatic theory of disease causation. I presume, however, that disease among both cattle and people were a consequence of hunger stress following the devastation of the crops by the locusts. Again, we may think of the desert locust. ■

ecclesiastical court in response to an emergency. More information from medieval times may lie hidden in local and regional chronicles, in leasehold deeds, and in the account books of convents and estates.

Intensity. The intensity of the outbreaks cannot be expressed in numbers. Some outbreaks must have been very severe, such as the locust plagues described by Livy (Box 8.1) and the rabbit infestation on the Balearic Islands (§ 4.2.4). Locust swarms often caused total loss of crops. Two 19th century examples from the Netherlands give a glimpse of the hopeless fight against uncontrollable insect pests (Box 8.2).

Weed problems must have been serious at times. De Herrera states that the farmer who has no time to remove all weeds should at least eliminate those weeds that take up much room, thistle, mallow, and chicory.[43] The promotion of thistle cutting to one of the twelve major agricultural operations, depicted in medieval art, is convincing evidence for the everyday reality of the thistle problem in the Middle Ages (§ 4.5.1).[44] One person complained in 1527 that near to the city of Cahors (SW France) the fields were '*spoiled by weeds*' with '*more wild oats than wheat*'.[45]

Box 8.2 Two examples of pest outbreaks in the 19th century

Cockchafers in the Netherlands, 1808 and 1809 (Wttewaall, 1864, p 92). The cockchafer, then called *Melolontha vulgaris*, is slow to multiply and under most conditions its natural enemies, mainly birds, keep it reasonably in check. But not always! In the province of Gelderland (NL), between Arnhem and Zutphen, a stretch of six hours on foot, their numbers were so large that the high beech trees and the lower oak coppice were defoliated. On Government Orders beetles were collected and killed, in 1808 about 100 million beetles. In the next year, when 250 million beetles had been caught, the available budget was exhausted and the campaign had to be stopped half-way. The method of collecting the beetles was not mentioned, probably hand reaping.

Caterpillars of the gamma moth, 1829 (Van Hall, 1929). The province of Groningen (NL) experienced a large outbreak of caterpillars of the gamma moth. Their appetite was fabulous. A field of spring sown colza (rapeseed) measuring some 14 ha was destroyed 'in the twinkling of an eye'. A farmer watched his field of colza being devoured between Wednesday and Saturday, only naked stalks left. The 'picking order' was colza, faba beans, peas, flax, clover, and even some potato foliage. Cereals remained untouched but the grain fields became well weeded. The vegetables were gone, a few spice plants excepted. Large swarms of caterpillars moved from field to field, ►

Extent. One may safely assume that many outbreaks on record were local or at best regional, as were - supposedly - the outbreaks in Table 8.1. Large-scale outbreaks might be expected from rusts (not on record) and locusts. In 1542 (or 1543?) locust swarms came supposedly from the Black Sea area and ravaged Hungary and Upper Germany.[46]

The available information suggests that pest outbreaks in pre-modern times must have been frequent, often localized (scale 10 km), more rarely regional (scale 100 km), and very rarely continental (scale 1000 km), due to a variety of organisms, occurring rather haphazardly in many places of Europe. The locust plagues of 873 and of 1542 were continental, though not all parts of Europe were affected.

8.4.3 Reality of pest control in pre-modern times

The books consulted contain paragraphs or chapters on crop protection but most recommendations are scattered throughout, as comments added to the discussion of individual crops (Box 5.1). Several plant protection problems were singled out by pre-modern authors since they could be handled, at least in principle (Box 8.3). These treatments were always labour-intensive but the cost of labour was crossing water-filled ditches and climbing hedges. The noise of thousands of gnawing animals could be heard. In some villages the soil was so studded with caterpillars that they could be collected by the handful. Caterpillars of the small cabbage white, a day butterfly, added to the destruction.

Control methods using soap water, tobacco water, chalk, ashes, rope drawing, and fumigation with gun powder or sulphur were of no avail. One farmer tried to protect a field of three ha with four labourers working continuously. Long trays were placed in the ditches. The crop plants were shaken over these trays, and the caterpillar-filled trays were carried away. The farmer collected four cartloads from one hectare. Though the method was effective the relief was of short duration as new hordes of caterpillars moved in. The author made a plea to foster birds as natural enemies mentioning sparrows, starlings, tits, wagtails, goldfinches, and white storks. In this one year the starlings neglected the cherry trees!

The causal moth is a migratory noctuid. The author mentioned that its caterpillars did great damage in Prussia in 1827 and 1828, and that swarms of moths were seen moving from east to west in early June, landing somewhat east or south east of the affected area. The peak of that infestation was about mid July. Some two weeks later a new generation of caterpillars appeared. These caterpillars, when numerous, assume 'a gregarious marching habit' (Imms, 1964). In August the summer generations of moths and whites migrated to the north. At one time the deck of a ship was coloured brown by moths, whereas a sandy isle was painted white by butterflies (small cabbage whites). ■

rarely taken into consideration.[47] Most of the recommended treatments could not be implemented on a large scale because of the relative scarcity of the material needed. One can only hazard a guess as to the efficacy of the recommendations, weed control excepted.

Manual control was, of course, far more important than it is today. Hand picking of weeds, diseased leaves, and insects (larvae and adults), is reasonably effective when the infestation is at a modest level. Low-level pests (and diseases) were probably disregarded. Small scale outbreaks, the size of a single garden, could be handled. Human hands were helpless against pests attaining high density over larger areas, even in former times when labour was cheap and citizens could be compelled to participate in manual pest control.

8.4.4 Precautionary approaches

In a period when curative means were scarce and of doubtful effectiveness precaution and prevention were of paramount importance. Three topics have been highlighted.

Box 8.3 Some modern equivalents of pre-modern treatments

Pre-modern plant protection can be revisited in the light of present knowledge. Here the old techniques are seen in terms of their modern equivalents, accepting the risk of '*Hineininterpretierung*'. A personal evaluation is given without an attempt at documentation.

Baits. The baits, some rather complicated, were probably effective. Akin to baiting was the use of ivy in vineyards, a simple method, but does it really lure pest organisms? Baits are still part of modern pest control.

Combination cultivation. The use of sea squill to protect (young) trees may have been effective against rodents and, maybe, against insects. Companion crops were often recommended. The texts provide no detail so that an interpretation as to whether trap crops or repellent crops remains questionable. Collecting and trampling or burning of the trapped vermin were mentioned several times. Combination cultivation is applied in modern 'organic agriculture' and in gardening.

Disinfection. Several wound treatments I consider to be effective though laborious. These treatments refer to mechanical wounds including the wounds inflicted by removing rots and insect larvae. In recent times wounds of trees are treated again with smears without synthetic pesticides.

Fire. Stubble burning to control over-summering weeds, insects, and pathogens can be very effective. It was common practice in parts of north western Europe until far into the 20th century.

Fumigation. The recommendations to fumigate the holes of voles and moles seem quite realistic. Incenses and smokes to deter insects may have been moderately effective. In recent times fumigation, tending to use rather dangerous pesticides, is on the decrease. ►

Risk management became visible in the discussions on the best location of manor, vineyard, and garden. In this category belong considerations of altitude, slope, and exposure to sun and winds, soil type, water availability, water management (drainage and irrigation), matters which are underexposed in this book. Mediterranean farmers had their plots scattered over the area, at different elevations and with different exposures to sun and winds.[48] Good seed care, intensive tillage, and careful timing of planting and harvesting, constituted a set of implicit methods to avoid risks. Multiple varieties and multiple sowing dates per farm were explicit methods. Risk management, somewhat neglected in modern high input agriculture, was as important and effective in pre-modern agriculture as it is in modern organic agriculture. Garnsey, writing on peasant farming in Roman times,

Granulates. This modern technique has no pre-modern equivalent, unless we see the broken acorn pieces to protect planted cuttings of grapevine as an early granulate.

Grease banding of fruit trees is still in use, though with modern materials.

Hand picking, today practically restricted to gardening, was a standard procedure.

Seed treatment. The notion of seed treatment existed but the effectiveness of the recommended treatments is uncertain. Soaking seeds in water with whatever addition seems quite reasonable to speed up germination and establishment. In modern times seed treatment is a standard procedure.

Sprays. Three methods approach spraying, spattering by brush or rag, spitting by mouth, watering with a perforated watering pot (L: *nassiterna*). Maybe we should add dabbing leaves with a wet rag. A few 'sprays' may have been moderately effective, such as dill extract on vegetables and olive oil on grapes. Since World War II spraying crops has become the standard in conventional agriculture.[49] Modern 'organic agriculture' has drastically reduced chemical treatment of crops though most pesticides of 'natural' origin are considered acceptable.

Adjusting the physical environment as with grape bunches in the field and with seed lots on the threshing floor played a more important role in early times than today. Such adjustments must have been reasonably effective. In modern agriculture with its high labour costs the interest in such physical adjustments has diminished but, in contrast, the environment of stored products is manipulated routinely by cooling, freezing, and storage under CO_2, not to speak of the covered crops in endless glasshouses. ■

stated: '*Subsistence farming is a minimum-risk enterprise. The farmer endeavours to reduce his vulnerability by dispersing his landholdings, diversifying his products and storing his surplus*'.[50]

Weed control is a case in point. Frequent and timely ploughing, hoeing, deep digging, and hand picking were laborious, tedious, slow, and effective. Grazing the weeds certainly helped. The use of pigeon manure to 'burn' grasses may have been effective under favourable conditions. Smothering weeds by dense sowing of a cover crop was certainly effective (§ 5.3.4).

Storage. Most recommendations in the old texts on storage of fruits are realistic. Many of the recommended actions intending to prevent fruit-to-fruit contamination continued to be applied far into the 20th century, in 'granny's attic'. Most remarks on treating grain storage rooms and on handling grain in storage seem to be quite realistic too. Special mention must be made of the grain pits that – in a modern interpretation – applied storage under CO_2.[51]

Year or Century	Location	Present country	Target animal	Comments	Ref [a]
548	la Mancha	Spain	*Schistocerca gregaria*? [b]	total destruction of crops	Wikip.
873	Germany [c]	Germany	Locusta migratoria?	swarm in flight audible by thin noise	B2.28
886	Rome	Italy	locusts		E313
12th q1	-	France	locusts	darkening the sky, pestilence	E 94
13th	Coire	Switzerland	*Rhynchites auratus* ? [d]	green beetles, Spanish flies	F3.433, E319
1320	Avignon	France	cockchafers	prosecutio	E314
1337/9	Upper Danube Area		*Locusta migratoria* ?	war on locusts (§ 4.4.1)	B2.31
1338	Bolzano [e]	Italy	locusts	numerous progeny	E 93
1445	St Julien	France	*Rhynchites auratus*	case ongoing in 1487	B1.240, F3.428
1451	Berne	Switzerland	leeches, rats	prosecution	E316
1460q1	Dijon	France	weevils	prosecution	F3.431, E317
1478	Berne	Switzerland	beetles [f]	type *Brychus*	E113
1479	Nîmes	France	rats, moles	prosecution	E318
1487	Macon	France	snails	prosecution	E318
1497	Lausanne	Switzerland	cockchafers	prosecution	B1.240
1516	Villenose	France	caterpillars	vineyards & lands	F3.433
1519	Stelvio	Italy	voles [g]	prosecution	F3.430, E111
1541	Lombardy	Italy	*Locusta migratoria* ?	Famine	E 93
1579	Lausanne	Switzerland	cockchafers	prosecution	B1.240
1587	St Julien	Savoy	green caterpillars	prosecution	B1.235
16th q1	Autun	France	rats	prosecution	F3.429
1866	Pozega	Slavonia	locusts	prosecution	E334

Table 8.1 Some legal cases brought against animals to show that various animals caused real problems.
[a] *Reference and page: B = Bodenheimer (1928, 1929), E = Evans (1906), F = Frazer (1919).*
[b] *An alternative is the Moroccan grasshopper,* Dociostaurus maroccanus.
[c] *Western Germany and northern France; for a two month period successive waves came from the east, they were blown into the sea in Brittany.*[52]
[d] *Coire (Grisons, Switzerland) – green beetles called Spanish flies (F432). The term 'Spanish fly' seems to have been used to designate* Rhynchites auratus.
[e] *Stelvio (Tirol, Italy) – voles (G:* Lutmäuse*) damaged the crops 'by burrowing and throwing up earth, so that neither grass nor green thing could grow' (F430).*
[f] *Very destructive to fields, meadows, gardens, herbs, vines, meadows, grain and other fruits.*
[g] *Austria, Bohemia, Moravia, southern Germany, Alsace.*[53]

8.4.5 Effectiveness of pest control in pre-modern times

The control portfolio was fairly large and its phenomenological aspect was not so different from today (Box 8.3). We have no information at all about the application of the many recipes given, we know nothing about the frequency of application, nor yet do we have any information on their effectiveness. I surmise that their application was limited to the gardens of the affluent and, possibly, to a few fields near the manor. Account books of convents and estates may disclose some complementary information.

The 'threshold theory' implies that action is taken only when a pest reaches a certain, unacceptable nuisance level, the 'damage threshold'.[54] Anno 2010 we have now left behind us the adage 'the only good bug is the dead bug', but in modern intensive agriculture, with high external inputs, a five per cent decrease in crop yield may make the difference between the farmer's profit and loss. Similarly, a small dip in product quality may be a catastrophe for the financially stressed farmer since it drastically reduces the sales price of his product. In other words, the damage threshold is quite low nowadays. The lower the yield, the less a treatment will pay, and the higher the damage threshold will be. In addition, high yield variability increases the damage threshold. Consequently, the damage threshold must have been much higher in medieval times than it is today. If the threshold theory holds for ancient times the willingness of pre-modern farmers to treat crops, certainly field crops, would have been low.

In modern crop protection we expect a nearly one hundred per cent effectiveness from a recommended crop protection chemical. With botanicals that figure is too high. It was speculated that today an efficacy of 10 to 15 per cent less than a comparable synthetic product might be acceptable if there is a market premium for a production that is 'clean and green'.[55] Pre-modern growers must have noticed treatment effects far below 85 per cent. A fifty per cent kill, maybe even a thirty per cent kill, would have been better than no kill at all. I have no inkling of the effect levels which were then considered worth the effort of preparing and applying botanicals.

8.4.6 Did we miss the clue?

If we do not find a modern clue for a pre-modern recommendation there are several options:

1. We missed the clue.
2. The recommendation, if executed, has a visible effect though far less than the effects desired today.[56]
3. There is no clue:
   a. The author conscientiously quoted older authors.
   b. The recommendation is a 'conversation item', only to talk about.
   c. The recommendation, if followed, soothes the grower's anxiety.

Option 3c is quite realistic. In recent times I have seen cases where, for the treating farmer, the psychological effect of a treatment was more important than the crop protection effect. To put it bluntly: 'Another treatment of the crop ensures the farmer a good night's sleep'.[57] This comment may have applied to farmers in pre-modern times and it certainly applies to various homeopathic and magical practices. Social pressure may have affected the attitude of the farmers but, once more, we have no clue.[58]

A millennium-long repetition of a particular recommendation is not an argument in favour of its regular use nor of its effectiveness.[59] Pre-modern crop protection was real, but how real? Was it practiced generally or incidentally? Was it applied to gardens and vineyards only, or also to field crops? Who was interested in crop protection in pre-modern times, the estate owners, the mass of peasant farmers, or both? Compendia of agriculture, including crop protection, were available indeed, for example the Geoponika, but their practicality, application, and effectiveness as to crop protection remain a conundrum.

8.4.7 Invisible pest control?

One form of pest and disease control remained practically invisible, namely selection for resistance. I found no evidence that selection for resistance was consciously aimed at. Plant breeding did not yet exist as an explicit activity but a strong selection pressure, consciously or unconsciously, may have been exerted by agronomists in their experimental gardens, by intellectuals in their show-gardens, and by farmers in their fields. The evidence shows the gradual adaptation of exotic crops to new environments, and the steady improvement of food crops. The change, little by little, of some uncultivated plants into cultivation followers, darnel in wheat and camelina in flax, demonstrates unintentional but effective selection.[60]

Some kind of intentional selection nonetheless must have occurred. In cereals this selection was done in two ways, the selection of well-filled ears to be set aside for next year's seed, or the use of larger and heavier kernels that sank to the bottom of the grain pile. In terms of genetics the procedure may be called 'positive mass selection'. The effect is that yield and yield stability are maintained or even improved notwithstanding ever changing pressures of pests and weather. The reward can be seen in 'landraces' that show moderate resistance to a variety of injurious effects and the ability to produce an acceptable yield irrespective of the circumstances.[61] The penalty is that even under the most favourable conditions yields are not high. The plant breeder might characterise such landraces as having 'horizontal resistance' and/or 'tolerance'.[62] The resulting plants are relatively large and leafy, with a modest but fairly constant yield under all conditions, cold or hot, wet or dry, whatever the harmful agents present.[63]

Positive mass selection favours horizontal resistance as demonstrated for farmer selection of maize resistant to tropical maize rust in western Africa.[64] Horizontal resistance against one or more pests is a flexible and adaptive mechanism, most efficient in wind pollinated crops, such as maize and rye. The mechanism is, nonetheless, also effective in self-pollinators such as wheat and barley because selfing is rarely one hundred per cent.[65]

The mechanisms described for cereals also operate in vegetables and fruit trees, but here the severely affected and otherwise undesirable individuals will be readily discarded. This procedure can be called negative mass selection. In addition, attractive trees – among them hybrids and mutants - will have been clonally propagated. The seed of good vegetables and herbs will have been collected for future use. Such selection, which comes naturally to the attentive grower, can be seen where commercial supply of seeds and planting material has not yet replaced the local self-supply.

Some details of the procedures mentioned here were found in the books (§ 3.4.3). However, the overall picture of a selection leading to maintenance or even slow increase of yields over time could not be documented. Nonetheless, I believe that there has been gradual adaptation to changes in climate, areas of cultivation, cultural methods (e.g. better ploughing, more manure), and pest portfolio. One example is a certain preference, lasting until the 13th century, for white wines produced from cultivars with white grapes. Cultivars with white grapes were better adapted to the rough northern climate than those with red grapes as they were more resistant to autumnal humidity and winter freezing and less susceptible to grey mould because of a thicker skin.[66]

8.5 Lavish abundance? - Food security and food safety

8.5.1 Food security

Capricious weather caused great variations in agricultural productivity, with or without pests coming in their wake, leading to food shortages and famines. Garnsey proposed two working definitions.[67] Shortage is '*a short-term reduction in the amount of available foodstuffs, as indicated by rising prices, popular discontent, hunger, in the worst cases bordering on starvation*' whereas '*Famine is a critical shortage of essential foodstuffs leading through hunger to starvation and a substantially increased mortality rate in a community or region*'. Garnsey critically examined data from Greco-Roman antiquity, and concluded that shortages were common but famines were rare.[68]

In Byzantium, for example, court politics were often chaotic but the populace had to be kept quiet at any cost. Pestilence and famine, *loimos* and *limos* (G: λοιμός καὶ λῑμός), did occur but the state-controlled economy created a fair degree of stability.[69] Wheat storage, distribution, and pricing were state affairs.[70] In the 8th and 9th centuries Byzantine agriculture was relatively productive. Peasant farmers and estates existed side by side but at the time of the Geoponika the estates had gained in importance, in particular those of the monasteries.

We may wonder how populations coped with food shortages. Seaside cities such as Athens, Byzantium, and Rome could easily import grain from afar, an opportunity not available to inland cities, such as Edessa (§ 4.4.1), because roads were poor and transportation facilities miserable. The biblical story of Joseph in Egypt, collecting grain during seven good years to be distributed in the seven bad years, is a model of coping (Genesis 41: 29-57). Public food stores existed in medieval Andalusia to be used in periods of war or famine.[71] Sometimes, the affluent opened their grain stores and distributed food to the needy at a reasonable price. In the famine year of 1315 some families of the Frisian landed gentry, names mentioned, supported the needy, paying weekly house calls. They tried to convince the rich monasteries to help their deeply destitute compatriots.[72] Many are the instances where city and state administrators kept large grain supplies in their warehouses in order to meet emergencies.

In several periods and places a silent agreement existed between the landowner and his farmers, the farmers paying tribute and respect to their lord and the lord caring for the needy in times of want.[73] When a real famine reigned such agreements did not always hold. People living on the land, having eaten whatever edibles were available, then left their homesteads and flocked into the cities to go begging, or they packed up and emigrated.[74]

Coping with food shortage at the producer level is twofold. One is to keep a large amount of grain in store. De Serres recommends having three 'harvests', one crop on the field, one with the miller, and one in the store. The other is to grow reserve food such as bitter vetch and lupine that are not normally used in human nutrition. Coping at consumer level follows a pattern too. When first class food is no longer available, second rate foods are eaten, bitter vetch and lupine replacing wheat and barley. Next come corpses of animals, grass, bark of trees, and whatever rotten left-overs that can be found. In the end there may even be cannibalism.[75] The pattern was the same in antiquity as in modern times, for example the famines of the 1840s in continental Europe and of the 1930s in Russia.[76]

In medieval Europe, certainly north of the Alpine ranges, population density and food production were in an unstable Malthusian equilibrium. With a yield ratio of about 3 even minor disturbances in food production could cause a serious unbalance leading to scarcity and hunger (§ 3.7.4). The chronicles abound with such instances.[77] Many of the cases were local, or at worst regional. Famines on a continental scale were, however, rare. 'The Great Famine' of 1315-1321 raged over most of north western Europe (§ 3.5.1).[78] Locust plagues caused serious famines on a (sub-)continental scale in the year 873 and around 1338 (§ 4.4.1).

8.5.2 Food safety

Though food safety is a modern concept not met in pre-modern writings, some awareness of food safety existed. The emphasis was different from today's one, being more on water than on food. Water was unsafe to drink, certainly in the towns.[79] Wine and beer were the popular drinks in the South and the North, respectively. Beer had a low alcohol level and wine was usually diluted with water, even unsafe water. A small amount of alcohol in the drink may have had a protective effect, or so it was thought. The demand for wine, difficult to transport, was ubiquitous so that vineyards appeared where the climate allowed the grapes to ripen. The need of red wine for the Eucharist stimulated local wine production. Barley, the usual raw material for beer, was grown everywhere.

There can be little doubt that the quality of the food the people consumed was positively related to their income. So far, the agronomic sources have provided no information on food safety. In the Atlantic zone stored grain could get mouldy and therefore grain in storage had to be turned over, by hand, up to four times per year.[80] Two plant diseases may have reduced food safety, head blight of grain and ergot of rye.

Fusarium-like fungi, that cause head blight of grain (wheat, barley, rye), can produce dangerous poisons.[81] These fungi occur in wet summers and the infestation can be quite severe when a sequence of wet summers occurs. Damp grain in storage will also be infested and when fed to animals it may kill them. Death of animals and disease or death of humans due to *Fusarium* poisons may have occurred but were not found in the records.

Very different is the situation with ergot on rye, a plant disease that rarely affects wheat. The ergot, where a fungal mass has replaced a rye kernel, contains poisons that cause 'ergotism' in humans, characterized by various symptoms such as hysteria, madness, loss of limbs, and finally death. Mass poisoning with bread made from infested rye was frequent in the Middle Ages. Animals fed with ergoted rye could die too. The subject, covered extensively in the literature, usually following the exhaustive study by Barger (1931), needs no discussion here.[82]

Emphasis on yield quantity may have shut farmers' eyes to yield quality, though customers in town will have valued quality. Ergotism may have persisted for a long time because ergot hardly affects yield quantity. We do not know if and how farmers handled quality problems in former times. In the 1980s I met with several peasant farmers in developing countries who were conscious about their food safety. They treated their crops intensively with pesticides, but kept small unsprayed plots for private consumption. In stark contrast, 18th century farmers in Sologne, a region in France, suffered miserably from their own ergot, though they were aware of its disabling effects.[83]

8.6 Modern times

Olivier de Serres, the educated Frenchman who chose to become a gentleman-farmer, laid down twenty years of farming experience in his book 'The theatre of agriculture', first published in 1600. This year is often used by historians to mark the beginning of the modern era. De Serres is modern indeed in many respects, with vestiges of medieval thinking. He knew the Roman authors, quoted them regularly, sometimes in the affirmative, sometimes rejecting their views.

As an empiricist Olivier de Serres had a clearly modern outlook. With a broad gesture he pushed aside all the petty remedies of the ancients thought to cure ailing vines. '*No more than by extravagant remedies the languishing, declining and weeping vines be helped. Let aside the pouring of urines, the rubbing with wine lees, the unguents made with pitch, ashes with vinegar, barley flour with purslane, rubbing the trunk with wine lees, and the pruning knife with bear or lion fat, or with mashed garlic, though these are the teachings drawn from antiquity. As they are too cumbersome for the grower, and so little accompanied by reason, it is better to leave them to the curious…*' [OS-3.5.180]. De Serres was averse to all kinds of magic and superstition.

He was also modern in his estate management, aware of both toil and cost of labour. His view was that some work can be done cheaply by women and children, but that one should not economise on the grain harvesters (i.e. they should be seasoned professionals). He relied mostly on his own experience, gained in an estate at the northern reach of the Mediterranean climate with its summer heat, but also affected by the temperate Atlantic climate with its frosts, storms, and rains. Some of the crops he discussed were still new to European agriculture, such as potato, sunflower, and tulip.

De Serres is very matter-of-fact, but nonetheless he fosters remnants of pre-modern thought, as on the influence of the stages of the moon. Many times he mentions at which stage of the moon a certain activity must take place but he is not dogmatic. He quotes a rhyme [OS-1.7.44].

Que l'homme estant par trop Lunier,
De fruicts ne remplit son panier.

(The man who is too 'Lunary' will not fill his basket with fruits.) The wheat harvest is too urgent to wait for the right phase of the moon [OS-2.6.116]. There is no need for the grape harvest to wait for the descent of the moon, just wait until the dew has evaporated [OS-3.7.189]. Some old ideas he simply brushed aside. But another old idea, hanging crayfish in the trees to control caterpillars (§ 5.2.2), is quoted in earnest, a recipe probably never tested by De Serres himself.

His attitude towards his predecessors is critical. De Serres spends pages to sum up and ridicule many ideas of 'the ancients', including those on the *mulier menstrualis* [OS-1.7.40/2] (§ 7.3.2). On a more technical level he also tones down some recommendations. Digging the vineyard three times a year, as the Roman authors wanted, is fine but twice is usually adequate [OS-3.4.159]. The emphasis on laying bare the crown of the tree and the major roots (F: *déchaussement*) is reduced to a few casual remarks. The *pulveratio*, cherished by the classics, is not even mentioned. As to the preparation of the threshing floor De Serres thinks the secrets of the 'ancients' to be ludicrous such as applying *amurca*, oxen blood, and other home remedies [OS-1.7.40/2]: '*about which to-day's managers don't care, contenting themselves with the foresaid simplicity to make a good threshing floor*'.[84] Contrary to most pre-modern authors De Serres wants the threshing floor near to the stables and sheds to keep transportation lines short.

The pre-modern crop protection lore tails off very slowly, remnants being present until far into the 19th century. Modernity in agriculture sets in with Olivier de Serres because he critically weighs the opinion of his predecessors against his own opinion, an opinion based on solid personal experience. He openly criticizes his forerunners. Such critical attitude is the birthmark of modernity. In his foreword he writes '*science more useful than difficult,*[85] *provided it should be understood by its principles, applied with Reason, led by Experience, and practiced with Diligence. Because that is the summary of its use, Science, Experience, Diligence, the foundation of which is the blessing of God…*'.

Chapter 9

Final comments

Some final comments are presented here, tentative conclusions. More in-depth studies of original medieval documents are needed before a definitive judgement can be given.

'However, forgive me if I go on, for my farmer's zeal has carried me away; besides, old age is naturally incline to talk too much - …'

Cicero, words attributed to Cato (*De senectute* = On old age, 16.55).

Chapter 1. This book is not the first attempt to present an overview of medieval crop protection and, hopefully, not the last. The body of the present book was selected from three major medieval authors living in different parts of the Mediterranean world, at different times, writing in different languages. Eclectic quotations from predecessors, contemporaries, and successors were given in order to obtain a broad overview of medieval crop protection problems and approaches. Around 1300 north western Europe began to contribute information on crop protection. Medieval documents such as estate records, diaries, leasehold deeds, and letters were not studied. They may provide more solid information on what was really done in crop protection at farm level, and how people felt about it.

Chapter 2. Three major medieval authors on Mediterranean agriculture gave considerable attention to crop protection issues. They are the compiler of the Geoponika in Byzantium (c.950), the encyclopaedist Ibn al-ʿAwwām (c.1200), and the practice-oriented Crescentio (c.1306), writing in Greek, Arabic, and Latin, respectively. They embedded 'crop protection', a modern concept that did not exist as such in pre-modern texts, in general agricultural lore and knowledge, arranged by crop. In addition, some sections were devoted to crop protection as we see it today, action-oriented. The medieval authors leaned heavily on their classical predecessors. Apparently, Greek authors in the centuries BCE had taken the lead, but nearly all of their manuscripts are lost. Theophrastus (c.300 BCE) was rightly held in high esteem.

Chapter 3. An outline of pre-modern agriculture was presented. Sown crops were contrasted with planted crops. The three major commercial products were wine, olive oil, and wheat. Vegetable gardening received due attention. In all cases, tillage was of prime importance. Repeated ploughing, by scratch plough, improved the soil, and was the major weed control method. The various kinds of manure were considered carefully, either to prevent weeds in arable land or to stimulate the greening of pastures. Risk avoidance was a major element in pre-modern crop protection. An active interchange of information between farmers, a horizontal spread of information, and between estate managers and peasants, a vertical spread of information, must have taken place at all times, but the evidence is scanty and mainly by inference.

Chapter 4. Production constraints were numerous. Human constraints were hardly mentioned in the old books, thieves excepted. Abiotic constraints, being highly visible, received much attention, in the old chronicles especially. Drought and flood, hail and frost, excessive rain and salt damage were much feared. Biotic constraints were recognized when visible with the naked eye, mainly insects and vertebrates. Symptoms of pathogens, yet unknown, and of nutritional disorders, sometimes recognized, were taken together. The expressions 'rust', 'rot', and 'jaundice' were general terms used for various diseases and mineral deficiencies. Harmful vertebrates were cattle, swine, foxes, rabbits, hares, moles, and voles. Insects and their larvae were seen and described but we can rarely add species names to them. Ants were considered dangerous. Locusts were held in awe, primarily the migratory locust, the desert locust, and the Moroccan grasshopper.

Chapter 5. Magic and superstition, leading to the most creative recommendations, were slowly eliminated. Sound advice on risk management was given, as on the correct location of the manor, garden, and fields. Multiple fields, crops, varieties and sowing dates were recommended. Various modes of mixed cropping were in use and several forms of companion cropping were advised. Numerous treatments were described and many of the recommended treatment methods had a modern look though they were very much 'low-tech'. Storage problems were addressed in detail.

Though chemical control was recommended in the medieval books, my impression is that cultural control was far more important, notwithstanding the great demand on labour. Excess of water and of nutrients, recognized in principle as possible causes of damage, could be handled. Tree surgery and wound treatment, e.g. with pitch or fresh cattle manure, were well developed. Biological control, as understood today, was recognized in a few cases only. The medieval balance between cultivated and non-cultivated land, and the accompanying interchange of harmful and beneficial organisms, warrants the presumption that unintentional biological control was far more operative than today.

Chapter 6. Medieval pesticides were all natural products. If processed, the processing was done on the estate or farm. Among the abiotic substances were sulphur, pitch, and ashes, substances still in use today. Some fifty botanicals were encountered. Mixtures were common. Preparation methods are seldom clear, and dosages are never specified. About their effectiveness we can only guess. Medieval pesticides, by and large, must be considered to be broad-spectrum insecticides. A few preparations were rodenticides. *Amurca*, considered a panacea, was applied as insecticide, herbicide (the first ever?), and as a general deterrent.

Chapter 7. The arrays of crops, pests, and treatments, respectively, were called 'portfolios'. The Crop Portfolio was stocked with crop species of European, Asian, and African origin. The Pest Portfolio was limited to vertebrates and insects mainly, due to lack of identification means. The medieval Control Portfolio, surprisingly, did not much differ from the modern one. The pesticides were, however, applied by means of a very simple technology. Weed control by appropriate tillage was a major issue. Hand picking of weeds and insects was a major method, though given little attention in writing. In north western Europe thistle control received special attention, represented even in the arts.

Repeating your predecessors was considered good scientific writing, and hence even poor recipes were repeated endlessly. Though occasional insightful remarks were found, no theory - as we understand it today - was developed. Empiricism dominated. Crop protection lore, with its superstition and magic, was gradually replaced by empirical knowledge, a change to which religious aversion to sorcery by both Muslims and Christians contributed. A relapse occurred when the Church stepped in with its legal cases brought against animals.

Chapter 8. For a more distant view of the various relationships in crop protection the 'pest tetrahedron' is an appropriate metaphor. In a modern way, it places man at the top as the great decision maker, but no medieval author would have dared to do so. In order to compare medieval agriculture, organic by necessity, and modern organic agriculture the 'theory of yield', with its four production situations and associated yield levels, was used as a unifying concept. Similarly, a 'theory of loss' provides some useful notions. The great difference in production situations and associated yield levels between medieval agriculture and modern agriculture, conventional as well as organic, does not allow a close comparison between the two agricultures.

The old books described many kinds of mishaps to crops but what happened in real life is far from evident, especially with respect to biotic constraints. Information on frequency, extent, and intensity of damage is disappointingly poor. The records so far consulted are quite lacunary and the necessary double checking is not always possible. The effectiveness of crop protection actions, when taken, is not known. Ironically, the undesirable side effects of crop protection in medieval agriculture and in modern, western organic agriculture may show resemblances where broad-spectrum pesticides were recommended.

Modern science is characterized by its critical analysis of facts and concepts. In this respect, Olivier de Serres (1600 CE), an experienced gentleman-farmer with an independent judgement, was 'modern'. He openly criticized the classical writers, even daring to ridicule many of their recommendations.

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Guarda de Dios la Ley,
y sirve à tu Rey,
y ara con buey,
y cogeràs pan.

Observe the Law of God,
And obey your King,
And plough with an ox,
And you will harvest bread.

M. Augustín (Libro de los secretos de agricultura, 1762 p 169).

Abū l-Jayr – see Carabaza (1991).

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Notes

Chapter 1

1 Among these are Ainsworth (1976), Braun (1965), Dark & Gent (2001). Dugan (2008), Howard (1996), Large (1940), Mayer (1959), Orlob (1971, 1973), Smith & Secoy (1975).
2 Zadoks (1991).

Chapter 2

1 Ibn Khaldūn (1377) - The muquddimah. – An introduction to history. Rosenthal (Transl.) – 1958. p 3.151/2.
2 Two Dutch books are mentioned here. Bakels (2009) described the development of agriculture in north-western Europe from its beginnings up to 1000 CE. Slicher van Bath (1963b) began his agrarian history of western Europe at about 500 CE.
3 Mane (2006). An old but excellent overview of pre-modern, non-Asian literature on botany and agriculture: Jessen (1864).
4 For the present purpose the older term Near-East, with its restricted geographical meaning, is more appropriate than the modern and highly politicised term Middle-East.
5 Compare Bolens (1981) p 1.
6 Carrara (2006).
7 Κωνσταντίνος VII πορφυρογέννητος, Emperor of Byzantium from 948 to 959.
8 The Abassids began in 750 CE and founded Baghdad in 756 CE. Masood (2009) speaks of 'The translation movement' and 'The language factory'.
9 The term Nabatean refers here to the farming communities of present Syria and Iraq.
10 Burgùndio of Pisa (1110-1193), ambassador of Pisa (Italy) to the Byzantine court in 1136 and 1157.
11 Experiments in crop protection in the modern sense began in the 18th century with Duhamel de Monceau, 1728 (Zadoks, 1981), Tessier, 1783 (Zadoks, 2008), Tillet, 1755 (Humphrey, 1937), and Jethro Tull (1733).
12 *Capitulare de villis*: http//www.le.ac.uk/hi/polyptyques/capitulare/site.html
13 The term 'Moors' is used here for the Arabic speaking Muslim invaders of Spain, a mixed group of Berbers mainly, Arabs, even Persians, and local converts.
14 Encyclopedia of Islam, New Ed. Vol. II p 899ff; Bolens (1981) p 34.
15 Andrés de Laguna, 2nd edition (1566), library of Wageningen Agricultural University.
16 General information in Baynes & Moss (1948), Giertz (1983, 1991), Kazhdan *et al.* (1991).
17 Meana *et al.* (1998) p 70.
18 Where deemed necessary recourse was taken to the Greek of Beckh's reconstruction. The quotations in this book are based on Meana *et al.* (1998). The English translation by Dalby (2011) appeared in time to check some quotations. A few of the more interesting differences are mentioned in notes.
19 Meana *et al.* (1998) p 35.
20 www.treccani.it/biografie/Pietro De' Crescenzi, consulted June, 2011.
21 The French translation by Clément-Mullet (1864) was used, covering some 1200 pages, with 35 chapters.
22 According to general opinion he meant his compatriot Junius Columella (Bolens, 1981 p 46; Meana *et al.*, 1998 p 69; Enc. Islam N.E. II p 899); but Hämeen-Anttila (2006 p 59) argues that Vindonius Anatolius is meant. Ibn al-ʿAwwām had no first-hand knowledge of the Roman agronomists (White, 1970 p 261).
23 Preface by Clément Mullet (1977) p 68.
24 Also Pier Crescenzio. The name has many spellings, see Italian Wikipedia.
25 Most probable date according to Alfonsi (1933) p 7.
26 Charles II of Anjou, born in 1254, King of Naples from 1285 to 1309. In 1266 the Pope crowned his father, Charles I of Anjou, as King of Sicily and South Italy; he settled in Naples. During the 'Sicilian Vespers' of 31March 1282 he was chased from Sicily. At the time of the dedication Charles II was King of Sicily in name only. He had no authority over Bologna.

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27 Amerigho (Aimerico de Placentia, Amerigo di Piacenza) was an important Dominican, born in Piacenza and died in Bologna (1327). He taught at the University of Bologna and for one term (1304-1311) he was chief of the Dominicans (*Maestro Generale dell'ordine dei predicatori*). He stimulated his friend Crescenzio to write the book. www.treccani.it/biografie/Pietro De' Crescenzi.

28 Some 17 % of the text is derived from the classics and 40 % from then modern authors, 43 % being Crescenzio's own contribution (Gaulin (1989/90) p 70).

29 Gaulin (1989/90) p 131, 142, 143.

30 Very practical, undoubtedly inspired by Palladius.

31 Also: *Ruralia commoda* and *Liber ruralium commodorum, De omnibus agriculturae partibus*.

32 Wageningen UR Library Catalogue, # 125983.

33 History of horticulture; http://hcs.osu.edu/hort/history/028.html; Balss (1947); www.treccani.it/biografie/Pietro De' Crescenzi.

34 For details see Alfonsi (1933); about illustrations see Mane (2006).

35 Alfonsi (1933); Dizionario Biografico degli Italiani (DBI, online); Italian Wikipedia.

36 German title: '*New Feldt und Ackerbaw, darinen ordentlich begriffen wie man auss rechtem grund der Natur, auch langwiriger Erfahrung, so beydes alhier in XV. Buecher beschrieben ist, jedes Landgut, bevorab den Acker und Fruchtfeldter des Landart und gelegenheit nach, bey rechter zeit auffs beste bestellen, und mit aller hand Feldarbeit recht versorgen: demnach allerley Lust und Fruechtgaerten ....*' Library Wageningen University #125985.

37 The term '*pater familias*' had a well-defined meaning in classical Roman law. He was a kind of CEO of the family business, deciding over life, death, and property of all members of the extended family, clients, personnel, and slaves. The meaning of the term softened in the course of time and the father-aspect became more prominent, certainly where the estate shrunk to the size a farm. Crescentio used the term a few times, as in [CR-1.13] and [CR-4.2], rather to indicate the man carrying the final responsibility for the estate.

38 Grau (1971) p 1. The *Hausväterliteratur*, written in the local language, considers the agricultural enterprise as a housekeeping affair, including the care for people and animals belonging to the household, broad but uncritical in outlook. In Germany it began before 1600, reached its peak before 1700, and disappeared before 1800.

39 Xenophon of Athens (G: Ξενοφῶν), Greek historian and soldier.

40 Publius Vergilius Maro (70-19 BCE), a farmer's son, published his poem '*Georgica*' (= On farming) in 29 BCE. Gaius Plinius Secundus, also known as Plinius Maior (= the Elder, 23/24-79 CE) wrote '*Naturalis historia*' = (Natural history), an encyclopedic work.

41 Marg (1968); Most (2006).

42 The snail *Theba pisana* O.F. Müller is a good candidate.

43 Diogenes Laertius (1925) 5.39 ff; Theophrastus wanted to be buried in his own garden, without pomp.

44 '*Palladius, qui sait son Columelle par coeur*, ..' Guiraud & Martin (2010) p 106.

45 Two examples: Guiraud (1976) p 156; Meana *et al.* (1998) p 461 *57 '*es fuente de Paladio 1.35.8*'. These authors state clearly that Palladius borrowed much from [an unmentioned early version of] the Geoponika.

46 Guiraud & Martin (2010); Martin (1976)

47 The Georgicas may be an original work.

48 [GE-0.*33; 5.11.5; 10.2.7]. Cassianus Bassus expressed his own opinion as to the orientation of a building [GE-2.3.6], used the experience from his Maratonimos estate as e.g. on planting grapevine in places without irrigation [GE-5.6.2/6] in autumn and not in spring, planting trees in autumn [GE-10.2.7], and planting crops between the rows of grapevine [GE-5.11.5].

49 A partial translation was made by Hämeen-Anttila (2006). His pupil and scribe, Abū Ṭālib Aḥmad ibn al-Ḥusayn ibn ʿAlī ibn Aḥmad ibn Muḥammad ibn ʿAbdalmalik az-Zayyāt, published 'Nabatean Agriculture' in 940 CE (Hämeen-Anttilla, 2006, p 93).

50 Aramaic was the international commercial language of the Near East. Jesus of Nazareth spoke Aramaic.

51 i.a. Jessen (1864) p 6; Sezgin (1971) p 328.

52 Meyer & Jessen (1867).

53 Nicolaus of Damascus (G: Νικόλαος Δαμσκηνός), was a Greek historian and philosopher (64 BCE - ~16 CE). Most of his vast output is lost. Among what remains is a text 'On plants' in an Arabic and a Syriac version, a compilation of older Greek works. Ishaq ibn Hunayn (~850 CE) translated it from Greek into Arabic and Alfredus Anglicus (Toledo, 1210) from Arabic to Latin.

54 Balss (1947).

55 Ibañez (1988) p 31 concluded that Ibn Luyūn traveled widely, but the Encyclopedia of Islam (New Ed. II p 902) stated that he hardly ever left Almería.

56 E.g. the method to scare wasps away [IL-61].

57 Talavera de la Reina is an old city on the River Tagus, in the province Toledo, Spain.

58 A '*vega*' is a fertile lowland plain; the *vega* of Granada has a character of its own up to this day.

59 Many examples given by Vallicrosa (1943).

60 Domaine du Pradel, Commune de Mirabel, Départment Ardèche, in the Languedoc, ~20 km W of the river Rhône, at the latitude of Montélimar.

61 The 4th edition, 1608, was available in the library of Amsterdam University.

62 Perpignan, a city in southern France, then part of Catalonia, the area with Barcelona (Spain) as its centre, where the language Catalá was and is spoken. Catalá: *Llibro dels secrets de agricultura*, Barcelona, 1617. 'Secrets' is a typical medieval word in book titles. It can be understood as 'tips' as with de Herrera on grafting vines [DH-2.13.68].

63 The tomato was imported into Spain in 1540. In 1608 the tomato was listed by the Hospital de la Sangre, Seville. The potato was introduced into Spain just before 1573 but its cultivation as a food crop began somewhat later in Piedmont, N Italy, and spread northward (Oliemans, 1988).

64 Barcelona, 1762: En la Imprenta de Maria Angela Martì Viuda, en la Plaza de San Jayme. Consulted in the Library of Wageningen Agricultural University #244261. This edition is still without the potato.
Another version of the book is is accessible via
http://www.cervantesvirtual.com/servlet/SirveObras/12048627559084844198624/ima0000.htm.

65 Clément-Mullet (1977), prim but curious about the original text, gave the translation in a note, in Latin!

66 Rosenthal (1958), Vol 3 pp 151/2.

67 I found no evidence that Agustín had read de Serres, though the book was available at the time; the coincidence is remarkable.

68 Hämeen-Anttila (2006) p 51.

69 White (1970) p 336, 412.

70 De Serres (1608) preface p 4/5. Cardinal de Cisnero distributed de Herrera's book for free among the farmers ('*cultivadores y campesinos*') on his estates, which implies that many were literate (Carreras (1970) p lvii). However, Ménendez Pidal (1951, pp 386, 428) quotes a brother of de Herrera who stated that the book should be written for the nobles in order to lay aside their frivolous reading and '*to contemplate the nature of things*'.

71 Bolens (1981) p 2.

72 Ibn Luyūn sometimes used the words of local practitioners (Encyclopedia of Islam, New Ed., Vol II p 902).

73 Generally speaking, medieval land owners in West Europe were not much interested in agriculture even though agriculture provided their major source of income. The apparent exception in S Spain may be due to the fact that these landowners were (descendants of) colonists. In later periods too colonial agriculture used to be of high standing (comment by CM).

Chapter 3

1 Ed. 1762, p 3 of Prologue.

2 The 'Theatre of agriculture' is a term in the title of the book by Olivier de Serres (1600, 1608).

3 At the orders of King Solomon (~970-943 BCE) a temple and a palace were built, huge structures, using cedars from the Lebanon, an early example of forest destruction (1 Kings 5.6ff and 7.2ff).

4 See i.a. Buisman (1995, 1996), Dark & Gent (2001), Lamb (1982), Le Roy Ladurie (2004).

5 Bolens (1981) p 19; Dark & Gent (2001); De Vries & Goudsblom (2002) p 50, 225.

6 Euphrates and Tigris (Iraq), Nile (Egypt), Guadalquivir (S Spain), Guadiana (Spain and S Portugal).

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7 A Tunesian '*ksar*' (plural '*ksour*') is a fortified centre for storage of grain and other agricultural produce in the hill country adjoining the Saharan desert. More wetness in Western Europe: Slicher van Bath (1963b) p 64.
8 Buisman (1996) p 640.
9 Buisman (1996) p 640 sees the Little Ice Age as extending longer, 1430-1860.
10 Le Roy Ladurie (1967) p 280/1.
11 Le Roy Ladurie (1967) p 291. Similar cases in 1765 (Tozzetti 1767 p 1) and in 1846 (Zadoks, 2008 Ch 2).
12 Yacoub (2003), various pictures.
13 Burford (1993) p 110.
14 In Andalusia a '*vega*' is an irrigated grain producing area; a '*huarta*' is an irrigated vegetable and fruit producing area (Bolens, 1981, p 16).
15 Forests tend to recuperate lost terrain when given the opportunity. An example: around 1350 the population of Southern France was decimated, fields were abandoned, and natural reforestation occurred during the ensuing century (Le Roy Ladury, 1966, p 148/9).
16 An old reference from Greece is Hippocrates. The Pontine Marshes near Rome were drained and freed from malaria during the interwar period. The coastal area of the Netherlands became malaria-free after World-War II thanks to DDT.
17 Postan (1966) p 76. Slicher van Bath (1963b) p 154 places a question mark as to the opening of new lands.
18 An example, heard in Ethiopia, 1979. Under the Mengistu rule all imports were brought to a halt. The shops were empty and the farmers had nothing to buy. Consequently, they stopped producing the favoured Ethiopian staple, t'eff (*Agrostis teff* L.), for the market. This, in turn, led to serious scarcities.
19 E.g. Slicher van Bath (1963b) p 136.
20 The Codex Alimentarius provides a kind of 'what': 'system of farm design and management practices that seek to create ecosystems which achieve sustainable productivity'/ 'weed and pest control through mutually dependent lifeforms' / 'recycling plant and animal residues' / 'crop selection and rotation, water management, tillage and cultivation' (Schmidt & Haccius, 1993). Modern regulations of the U.S.A. and the European Union do not define 'what' but prescribe 'how' and 'how not'.
21 LEISA Low External Input Sustainable Agriculture (Zadoks, 1992); term now in disuse.
22 Alcock *et al.* (1994).
23 Alcock *et al.* (1994) provide an interesting overview of the use of manure in ancient Greece, that might be extrapolated to the Byzantine period, and after. Manure was usually in short supply.
24 [NH-18.4.18]. Around 290 BC officials considered 7 acres per family to suffice.
25 Tiberius Sempronius Gracchus, Roman tribune, reformed land laws in 133 BC, with temporary success at best.
26 Stein (1937).
27 Van Dolen (2009) pp 81 & 90
28 Bolens (1981) p 9.
29 Badler *et al.* (1990).
30 McGovern (2003), Badler *et al.* (1990).
31 See Mane (2006) p 178 ff.
32 Frankel (1999) p 37.
33 Lumaret & Ouazzani (2001).
34 G: ἀμόργη, L: *amurca*, I: *murchia*, S: *alpechín*.
35 The history of the wheats is complex, see Zohary & Hopf (2000) pp 35-58. Some scientific names are:
T. monococcum = Einkorn (diploid, hulled).
T. turgidum L. ssp *dicoccum* (Schrank) Tell = emmer (tetraploid, hulled).
T. turgidum conv. *durum* (Desf.) MacKay = durum, hard, or macaroni wheat (tetraploid, free-threshing).
T. spelta L. = spelt wheat (hexaploid, hulled).
T. aestivum L. = bread wheat (hexaploid, free-threshing).
36 Zohary& Hopf (2000) p 43, Decker (2009), Comet (1992) p 226. Meana at al. (1998) suggest that it was mainly *T. aestivum*

37 Comet (1992) p 226.
38 Comet (1992) p 149/50.
39 Today (c.2000) wheat varieties ripen evenly; varieties are selected not to shed their grains so that they can ripen fully and be combine-harvested.
40 For wheat this is roughly 160 kg.ha^{-1}, today an acceptable seed rate. Repeated by several authors among whom [OS-1.2.110].
41 In the dry mesetas of Spain, for example, rainy summers may lead to high wheat yields and high rust levels, the yield increase by the rains outweighing the yield loss by the rust (personal communication 1953, Dr. J. Salazar†).
42 Development stage c.47 in Zadoks *et al.* (1974).
43 Growth Stages 1.4 and 1.5 in Zadoks *et al.* (1974).
44 Zadoks (2003).
45 Helbaek (1960).
46 What the grass does to the barley crop, or the beer brewed from it, is not mentioned.
47 '*It is moderately nutritious and it binds the bowel*' – Dioscorides 2.95.
48 Wickham (2009) p 361.
49 Schiemann (1948).
50 Rösch *et al.* (1992).
51 [CR-12.9]. A vegetation period of cereals lasting 12-13 months was not exceptional; the same was true for wheat in some parts of Sweden up to the mid 20th century. [DH-1.14.33], [AG-177]. In the 1950s I saw much rye in the hilly areas of N Spain, on slopes with shallow sloping terraces for water harvesting.
52 The explanation given for the beneficial effect of legumes is not correct. The roots of legumes, not very heavy indeed, live in symbiosis with nitrogen fixing bacteria of the genus *Rhizobium*.
53 *Vicia faba* appears in many shapes and has many names (Faba bean = broad bean = field bean, ec.). Hence I chose a neutral designation. We ignore beans of African origin, cowpea and hyacinth bean (*Lablab purpureus* (L.) Sweet). The common bean from South America was not yet known in Eurasia.
54 Consumption of faba bean may lead to favism, a hemolytic anemia in patients with G6PD deficiency, that may kill. This deficiency occurs in malaria-ridden areas, such as Magna Graecia (Greater Greece), as it gives some protection against malaria, especially that caused by *Plasmodium falciparum*.
55 [DH-1.18.37], [DH-1.18.38]. Bean weevils (i.a. *Bruchus fabae*).
56 The ill effect of chickpea on soil fertility was common knowledge in classical times, [HP-8.7.2], [CO-2.10.19/20].
57 [GE-2.12.2], [OS-110].
58 Van Zeist & Bottema (1971).
59 The forage was primarily needed for riding horses; horse-drawn chariots date from before 1500 BCE.
60 Lupine has a taproot. When lupine is sown in shallow soil the taproot cannot go straight down. If the taproot is damaged by weeding, digging, or turning the soil the plant will die [GE-2.39.8; 2*165], and all work is in vain [AG-179].
61 For poison hemlock see also under 'konion' in § 6.2. Alternative translations are 'ashes' or 'caustic soda'.
62 Van Zeist & Bottema (1971).
63 Other names are chickling, white or Indian vetch, and grass or blue sweet pea
64 [CR-4.3], [DH-2.2.51ff].
65 'Sunn Pest' is a very damaging infestation of wheat ears by some pentatomids among which in Algeria *Aelia* spp. The wheat cultivar Florence-Aurore was an old French breeding product from INRA. Montpellier. Personal observation, 1980.
66 [CO-2.9.11], [IA-2.16], [AG-171]. In 1988 a Malian farmer explained to me how he selected his pearl millet. He marked the best ears with a red woollen thread and ordered his sons to collect these ears just before the harvest. The ears were carefully dried, threshed and the seed stored separately; a form of positive mass selection.
67 [IA-2.16]. Similar comments in [VA-1.52], [CO-2.9], [GE-2.16], [DH-1.6.19].
68 [DH-1.6.19], repeated in part in [AG-171].

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69 [AG-61], [GE-2.15], [PA-7.9]. The Spanish text says '*salida del canículo*', that is Sirius' first appearance as a star visible in the morning sky following its period of invisibility (lemma '*canícula*' in Spanish Wikipedia), that was in August.

70 Comet (1992) p 143. [DH-1.6.19], [IA-1.346], [AG-171], [OS-5.4.93].

71 Seed exchange between areas of different ecology was common practice in NW Europe during the 19th century and later. These recommendations were followed frequently, probably under the influence of the classical authors, in the case of potato often with great success, and in the case of wheat usually with temporary success. One advantage is that some seed-borne pests and diseases are avoided. Others, however, may be inadvertently be introduced.

72 Dalby (2011) p 101. ί

73 Greek: συκη, σῦκέα = fig, ἐρῑνεός = συκῆ ἄγρία = wild fig.

74 Lines [5.1367/9] in Rouse & Smith (1975). Lucretius lived in Rome, 99-55 BCE.

75 Trees grown from seed are heterozygous in many characters so that severe selection for desirable characters has to be made.

76 [CP-4.1.5/6], truncated quotation, also [HP-2.2.4]. A practical note: the lack of true breeding was a great obstacle in the diffusion of citrus through the Islamic World.

77 [GE-10.86.3], conform [HP-2.2.5/6].

78 [IA-1.145; 1.207]. G: κ ότινος = ἀγριέλαιον = wild olive [GE-10.86] = oleaster = qartanon.

79 [CP-4.1.7]. Similar comments in [HP-2 4.1/2; 8 5.1; 8 8.3] and [CP-8.7.1].

80 Book V, Chapter VII, § 54 ff.

81 The regress from cultivated and neatly pruned trees to neglected trees run wild is normal, but the 'mutation' from wild to cultivated rather seems wishful thinking; centuries of selection are needed to obtain good cultivated fruit tree varieties.

82 The comment stems from Albertus Magnus who knew rye cultivation north of the Alps; the explanation is not good enough but it has an element of truth. Careless harvesting of the one crop may lead to displacement by the other, and certainly rye could displace wheat. The soil type is relevant when wheat is cultivated on relatively poor soil to which rye is better suited.

83 'biotic' = relating to life or to living things, caused by living organisms (Oxford and Webster's dictionaries); Hence 'abiotic' is relating to or caused by non-living things.

84 Zadoks (2008) Ch 1.

85 [CP-3.24.4]. See i.a. Zadoks (2008) Ch 2. Bolens (1981, p 156) states that the Spanish air is too dry for rust. This is not my experience. Spain has known severe wheat rust in wet years. Rust can also appear on irrigated wheat, as I saw in the Ebro valley.

86 [GE-2.25.4; DH-1.10.31], Albertus Magnus, Book VII § 130.

87 [IA-1.148]. Gathering stones is a nasty job as I experienced myself working in a farm on the stony southern slope of the Jura mountains, Switzerland, 1947.

88 [CO-5.19], [CO-On trees-4.4/5], [IA-1.214].

89 Dury (1984).

90 As in 1765 in Tuscany (Tozzetti, 1766, p 1).

91 Osmaston (1985) p 499 describes the concatenation of mishaps as the 'knock-on effect of one bad harvest'. He clearly suggests the exacerbating effects of plant pests and diseases on exceptional weather effects. Similarly: Dury (1984).

92 Many publications exist on ecosystem services, as e.g. Kumar (2010) p 26, with a typology of ecosystem services.

93 Buisman (19956) p 22.

94 All organisms now called pests and pathogens originally developed in natural habitats undisturbed by man.

95 Zadoks (2008) Ch 1; Hogg *et al.* (1969) p 42.

96 Stem rust, leaf rust, and stripe rust, especially the latter two.

97 I visited Eastern China several times and it struck me that there were practically no birds. The explanation given was twofold: 1. Everything eatable had been eaten during the Great Leap Forward, and 2. the extensive use of pesticides did not allow recovery of the avifauna.

98 On the West side of the Peruvian Andes where it hardly ever rains plant species live on dew as their only water source.

99 melon [IA-2.218], flax [IA-2.109].

100 Dividing the month [DH-6.0.350ff], wheat [DH-4.7.216], pastures[DH-4.5.215].

101 Mane (2006) p 41.
102 Biological effects of the moon's stages were described i.a. by Rachel Carson (1951) p 163.
103 Aesop's fables, written in the Greek of the 3rd century BCE, probably of Anatolian origin, date from the 6th century BCE. Aesop may have been a fictitious person. Translation by Vernon Jones (1912, 1972).
104 [CP-3.10.1].
105 A medieval alternative was a hammer with a long handle and a big wooden head.
106 [CA-61] ; As so many statesmen in antiquity Cato, an estate holder himself, had a keen interest in agriculture.
107 As in the Archaeological Museum of Gela, S Sicily (Italy).
108 As the ox turns in ploughing, boustrophèdon (βουστροφηδόν), term used for writing lines alternatively from left to right en from right to left.
109 Pliny [NH 18.48.172] mentions a wheeled plough used by the Gauls in the wide plain of the river Po (N Italy). This was probably a mouldboard plough fit for heavy soils.
110 Mane (2006) p 111.
111 Mane (2006) p 102.
112 Today, the hoe is still in common use in Africa and S Asia, mainly by women, whereas the plough is primarily a men's implement (Comment: Savary).
113 Werth (1954) p 151, Van der Poel (1961/2) Fig. 22.
114 No wonder that in the sandy Sahelian zone, during the 1980s, I always saw people using the hoe, never the spade. The pushing hoe, so popular a weeding implement in NW Europe, I saw rarely in the Sahelian zone and only where catholic missionaries from NW Europe had been active (so I was told).
115 Mane (2006) p102.
116 [CA-61], [VA-1.29.2/3], [VE-1.48], [NH-18.35;49].
117 Corcos (1976) p 39, 89. Méchoulan (1993) p 33. Stillman (2010) p 516.
118 In the Muslim area many Jews were among the poorest city dwellers, some earning a living by emptying cesspools and drying their content to sell as fuel (or manure?). Cohen (1993) p 40.
119 Katan & DeVay (1991).
120 [IA-1.484], [CR-2.15], [DH-1.5.15].
121 Virgil mentions the harrow [VE-1.164]; White (1975) does not!
122 [NH-18.48.173; NH-18.49.179].
123 Bolens (1947) p 111. [IA-2.444] illustrates the Andalusian harrow, a wooden construct with teeth. [CR-2.15].
124 Mane (2006) p 124, 144; White (1962) p 5, 60.
125 Not everybody agrees with this theory according to Mane (2006) p 131.
126 Bockus & Shroyer (1998). My own observations in the Netherlands showed clearly that poor tillage caused excessive oversummering, and subsequent overwintering, of foliar diseases on wheat, including yellow stripe rust, brown leaf rust, mildew, and speckled leaf blotch.
127 This is a matter of soil water balance. On the positive side are the precipitations of two seasons, on the negative side the evapotranspiration of a crop and the continuing evaporation of the fallow field. The balance is usually positive, so that one grain crop with higher yield in two years is more profitable than two successive grain crops with lower yields.
128 See White (1970) p 121ff.
129 Bolens (1981) p 110.
130 Jardé (1979). The French terms are *jachère morte* and *jachère verte*.
131 White (1970) p 122.
132 Braudel (1986) p 131.
133 S Flanders and Artois: Slicher van Bath (1963b) p 177. Norfolk: Campbell (1983).
134 White (1970) p 179/180.
135 Mane (2006) p 145 fig. 53.
136 [NH-18.45.157 ff], [AG-47]. General recommendation to treat all seeds, quoting Columella.
137 Supposedly the European crayfish.
138 Watson (1983) p 103 ff.
139 Hill (1998) p XVIII.2; Watson (1983) p 103.

140 The cold water is the melting water coming from the mountains (Sierra Nevada). The grubs may be the voracious larvae of the cockchafer, that live for a few years in the soil [IL-12]. In Algeria, 1980, I saw several fields of sugar beet with white grub damage up to some 20 per cent.
141 Here Ibn al-ʿAwwām quoted Ibn Waḥshiyya who in turn quoted Kutzami.
142 [CA-11.3] mentions the watering-pot (L: *nassiterna*) as a necessary piece of equipment in a vineyard; White (1975) p 174.
143 Rotem & Palti (1969).
144 [CO- 2.2.9, 2.8.3].
145 Oschinsky (1971) p 165.
146 Payne & Herrtage (1878) p 48 #7.
147 NL: *zicht*, F: *sape*; a short corn scythe in the right hand used with a reaping hook in the left hand.
148 Mane (2006) p 152.
149 [GE-2.25.1]. Grain shedding was a serious threat, even in more recent times. During the 1950s I have seen cases of harvest loss due to grain shedding during a thunderstorm in the order of 1 to 2 tonnes.ha^{-1}, or 15 to 25 per cent of the wheat yield.
150 [GE-2.25.2]. Straw for fodder rather than for litter? Dutch farmers used to feed straw to their cattle in times of fodder scarcity as during World War II (author's experience; oat straw was preferred by cattle).
151 [GE-2.26.1, 12.2.2], [CR-3.1], [AG-175]. Columella advised making the threshing floor of stamped soil or even masonry. In Spain I have seen high and exposed threshing floors, round and stone-covered, in the 1950s, when some were still in use for threshing by animals. Up-hill (anabatic) wind was needed for winnowing but the dust, irritating to eyes and skin, should not be blown toward the living quarters and vegetable gardens.
152 Fraud [CR-3.1], help [DH-1.10.29], chaff [CR-3.1], smells [DH-1.10.29], shower [CO-1.6.23].
153 Comet (1992) p 558; Mane (2006) p 180.
154 Seed weevils, in wheat and barley mainly *Sitophilus granarius* Hust., the granary weevil; in legumes various species of Bruchids such as the pea weevil *Bruchus pisorum*.
155 Vitruvius on architecture § 6.6.4. in Granger, 1970.
156 [NH-15.18.67]. Detailed instructions for grape storage are given by Columella [CO-12.44.2/5].
157 Dust [NH-15.18.67], [GE-4.15.12], purslane sap [GE-4.15.19], [AG-202].
158 In a way, this is a precursor of the modern technique to wrap individual fruits and flowers in plastic foil.
159 The South winds are considered too hot, I suppose.
160 'House-leek' is placed within quotation marks as the translation of ἀειζώων βότάνη is questionable (§ 5.7).
161 The proportion is described as 1 *quénice* (= ~1.2) l on 1 *medimno* (= ~55 l) or roughly 1:50.
162 The nature of the dust matters; the finer the better. The dust has an abrasive effect on the cuticle so that the affected insect dries and dies (van Huis, 1991).
163 There may be an insect repellent effect and/or an effect of improved ventilation. Changes during storage in kernel size and weight were a concern mentioned several times in the Geoponika.
164 The insect repellent effect is understandable but I cannot explain the gain of weight except for the weight of the powders added to the grain.
165 [CO-1.6.17], [DH-1.10.29].
166 [OS-2. 7.123], [AG-176].
167 [OS-2. 7.123], [AG-176].
168 If we are to believe Sir Albert Howard (1947), a pioneer of modern organic farming, yields of the farms, necessarily organic, in Bengal before World War II were rather low but fairly stable during at least a thousand years, with amazingly few pests and diseases. This is probably too idealistic a view, but it must be said that alarming yield failures around the 19th century seldom occurred.
169 [CO-3.3.4]. White (1970) p 49.
The 'seed return factor' (or 'yield ratio') is the yield (in weight or volume) of a plot relative to the seed sown in that plot. In medieval times the yield ratio of wheat was c.3, today it can go up to 50 and more. A seed return factor of R means that R seeds are harvested for every single seed sown. For food and feed (R-1) seeds are available. People have to eat, the oxen must be fed to let them work. Pre-war 20th century data from Bengal with its ages-old agricultural systems are similar. Farms that kept cattle for manure, meat and milk, and oxen for ploughing, may have produced regular wheat yields between

0.7 and 1.1 tonnes.ha^{-1}, without and with irrigation, respectively, roughly equivalent to a seed return factor of 5 to 8 (Howard, 1947). The run-off farming system in the Central Negev desert - in fact a well-watered system -, 6th and 7th century CE, had a wheat yield ratio of c.7 (Bruins, 1986). Pliny [NH-18.21.95/5] mentioned some odd values, up to 150, which he thought to be curiosities only: I agree.

170 The specification is up to 40 *modioi* per *plethron* (or *iugerum*), equal to ~1,000 litre per 0.26 ha, at 70 kg.hl^{-1} equivalent to c.2.7 tonnes.ha^{-1}. In view of many uncertainties this is a very rough calculation.

171 Richardson & Sayles (1955) p 256.

172 Astill & Langdon (1997) quote many comparable figures but yields in some areas such as Flanders could be much higher, c.10:1. Campbell (1983).

173 There seems to be a discrepancy between Slicher van Bath (1963b) p 21 fig. 6 (2-4 ha of land needed per person) and White (1970) p 345 comment on Roman intensive family farms of c.2 ha. The discrepancy could be solved in part if the Roman peasants could do without fallowing.

174 Garnsey (1988) p 104.

Chapter 4

1 Dyson (1998) p 1155.

2 Examples in Zadoks (2008) Chapters 3 to 5.

3 From the Mishnah, the rabbinical book with interpretations of religious prescriptions; gentiles = non-Jews.

4 Fischer Drew (1992) p 88. The Salian Law is ascribed to the Frankish king Clovis, in present-day France.

5 *De capitulare villis*, Chapter 51, see http://www.le.a.uk/hi/polyptiques/capitulare/trans.html.

6 Oschinsky (1971) p 323 c.54; 16th century translation. Original French version: *A fere la yssue de grange eez un leal homme qe pusse charger le provost leaument, qar hom veit sovent qe le granger et le gerenter se ioinent ensemble pur mal fere*.

7 Fleta, book 2, chapter 82. *Of the issues of the barn*. Richardson & Sayles (1955) p 257.

8 Ibn Khaldūn after Monteil (1968) p 807. P 613 suggests that farmers no longer produced because they were overtaxed. In Ethiopia I noticed a comparable phenomenon in about 1980, when farmers did not sow their fields because the yield had lost its value, the shops being empty. There was nothing to buy.

9 [DH-1.18.38], [AG-180].

10 Payne & Herrtage (1878) p 57 #15.

11 From Dyson (1998) Ch 22 p 1155. Of course St Augustine knew 2 Kings 6:28/29: '*This woman said to me, Give thy son, that we may eat him today, and we will eat my son tomorrow. So we boiled my son, and did eat him*.' The patriarch was not the only one mentioning parents eating their children. Such stories are known from several famines including the Russian famine of 1932 (Zadoks, 2008 § 6.4).

12 Ebert (2004) in 'Phaidon' 110.E.

13 The straw should be ploughed in but that is not stated.

14 [IA-2.3, IA-2.45, IA-2.168]. Wild beets were halophyts. Early cultivated beets may have been salt-tolerant.

15 Winsemius (1622) pp 162/3 and 288. In 1953, islands in the south west of The Netherlands were flooded once more. Gypsum was strewn over the land to speed up the elimination of salt from the soil, with good results.

16 Buisman (1996) p 546.

17 Buisman (1995) p 347.

18 Buisman (1995) p 389.

19 Leguay (2005) p 134.

20 Leguay (2005) p 52.

21 Abū 'l-Khayr (1991) p 246 is precise, 'rust' of trees occurs when the leaves turn yellow.

22 In Algeria, 1980, I saw several cases of leaf curl in peach due to the fungus *Taphrina deformans*.

23 The quote continues and refers to the religious plays performed, the tragedies. This word relates to G: tragos = τράγος = goat.

24 Ashburner (1912) rule #38.

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25 Vineyards [CR-4.18], gardens [DH-4.1.207], fields - Mane (2006) p 95, oats [DH-1.16.34].
26 Lindemans (1952) p 236, 337 ff, 347ff,
27 Mane (2006) p 398, 405.
28 Lewysohn (1858) p 78.
29 'Low grapevines' [IA-1.337]; Mane (2006) p 188, also in W Europe.
30 Strabo (~64 BCE – 19 CE) 3.2.6 and 3.5.2 in Jones (1969).
31 Bennassar (1996) p 22.
32 Buisman (1996) p 338.
33 Imamuddin (1962) p 64. The hare species may have been the Iberian or Granada hare, somewhat smaller than the European brown hare.
34 Supposedly, with μῦς ἀρουραῖος the field mouse is meant, the main culprit of a genus that contains over forty species, among which a related species common in the Near East and Balkans.
35 Emerods = haemorrhoids, probably the inflamed swellings caused by bubonic plague. In antiquity, an association was seen between plague and field mice, both represented by Apollo smyntheius. Apollo smyntheius is the God of the voles, minted on coins of Alexandreia Troas. When Titus conquered Jerusalem he shipped the Ark of the Covenant to Rome, where the golden voles were on display.
36 Lewysohn (1858) p 107.
37 According to Aristotle, heavy rains made them disappear rapidly (Louis, 1964, book 6.37), which is correct.
38 Presumably, with μῦς κατοικίδιος the house mouse is meant but other mice occasionally enter houses.
39 *Mulsum* (S: *vinomiel*) was an alcoholic beverage, a fermented mixture of wine and honey in a proportion of ~4:1, popular among Romans and Visigoths. Its counterpart was *hydromeli* (G: ὑδρομελι), a fermented mixture of water and honey.
40 Rats were also associated with plague of humans though nothing was known about the transmission of the plague bacterium (*Yersinia pestis*) from rats to humans by rat fleas. Read '*La peste*' by the famous French writer Albert Camus, describing a 20th century plague outbreak in Oran, Algeria.
41 The Dutchy of Guelre is approximately the present province Gelderland (NL), Klijn (1979) p 28. The Pied Piper is depicted in a glass window of ca.1300, Market Church, Hameln (D).
42 Bennassar (1996) p 23.
43 The genus *Spalax* has many species among which the Balkan mole-rat and the lesser mole-rat. France (1986) p 107: In Bible lands there are no moles but the Palestine or Middle East blind mole rat is common.
44 Payne & Herrtage (1878) p 54 #25.
45 Buisman (1996) p 409.
46 O'Connor & Shrubb (1986).
47 We think of the wood pigeon or ring dove and the stockdove, both species being also present in southern Europe. They mostly eat vegetable matter, grain and other seeds, dry and germinated, caterpillars, pupae, molluscs, more rarely acorns and beechnuts.
48 We think of the house sparrow (at present not in Italy), following human activity, the Spanish sparrow (Spain and Balkans), and the tree sparrow (at present not in Greece). House and tree sparrows eat corn, weed seeds, insects, spiders, and fruit buds (Peterson, 1969).
49 In wintertime the common starling roams about in large flocks. Its menu consists of insects and other small animals, grain, berries and fruits, and various seeds. At present, the starling, a bird of the cultivated steppes, does not occur on the Iberian Peninsula, in Greece, and along several Mediterranean coasts.
50 Also in Mane (2006) p 141.
51 Mane (2006) p 141 ff.
52 In the Netherlands, in early spring, the Brent geese arrive in great numbers to feed and fatten before they migrate to the Siberian tundra. They do great damage to grasslands and sometimes to winter cereals.
53 Mane (2006) p 141.
54 The red arsenic is AsS (realgar). Clément Mullet (1977) believes the asafoetida to be the classic silphion; if so, these recipes were already obsolete in Ibn al-ʿAwwām's time because the real silphion had been eradicated centuries before.
55 Payne & Herrtage (1878) p 39 #14.

56 Carabaza (1991) p 233.
57 Mane (2006) p 141.
58 Trappman (1939) ex Braun (1933) p 10.
59 Cicero in *De senectute* XV.51, translated by Falconer (1971). Also [NH-5.18.53].
60 L: *milio* and L: *panico*, probably proso millet and foxtail millet.
61 Megenberg's *Buch der Natur* (14th century): 'Von dem starn' – *sturnus* – '*Si tůnd auch grozzen schaden in de weingarten herbst zeiten*' in Luff & Steer (2003) p IIIB66.
62 Anonymus (2012) p 11.
63 [CO-Arbor 15], [NH-17.265], [PA-1.35.6].
64 [VE-3.414/5]; [NH-12.126; 24.19; 28.71]; [PA-1.35.11]; [GE-13.8.1/2].
65 Quintus Gargilius Martialis was a Roman author on horticulture. Here he dealt with creeping thyme. He has been identified by some as a military commander who died in Mauretania, 260 CE.
66 Maire (2002).
67 At the time insect taxonomy was non-existent. References to insects are quite vague. The following is an interpretation, no more.
68 The two species are about equal in size and in the behaviour of their hopper bands and adult swarms, but they differ in breeding ground preference. The desert locust breeds in dry areas (primarily in Africa), the migratory locust in more humid areas (primarily in Europe). The migratory locust used to breed in the large reed swamps along the bigger rivers, Elbe, Danube, and the rivers of present-day Ukraine. I disregard the Moroccan and Italian grasshoppers which occasionally show gregarious habits.
69 For once I did not follow the King James Bible but the 2004 edition of the Dutch Bible translation published by the Catholic Bible Foundation ('s-Hertogenbosch).
70 The indicated passage itself does not contain the word locust, which appears in Joel 2:25.
71 Evans (1987) p 64/5: Around Rome, at the end of the 9th century '*Peasants gathered and destroyed them by millions*'. '*Finally Pope Stephen VI prepared great quantities of holy water and had the whole country sprinkled with it, whereupon the locusts immediately disappeared*.' France (Evans, 1987). The Netherlands, especially the province of Friesland (Steenstra, 1843, p 1.232), Hungary and Upper-Germany, 1542 (Dioscorides & Laguna, 1566, p 150). Mesopotamia (Bodenheimer, 1960).
72 Livy = Titus Livius: Vol. 14. '*Julius obsequens*'. 125 BCE. Consulship of Marcus Plautius and Marcus Fulvius.
73 Pausanias (G: Παυσανίας) was a Greek traveller from the 2nd century CE.
74 Edessa is present Şanliurfa in E Turkey, near the Syrian border, between the rivers Euphrates and its tributary Güllab. From Edessa to the Mediterranean is a stretch of over 300 km. Edessa was not a poor city.
75 Anonymus (1864), Garnsey (1988) p 3 ff.
76 Manual collection of insects or their larvae used to be common. As a primary school child I collected larvae of the Colorado beetle and I received 10 Dutch cents per marmalade jar, quite a sum for a small boy about 1940.
77 The preparation of *garum* is described in [GE-20.46]. It is a sauce obtained by autolysis of certain fishes (more recently fish refuse) conserved with salt, and served with oil or vinegar. This pickle, much appreciated in antiquity, is still in use as a condiment.
78 See Box 8.2.
79 Stadler (1920) p 1587: 26.22.
80 Similarly [IA-1.595], [AG-159].
81 Buisman (1995) p 219; Leguay (2005) p 51.
82 Only the seraphs, the highest rank of angels, were said to have six wings.
83 Steenstra (1843) 1.232.
84 Box 8.1.
85 Bodenheimer (1929) p 31. The source area of the locusts was thought to be 'Tartary'. The 'War on Locusts' was conceived as defending Europe against invasion by Asiatics, Tartars, or Huns. This language refers to the disastrous invasion of Europe by the Huns in the 5th century CE.
86 Megenberg (2003) IIIF16 '*Von den haeschrechen. Der war gar vil pey chayser Ludweiges zeiten vnd taten grozzen chaden, als ich in dem andern stuck dez puochs geschrben han von dem geschopften stern*'.
87 Leraut (2003) pp 74 & 78. Montemayor (1996) p 262.
88 Bodenheimer (1928) p 226.

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89 Mishna, chapters *Peah* (Gleanings) 2.7 and 4.11, *Maaseroth* (Tithes) 5.7 (Danby, 1972). The rules about use of grain from ant holes were made explicit by Maimonides (Klein, 1979 p 63,197).
90 *Maaseroth* 5.7.
91 The Mediterranean harvester ant *Messor barbarus* L. makes nests down to 2 m deep that contain 50 to 200 grain stores, Leraut (2003) p 256.
92 In modern Israel the most frequent species is *Messor semirufus* (Freedman *et al.*, 2000). *Atta barbata* and *A. structor* are mentioned as 'Bible animals', France (1986) p 12.
93 Imms (1964) p 725.
94 Latex from Cyrene probably refers to the gum of a *Ferula* species from Cyrenaica, in the 10th century CE already extinct by over-exploitation. This biological, if ever used for the present purpose, would have been extremely expensive since the substance was in high demand as a condiment and medicine.
95 [G-13.10.5]. Same recipe in Megenberg (2003) III.F.13 *Von der amaizzen – Formica haizt ein ameizz. Wer daz chraut [= orchraut = Origanum] nimt vnd puluert ez mit dem schwebel vnd legt das puluer auf ainen amaizz hauffen, so vliehent si zehant vnd lazzend ir wonung, vnd in eygendem mon hoernt zi all zei auf zu arbeiten*.
96 [GE-13.10.4]. Styrax is a resin, probably from the levantine styrax, maybe from (official) storax. In the Geoponika area it must have been readily available.
97 Info S. Savary.
98 According to Meana *et al.* (1998) still common practice in Spain though purslane is used in stead of fig.
99 Personal observations i.a. Algeria (1980) and Turkey (2011).
100 Bodenheimer (1928) p 46; Lewysohn (1858) p 329.
101 Guet (1995) p 136.
102 The worms are the larva of the very damaging granary weevil. This story, which dates from the 12th century or before, was edited by Bin Gorion (1917) p 59/60.
103 Wehnelt (1935).
104 Ali: (2001) Qur'ān, surāh Joseph 12.47, but not in Genesis 41: 47/49.
105 Krauss (1911) p 193. Mealworm, European grain moth.
106 [CO-2.20.6]: *frumenta … sunt expolitiora* was wrongly translated by 'the grain should be threshed again' where the author meant 'polished', that is cleansed.
107 As in [GE-2.25.4], [CR-3.1], [IA-2.319, 322].
108 The Latin word *sirus* lead to the modern word 'silo' for grain store.
109 [CO-1.6.17], [NH-18.73.301/2].
110 Bakels (2009) p 48 described grain storage pits from about 5000 BCE.
111 In western Europe they had to be convicted by an ecclesiastical court (Bodenheimer, 1928; Evans, 1987).
112 *Galbanum* is the gum of an umbelliferous plant from Syria, probably a *Ferula* spp., used for incense. The literature expresses a general feeling that a stench, abhorrent to people, is also abhorrent to the animals to be chased.
113 Identification by Bodenheimer (1928) p 185. This snout weevil is a leaf roller, rolling leaves together to make a chamber for its eggs and young larvae. The rolled leaves look like a cigar, hanging on the tree, hence the name cigar maker, NL: *berkesigarenmaker* and F: *cigarier*. D: *Rebenstecher* refers to the twig boring habit.
114 [CA- 95]: *'To keep caterpillars off the vines: Strain stored amurca and pour 2 congii into a copper vessel; heat over a gentle fire, stirring constantly with a stick until it reaches the consistency of honey. Take one-third sextarius of bitumen, and one-fourth sextarius of sulphur, pulverize each in a mortar separately, and add in very small quantities to the warm amurca, at the same time stirring with a stick, and let it boil again in the open … When it reaches the consistency of glue let it cool. Apply this around the trunk and under the branches, and caterpillars will not appear*'.
115 Quotation after Dalby (2011) p 250; Meana *et al.* (1998) p 411 use the word soap instead of ash.
116 [CP-5.10.2], [HP-4.14.10], [IA-1.566].
117 Bodenheimer (1928) p 72.
118 *Vespa crabro* L. Another candidate is the Oriental Hornet (*Vespa orientalis* L.), which is slightly larger than *V. crabro*.
119 [NH-15.18.67].

120 Abū 'l-Khayr in Carabaza (1991) p 244.
121 In Israel, in the north Jordan valley, I saw banana bunches covered in paper, mainly to protect them against low night temperatures. In modern times protecting fruits in plastic bags is not unusual.
122 [HP-3.1.1], [CP-2.17.1].
123 The scarlet dye is made from the dead bodies of the females of the Kermes scale insect.
124 Anonymous (2012) p 12; Graber & Suter (1991) 13. Recently, slugs have become a great problem in some areas possibly due to the use of relay crops and of conservation tillage (info: S. Savary).
125 Touring Sicily in May 2009 I saw large amounts of snails on grasses, sometimes hundreds per m^2. The most probable candidate is the Mediterranean (coastal) snail.
126 One of the snails that may damage grapevine buds is the Burgundy snail (Graber & Suter (1991) p 29), depicted in some illuminations and reproduced in Anonymus (2012) p 21.
127 Löw (1881) p157. *'Ein Feld, das voll Dornen ist, taugt zu Weizen, eines voll Unkraut, zu Gerste'. Syrische Bauernregel: 'Im šibrik (Dorn-)-Boden glänzt das Gold.', d.h. es ist vorzügliches Ackerland.*
128 'Mildew' feeding on the wheat stem, a good description of black stem rust, that indeed typically feeds on the wheat stalk. 'Mildew' is an old English word for black stem rust (Zadoks, 2008 Ch 1).
129 Long (1979) speculated that weediness was a major cause of medieval yield decline in wheat.
130 Astill & Langdon (1997) p 255. The yields dropped from four to twice the seed. The reason remains obscure, maybe socio-economic change leading to neglect or climatic change, or both. A weedy wheat crop may retain moisture and so stimulate the appearance of 'mildew', an old world for black stem rust.
131 Payne & Herrtage (1878) p 112 #10.
132 Payne & Herrtage (1878) p 112 #11. Cockle = weed in general, later gith or corn-pink, also darnel.
133 Comet (1992) p 169. Latin names in same order *Cirsium arvense*, *Avena sterilis*, *Sinapis arvensis*, *Thlaspi arvense*, *Lolium temulentum*, *Tussilago farfara*, *Convolvulus arvensis*.
134 Jordan (1996) p 28. Broom = *Cytisus laburnum*, furze = *Ulex europaeus*.
135 [DH-1.9.27]. Thistle (e.g. *Carduus pycnocephalus* L., *Centaurea pullata* (L.) Cass., mallow (e.g *Althaea hirsuta* L.), chicory (*Cichoria intybus* L.).
136 Skeat (1882) p 30.
137 These effects of darnel are ascribed to the products of two endophytic fungi, *Alternaria loliitemulenti* Agostini and *Loliomyces temulentus* Maire (Kislev, 1980).
138 Löw (1881). #133. Lolium spec. L.. "*Nach Maimonides ist es eine geringe Weizenart, welche wegen ihrer Verwandlung in der Erde zônîn, die Treulose, genannt wird….*". Maimonides was a Jewish physician and theologian who lived in the 12th century.
139 Dioscorides & de Laguna (1566) p 187/8.
140 White (1975) p 238. Bracken and fern were used as bedding in sheep pens.
141 Dalby (2011) p 108 translates as lye, a strong alkaline solution made from vegetable ashes or minerals. See under 'konion' in § 6.2.
142 Balss (1947) p 106. Megenberg (2003) IVA15
143 Payne & Herrtage (1878) p 89 #14.
144 Illustrations in Webster (1970). Thistle cutting, Webster modestly writes 'weeding', as a representation of June was not infrequent but certainly not dominant. Once it stood for July, as the symbols of the months were not completely fixed.
145 Skeat (1882) p 29. '*The thistle is a bad weed, rough and sharp to handle, and eats away the corn near it, and causes the cutters or reapers not to work cleanly*'.
146 Mane (2006) p 150 *820. In the Fleta weed control in continuous wheat cropping is valued at 1.3 % of the production costs. Richardson & Sayles (1955) p 256.
147 Skeat (1882) p 31.
148 Oschinsky (1971) p 323, c 52.
149 Fleta, book 2, chapter 81. *Of the autumn season*. Richardson & Sayles (1955) p 256.
150 The word ὀροβάγχη is used for both European dodder and crenate broomrape; identification should be done according to context. Crenate broomrape parasitizes leguminous plants.
151 Beck (2005) p 152 # 2.142. 'οροβάγχη (chokefitch = crenate broomrape). Confusingly, the name means vetch-strangler from G: ὄροβός = orobos = bitter vetch, and G: ἄγχω = angoo = to strangle.
152 Dioscorides & de Laguna (1566) p 225.
153 [NH-18.44.155]. This *orobanche* is not *Orobanche* (= broomrape), but either dodder or bindweed.

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154 Löw (1881) p 230/1. For date wine see Newman (1932) p 23: people were relatively healthy due to drinking beer flavoured with *Cuscuta* fruits.
155 Oak mistletoe also on silver-fir and pine, European mistletoe on kermes-oak and other trees [CP-2.17] [HP-3.1.1]. In present-day north western Europe, the European mistletoe occurs mainly on poplar and apple trees.
156 Balss (1947) p 105.
157 Jones & Aldwinckle, 1990; Ogawa *et al.*, 1995; Whiteside *et al.*, 1989.
158 [GE-5.39.1], [IA-1.557].
159 Pearson & Goheen (1988) p 48; info S. Savary.
160 The headings were given by the translator. Theophrastus did not use headings.
161 'He-goat' is apparently a symptom of the vine looking like the horns of male goats. In [HP-4.14.6] the symptom appears when the shoots are struck by winds, when the vine has been hurt during cultivation, or when the vine is pruned so that the cut faces up.
162 Similar statements in [HP-2.2.11], [CP-1.17.10], [CP-2.14.1], [NH-7.253].
163 Newman (1932) p 82; period 200-500 CE.
164 Supposedly, the furrow's top will be the level of the ridge; the crop will then have a height of 10-15 cm [NH-18.45.161]. Pliny reiterates the recommendation, stating that repeated grazing does not injure the ear --- I doubt.
165 Lindemans (1952) 353. In medieval Belgium spring grazing of corn by sheep was permitted, but damage by sheep and more so by pigs was feared.
166 The extensive literature on ergot cannot be cited here. The most important historical study on ergot is by Barger (1931). See also Zadoks (2008) pp 150-170.
167 The 'Annals of Xanten'. Xanten is a German town on the river Rhine, some 50 km east of the German-Dutch border. Quoted from Barger (1931) p 43.
168 Barger (1931 p 45) mapped the outbreaks in France. Their frequency diminished considerably, the region of Sologne excepted, but even in the 20th century a few localised outbreaks are on record.
169 Pearson & Goheen (1988) p 34.
170 Suggestions S. Savary. Pearson & Goheen (1988) p 17, 27.
171 [IA-1.558]. The symptom description points to *Botrytis* bunch rot, common in grapes. Note that powdery and downy mildew appeared in Europe only in the 19th century. An alternative suggested by S. Savary may be black rot caused by *Guignardia bidwellii* (Peason & Goheen (1988) p15).
172 Dioscorides & de Laguna (1566) p 261.
173 Meana (1998) p375 *92.
174 [CP-5.9.12], [HP-4.14.5], [NH-17.225], [GE-10. 50].
175 Bodenheimer (1928) p 72.
176 Zadoks (2007); (2008) Ch 1.
177 [CP-3.24.4], [HP-8.10.2]. Zadoks (2008) Ch 1.
178 I: *nebia* (old), *nebbia* (modern). The French equivalent *nielle* is often used for 'ear-cockle', caused by the seed-gall nematode *Anguina tritici* (Chitwood, 1935), a disease stimulated by wetness indeed but now practically extinct in Europe. Other candidates are fungal diseases including black stem rust (*Puccinia graminis*), loose smut (*Ustilago tritici*), glume blotch (*Stagonospora* (*Septoria*) *nodorum*), or one of several sooty head molds (Wiese, 1987).
179 Black stem rust and *Septoria* glume blotch are the main candidates. To control black stem rust cord drawing is recommended by Heuzé (1872). His illustration is reproduced in Zadoks & Bouwman (1985) p 332. Other candidates are loose smut and black (or sooty) head molds.
180 Lucretius (1st century BCE) '*De rerum natura*' 5.213/7.
181 Grand (1950) p 317.
182 In the north Jordan valley of Israel banana bunches used to be covered with paper bags to avoid damage by low night temperature (not necessarily frost). Plastic bags to protect banana bunches are in wide-spread use.
183 Braudel (1996) p 226.
184 [GE-5.32.2], [IA-1.563].
185 [CR-4.18], [AG-200].
186 Citrus orchards in Texas are protected against nightly cold by burning old tyres, as seen during a 'northern' in 1974. The heat causes turbulence which mixes lower colder with higher and warmer air.

187 Braudel (1966) p 224.
188 Guet (1995) shows a diagram with the safety zone for grain storage in organic agriculture, roughly a temperature <19° C and a water content ≤ 12 per cent.
189 The drier the grain the better the keeping quality in storage. Agustín's advice (§ 3.7.2) seems to be in conflict with the Geoponika's opinion.
190 Steenstra (1843) p 2.108, Winsemius (1622) f 158.
191 Braudel (1966) p 543.
192 The Dog Days refer to the hottest period of the Mediterranean summer, around 1 August, traditionally considered a time of evil.
193 Zadoks (2008) p 92.

Chapter 5

1 Dark & Gent (2001).
2 Orlob (1973) p 85. For ancient history of black stem rust, *Puccinia graminis*, on wheat in the Mediterranean area see Zadoks (2007, 2008 Ch 1).
3 E.g. Braun (1965), Dugan (2008), Orlob (1971).
4 Millás Vallicrosa (1943) p 290. In fact, he published a copy of the original translation.
5 During World War II I was engaged in 'organic' agriculture, not by choice but by necessity, since artificial fertilizers and crop protection chemicals were not available.
6 [NH-19.58], [OS-6.27.661].
7 [IA-2.449]. 'Lion's weed' (F: *herbe de lion*, A: *hashīsat al assad*) was wrongly translated as *Orobanche*, according to Hämeen (2006) p 309, it should be dodder (Text 50 NA 274-275).
8 Kieckhefer (2000) p 162.
9 The term 'homeopathy' is an anachronism. Homeopathy as a medical approach was developed by the German physician Samuel Hahnemann as of 1795. The motto was 'like cures like' (Latin: *similia similibus curentur*). Among the remedies were 'nosodes', made from diseased products such as faecal discharges and vomits.
10 Albertus Magnus was such a great name that, in the later Middle Ages, it was used to lure buyers of so-called Pseudo-Albertine works. One such book was 'The booke of secretes of Albertus Magnus of the virtues of herbes, stones and certayne beastes', a. http://www.farlang.com/gemstones/agnus-virtue-stones.
11 Dalby (2011) – 'folded', Meana (1198) - 'lost'.
12 Today, the use of various decoctions and ashes, often highly diluted, is advocated in biodanymic agriculture (info MF).
13 [GE-10.83.1/2], [IA-1.517]. Abū 'l-<u>Kh</u>ayr († ~1200) p 240 calls it a ruse.
14 Abū 'l-<u>Kh</u>ayr a famous predecessor of Ibn al-ʿAwwām. http://www.filaha.org/author_khayr.html.
15 Meana (1998) p 382/3 *138 stresses the formal aspect: a dialogue between two persons, and the spiritual point, trees were often considered to be holy so that they could not be cut down without ado. The parable contains the agronomical point of digging around the tree and adding dung (§ 5.6.2) and another, probably fantasticated point, an antipathy of fig against grapevine; is there also an antipathy in reverse? (§ 5.3.6).
16 Excommunication of a person by a community is only possible when the person belongs to that community; insects do not belong to the Church community and cannot be excommunicated, as several laywers argued. Anathema, the religious curse, is the better choice. Some courts were mild and granted the animals some time to withdraw before action would be taken, often with good result.
17 Bodenheimer (1928) p 234.
18 Zadoks (2008) Ch 1.
19 Compare Palti (1981).
20 The German term is quite telling, *Standortgerechter Anbau* (cultivation appropriate for the location).
21 Also [IA-1.338/9]. --- A marsh was thought to produce a *miasma*, a 'bad air', *mal-aria*, that caused sickness among men and crops. The idea, already expressed by Hippocrates (c.400 BCE), was developed in the 18th century into the 'miasmatic theory' on the origin of disease, and inspired early attempts on public hygiene in the 19th century. Note that the text can be read as a suggestion to reclaim the marshes. In the 20th century malaria was successfully controlled near Rome by draining and reclaiming the Pontine Marshes.

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22 'The' grape rust originated in East Asia (Japan?) and occurs widely in East Asia and the Americas, but not in the Mediterranean area. For brown to red flecks there are many causal agents, the grey mould being the number one candidate (Pearson & Goheen, 1988).
23 Grapevines are lianas climbing the trees that support them; low temperature and fog at ground level will not harm their foliage or bunches higher up in the trees.
24 [CP 8.10.2], [HP 3.24.4], [NH-18.154].
25 Meana (1998) - 'does not stand'; Dalby (2011) p 110 - 'does not demand'.
26 [GE-2.14.8], [IA-2.34].
27 [PA-3.9.11], [GE-5.16], [CR-4.18], [IA-1.331], [DH-2.5.56], [OS-5.3.138].
28 *Capitulare de villis* #70.
29 So called HEIA, High External Input Agriculture (Zadoks, 1992), somehow the opposite of LEISA.
30 A four-pronged iron hoe from c.300 BCE can be seen in the Archeological Museum of Gela on Sicily (Italy).
31 This is common practice in developing countries. When in Mali, around 1980, a peasant farmer explained to me in detail how he selected appropriate ears of millet to preserve next year's seed.
32 Hämeen-Anttila (2006) p 64.
33 Hämeen-Anttila (2006) p 259, NA1061/5.
34 The typical V-sign formed by forefinger and middle finger, usually made with the palm of the hand toward the signalling person, is now known as the 'victory sign'. In the Mediterranean area (southern Italy in particular) the V-sign, usually made with the back of the hand toward the signalling person, was for centuries used to avert the 'evil eye', an apotropaic gesture.
35 Hämeen-Anttila (2006) p 310.
36 Hämeen-Anttila (2006) p 346.
37 Bithynia (G: Βιθυνία) is an area in the north western corner of Asia Minor, nor far from Byzantium. One may wonder whether an experience from Bithynia is an editor's addition to Cassianus Bassus' original text.
38 Pliny [NH-17.5.49] made an interesting observation. Some farmers burn stable dung to get the ash, obviously a costly type of ash. When sprinkled over the young grapes it would help their growth. This fine, probably rather alkaline ash may have protected the grapes against fungi (and insects?). In Narbonne (southern France) the ash would do better than sunshine to produce vintage grapes. The Mishna 2.4 recommends to protect saplings with ashes (Danby, 1933).
39 The 'saltiness' of the ashes might prevent the formation of damaging ice cristals (info MF).
40 Meana (1998) 'straw', Dalby (2011) p 129 'pods', elsewhere 'shucks'.
41 Heat conductivity in compacted soil is greater than in loose soil. This was dramatically illustrated in the Netherlands when a field was planted with potatoes, one half of the field ploughed in the autumn and the other half in the spring. After a severe night frost the crop in the spring-ploughed part was dead, but the crop in the autumn-ploughed part remained undamaged because the soil hat settled.
42 Cicero in '*De senectute*' 14.51, see Falconer (1971) p 63.
43 Campbell (1983) p 31: 6-8 bushel/acre, seed ratio c.1:2.8, yield c.13.2 bushel/acre = c.500 kg.ha^{-1}.
44 Payne & Herrtage (1878) p 89 #14.
45 White (1970) p 121ff.
46 Bolens (1947) p 124ff.
47 When farm mechanisation brought the raised bed system to an end, common windgrass became a problem on the loamy soils: Lindemans (1952) p146.
48 Lindemans (1952) p 43. One may think of common chickweed, sheep's sorrrel, and field horsetail.
49 Mane & Wilmart (2011).
50 Montemayor (1996) p 265; most probably the Moroccan grasshopper.
51 Pigeon manure [GE-2.21.5], human manure [GE-2.21.6]. Human food and excrements contain few living weed seeds. The term 'eliminates' seems to be ill-chosen, 'avoids' may be meant. Human manure may recycle human pathogens, a fact unknown at the time. The suggestion is given that human manure was dried before use.
52 [XE-16.14/15]. 'Baking the soil' was an essential element in pre-modern Mediterranean agriculture contributing to soil structure and possibly soil mineralisation (§ 3.5/6) and disinfection.
53 [GE-2.24.1/3]. The first statement suggests mechanical weeding, turning over by hoe, not hand-weeding. Harrowing and hoeing loosen the soil indeed, more than uprooting or pulling the weeds, but the harrow is not mentioned in the Geoponika.

54 Apart from spiny rush other wetland plants may be meant such as soft rush and club-rush. The mention of the flowering rush is curious as it grows in water rather than on wetlands.
55 Growth stage 1.4 or 2.4, Zadoks *et al.* (1974).
56 Beginning to ear, growth stage about 4.9 (Zadoks *et al.*, 1974); obviously, the ears should not be damaged.
57 After World War II, East Germany, lacking a pesticide industry and without money to buy pesticides on the international market, grew varietal mixtures of barley to avoid high incidence o foliar diseases, primarily barley mildew (Zimmermann, 1982).
58 Campbell (1983) p 38.
59 At least in England. Millar (1932) Plate 96 (f 176). Man and woman are weeding corn with crotches and hooks. The man wears heavy brown gloves.
60 Lindemans (1952) p 41, 352. Durng and after World War II relay cropping, of rye followed by turnip (not undersown), was common on the high sandy soils in the Netherlands.
61 For olive-wheat cobination see White (1970) photos 10, 11.
62 Info Ms P. Mane and Enciclopedia italiana (www.Treccani.it). In several areas of Italy the mixed cropping has been modernized, being replaced by a single crop of grapevine, with European Union subsidy.
63 The tropical system of shade trees, there protecting coffee and cocoa trees against too strong an insolation, may also have existed in the Mediterranean area but I did not see explicit references to it.
64 A wealth of literature exists on mixed cropping and its many merits: Anderson (1952), Finck *et al.* (2000), Innis (1997), Vandermeer (1989), Wolfe (1985), Zadoks & Schein (1979), author's observations in the tropics.
65 Anderson (1952 p 139) provided a nice illustration of mixed gardening from Guatemala. In the Sahel (1984, 1988), I saw several food gardens, usually a mix of unimproved sorghum (3-4 m tall) and cowpea. At AVRDC (Taiwan, 1988) I visited several small tropical food gardens of 4x4 m^2 with crop mixtures in both horizontal and vertical directions specially designed the feed a family year-round.
66 Also Deuteronomy 22.9.
67 Klein (1979) p xxv. The details of the prohibition, elaborated in the Mishna, were arranged systematically by Maimonides. The prohibition applies only to food crops within classical Israel. Klein (1979) p 5: '*He who sows two species of seeds together in the Land of Israel is liable to a flogging*, …' (thus, barley-wheat mixture is forfeit); '…. *One is forbidden to retain diverse kinds of seeds in his field, and he must uproot them. But if he does retain them, he is not liable to a flogging*.' (encouragement to weed?). Neusner (2005) p 115 on Kilaim: '*The tractate concerns the Scriptural prohibitions against commingling different kinds of plants, animals and fibers*.' (Lev. 19:19, Dt. 22:9-11). Do not mix what the creation separated. The comment does not refer to botanical taxons but the visible aspect (p 367).
68 Blöte Obbes (1946) 130 ff.
69 For documentation see e.g. ICRISAT-reports. In Sahelian Africa modern sorghum-peanut combination row plantings were recommended in the 1980s.
70 C.T. de Wit (1960) and many other studies.
71 In northern France and southern Netherlands no trace of maslins was found from the 6th to the 12th century (Bakels, 2005, p 107).
72 Astill & Langdon (1997) p 268.
73 Payne & Herrtage (1878) p 39 #12. The word 'mestlen' is used p 90 #21.
74 Tozetti (1767) p 24.
75 [CR-3.17] in the 1511 edition.
76 [DH-1.22.41, 42].
77 [DH-1.10.31]. Having done both, using sheaf tie bands of rye for rye and of wheat for wheat, I agree fully.
78 The original writes θηρίος = animal. I follow Dalby (2011) p 249 with 'flea beetle'; Meana (1998) translates as 'flea'; flea beetles are often found on crucifers.
79 [HP-7.5.4], [NH-19.179], [PA-1.35.16], [GE-12.7.1], [IA-2.139], [AG-158]. Theophrastus, Pliny, Palladius, Geoponica, Ibn al-ʿAwwām, Agustín, a nice line of descent.
80 Millás Vallicrosa & ʿAzīmān (1955) p 142, 154.

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81 [DH-4.7.216]. S: *yerba buena*, *yerba Santa*, or *yerba del huerto*, that is good, holy or garden herb, refers to mint. No garden could do without. The herb was primarily used in medicine but also in crop protection.
82 To provide shade and a humid microclimate.
83 Dalby - 'caustic soda'; Meana (1998) - 'soap'. Probably a strongly alkaline extract of plant ash is meant.
84 Mane (2006) p 189, with illustrations.
85 [GE-4.1.12], [IA-1.335].
86 Conform White (1970). In southern Spain, during the 1950s, I saw many olive groves inter-sown with wheat.
87 Possibly Bolos Demokritos of Mendes (Egypt), Alexandria, c.200 BCE, who is considered to be an originator of paradoxographical literature (Wellmann, 1921). He was a physician and scientist who wrote several books including one on agriculture.
88 [NH-17.239/40]; see also § 4.5.1- ivy. I found no confirmation for the destructive character of tree medick.
89 [GE-12.17.21], [IA-2.159].
90 Crescentio may have taken the hazel-vine antipathy from Virgil [VE-2.298].
91 [CP-1.2.7.4].
92 [IA-1.518, 1.527, 1.542]. The statement contradicts Theophrastus [CP-3.10.6] '*The worst neighbours not only for the vine but for the rest are fig and olive, since they both take a great amount of food and cast a very large shade*.' Such contradictions between authors are not infrequent.
93 [IA-1.275, 1.520]; [IA-1.300].
94 The walnut tree produces an allelopathic substance, juglone, in roots, leaves, and fruits. Juglone has herbicidal and insecticidal properties. Some plant species are tolerant such as beech and wheat.
95 [GE-13.9.9], [IA-1.255,1.327].
96 Willis (1985) p 75. De Vries & Goudsblom (2002) p 246: Romans preferred light soils. Decline of yields is attributed, at least in part, to exhaustion of the soil.
97 France - Grand (1950) p 321. S England - Dury (1984). Netherlands – van Hoof *et al.* (2006).
98 Replant disease is a ubiquitous problem when apple orchards have to be renewed (e.g. Rumberger *e.a.*, 2007).
99 E.g. Orlob (1973) p 96. Hsi Han describes the commercialisation of predatory ants for biocontrol in orange groves in his 'Records of the plants and trees of the Southern Regions", 340 CE. The practice is said to be much older.
100 Klijn (1979) p 19. Info MF.
101 Newman (1932) p 130.
102 Dioscorides & de Laguna (1566 M) p 161.
103 Possibly *Microtus arvalis.* Grzimek XI p 374: Similar decrees in 1623, 1635, and 1648. Vole hunters are foxes, weasels, and polecats; among the birds white stork, grey heron, owls, common kestrel, and carrion crow.
104 Trap crops and trap plants are still in use in many countries to trap pest insects and to protect crops. One example is the use of bean plants to trap whitefly for the protection of tomatoes, seen in Nicaragua, 1992.
105 Bitter vetch [GE-12.7.1], garden rocket [GE-12.7.2], [AG-158], chickpea [DH-4.7.217].
106 Mouse traps - Roth (1956); vole traps - Van der Poel (1977/8).
107 [NH-17.47.264], from Cato [CA-95].
108 Bolens (1981) p 211.
109 Bodenheimer (1928) p 185.
110 Male calf [DH-4.7.217], elsewehere a ram [DH-2.15.74], probably quoted from Ibn Wāfid.
111 Anonymus (2012) p 12.
112 Hand picking [DH-2.15.75], other data [DH-4.7.217], bags in appendix to [2.15] *1 on p 376, addition from the 1528 Edition. According to what the farmers tell (*Según dicen los agricultores*).
113 The description reminds one of the hazel leafroller (*Byctiscus betulae* L.), a snout weevil.
114 Livy Vol 12, book XLII x 7.
115 Up to 1000 egg masses per m^2 can be found. If each egg mass measures 1 cm^3, we get ten thousand litres per hectare, a kind of upper limit. A hundred hectares of severely infested soil could produce up to a million litres of egg mass. Thus the amount of 2.4 million litres is not an impossibility.

116 Kitchell & Resnick (1999) p 1750 (§ 26.17), Stadler (1920) Vol. 16, p 1587: 26.22.

117 Dozy & Pellat (1961) p 62. The 'Calendar of Cordova' is a ritual calendar with a few remarks on agriculture.

118 Montemayor (1996) p 265. A Moroccan grasshopper measures about 2 cm in length.

119 Billiard (1928) p 111.

120 [GE-2.18, 12.7.3/4], [DH-4.5.216].

121 [DH-1.18.38]. The recommendation to sow when the moon is full is unusual (§ 3.5.4); the usual advice is to sow at waxing moon.

122 In Pliny's time already the real *Silphium* was practically eradicated, hence Dalby (2011) p 94 wrote 'fig sap'. Oil - [NH-18.73], [GE-2.37.1]. Cow dung - [GE-2.37.1].

123 The tortoise shell could prevent soil-borne organisms from attacking the plantlets.

124 It is said that garlic and olive oil work as mild disinfectants (Info MF).

125 Van der Groen (1670) p 12 gave a similar recommendation, advising the use of cow hair.

126 Pigeon and pig manure - [NH-17.47.259], cow dung - [GE-10.18.10]. In the Netherlands, and probably elsewhere, wounds of fruit trees used to be treated with fresh cow dung, well into the 19th century.

127 [DH-2.15.74, 75].

128 [OS-6.27.661]. Caterpillars of the goat moth tunnel in the wood, live there for at least two years and pupate in the tunnels. Excrements are ejected and found at the foot of the tree. They produce a bad goat-like smell. The damage can be considerable, especially in older trees.

129 [NH-15.18.67], [GE-4.10], [AG-203]. Agustín (p 203) offers some more ideas to protect grapes from wasps, such as spraying the sap of wild malva, artemisia boiled in goat milk, or pigeon manure mixed in olive oil.

130 The term repellent is used here in a general sense since the details of the relations between the chemical substances involved and the ensuing animal behaviour are not known (Dethier *et al.*, 1960).

131 Dalby (2011) p 234 - lead oxide; Meana (1998) p 360 - ochre from Lemnos.

132 The 'how' is not clear. Some texts suggest powdering dust by hand. Theophrastus says 'by raking' [HP-2.7.5]. Later texts usually suggest stirring up the dust by hoeing , L: *pulveratio*.

133 [CO-11.2.60, de arboribus 12.1].

134 Pliny is ambiguous with his fruits and roots, possibly meaning both. '*Some are of the opinion that dust helps the growth of grapes, and they sprinkle it on the fruit when it is forming and scatter it on the roots of the vines and the trees [on which the vines are trained]. It is certainly the case that in the Province of Narbonne a wind from west-north-west ripens vintage grapes, and in that district dust contributes more than sunshine*' [NH-17.5.49].

135 [IW-(43)323]. He states the same for olives in August [IW-(44)324]. Repeated in [IA-II.429].

136 Ebeling (1971).

137 [GE-13.10.5], [DH-4.7.216].

138 Compare today's natural herb mosquito coil that can protect an entire room up to eight hours.

139 Trees [GE-12.8.1], [IA-1.591/2], cabbage [IA-1.593].

140 Ilias 21.12. Homer's poetical metaphors are always rooted in reality. An example is his frequent 'sunset in a wine-red sea'. Indeed, I saw such a wine-red sea at sunset, unimaginable in western Europe, on the west coast of Greece. Thus I am inclined to take the metaphor of the locusts literally. Translation Murray & Wyatt (1999). Passage quoted by Bodenheimer (1928).

141 [XE-18.2], [VE-1.84]. White (1970) p 141,184.

142 Hardison (1976).

143 Ibn al-ʿAwwām frequently recommended scarification as e.g. [IA-1.547;1.571].

144 The practice was continued at least up to the 1950s (Levadoux , 1966, p 11). In a recent (October, 2012) television film on organic wine production the practice was shown.

145 [GE-10.50]. See also § 4.7 under Rugosity.

146 The French term is *déchaussement*.

147 [IA-1.534, 1.535, 1.543, 1.551].

148 [GE-5.41.2], [IA-1.558].

149 Meana *et al.* (1998) comment that *Faba* bean straw is a favourite in the Geoponika, mentioned ten times.

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150 Millás Vallicrosa (1955) p 221. The public baths had a hot-water section heated by wood fires. Hence the term 'ashes from the baths'. The ashes probably contained many pieces of charred wood that could improve soil quality. Ash is alkaline and when wet it may kill vermin (and also seedlings?).
151 Ibn Baṣṣāl (1955) p 99.
152 The Maghreb is the western part of North Africa, including Morocco. It was inhabited by Berber tribes.
153 Buekers (1915).
154 Recipes contain *Aconitum* spp (i.a. *A. vulparia* Reichenb.), *Adiantum capillus-veneris* L., *Atropa belladonna* L., *Datura stramonium* L., *Euphorbia* spp (i.a. *E. esula* L., *E. cyparissias* L., *E. helioscopia* L., *E. seguieriana* Neck.). *Hyoscyamus niger* L., *Osmunda regalis* L., *Sempervivum tectorum* L., *Solanum nigrum* L., and *Verbena officinalis* L. (Blöte-Obbes, 1946 p 9). Which plant contributes what to the hallucinations was not specified.
155 [HP-7.15.2]: '*Such pecularities are common in other plants also; thus it is in the nature of the house-leek to remain always moist and green, its leaf being fleshy smooth and oblong. It grows on flat shores, on the earthy tops of walls, and especially on tiled roofs, when there is on them a sandy accumulation of earth*.'
156 Dioscorides wrote in Greek 'Περί ὑλης ἰατρικης', 'On medical matters' (L: *De materia medica*). The oldest version available is the Vienna Codex (510 CE) with about 600 plant descriptions, with their medical uses, and 383 plant drawings. With the advent of printing the book has been re-edited and amended countless times.

Chapter 6

1 Ibn Khaldūn (1377) in The muquddimah, Translation Rosenthal (1958) p 2.357.
2 Alum (L: *alumen*), a K-Al-sulphate, was found on Sicily. In the Middle Ages alum was used to conserve timber of the truss supporting palace roofs, a perfect protection against insects effective up to this very day. Wikisource: Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle – Tome 2, lemma Bois.
3 [VE-3.414], [NH-12.56.126], [GE-13.9.3].
4 [CO-4.26], [NH-17.47.261].The red earth of Cato [CA-128] to be used in wall plaster is surely no sandarach.
5 [GE-13.1.4], [AG-159].
6 Guiraud (1976) p 161.
7 Tillet (1755) p 25. In the 18th century it was found that brining of wheat seed controlled bunt (covered smut) due to *Tilletia caries* (DC.) Tul.
8 Shepherds protect trees with sheep dung to this day (info MF).
9 Theophrastus discussed dusting of the fruits at some length [CP-3.16.3, HP-2.7.5]. In translation the passages are not too clear. The translation of πέψις as 'concoction' does not make sense. My dictionary says i.a. 'further ripening', a better translation.
10 [CO-4.28.1], [NH-17.5.49].
11 [CO-*De arboribus* 12.1].
12 E.g. 'mealworms' of *Tenebrio* and *Tribolium* spp in stored grain; also Bruchidae (Coleoptera) in stored pulses.
13 [NH-15.67], [CO-12.44.4].
14 Billiard (1928) p 223. Authors from Theophrast to the Geoponika recommended dusting the grapes. [CP-3.16.3/4], [HP-2.7.5/6], [VE-2.418/9], [CO-11.2], [NH-17.49], [GE-3.11.1].
15 Kroonenberg (2011) p 205.
16 [GE-13.4.3], [AG-161].
17 Smith & Secoy (1976) p 1182.
18 Info MF.
19 Ebeling (1971).
20 Pascual *et al.* (2010). The Kaolin preparation was Surround ® WP, used to control the olive fly.
21 E.g. Buehlmann *et al.* (2012).
22 Pigeon manure is highly concentrated and, in powdered form, may be most effective in the garden. Dusting will be effective in grain storage. Pigeon manure was a valued product in antiquity. In the Netherlands pigeon manure was an important commodity until far into the 19th century, shipped over long distances.

23 Du Breuil (1861) p 327, as in 'Forsyth's unguent'.
24 [VE-1.193/5], [GE-2.18.12].
25 Pitch and bitumen, possibly interchangeable terms, were petroleum products known from the Near East, the Caspian Sea area, and Sicily.
26 After [NH-17.47.266].
27 Abū 'l-Khayr p 242.
28 [GE-5.36.2], [IA-1.571].
29 Bloksma (1987) p 202; Guet (1995) p 123.
30 Homer, Odyssee 22.481; another mention in Homer, Ilias 16.228.
31 [GE-5.49.2, 10.89.2], [IA-1.574].
32 The Geoponika repeatedly mentions that wild plants perform better than cultivated plants, e.g. garlic [GE-12.30.7].
33 Wink (1999) p 1.
34 Many of the plants listed below produce phytoalexins, molecules formed upon challenge in defence against fungal pathogens. These have not been mentioned since they are considered irrelevant in the present context.
35 Ramsay (1996) 6.592 and 6.595.
36 Deanesly (1960) p 147.
37 Riddle (1997) p 91 ff.
38 There is no evidence that potentiation was applied. Potentiation is the method in which a plant product is diluted with water by ten-folds, that is ten, hundred, .. million, or more times.
39 General sources for the sections *Botanical* are: Moldenke (1952), Krommenhoek (2008_, Megaloudy (2005), Polunin & Huxley (1967), Secoy & Smith (1983), Van der Meyden (1996), Vincent & Goettel (2007).
40 General sources for the sections *Historical* are: Veltman & Veltman (1974), Zeven & de Wet (1982), Zohary & Hopf (2000).
41 These quotes are usually limited to the Geoponika.
42 General sources for the sections *Comment* are: Bloksma (1987); Blöte-Obbes (1946); Copping (1996); Cutler (1988); Guet (1995); Godfrey (1995); Hanson (2007); Harborne *et al.* (1999); Rai & Mares (2003); Rimando & Duke (2006); Ross (2001/5); Van Genderen *et al.* (1996); Watson & Preedy (2008); Wink & van Wyk (2008).
43 E.g. Blumenthal *et al.* (2003); Mazza & Oomah (2000); Ross (2001/5); various web-sites.
44 Among the more informative non-commercial web sites are 'www.orgprints.org' (organic eprints), 'www.betriebsmittelliste.de' (Research Institute for Organic Agriculture), and 'www.icrofts.org/index.html' (International Centre for Research in Organic Food Systems). An official American website is 'www.ars-grin.gov/cgi-bin/duke/farmacy2.pl?1051'.
45 The hallucinating effect of witches' salve has been tested and confirmed several times.
46 To protect the grapes from hornets.
47 Bear's garlic (*Allium ursinum*) is strongly allelopathic, reducing seed germination (Block, 2010 p 304).
48 (Hartmans *et al.*, 1995); the commercial product, somewhat expensive, is called 'Talent'.
49 *Artemisia maritima* L. = *Seriphidium maritimum* (L.) Polj. has been used as a 'flea herb' by the farm women on the Dutch island of Terschelling, who put the fragrant branches in their wardrobes (personal information). *S. maritimum* was used as vermifuge (Hanson, 2007).
50 The word pesticide is, in fact, not correct. Fruit extracts are not insecticidal but insect repellent, antifeedant, and deter insects from oviposition. Regular applications are needed. Schmutterer (2002) describes anthelmithic, antibacterial, antiviral, insecticidal, miticidal. and molluscicidal effects.
51 For 1 kg of saffron containing ~150,000 dried stamens one needs ~75,000 flowers. Saffron is highly labour-intensive. Falsification was attractive but punished with the death penalty by the Roman Emperors (Blöte-Obbes, 1946) p 56.
52 For horses, to cure inflammation of the eye [GE-16.5.1].
53 Meana (1998) p 166 *86 refers to Columella and Palladius.
54 Tripathi *et al.* (1990).
55 Riddle (1997) p 53. G: ἐκβαλλώ = throw out, miscarry.
56 Dioscorides *et al.* (1934): '*And Elaterium also in a Pessum doth move ye menstrua & kill ye Embrya* …' (*pessum* refers to the rounded stone used in antiquity by way of pessarium).

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57 Here we follow Huxley (1992) 292/3.
58 Possibly *Ferula silphium* (Oersted) Thellung, a posthumous name?
59 Riddle (1997) p 44 ff.
60 The latex in the books may have been taken from fennel species but it is more probable that latex from spurges and (wild) figs was used.
61 Nine was the power number in witchcraft. Flying ointment (or witches' salve) should contain at least nine herbs (Teirlinck, 1930).
62 Both terms refer to the sediment of wine or oil, primarily. French uses the term *la lie*, Spanish has the word *alpechín*, obviously of Arabic origin. Note that in modern consumer terminology the first pressing produces the prime (I: *vergine*) quality, the second pressing a standard quality.
63 [CA -96], [VA-1.51].
64 Ross (2005) Vol. 3, p 373-388.
65 In western USA and Australia lupinosis occurs in cattle due to a mycotoxin from the fungus *Diaporthe toxica* (Williamson *et al.*, 1994).
66 [NH-17.47.266], [GE-13.10.7].
67 Lewis *et al.* (2003) p 494.
68 Wagstaff (2008) p 253.
69 Bruneton (1995) p 520.
70 Confusion may exist with δίκτα(μ)νον = *Origanum dictamnus* L. = dittany of Crete [GE-10.67.3], a perennial sub-shrub up to 0.6 m high.
71 [GE-2.29, 13.10.3, 13.10.5].
72 Ibn Wāfid, Ch 75, p (35)315. An alternative translation could be 'mulberry [fruit]'.
73 Dalby (2011) translates as burning green tamarisk and haematite in a censer.
74 [IA-1.46]: Sea squill grows in dry, arid terrain, in firm soils consisting of sand and gravel.
75 Theophrastus [HP-7.13.4]: Conserves the pomegranate fruit with its stalk inserted in the bulb. Pliny [NH-17.16.87] recommends to plant a fig-tree stuck in a squill [bulb] to avert attack by worms.
76 In Goodyer's 1655 translation, see Dioscorides (1934) p 213.
77 [CP-2.18.1]: Planting bitter vetch among the radish keeps the vermin (ψύλλᾰς, as e.g. aphids) away.
78 Alcaloid from A: *al qualja* = plant ash.
79 E.g. Hammer *et al.* (1999), Isman (2000).
80 In organic farming essential oils are also used in storage. See also Research institute for Organic Agriculture (FiBL) www.betriebsmittelliste.de and International Centre for Research in Organic Food Systems (ICROFS) www.icrofs.org/index.html.
81 Foliar application of algal products may enhance disease resistance (source MF). See also Research institute for Organic Agriculture (FiBL) www.betriebsmittelliste.de and International Centre for Research in Organic Food Systems (icrofs) www.icrofs.org/index.html.
82 Sharma *et al.* (2012).
83 Two very different options are offered, one being the lowering of the freezing-point at the plant surface, the other being the resistance inducing action of potassium (Info MF).
84 Millás Vallicrosa (1955) p 221. The public baths had a hot-water section heated by wood fires. Hence the term 'ashes from the baths'. The ashes probably contained many pieces of charred wood that could improve soil quality. Ash is alkaline and when wet it may kill vermin (and also seedlings?).
85 [GE-13.10.2]. Meana *et al.* (1998) translate *kedria* (G: κεδρία) (as [cedar] resin, Dalby (2011) p 129 as [cedar] oil, made from resin. The source is the Lebanon cedar (*Cedrus libani*) or the Syrian cedar (*Juniperus excelsa*).
86 Sea weeds may have hormonal effects on plants, and they even might be resistance inducers (Info MF).
87 Latex - Meana (1998) p 175 *155 suggests sap of *silphium*, Dalby (2011) p 94 fig sap, the more probable.
88 Riddle (1997), herbs were used extensively in birth control, regulation of lactation, and regulation of male and female fertility.
89 PAN Germany Pestizid Aktions-Netzwork e.V. with OISAT = Online Information Service for Non-Chemical Pest Management in the Tropics. http://oisat.org/controlmap.htm.

Chapter 7

1 The concept 'plant health', brilliantly problematized by Döring *et al.* (2012), is used here in a trivial sense.
2 Lamb (1967) Plato in twelve volumes. III. Lysis, Symposium, Gorgias. London, Heinemann (§188A,B. p129/10). 'The Symposium' is also called 'The Banquet'.
3 He used the Greek words for disease, νόσος and νόσημα, as in [HP-4.14.7] and [HP-8.10].
4 Darwin (1800) p 316.
5 [VA-1.55.2]. Today, tree surgeon is an honourable occupation.
6 [HP-4.14], [CP-5.8.2].
7 [IA-2A.330/9] Article 6 on fumigations and Article 7 on wild animals in Chapter 29.
8 '*Della medicina degli arbori*' [CR-11.18].
9 '*De algunas enfermedades de las vides y sus curas*.' [DH-2.15.74/6] and '*En que generalmente habla de algunas enfermedades de hortalizas y otras particularidades*.' [DH-4.7.216].
10 Abu l'Khayr in Carabaza (1991) p 248.
11 See e.g. Magner (1994) p 18, 71.
12 Wikipedia: The dictum is attributed to Thomas Sydenham (1624-1689).
13 There are some identification problems so that numbers are approximative.
14 For the distinction between poor man's diseases and rich man's diseases see Zadoks (1974) p 920. A similar distinction was made by Isman (2008). Low external input agriculture is the poor man's domain, high external input (seeds, fertilizers, irrigation, pesticides) the rich man's fief.
15 Cease *et al.* (2012).
16 Zadoks & Schein (1979) p 182.
17 Suggestion S. Savary.
18 Dark & Gent (2001).
19 [CP-6.4.4], also [CP-2.9.5; 2.9.6; 3.22.4; 5.10.5].
20 Vincent *et al.* (2007), Watson *et al.* (2008).
21 The irony of recent development is that very rich countries, who no longer want to use pesticides, explore biologicals again, more costly but thought to be safer for the consumer and the environment.
22 Hämeen (2006) p 203 (NA49).
23 [IA-1.546]. It is about a method to treat apple trees against red worms.
24 Crescentio (1511) *Prohemio* p 2 v°.
25 Carreras (1970) p LX.
26 For the Romans *domus* was the town house, *villa* the country house (usually on an estate).
27 A modern anthropological view on innovation by peasant farmers is given by e.g. Bentley & Andrews (1991).
28 Such was my own experience when introducing the crop surveillance and protection system EPIPRE in the early 1980s. EPIPRE has been widely published, e.g. Zadoks (1989).
29 Gibb *et al.* (1960) Lemma Filāḥa. In Europe, Muslim Spain saw the first royal botanical gardens in the 11th century; they were pleasure garden, food garden, and trial ground. Botanical gardens linked to universities appeared in 16th century Italy. Monasterial gardens are much older, that of St Gallen (Switzerland) existed already in c.820; medicinal herbs and vegetables were grown.
30 In its expansion period the Order observed extreme austerity and self-sustenance, developing new agricultural land in remote places (Wikipedia: Cistercians), or at least rationalizing existing methods at a large scale.
31 Numerous examples in Meana *et al.* (1998).
32 Bithynia is a small area with agriculture in the north western corner of Asia Minor, not far from Byzantium.
33 Ibn Khaldūn (Tunis 1332-1406 Cairo) wrote several books on geography, history and sociology. He made a clear difference between city dwellers and country folk, the latter indicated as Bedouins. In his view the strong Bedouins were nomads, weaker Bedouins being sedentary and engaged in agriculture and cattle breeding.
34 Pedanius Dioscorides c.40-c.90 CE: Περὶ ὕλης ἰατρικης = *De Materia Medica* = On Medical Matters.
35 Riddle (1997) p 117.
36 E.g. Isman (2008). CABI under www.plantwise.org.

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37 Some legal documents on cases against animals evoke the impression of a playful game in which lawyers could show off (comment CM).
38 Compare Foucault (1966) Ch. 2.1.
39 [CO-1.1.17]. Columella used the word *scientia*, which does not mean (natural) science in the modern sense but familiarity with or knowledge of something, also science in a broad sense.
40 Internet: Dizionario Biografico degle Italiani, lemma Pietro de' Crescenzi.
41 Laudani (2004): *Moretum*, a Latin poem in 122 hexameters. *Moretum* means 'stew'.
42 'Taught by example and learned by doing', certainly the way I picked up practical matters.
43 Bolens (1981) p 143.
44 [DH-6.0.349]. Compare Foucault (1966) Part 1, Ch 2.3. *Les limites du monde*.
45 Boyd Ash (1967) p 161.
46 [NH-19.56.176].
47 Plants [NH-7.15.64]; cabbage [IA-2.160]; caterpillars [NH-17.47.267]; hailstorms (§ 5.3.3); dodder (§ 5.2.1).
48 [NH-19.57.177], [CO-11.3.38], [IW-83(39)319], [GE-12.25.2]; cabbage [IA-2.160], cucumbers [GE-12.20.5], [AG-74]; cucurbits [IA-2.218]; wallflower [IA-2.260], probably the Aegean wallflower, an odorous perennial.
49 Meana *et al.* (1998) p 441 *97. [PA-1.35.3; NH-19.57.177; NH-28.23.78;CO-10.356/363; 11.3.38]. '*Metrodorus of Scepsos* (145-70 BCE) *states that the discovery was made in Cappadocia owing to the plague there of Spanish fly*, …'. 'Spanish fly' was the name often used for *Rhynchites auratus*.
50 'menstruating woman', Dalby (2011) p 250 translates 'ritually pure woman'. Both translations are acceptable (Liddell & Scott, 1961) but the first one follows the tradition and better fits the context.
51 [GE-12.8.5/6]. Compare § 5.2.1.
52 [DH-4.7.217], '*como por experiencia se ve*'.
53 Cappadocia in Asia Minor. [NH-28.23.78]. Guiraud & Martin (1976, 2010) p 159.
54 Talisman -Le Roy Ladury (1975) p 275. Love potion - Hoffmann-Krayer (1927/42) I p1436, VIII p 115.
55 Lent = spring time. Lent is also the 40-days fasting period preceding Easter in Christianity.
56 Zadoks (2008) Ch 1; Zadoks (2007).
57 In the Protestant parts of the Netherlands a Prayer Day for the crops used to be held on the second Wednesday of March and a Thanksgiving Day on the first Thursday of September, a tradition hardly observed today.
58 Houtsma *et al.* (2008) p 134. St Augustine (354-430 CE) lived in Hippo, N Africa (present Annaba, Algeria).
59 Evans (1906) p 53.
60 Evans (1906) p 38 says greenish weevil (F: *charançon*), probably *Rynchites auratus* Scop. = golden apricot weevil = golden green snout beetle. We have an identification problem. *R. auratus* is primarily a parasite of stone fruits such as wild cherry. It is not a typical grapevine parasite as is *Bytiscus betulae* L. 1758, the birch or grapevine weevil, also called 'cigar maker'.
61 A stern warning was given by Rachel Carson in 'Silent Spring' (1962).
62 FAO invited me to participate in an evaluation mission, 1986, of a project on Integrated Pest Management in rice, in SE Asia.
63 As far as I remember it was in the Da Ming Temple in the city Yangzhou, on the Yangtze River in Jiangsu Province, China. It was said that monks from this temple brought Buddhism to Japan.
64 Fleta book 2, chapter 78: *Of drivers of ploughs*. Richardson & Sayles (1955) p 251.
65 See also Burford (1993) p 100.
66 The 'Gaulish harvester' is mentioned in [NH-18.30.72] and described in detail in [PA-7.2], though both authors probably used hear-say evidence only. The apparatus has been depicted in a few Roman provincial reliefs (White, 1967). Crescentio [CR-3.7], apparently enthusiastic about the idea, closely followed Palladius, probably again without having seen the equipment. Mane (2006), very detailed on medieval agricultural equipment, did not mention the implement.
67 Watson (1974, 1983), White (1970) p 454.
68 Frayn (1979) p 148/9 and other authors.
69 Frayn (1979) p 148.
70 Frayn (1979) p 152.
71 Frayn (1979) p 159.

72 Upon his return to Ithaca Odysseus was referred to the smithy, a warm place where the aged sat and chatted (Odyssey 18.329; Bérard, 1924). [HE-493] 'the bronze-worker's bench and his warm lounge in the wintry season, when the cold holds men back from fieldwork …'. Klaver (1974, p 33) mentioned field labourers spending evenings together with small talk, around 1900.
73 Meana *et al.* (1998) p 70.
74 The situation may have been typical of a colonized area with a new and keen landed gentry descending from the invaders. Compare the establishment of economically flourishing estates of white colonists in the tropical colonies of European powers (suggestion CM).
75 [IK-2.284]. Two contrasts emanate from Ibn Khaldūn's remark. (1) The remarkable contrast between Andalusia and Tunesia, and (2) the great contrast in agricultural profitability between Roman imperial Tunesia as depicted in the numerous mosaics of luxurious mansions and vacation houses (Yacoub, 2003) and Ibn Khaldūn's Tunesia.
76 During the Cold War, c.1950 to c.1980, the West realized that SE Asia, thought to be threatened by Communism, would be more resilient when well fed. An agricultural crash programme was set up to improve food security in SE Asia, first and foremost, by producing more rice. The elements of the programme were (1) new high-yielding varieties, (2) two crops per year, (3) adequate irrigation, (4) high fertilizer use, (5) intensive pest control, and (6) appropriate government incentives. (7) Later, new cropping systems were added. As to food security this revolutionary programme was a great success. The result became known as 'the' Green Revolution. This term was applied retrospectively to some comparable developments in history. One such Green Revolution, also government sponsored, took place in China, around 1200, in the Yang Tze River Basin. New rice varieties were introduced, allowing two crops to be grown per year (wheat and rice), and high manure use was encouraged (Bray, 1986). These are typical Green Revolution elements.
77 According to Butzer's (1985) critical analysis key additions of the Arabs were rice, sugar cane, citrus spp., sorghum, and silk worm (grown on native mulberry trees).
78 Numerous publications deal with the plague of 1348, i.a. Herlihy (1997). Turner (1978) is easy reading.
79 *Cirsium arvense* (L.) Scop.
80 Bolens (1981) p 209.
81 [HP-8.7.1; 8.8.3], [AG-167].

Chapter 8

1 Buisman (1995, 1996, 2000).
2 Zadoks (1985).
3 McNew (1960) p 58 phrases the basic idea of the three elements, host, parasite, and environment. However, his Fig. 1 with a triangle illustrates a different point.
4 Title of Chapter 9 in Zadoks & Schein (1979). For scaling in ecology see e.g. Wiens (1989).
5 Food security refers primarily to the availability of enough calories, food safety to the absence of contaminants, and nutritional security to the availability of sufficient proteins, vitamins and minerals.
6 When serious misfortune threatened a farmer's existence he often packed up and moved.
7 Zadoks & Schein (1979) p 245.
8 De Wit & Penning de Vries (1982) p 25.
9 Rabbinge (2011) p 9, Rabbinge & de Wit (1989) p 10.
10 The term 'unifying concept' was used by Rabbinge (2011) p 5.
11 A wealth of literature exists. Here Savary *et al.* (2011) and Rabbinge (2011) are followed.
12 Rabbinge (2011) p 5 exposing the theory of yield mentioned crop genetics.
13 Lammerts van Bueren *et al.* (2011).
14 Large (1966).
15 Zadoks (1976).
16 Conceptual – Zadoks (1985), physiological - Waggoner & Berger (1987), methodological - Teng (1987).
17 Rabbinge *et al.* (1983).
18 E.g. Rust and mildew – Daamen *et al.* (1989). Aphids – i.a. Rossing (1991).

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19 Zadoks (2003) p 5. Biotrophic pathogens need living cells to feed upon, perthotrophic pathogens first kill cells and then feed on the dead cell contents.
20 Coccinellids, carabids, staphylinids, and especially syrphids.
21 Spiertz (1989) Table 4.4. CV of 'organic farm' much higher than of 'current farm' for potatoes, sugar beet, and winter wheat, over a period of five years. Compare Jaradat & Weyers (2011) with period of four years.
22 South England – Reynolds (1979).
France - *Le village archéologique de Melrand*, Melrand in Brtittany.
www.melrand.fr/fr/information/12462/village-an-mil.
Catalonia - *Arqeologia Experimental l'Esquerda : Aplicació a l'agricultura medieval mediterràneo.* A 13th century farm is reconstructed on its original site, a rock spur not far from Barcelona.
www.lesquerda.cat.
23 Overview influx and outflow in Lenné (1999).
24 Seufert *et al.* (2012).
25 This was still true in the 19th century (Zadoks, 2008, p 107).
26 Foxhall (1998).
27 The value of biological control on crop land is estimated at 24 $US\$_{(1994)}.ha^{-1}.year^{-1}$, averaged worldwide. The value delivered by ecosystems services worldwide is estimated at 33 x 10^{12} US\$(1994) $.year^{-1}$, of which 417 x 10^{9} US\$(1994) $.year^{-1}$ is attributed to biological control (Costanza *et al.*, 1997).
28 The world's largest producer of biological control agents is the Dutch company Koppert Biological Systems.
29 Two exceptions. (1) In many developing countries areas exist with production situations 4 and 3. (2) In many developing countries self-help with home-made biologicals can be found, irrespective of production situation.
30 Meentemeyer *et al.* (2012).
31 In statistical terms: the coefficient of variation CV of the yield ($kg.ha^{-1}$) of a field (or set of fields), averaged over a sequence of years, was high. The CV is calculated as the standard deviation divided by the mean.
32 Buisman (1995) p 47.
33 Buisman (1996) p 457.
34 Landscape resistance (Margosian *et al.*, 2009). Landscape characteristics (Letourneau & Goldstein, 2001).
35 The contribution of plant disease to the mishaps is inferred only, the records did not mention plant disease.
36 Buisman (2000) p 166 quotes two independent primary sources. Steenstra (1834) p 2.439 is an independent, though secondary, source.
37 Malachi 3.9: '*Bring ye all the tithes …*' and 3.11: '*And I will rebuke the devourer [= locust] for your sakes …*'
38 Zadoks (2007), (2008) chapter 1.
39 Evans (1906).
40 Cramer (2007) p 43.
41 Livy - Volume 12. Book XLII x 7.
42 Livy - Volume 14. Summaries LX. '*Julius obsequens*'. 125 BCE. Consulship of Marcus Plautius and Marcus Fulvius.
43 According to present-day standards, candidates are *Carduus pycnocephalus* L., *Centaurea pullata* (L.) Cass., *Althaea hirsuta* L., and *Cichorium intybus* L.
44 Illustrations in Webster (1970). Thistle cutting, Webster modestly writes 'weeding', as a representation of June was not infrequent but certainly not dominant. Once it stood for July.
45 Braudel (1986, III) p 119: '*champs "gastés des herbes" "plus de coyouls noires (de folle avoine) que de bled*".
46 Dioscorides & de Laguna (1566) p 150; Braudel (1966) p 222 mentions Hungary, 1543.
47 Slave labour was common in certain periods and regions, but even slave labour was not without costs. Labour scarcity occurred sometimes; it became urgent following the 'Black Death' around 1348 that killed a quarter to a third of Europe's populace.
48 Garnsey (1988) p 49.

49 Regulatory authorities have greatly contributed to the reduction and safety of pesticide use.
50 Garnsey (1988) p 48.
51 Grain pits, accessible by ladder, are also mentioned in [OS-2. 7.124].
52 Buisman (1995) p 219. Famine in Germany and Italy.
53 Buisman (1996) p 127.
54 Zadoks (1985).
55 Stewart *et al.* (2007). They added '*provided that the efficacy is steady through the seasons*', in pre-modern times an unrealistic proviso.
56 Modern experimentation, with at least one treatment and an untreated control, in replicated trials, did not exist in antiquity. This does not exclude the existence of simple 'with and without' trials in a corner of the field, as I have seen so often in the Netherlands around 1980. It is still an acceptable method of learning in developing countries, often dubbed 'experiential learning'.
57 My own experience was that modern farmers sleep better if they 'do some goddamn thing', even if it does not work, its effect cannot be ascertained, or is at least an extra expense. The comment was also applicable to some farm advisers.
58 There is good evidence that in modern times a social factor affects crop protection behaviour. This is obvious in government- and bank-sponsored programmes, where the 'progressive farmer' was expected to spray his crops regularly.
59 Smith & Secoy (1975).
60 False flax, *Camelina sativa* (L.) Crantz.
61 In western Europe I saw landraces of wheat as late as 1947. A mixture of unusual phenotypes was grown in small plots at the *Talschulter* (= valley shoulder) of the Swiss Rhône valley, an exposed place.
62 'Horizontal resistance' and 'tolerance' were current concepts in plant breeding defined e.g. in Zadoks & Schein (1979 p 53, 268). In Amazonian Peru (1974) I have seen plots of newly created high-yielding cultivars of rice near to a landrace, broadleaved and tall. The cultivars were totally destroyed by the fungus *Pyricularia oryzae* whereas the landrace looked normal notwithstanding its many fungal lesions. When both had been healthy, the cultivar would have outyielded the landrace. Under the local conditions, with disease, the landrace outyielded the newly selected cultivars by far.
63 In physiological terms we say that the source of assimilates (the leaves) is large relative to their sink (the kernels in size and number).
64 Vanderplank (1963) p 247, (1968) p 157.
65 With wheat, said to be self-pollinating, I experienced great difficulties to maintain pure varieties due to occasional cross-pollination; this occurs especially in climatically ill adapted genotypes.
66 Anonymus (2012) p 5. Today a Spanish white wine, produced in a very rainy district just north of Portugal, is made from cv albariño, which has small white grapes with thick skins that tolerate the wetness.
67 Garnsey (1999) p 6.
68 Similarly Cramer (2007) p 21. Rome and most classical Greek cities had sea ports and thus could supply their citizens without great transportation problems.
69 A devastating pest epidemic (541-544 CE) caused a demographic catastrophe in the eastern part of the Byzantine empire, leading a.o. to a great lack of agricultural labour. A severe famine ravaged the area in 746/7 CE. On the whole scarcities were frequent but famines rare in antiquity and in the Byzantine era (Garnsey, 1999).
70 At its peak the city of Byzantium may have had c.500,000 inhabitants; it probably had c.100.000 inhabitants around 900 CE; grain was imported mainly from the areas bordering the Aegean Sea and the Black Sea (Wickham, 2009). Grain was stored in state warehouses and bread price was regulated (p 348/50).
71 Imamuddin (1962) p 67.
72 Steenstra (1843) 2.119. The wording suggests that the nobles may not have convinced the monasteries.
73 Examples 19th and 20th century in Zadoks (2008) § 3.3.6/7, 6.5.1.
74 As in the mid-19th century (Zadoks, 2008, p 106).
75 Cannibalism on record i.a. from Egypt, 1065 (Garnsey,1999 p 37) and Ireland, 1318 (Buisman, 1996 p 70).
76 Zadoks (2008) Box 3.3, § 6.4.

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77 Buisman (1995, 1996, 2000).
78 Jordan (1996).
79 Buisman (1996) p 162.
80 Jordan (1996) p 37.
81 i.a. Bai & Shaner (1994); Xu & Nicholson (2009).
82 Ergot is due to a plant-pathogenic fungus, *Claviceps purpurea*, see a.o. Barger (1931), Zadoks (2008) Ch 6.
83 Zadoks (2008) p 166.
84 That is, making a level threshing floor of clay mixed with watery infusion of fresh cattle dung [OS-2.6.118/9].
85 In French this is nicely phrased: '*Science plus vtile que difficile* …'.

Annex 1

Plants

From common to scientific names

Alfalfa	lucerne
Almond tree	*Prunus amygdalus* Batsch
Apple	*Malus sylvestris* L.
bitter -	*Citrullus colocynthis* (L.) Schrad.
Artichoke	*Cynara cardunculus* L. var. *scolymus*
Axeweed	vetch, crown
Azarole	*Crataegus azarolus* L.
Banana	*Musa sapientium* L.
Barberry	*Berberis vulgaris* L.
Barley	*Hordeum vulgare* L.
Basil	*Ocimum basilicum* L.
Bay laurel	*Laurus nobilis* L.
Bean	
common -	*Phaseolus vulgaris* L.
faba, field, horse -	*Vicia faba* L.
hyacinth-	*Lablab purpureus* (L.) Sweet
Bedstraw	*Galium* spp.
Beet	*Beta vulgaris* L. ssp *vulgaris*
Bermuda grass	*Cynodon dactylon* (L.) Pers
Bindweed	*Convulvulus* spp.
Field -	*C. arvensis* L.
Bracken	*Pteris aquilina* L.
Bramble	*Rubus fruticosis* L., *Rubus ulmifolius* Schott.
Broccoli	*Brassica oleracea* L. var. *italica*
Broom, bushy/Spanish	*Spartium junceum* L.
Broomrape	*Orobanche crenata* Forssk.
Burdock, greater	*Arctium lappa* L.
Cabbage	*Brassica oleracea* L.
Calamint (common)	*Calamintha sylvatica* Bromf. = *Clinopodium menthifolium* (Host) Stace
Caltrop	either *Tribulus terrestris* L. or starthistle
Cane, giant	*Arundo donax* L.
Caper bush	*Capparis spinosa* L.
Caraway, black	*Nigella sativa* L.

Carrot	*Daucus carota* L.
Castor bean	*Ricinus communis* L.
Catmint	calamint
Cedar	*Cedrus* spp.
Atlas -	*Cedrus atlantica* Manettti
Lebanon -	*Cedrus libani* A.Rich,
salt -	tamarisk
Syrian -	juniper, Greek
Celery	*Apium graveolens* L.
Chamomille	*Matricaria recutita* L.
Chard	*Beta vulgaris* ssp. *cicla* (L.) Moq.
Cherry tree	*Prunus* spp
sour -	*Prunus cerasus* L.
sweet -	*Prunus avium* L.
Chickpea	*Cicer arietinum* L.
Chickweed, common	*Stellaria media* L.
Chicory, common	*Cichorium intybus* L.
Chokefitch	broomrape
Citron tree	*Citrus medica* L.
Cleavers	*Galium aparine* L.
Cockle	darnel
Coconut palm	*Cocos nucifera* L.
Collard	kale
Colocasia	*Colocasia antiquorum* Schott.
Coltsfoot	*Tussilago farfara* L.
Coriander	*Coriandrum sativum* L.
Corncockle	*Agrostemma githago* L.
Cornflower	*Centaurea cyanus* L.
Couch grass, creeping	*Elytrigia repens* (L.) Desv.
Cowpea	*Vigna unguiculata* (L.) Walp.
Crown vetch	*Securigera coronilla* L.
Cucumber	*Cucumis sativus* L.
bitter -	apple, bitter
squirting -	*Ecballium elaterium* (L.) A. Rich.
Cumin	*Cuminum cyminum* L.
wild -	*Lagoecia cuminoides* L.
Cypress, Mediterr.	*Cupressus sempervirens* L.
Darnel	*Lolium temulentum* L.
Date palm	*Phoenix dactylifera* L.
Devil's dung	*Ferula asafoetida* L.
Dill	*Anethum graveolens* L.
Doddder	*Cuscuta* spp.
European	*Cuscuta europaea* L.
(Near Eastern?)	*Cuscuta monogyna* Vahl
Dog's-bane	*Cynanchum acutum* L.

Dog's-tooth grass	*Cynodon dactylon* (L.) Pers.
Dog-strangling vine	*Cynanchum acutum* L.
Eggplant	*Solanum melongena* L.
Einkorn wheat	*Triticum monococcum* L.
Elm tree (common)	*Ulmus procera* Salisb.
Endive	*Cichorium endivia* L.
Fennel	*Foeniculum vulgare* Mill.
giant -	*Ferula communis* L., or *Ferula gumosa* Boiss., or *F. tingitana* L.
Fenugreek	*Trigonella foenum-graecum* L.
Fig, common	*Ficus carica* L.
Flax	*Linum sativum* L.
Fleabane, sticky	*Dittrichia viscosa* (L.) Greuter
Fodder vetch	*Vicia sativa* L.
Garden orache	*Atriplex hortensis* L.
Garden rocket	*Eruca sativa* Mill.
Garlic	*Allium sativum* L.
bear's -	*Allium ursinum* L.
Goat grass	*Aegilops ovata* L or *A. geniculata* Roth
Gourd (bitter)	*Momordica charantia* L.
Grapevine	*Vitis vinifera* L.
Grass pea	*Lathyrus sativus* L
Hellebore	
black -	*Helleborus niger* L.
white -	*Veratrum album* L.
Henbane, black	*Hyoscyamus niger* L.
Hoary stock	*Matthiola incana* (L.) Ait
Horehound, white	*Marrubium vulgare* L.
Horsetail, field	*Equisetum arvense* L.
Houseleek, common	*Sempervivum tectorum* L.
Iris, German	*Iris germanica* L.
Ivy	*Hedera helix* L.
Jujube	*Ziziphus jujuba* Miller
Juniper, Greek	*Juniperus excelsa* M.Bieb.
Kale, collard	*B. oleracea* var. *viridis*
Laurel	bay laurel
Leek	*Allium porrum* L.
Lemon	*Citrus* x *limon* (L.) Burm.f.
Lenten rose	*Helleborus orientalis* Reut
Lentil	*Lens culinaris* L.
Lentisc	*Pistacia lentiscus* L.
Lettuce	*Lactuca sativa* L.
Love-in-a-mist	*Nigella damascena* L.
Lucerne	*Medicago sativa* L.

Lupine, white	*Lupinus albus* L.
Madonna lily	*Lilium candidum* L.
Male fern, common	*Dryopteris filix-mas* (L.) Schott.
Marshmellow	*Althaea officinalis* L.
Mastic	lentisc
Medlar, Mediterr.	azarole
Melon	
bitter -	*Momordica charantia* L.
water -	*Citrullus lanatus* (Thunb.) Mansf.
Millet	
foxtail -	*Setaria italica* (L.) P. Beauvois
common -	*Panicum miliaceum* L.
Italian -	Foxtail millet
proso -	common millet
Mistletoe	
common -	European mistletoe
European -	*Viscum album* L.
oak -	*Loranthus europaeus* Jacq.
Mole's weed	castor bean
Moon trefoil	tree medick
Mugwort	*Artemisia* spp.
common -	*Artemisia vulgaris* L.
great -	*Artemisia arborescens* L.
Muskmelon	*Cucumis melo* L.
Mustard, wild	*Sinapis arvensis* L.
Myrtle, common	*Myrtus communis* L.
Neem tree	*Azadirachta indica* A. Juss.
Nettles	*Urtica dioica* L.
Nightshade	
deadly -	*Atropa belladonna* L.
garden -	*Solanum nigrum* L.
stinking -	*Hyoscyamus niger* L.
Nutmeg flower	*Nigella sativa* L.
Oak	*Quercus* spp.
holm -	*Quercus ilex* L. '*rotundifolia*'
kermes -	*Quercus coccifera* L.
sessile -	*Quercus petraea* (Matts.) Liebl.
Oats	*Avena* spp.
cultivated -	*Avena sativa* L.
wild -	*Avena sterilis* L.
Oleander	*Nerium oleander* L.
Oleaster	*Olea oleaster* Hoffm. &Link.
Olive	*Olea europea* L.
Onion	*Allium cepa* L.
Orange tree	*Citrus* x *sinensis* (L.) Osbeck

Oregano	*Origanum vulgare* L
Osier	*Salix viminalis* L.
Pea	*Pisum sativum* L.
Peach tree	*Prunus persica* (L.) Batsch
Pear tree	*Pyrus communis* L.
Penny-cress, field	*Thlaspi arvense* L.
Peony, common	*Paeonia officinalis* L.
Pine tree	*Pinus* spp.
stone, umbrella -	*Pinus pinea* L.
Pistache tree	*Pistacia vera* L.
Plane tree	*Platanus* x *acerifolia* (Aiton) Willd., or *P. orientalis* L.
Plantain	*Musa paradisiaca* L.
Poison hemlock	*Conium maculatum* L.
Pomegranate	*Punica granatum* L.
Pumpkin	*Cucurbita pepo* L.
Purslane, common	*Portulaca oleracea* L.
Quince	*Cydonia oblonga* Mill.
Radish	*Raphanus sativus* L.
Rice	*Oryza sativa* L.
Rue, common	*Ruta graveolens* L.
wild -	*Ruta graveolens* L.
Rush	
club -	*Scirpus lacustris* L.
flowering -	*Butomus umbellatus* L.
spiny -	*Juncus acutus* L.
Rye	*Secale cereale* L.
Saffron crocus	*Crocus sativus* L.
Sea beet	*Beta vulgaris* L. ssp *maritima* (L.) Arcang.
Seakale	*Crambe maritima* L.
Sea squill	*Urginea maritima* (L.) Baker
Sedum	*Sedum* spp.
Shallot	*Allium cepa* L.
Sheep's sorrel	*Rumex acetosella* L.
Silphium, Sylphium	*Ferula* spp.
Snowdrop bush	*Styrax officinalis* L.
Soft rush	*Juncus effusus* L.
Spinache	*Spinacia oleracea* L.
Spurge	*Euphorbia* spp.
caper -	*Euphorbia lathyrus* L.
cypress -	*Euphorbia cyparissias* L.
sun -	*Euphorbia helioscopia* L.
Starthistle	*Centaurea calcitrapa* L.
Stonecrop, biting	sedum
Strychnine tree	*Strychnos nux-vomica* L.

Styrax	
Levantine -	*Liquidambar orientalis* L.
(official) storax	*Styrax officinalis* L.
Sugar beet	*Beta vulgaris* L. ssp. *vulgaris*
Swallowwort	*Cynanchum acutum* L.
Sweetgum, oriental	*Liquidambar orientalis* L.
Syrian cedar	Greek juniper
Tamarisk	*Tamarix africana* Poir.
Tansy, common	*Tanacetum vulgare* L.
Tare	darnel
Thistle	*Cirsium arvense* (L.) Scop.
Thyme, creeping/wild	*Thymus serpyllum* L.
Thymelaea	*Thymelaea hirsuta* (L.) Endl.
Tree medick	*Medicago arborea* L. (= moon trefoil)
Turnip	*Brassica campestris* L.
Umbrella pine	stone pine
Vetch	*Lathyrus sativus* L.
bitter -	*Vicia ervilla* (L.) Willd.
chickling -	grass pea
crown -	*Securigera coronilla* L.
fodder -	*Vicia sativa* L.
Wallflower, Aegean	*Erysimum cheiri* (L.) Crantz
Wall pepper	sedum
Walnut tree	*Juglans regia* L.
Wheat	
durum -	hard wheat
einkorn -	*Triticum monococcum* L.
emmer -	*Triticum dicoccoides* Körn.
	= *T. turgidum* L. ssp *dicoccoides* (Körn.) Thell.
hard -	*Triticum durum* Desf.
	= *T. turgidum* L. conv. *durum* (Desf.) MacKay
soft -, common -	*Triticum aestivum* L.
spelt -	*Triticum spelta* L.
	= *Triticum aestivum* L. ssp. *spelta* (L.) Thell.
Whitebeam	*Sorbus* (*Pyrus*) *aria* L.
Willow	*Salix* spp.
Woodland calamint	calamint
Wormwood	*Artemisia* spp.
common -	*Artemisia absinthium* L.
sea -	*Artemisia maritima* L.

From scientific to common names

Aegilops geniculata	goat grass
Aegilops ovata	goat grass
Agrostemma githago	corncockle
Allium cepa	onion, shallot
Allium porrum	leek
Allium sativum	garlic
Allium ursinum	bear's garlic
Althaea officinalis	marshmellow
Anethum graveolens	dill
Apium graveolens	celery
Arctium lappa	greater burdock
Artemisia absinthium	wormwood
Artemisia arborescens	great mugwort
Artemisia maritima	sea wormwood
Artemisia vulgaris	mugwort
Arundo donax	giant cane
Atriplex hortensis	garden orache
Atropa belladonna	deadly nightshade
Avena sativa	cultivated oats
Avena sterilis	wild oats
Azadirachta indica	neem tree
Berberis vulgaris	(common) barberry
Beta vulgaris	
ssp. *cicla*	chard
ssp. *maritima*	sea beet
ssp. *vulgaris*	sugar beet
Brassica campestris	turnip
Brassica oleracea	cabbage
v. *italica*	broccoli
v. *viridis*	kale, collard
Butomus umbellatus	flowering rush
Calamintha sylvatica	common calamint
Capparis spinosa	caper bush
Cedrus atlantica	Atlas cedar
Cedrus libani	Lebanon cedar
Centaurea calcitrapa	starthistle
Centaurea cyanus	cornflower
Cicer arietinum	chickpea
Cichorium endivia	endive
Cichorium intybus	(common) chicory
Cirsium arvense	thistle
Citrullus colocynthis	bitter apple, b. cucumber
Citrullus lanatus	water melon

Citrus x *sinensis*	orange tree
Citrus x *limon*	lemon tree
Citrus medica	citron tree
Clinopodium calamintha	calamint
Clinopodium menthifolium	calamint
Cocos nucifera	coconut palm
Colocasia antiquorum	colocasia
Conium maculatum	poison hemlock
Convolvulus arvensis	field bindweed
Coriandrum sativum	coriander
Crambe maritima	sea kale
Crataegus azarolus	azarole
Crocus sativus	saffron crocus
Cucumis melo	muskmelon
Cucumis sativus	cucumber
Cucurbita pepo	pumpkin
Cuminum cyminum	cumin
Cupressus sempervirens	Mediterranean cypress
Cuscuta spp.	doddder
Cuscuta europea	European dodder
Cuscuta monogyna	Near-Eastern dodder
Cydonia oblonga	quince
Cynanchum acutum	swallowwort, dog's-bane
Cynara cardunculus var. *scolymus*	artichoke
Cynodon dactylon	dog's-tooth grass, Bermuda grass
Cytisus scoparius	broom
Daucus carota	carrot
Dittrichia viscosa	fleabane (sticky)
Dryopteris filix-mas	(common) male fern
Ecballium elaterium	squirting cucumber = wild gourd
Elytrichia repens	(creeping) couch grass
Equisetum arvense	field horsetail
Eruca sativa	garden rocket
Erysimum cheiri	Aegean wallflower
Euphorbia	spurge
E. cyparissias	cypress spurge
E. helioscopia	sun spurge
E. lathyrus	caper spurge
Fagopyrum esculentum	buckwheat
Ferula spp.	fennel, silphium
F. asafoetida	devil's dung
F. communis	giant fennel
F. gumosa	giant fennel
F. tingitana	giant fennel

Ficus carica	fig, common
Foeniculum vulgare	fennel
Galium aparine	cleavers
Hedera helix	ivy
Helleborus niger	(black) hellebore
Helleborus orientalis	lenten rose
Hordeum vulgare	barley
Hyoscyamus niger	(black) henbane, stinking nightshade
Iris germanica	German iris
Juglans regia	walnut tree
Juncus acutus	spiny rush
Juncus effusus	soft rush
Juniperus excelsa	Greek juniper
Lablab purpureus	hyacinth bean
Lactuca sativa	lettuce
Lagoecia cuminoides	wild cumin
Lathyrus sativus	chickling vetch, grass pea
Laurus nobilis	bay laurel
Lens culinaris	lentil
Lilium candidum	madonna lily
Linum sativum	flax
Liquidambar orientalis	Levantine styrax, Turkish (oriental) sweetgum
Lolium temulentum	darnel, cockle
Loranthus europaeus	oak mistletoe
Lupinus albus	white lupine
Malus sylvestris	apple, common
Marrubium vulgare	horehound, white
Matricaria recutita	chamomille
Matthiola incana	hoary stock
Medicago arborea	tree medick, moon trefoil
Medicago sativa	lucerne, alfalfa
Momordica charantia	bitter melon, - gourd
Musa paradisiaca	plantain
Musa sapientium	banana
Myrtus communis	(common) myrtle
Nerium oleander	oleander
Nigella damascena	love-in-a-mist
Nigella sativa	nutmeg flower, black caraway
Ocimum basilicum	basil
Olea europea	olive
Olea oleaster	oleaster, wild olive
Origanum vulgare	oregano
Orobanche crenata	(crenate) broomrape.
Oryza sativa	rice

Paeonia officinalis	common peony
Panicum miliaceum	proso = common millet
Phaseolus vulgaris	common bean
Phoenix dactylifera	date palm
Pinus spp.	pine tree
Pinus pinea	stone = umbrella pine
Pistacia lentiscus	mastic, lentisc
Pistacia vera	pistache tree
Pisum sativum	pea
Platanus x *acerifolia*	plane tree
Platanus orientalis	plane tree
Portulaca oleracea	(common) purslane
Prunus amygdalus	almond tree
Prunus avium	sweet cherry
Prunus cerasus	sour cherry
Prunus amygdalus	almond tree
Prunus persica	peach tree
Pteris aquilina	bracken
Punica granatum	pomegranatee
Pyrus communis	pear tree
Quercus coccifera	kermes oak
Quercus ilex	holm oak
Quercus petraea	sessile oak
Raphanus sativus	radish
Ricinus communis	castor bean, mole's weed
Rubus ulmifolius	bramble
Rubus fruticosus	bramble
Rumex acetosella	sheep's sorrel
Ruta graveolens	common rue, wild rue
Salix spp.	willow
Salix viminalis	osier
Secale cereale	rye
Scirpus lacustris	club-rush
Securigera coronilla	crown vetch, axeweed
Sedum acre	biting stonecrop, wall-pepper
Sempervivum tectorum	common houseleek
Setaria italica	Italian = foxtail millet
Sinapis arvensis	wild mustard
Solanum melongena	eggplant
Solanum nigrum	(garden) nighshade
Sorbus (*Pyrus*) *aria*	whitebeam
Spartium junceum	Spanish broom
Spinacia oleracea	spinache
Stellaria media	common chickweed
Strychnos nux-vomica	strychnine tree

Styrax officinalis	snowdrop bush, (official) storax
Tamarix africana	tamarisk
Tanacetum vulgare	Tansy (common)
Thlaspi arvense	field penny-cress
Thymelaea hirsuta	thymelaea
Thymus serpyllum	creeping thyme
Tribulus terrestris	caltrop
Trigonella foenum-graecum	fenugreek
Triticum aestivum	common wheat
Triticum dicoccoides	emmer
Triticum durum	hard wheat
Triticum monococcum	einkorn wheat
Triticum spelta	spelt wheat
Triticum turgidum	emmer wheat
Tussilago farfara	coltsfoot
Ulex europaeus	European furze (= gorse = whin)
Ulmus procera	common elm
Urginea maritima	sea squill
Urtica dioica	nettles
Veratrum album	white hellebore
Vicia ervilla	bitter vetch
Vicia faba	faba = horse = field bean
Vicia sativa	fodder vetch
Vigna unguiculata	cowpea
Viscum album	European mistletoe
Vitis vinifera	grapevine
Ziziphus jujuba	jujube

Annex 2

Animals

It is hazardous to allocate modern scientific names to pre-modern trivial names, but an attempt is made to equate trivial names to modern taxon names.

Mammals **- from common to scientific names**

Deer, red	*Cervus elaphus* L.
Dormouse, hazel	*Muscardinus avellanarius* L.
Ferret	*Mustela furo* L.
Fox	*Vulpes vulpes* L.
Goat	*Capra aegragus hircus* L.
Hare	*Lepus* spp.
European brown -	*Lepus europaeus* Pallas
Granada (Iberian) -	*Lepus granatensis* Rosenhauer
Mole, European	*Talpa europea* L.
Mole-rat	*Spalax* spp.
Balkan -	*Spalax graecus* Nehring
Lesser -	*Nannospalax leucodon* Nordmann
Middle East blind -	*Spalax ehrenbergi* Nehring
Mouse	
field -	vole
house -	*Mus musculus* L.
Polecat	*Mustela putorius* L.
Rabbit, European	*Oryctolagus cuniculus* L.
Rat	*Rattus* spp.
black -	*Rattus rattus* L.
brown -	*Rattus norvegicus* Berkenhout
Swine	*Sus scrofa* L.
Vole (many species)	*Microtus arvalis* Pallas, *M. Güntheri* Danford & Alston, etc.
Water vole, European	*Arvicola amphibius* L.
Weasel, least	*Mustela nivalis* L.
Wild boar	swine

Mammals - from scientific to common names

Arvicola amphibius	European water vole
Capra aegragus hircus	goat
Cervus elaphus	(red) deer
Lepus europaeus	European brown hare
Lepus granatensis	Granada (Iberian) hare
Microtus arvalis	vole = field mouse
Muscardinus avellanarius	hazel dormouse
Mus musculus	house mouse
Mustela furo	ferret
Mustela nivalis	(least) weasel
Mustela putorius	polecat
Nannospalax leucodon	lesser mole-rat
Oryctolagus cuniculus	(European) rabbit
Rattus norvegicus	brown rat
Rattus rattus	black rat
Spalax	mole rat
Spalax ehrenbergi	Middle East blind mole-rat
Spalax graecus	Balkan mole-rat
Sus scrofa	wild boar, (domesticated) swine
Talpa europea	European mole
Vulpes vulpes	fox

Birds - from common to scientific names

Barn owl	*Tyto alba* Scopoli
Brent goose	*Branta bernicla* L.
Carrion crow	*Corvus coronae* L.
Dove	pigeon
Goldfinch, European	*Carduelis carduelis* L.
Gull	*Larus* spp.
Heron, grey	*Ardea cinerea* L.
Kestrel, common	*Falco tinnunculus* L.
Magpie, European	*Pica pica* L.
Pigeon	*Columba* spp.
wood – (ring-dove)	*Columba palumbus* L.
stock dove	*Columba oenas* L.
Rook	*Corvus frugilegus* L.
Sparrow	*Passer* spp
house -	*P. domesticus* L.
Spanish -	*P. hispaniolensis* L.
tree -	*P. montanus* L.
Starling, common	*Sturnus vulgaris* L.
Stork, white	*Ciconia ciconia* L.
Tit, great	*Parus major* L.
Wagtail	*Motacilla alba* L.

Evertebrates - from common to scientific names

Ants	formicidae
black -	*Tapinoma nigerrimum* Nylander
harvester -	i.a. *Messor barbarus* L., *M. semirufus* Andre
Aphids	aphidoidea
Beetles	
click -	elateridae
ground -	carabidae
Cockchafer, common	*Melolontha melolontha* L.
Crane flies	tipulidae
Crayfish, European	*Astacus astacus* L.
Ermine moths	yponomeutidae
Fig wax scale	*Ceroplastes rusci* L. (coccidae)
Flea beetles = leaf -	chrysomelidae
Gamma moth	*Autographa gamma* Schadewald (*Plusia gamma* L.)
Goat moth	*Cossus cossus* L.
Grain moth, European	*Nemapogon granella* L.
Granary (wheat) weevil	*Sitophilus granarius* Hust. (*Calandra granaria* L.)
Grasshopper	
Italian -	*Calliptamus italicus* L.
Moroccan -	*Dociostaurus maroccanus* Thunberg
Greenish weevil	*Rhynchites auratus* Scopoli
Hazel leafroller	*Byctiscus betulae* L.
Hawk moth	*Cossus* spp.
Hornet	*Vespa* spp
European -	*Vespa crabro* L.
Oriental -	*Vespa orientalis* L.
Kermes scale	*Kermes vermilio* Planchon
Ladybirds (coccinellids)	coccinellidae
Leatherjacket	larva of crane fly
Locust	
desert -	*Schistocerca gregaria* L.
migratory -	*Locusta migratoria* Forssk.
Mealworm	larva of *Tenebrio molitor* L.
Mole-cricket	*Gryllotalpa gryllotalpa* L.
Olive black scale	*Saissetia oleae* Olivier
Olive (fruit) fly	*Dacus oleae* Gmel. = *Bactrocera oleae* Rossi
Olive psyllid	*Euphyllura olivina* Costa
Pea weevil	*Bruchus pisorum* L.
Pine processionary	*Thaumatopaea ptyocampa* Denis & Schiffermüller.
Scales	coccidae
Silver Y moth	gamma moth

Slug	land mollusc without shell
Small cabbage white	*Pieris rapae* L.
Snail	land mollusc with shell
Burgundy -	*Helix pomatia* L.
Mediterranean (coastal) -	*Theba pisana* O.F. Müller
Spider mites	tetranychidae
Staphilinids	rove beetles
Sunn pest	pentatomidae such as *Aelia acuminata* L. and *Eurygaster testudinaria* Fourcroy
Syrphids (hoverflies)	syrphidae
Thrips (thunderflies)	thysanoptera
Wheat weevil	granary weevil
White flies	aleyrodidae
White grub	larva of *Melolontha* spp.
Wireworm	larva of click beetle

Annex 3

Plant pathogens

Only few plant pathogens could be identified with any certainty.

Trivial name	**host**	**scientific name**
Blast fungus	rice	*Magnaporthe grisea* Yaeg. & Udag. (*Pyricularia oryzae* Cavara)
Black mould	wheat	sooty mould
Blight	grapes	botrytis rot
Botrytis rot	grapes	*Botryotinia fuckeliana* (De Bary) Whetzel = *Botrytis cinerea* Pers.
Brown spot	rice	*Helminthosporium oryzae* Breda de Haan = *Cochliobolus miyabeanus* (I & D) Drechsler
Bunch rot	grapes	botrytis
Bunt, common	wheat	covered smut
Covered smut	wheat	*Tilletia caries* (DC.) Tul.
Downy mildew	grapevine	*Plasmopara viticola* (Berk. & Curt.) Berl. & de Toni
Downy mildew	potato	Potato late blight
Ergot	rye	*Claviceps purpurea* (Fr.) Tul.
Eyespot	wheat	*Pseudocercosporella herpotrichoides* (Fron) Dei.
Grey mould	rice	blast fungus
Grey mould	grapes	botrytis rot
Leaf curl	peach	*Taphrina deformans* (Berk.) Tul.
Loose smut	wheat	*Ustilago tritici* (Pers.) Rostr.
Mildew	general	erysiphaceae
powdery -	cucumber	*Erysiphe cichoracearum* DC and *Sphaerotheca fuliginea* (Slechtend.) Pollacci
powdery -	grapevine	*Uncinula necator* (Schw.) Burr.
powdery -	wheat	*Blumeria graminis* (DC.) Speer = *Erysiphe graminis* DC f.sp. *tritici* E. Marchal
Mildew, antiquated	wheat	black stem rust
Potato late blight	potato	*Phytophthora infestans* (Mont.) de Bary
Rust		*Puccinia* spp.
tropical maize -	maize	*Puccinia polysora* Underw.

black stem -	wheat	*Puccinia graminis* Pers.
brown leaf -	wheat	*Puccinia tritcina* Erikss.
yellow stripe -	wheat	*Puccinia striiformis* Westend.
Seed gall nematode	wheat	*Anguina tritici* (Steinb.) Chit.
Sooty head mould	wheat	*Alternaria* spp., *Cladosporium* spp.
Take-all	wheat	*Gäumannomyces graminis* (Sacc.) Arx & Oliv.

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Abbreviations

The sources of the quotations are indicated by means of a code.

Agustín	[AG-159]	Page 159. Libro de los secretos de agricultura, casa de campo y pastoril. Barcelona, s.n., 1762.
Cato	[CA-12]	Paragraph 12. Translation by Hooper & Boyd Ash, 1967.
Columella	[CO-12]	Paragraph 12. Translation by Boyd Ash – 1941.
Crescentio	[CR-11.19]	Book 11, Chapter 19. Translation from the 1511 edition.
De Herrera	[DH-4.5.213]	Book 4, Chapter 5, page 213. Spanish edition by Martinez Carreras, 1970.
Geoponika	[GE-2.16.4]	Book 2, Chapter 16, Line 4. Spanish edition by Meana *et al.*, 2008.
Hesiod	[HE-153]	Line 153. Translation by Most, 2006.
Ibn al-ʿAwwām	[IA-1.484]	Volume 1, Page 484. (p = preface, 1 = volume 1, 2 = volume 2A). French edition by Clément Mullet, 1977.
Ibn <u>Kh</u>aldūn	[IK-2.284]	Volume 2, page 284. Ibn Khaldûn, The Muqaddimah. Rosenthal (transl.) 1958.
Ibn Luyūn	[IL-116]	Paragraph 116. Spanish edition by Ibáñez, 1988.
Olivier de Serres	[OS-1.12.120]	Book 1, Chaper 12, Page 120. French edition of 1608.

Palladius	[PA-1.35.12]	Book 1, Chapter 35, Alinea 12. French edition by Guiraud & Martin, 2010.
Pliny	[NH-.....]	Book, Chapter, Paragraph. Pliny. Natural History, Translation by Rackham, 197l.
Theophrastus	[CP-......]	Book, Chapter, Paragraph. De causis plantarum = Περὶ αἰτιων φυτικῶν. Einarson & Link, 1976. On plant: the explanations.
Theophrastus	[HP-......]	Book, Chapter, Paragraph. 3 vols. Historia plantarum = Περὶ φυτῶν ἱστορία. Hort, 1961. Enquiry into plants. 2 Vols.
Varro	[VA-12]	Paragraph 12. Translation by Hooper & Boyd Ash, 1967.
Vergil	[VE-1.197]	Book 1, Line 197. Georgics, English edition by Rushton Fairclough, 1978.
Xenophon	[XE-12]	Paragraph 12. Translation by Marchant, 1959.

--- Separates statements of fact or quotations from personal comments.

c. =	approximately	H =	Hebrew
A =	Arabic	L =	Latin
F =	France, French	NL =	Netherlands, Dutch
G =	Greece, Greek	S =	Spanish

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The enthousiasm and promptness of the publisher, 'Sidestone Press', is much appreciated.

With apologies to those helpers who have not been mentioned I claim all the flaws in this book to be mine.

Curriculum Vitae

Jan C. Zadoks, born in Amsterdam, 1929, studied biology at the University of Amsterdam, graduating in 1957. He received his Ph.D. from the University of Amsterdam in 1961, with honours, and joined the Wageningen Agricultural University as a plant pathologist. He developed various courses in the area of plant disease epidemiology. One course led to the book 'Epidemiology and plant disease management' by Zadoks & Schein, 1979. He served three years as Dean of the Wageningen School of Agriculture. His research was in wheat diseases mainly. He lectured in many countries and presented invitational key-note lectures to diverse assemblies. His 1974 scale for growth stages of cereals became UPOV and FAO standard.

Jan Zadoks served on several local and national committees, among which the Pesticides Registration Board of The Netherlands and the Committee on Genetic Modification of The Netherlands. Founding the 'European and Mediterranean Cereal Rusts Foundation', 1969, he took an interest in international agriculture. He performed consultancy missions overseas for FAO and for the Dutch and French governments. He participated in quinquennial reviews of Dutch, French, and International Agricultural Research Institutes. After retirement, 1994, he organised the XIIIth International Plant Protection Congress, 1995, in The Netherlands. He was awarded several national and international honours.

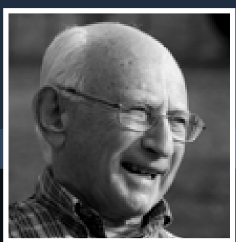
Crop protection
in medieval agriculture

Mediterranean and West European pre-modern agriculture (agriculture before 1600) was by necessity 'organic agriculture'. Crop protection is part and parcel of this agriculture, with weed control in the forefront.

Crop protection is embedded in the medieval agronomy text books but specialised sections do occur. Weeds, insects and diseases are described but identification in modern terms is not easy. The pre-modern 'Crop Portfolio' is well filled, certainly in the Mediterranean area. The medieval 'Pest Portfolio' differs from the modern one because agriculture then was a Low External Input Agriculture, and because the proportion of cultivated to non-cultivated land was drastically lower than today. The pre-modern 'Control Portfolio' is surprisingly rich, both in preventive and interventive measures. Prevention was by risk management, intensive tillage, and careful storage. Intervention was mechanical and chemical. Chemical intervention used natural substances such as sulphur, pitch, and 'botanicals'. Some fifty plant species are mentioned in a crop protection context.

Though application methods look rather modern they are typically low-tech. Among them are seed disinfection, spraying, dusting, fumigation, grease banding, wound care, and hand-picking but also scarification, now outdated. The reality of pest outbreaks and other damages is explored as to frequency, intensity, and extent. Information on the practical use of the recommended treatments is scanty. If applied, their effectiveness remains enigmatic.

Three medieval agronomists are at the heart of this book, but historical developments in crop protection from early Punic, Greek, and Roman authors to the first modern author are outlined. The readership of these writers was the privileged class of landowners but hints pointing to the exchange of ideas between them and the common peasant were found. Consideration is given to the pre-modern reasoning in matters of crop protection. Comparison of pre-modern crop protection and its counterpart in modern organic agriculture is difficult because of drastic changes in the relation between crop areas and non-crop areas, and because of the great difference in yield levels then and now, with several associated differences.



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