at NIRD may be quite right when they downgrade the importance of free fatty acids in their aseptic cheese. It is probably true also that, in pasteurized milk cheese typical of the United States market, H_2S and fatty acids are important contributors to the flavor. In old raw-milk Cheddar other components such as phenolics and, perhaps, pyrazines also may be significant.

When we have identified all of the volatile components that occur in significant quantities in Cheddar, we may be able to determine the combinations that are essential to reproduce the various qualities and intensities of flavor that occur. At that time, those working on mechanisms of flavor development will no longer have to be guided by correlations that may often have little to do with the production of essential flavor components.

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Forerunners of Pesticides in Classical Greece and Rome

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Various methods for pest control described by the classical writers are discussed. These include religion, folk magic, and the use of what may be termed chemical methods for the control of plant diseases, weeds, and insect and animal pests. These last are described in some detail and attempts are made to assess their possible success. Although the efficacy of such methods may be open to conjecture, the principles of seed treatment, fumigation, tree banding, and the use of preparations to control pests appear to have been widely used.

Although the science of pest control is considered to be of recent origin, dating from the latter part of the nineteenth century, it is probably true that man has practiced some form of pest control since the beginnings of agricultural times. The earliest implement, other than the hand, used for weed control may have been a stick for grubbing out unwanted plants in crops, while some form of whisk may have been used to remove troublesome insects.

During the classical ancient Mediterranean period there were several men whose writings on agricultural subjects have survived to modern times. Of these the Greeks Demo-

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critus (5th century B.C.) and Xenophon and Theophrastus, who wrote a century later, are well known. Among the Roman writers whose books may still be read today are Cato (234–149 B.C.), Varro (116–17 B.C.), Virgil (70–19 B.C.), Pliny (23–79 A.D.), Columella (1st century A.D.), and Palladius (4th century A.D.). In addition there was a host of writers whose works are no longer extant but whose writings are referred to either by contemporary authors, or in the "Geoponika". This book is a compilation of agricultural writings collected and published in the 6th or 7th centuries A.D. by Cassianus Bassus. For the most part little is known about the individual authors of the various sections except that many lived during the period 200 B.C. to 200 A.D. As with much of the writing of this time, the "Geoponika" is an undiscriminating collection of earlier works, many of which have been lost and can no longer be examined. The content is of great interest to anyone studying agricultural history.

Thus, from the writings of the above authors one can derive an understanding of methods that may have been used at the time for pest control. As there was no chemical industry, any products used had to be either of plant or animal derivation, or, if of mineral nature, easily obtainable or available. In addition to what may be loosely termed chemical methods for pest control, other practices were based on religion and folk magic. These will be referred to only briefly for, although interesting, they are outside the scope of this paper.

The main purpose of this review is to discuss some of the methods prescribed by the classical authors for the control of fungus diseases, weeds, insect, and higher animal pests, which may be taken as forerunners of the modern pesticides.

RELIGIOUS PRACTICES

Religious practices probably formed some of the earliest methods for crop protection. Xenophon (V, 19) wrote that the operations of husbandry, like those of war, were in the hands of the gods. He also observed (V, 20) that right-minded men offered prayer for fruits and crops, and asked the blessing of the gods.

According to Pliny (XVIII, 2) Romulus, after the founding of Rome in the 8th century B.C., instituted the 12 *Fratres Arvales* or Priests of the Fields, who offered a yearly sacrifice to the Lares of the fields in order to secure good harvests. Pliny also mentions (XVIII, 2) the goddesses Seia, named from the sowing of the seed, and Segesta, named from the harvest, to whom statues were erected.

Many of the classical authors list gods and goddesses to whom sacrifices should be made, and certain among these may be considered to safeguard crops against diseases and pests. Thus, although Apollo was first of all a sun god he could also protect crops by destroying the mice which infested the fields and drive off the locusts which devastated the harvests. Similarly, Pliny (XVIII, 69) makes reference to the establishment in the 7th or 8th centuries B.C. of the festival of Robigalia, which was kept on April 25th because that was the most likely time for the crops to be attacked by rust or mildew. The deity Robigus and the goddess Flora were responsible for rust and mildew, but when they were propitiated these diseases would not harm the grain and trees (Varro, I, 1). In honor of Robigus the solemn feast of the Robigalia was thus established, during which a rust-colored dog was sacrificed (Columella, X, 1), while for Flora there were games called Floralia. There also appeared to be a god Spiniensis whose aid was invoked to help clear a field of thorns.

FOLK MAGIC

Should the gods not succeed in keeping pests from the crops then there were a host of folk remedies that could also be practiced. Thus, in the "Geoponika" (XIII, 5) a spell is given to get rid of mice. Snakes also appear to have been troublesome and both Varro (I, 38) and Pliny (XVII, 8) recommend that an oak stake driven into a manure pile would prevent the snakes from breeding in the dung. Pliny seems to have made a point of collecting such remedies and wrote (XVII, 47) that some folk protected their trees against caterpillars by touching the tops with the gall of a green lizard. A crayfish hung up in the middle of a garden was thought to afford protection against caterpillars (Pliny, XIX, 58). Caterpillars could also be exterminated in gardens by fixing the skull of a female horse or ass, on a stake, in the middle of the garden (Pliny, XIX, 58).

Mildew would be controlled (Pliny, XVIII, 45) by placing branches of laurel in the ground, near to growing wheat, thus causing the mildew to pass from the fields to the foliage of the laurels.

Diseases of millet (Pliny, XVIII, 45) could be prevented by carrying a toad around the field at night and then burying the creature in the middle of the field in a pot. This treatment was also supposed to prevent damage by sparrows and worms. However, the farmers were advised to dig up the pot before the field was sown lest the land turn sour.

The "Geoponika" lists several methods (II, 42) for clearing land of a weed referred to as "osproleon" or "orobanche", which may possibly have been a type of dodder or bindweed. Branches of rhododaphne placed at the four corners and center of the field were reputed to keep the land clear of this weed. Another method for removing this twining plant was to take five shells and draw on them in chalk, or with some other white pigment, Hercules strangling a lion, and place them at the corners and center of the field.

The popular superstition of the power of virgins and menstruating women to affect growing things is made reference to by many of the writers. Columella noted (XI, 3) that shrub rue lasted for many years without deteriorating unless touched by a woman in her menstrual period, whereupon it dried up. Columella also considered (X, 1) that a menstrual or nubile virgin with bare breast and unbound hair led thrice round a garden hedge caused caterpillars to fall to the ground. This general idea, with slight variations, was also mentioned by Pliny (XVII, 47), the "Geoponika" (II, 42), and Palladius (I, 123).

Although many more of these folk remedies were mentioned by the various writers of antiquity the above will suffice as examples.

FUNGAL DISEASE CONTROL

References to what would appear to be plant diseases are made in the works of the early authors. Thus, the mention of a disease translated as "blight" is made by Xenophon (V, 18), while plant diseases translated as "rust", "mildew", and "rot" are to be found in the writings of Theophrastus (VIII, 10). The latter also observed that cereals, barley in particular, were more susceptible to rust than were pulse crops.

Care must be exercised in assuming that the diseases being referred to are akin to those of modern times; Owen, the translator of the "Geoponika", considered that ἐρυσίβη, the Greek word used to describe the blight on cereals, was called *robigo* (or *rubigo*) by the Romans because of the reddish coloration imparted to the grain by the disease. Thus, in this case ἐρυσίβη and robigo may be intended for what now would be called rust. Virgil writes of "mildew" (robigo) feeding on the stems of cereals (I, 150) and this could be a reference to either rust or a mildew. The deity, Robigus, who has already been encountered, was purported to be a god of rust and mildew. In modern translations robigo appears as "rust", "mildew", "blast", or "blight", depending to some extent upon the context. The only other Latin word, seemingly in general use and referring to "blight" upon plants, or the "blast" on trees or herbs, was *uredo*.

Many other diseases of crops and trees are mentioned by

the various writers, but usually under such general terms as rots, blights, blasts, scabs, and cankers that little can be deduced about the complaint. Some of these infections could have been fungal in origin but many were probably not. For the purposes of this paper, only diseases referred to by the Latin authors as robigo and uredo will be assumed to be of fungal origin.

Both Theophrastus (VIII, 10) and Pliny (XVIII, 44) observed that rust on vines and cereals occurred most frequently in areas exposed to dew, and in windless valleys. Later Pliny considered (XVIII, 68) that rust and blight could be caused by frost, while Columella held ("De Arboribus", 13) that fog was responsible for mildew on vines.

Against what may be described as fungal diseases there appeared to be two main remedies. The first was more preventative in nature and involved some form of seed treatment prior to sowing, while for the cure of blights and mildew in orchards, crops, and vineyards fumigation, with a variety of smokes, was practiced.

The treatment of seeds with various animal, vegetable, and mineral products was commonly used throughout this era, and, as will be seen later, was also considered to be useful against insect and other animal pests. Democritus, according to Pliny (XVIII, 45), advised that all seeds be soaked in the juice of the house-leek before planting, while Virgil (I, 190) mentioned the steeping of seed in a mixture of amurca (olive oil lees) and native soda so that greater yields would be forthcoming. Columella held (II, 10) that this latter treatment was successful also in reducing attack by weevils in the mature seed. The steeping of seed in wine to reduce the incidence of infections, both in the seed and around the roots of the germinating seedlings, was noted by Pliny (XVIII, 45). Mixing of seed with ashes or the soaking of beans in stale urine before sowing seems also to have been tried (Pliny, XVIII, 45).

The general use of smoke as a preventative against mildew and blights is recorded by Pliny (XVIII, 70), Columella ("De Arboribus", 13), Palladius (I, 119), and the "Geoponika" (V, 33). The principle was to burn some materials such as straw, chaff, hedge clippings, crabs, fish, dung, ox, or other animal horn to windward so that the smoke would spread throughout the orchard, crop, or vineyard. It was generally held that such smoke would dispel the blight or mildew. It will be noted that most of the substances mentioned would produce a malodorous smoke which seemed to be considered more efficacious than less odorous fumes.

The pounded roots and leaves of the wild cucumber when macerated in water and sprinkled on vines ("Geoponika", V, 33) seem to have been used for mildew control, while the ash of a fig or oak tree when macerated and sprinkled was supposed to have a similar effect. Another remedy for blight (Pliny, XVIII, 45) was to sprinkle the infected plant with amurca.

A mixture of ashes and sandarach when smeared on grapes was held to be effective against rot, while ashes applied to fig trees and rue plants prevented rotting of their roots (Pliny, XVIII, 47). Owen, translator of the "Geoponika", mentions that the red arsenic of the Greeks was called sandarach and there is other evidence to support this (see Discussion).

WEED CONTROL

In the previous section certain difficulties were experienced when trying to identify plant diseases mentioned by the classical authors and the same problem exists in trying to assign English names to the weeds that troubled the Mediterranean farmer. The names of weeds given here are those used by the scholars whose translations were used in the preparation of this paper. Xenophon mentions nightshade (I, 13) while darnel, grasses, dodder, broomrape, and wild oats are listed by Theophrastus. Other weeds seemingly referred to by the Latin authors include wild oats (Cato); barren oats, darnel, burs, caltrops, and thistles (Virgil); rushes, ferns, grasses, and thorns (Columella); bracken, darnel, caltrops, thistles, burs, brambles, and horse-tail (Pliny); and dodder and darnel ("Geoponika"). In addition to these plants there are others mentioned for which no specific names are given. The Latin words *herba* and *herba inutilis*, generally translated as "weeds", imply a term for unwanted grasses or plants in croplands, orchards, vineyards, and gardens.

Agricultural problems associated with weeds appeared to be well understood and the knowledge of the necessity for sowing good seed in weed-free soil, and for keeping the growing crops free of weeds to increase crop yields, is well documented. The tendency for certain weeds to be associated with specific crops was noted by Theophrastus (VIII, 8) which may have led him to conclude (VIII, 7) that weeds could result from the degeneration of cereal seeds with barley, flax, and wheat changing into darnel, especially in wet areas.

Weeding was carried out either by hand (Theophrastus, II, 7) or by ploughing (Xenophon, XVI, 14; Pliny, XVIII, 8). Virgil recommended (I, 155) the use of a hoe (*raster*) for weed control while Columella (II, 2) advocated the use of a sickle against fern, and repeated grubbing for eradication of rushes and grass. A type of light hoe called a *sarculus* was also used by the Roman farmers for weed control ("Geoponika", II, 24).

Virgil mentions (I, 85) the practice of burning the cereal stubble following the harvest, which may have been effective in burning up weed seeds (Pliny, XVIII, 72).

In addition to the mechanical methods for vegetation control a variety of other methods, which may be described as chemical, were available. According to Pliny (XVIII, 8) Democritus proposed that forest may be cleared by soaking lupin flowers in hemlock juice for a day, and then sprinkling the mixture over tree roots. Theophrastus wrote (IV, 16) that trees could be killed by pouring oil (presumably olive oil) over their roots, young trees being more susceptible to this treatment than mature ones. As well as olive oil, pitch and grease were known to be detrimental to seeds (Pliny, XVIII, 44).

Cato and Varro extol the virtues of olive oil lees, or amurca, the watery residue obtained when the oil is drained from crushed olives. Amurca had many uses in agriculture, some of which have been mentioned in the previous section. Both Cato (XCI) and Varro (I, 51) recommend that threshing floors be made from a mixture of soil and amurca so that weeds would not grow. Mention of this practice was also made by Columella, Palladius, and the "Geoponika". In this instance the amurca and soil mixture seems to have dried to a hard plaster-like finish which was thus impervious to weeds, since Cato (CXXVIII) later described how amurca, earth, and straw could be made into a plaster or stucco. However, Varro specifically noted (I, 51) that amurca was poison to weeds, ants, and moles. Varro also observed (I, 55) that where the amurca flowed from the olive presses onto the fields the ground became barren, and he went on to state that amurca was poured around olive tree roots and "Wherever noxious weeds grow in the fields". This latter use must be one of the earliest references to a specific weed killing preparation.

This use of amurca and the question of its phytotoxic properties must be viewed with the knowledge that in some districts salt was added to the olives before pressing (Columella, XII, 52; Palladius, XI, 16). Also, amurca was used as a fertilizer for olive trees (Cato, XCIII) and vines and fruit trees (Columella, XI, 2; "Geoponika", II, 10), and these latter sources both noted that amurca used for this purpose must be free from salt. Thus, it is impossible to state whether the ancient amurca was effective against some weeds, or the salt associated with it was the control agent.

Salt and sea water were known to be harmful to plants as

references by Xenophon (XX, 12), the "Geoponika" (II, 10), and Palladius (I, 9) imply, and the application of salt to the fields of vanquished enemies was often used as a method of punishment. In 146 B.C. when the Romans sacked Carthage they ploughed salt into the ground to ensure that crops could not be grown there. Although the phytotoxic effects of salt seemed to be well known none of the classical writers studied refer specifically to its use for the killing of unwanted plants.

A method is given in the "Geoponika" (II, 21) for the treatment of human feces so that they would become destructive to weeds. As this involved maceration of the dried material with water and subsequent re-drying of the solid matter (which was thought to contain the active principle), it is rather difficult to believe that this was an effective method of weed control.

An interesting method for the killing of bracken, involving both mechanical and possible chemical control (Pliny, XVIII, 8), was to knock the stalk off the budding plant with a stick. In this way it was thought that the sap trickling down the fern over a period of time would kill the roots.

INSECT CONTROL

From the numerous references to insects which attacked the crops of the Greek and Roman farmers one must assume that they recognized many of the same insect pests as we do today. The insect control practiced by these ancient agriculturalists relied almost entirely on the use of natural products and preparations derived from such materials, though mention is made in the "Geoponika" (XIII, 1) that if bats are caught and tied to tall trees locusts would pass over the area.

The practice of seed treatment to keep pests from germinating plants was generally used and the soaking of seed in the juice of the house-leek to prevent destruction by insects was popularly attributed to Democritus. The similar use of house-leek and wild cucumber extracts for seed steeps is also to be found in the writings of Columella (II, 9) and in the "Geoponika" (II, 18) as well as in the writings of Pliny (XVIII, 45). Seeds mixed with crushed cypress leaves and sown just before a new moon were considered to be safe from maggots (Pliny, XVIII, 45; "Geoponika", II, 18) while a remedy against caterpillars was to soak the seed in water in which crayfish had been steeped ("Geoponika", V, 50; Palladius, I, 128). Powdered stag antler or elephant tusk, when sprinkled over seed, was thought to be effective in keeping worms and insects away ("Geoponika", II, 18). Radish seed soaked in a mixture of powder obtained from "arched roofs" and water, or soot and water, before sowing, would protect the germinating plants from the ground flea which attacked the young leaves (Columella, XI, 3).

Theophrastus noted (IV, 14) that rain at the right time seemed to prevent larvae from appearing in olive trees, and this may have led him to suggest that rain water was good for the watering of plants as it appeared to destroy the pests damaging the foliage (VIII, 5).

The sprinkling of trees and their leaves with cow dung and water before a shower of rain was thought to afford protection to the foliage from caterpillars and other pests (Pliny, XVII, 47).

There are numerous references to be found in the "Geoponika" (V, 30) and Columella ("De Arboribus", 15) to the practice of smearing pruning knives with bear's blood, bear's fat, goat's fat, frog's blood, the oil in which insects have been left to rot, a beaver's skin, and many other similar animal preparations, before use to keep adult insects and larvae from vines and trees. Caterpillars could also be kept from vines by rubbing the bark with bear's fat ("Geoponika", V, 30).

Extracts of bitter lupin or wild cucumber seem to have been widely used against a variety of pests. Varro (I, 2) and Columella (II, 9) both mention the latter as a general procedure for killing bed bugs, and frequent references in the "Geoponika (XIII, 1, 15, 16) advise their use against locust, cantharids, and fleas.

Other plants mentioned by the classical writers, with the reputed properties of being able to kill or repel insects and their larvae, were legion and included absinthe, asafoetida, and other aromatic plants such as bay, cassia, cedar, citron, cumin, elder, fig, garlic, heliotrope, hellebore, ivy, oak, origanum, pomegranate, rhododaphne, and squill. Many concoctions utilizing these plants for application to crop or pest are to be found in the "Geoponika" (cf. XIII).

Olive oil seems to have had use as an agricultural product and when sprinkled over vines and grapes or other fruits was considered to be effective in keeping wasps away ("Geoponika", IV, 10). To safeguard plants from insect pests, additives such as citron, ivy, lupins, and a host of other animal and plant products could be mixed with the olive oil prior to application ("Geoponika", XIII, 12, 14, 16).

Amurca, which has already been encountered, was also used for insect control. Thus, it is mentioned (Columella, II, 9) that unsalted amurca when applied to the furrows at the outbreak of an infestation would drive away the "destructive creatures", while applications of amurca and red earth (possibly sandarach) would keep vines free from beetles and ants (Columella, IV, 26). When mixed with soot gnats could be driven away, and locusts were dispelled by using amurca containing extracts of cucumber or lupins, while caterpillars on cabbages were killed by an application of amurca and ox urine (Palladius, I, 122, 125, 135, 136).

Amurca, when incorporated into threshing floors, was helpful in keeping ants away (Cato, XCI; Varro, I, 51) and, on being made into a paste with chaff and applied to granary walls, appeared to be instrumental in keeping the grain free from weevils (Cato, XCII). Amurca was also used as a means of protecting clothes from moths and as a preservative for dried fruits (Cato, XCVIII, XCVIX).

Bitumen, too, had a place in agriculture and Columella ("De Arboribus", 14) advocated the smearing of a boiled mixture of bitumen and olive oil around the stems of the vines so that ants would not crawl beyond. A similar recommendation involving a mixture of red earth and tar is made by Pliny (XVII, 47).

Sulfur was used in a variety of remedies. When heated with amurca and bitumen in a copper vessel the resulting gluey substance was applied to the trunks and branches of vines for control of caterpillars (Cato, XCV; Pliny, XVII, 47). Sulfur when mixed with oil or origanum was held to be effective against bugs and ants ("Geoponika", XIII, 10, 14).

The killing of flies and other insects using poisoned bait seems to have been another practice in general use ("Geoponika", cf. XIII). Flies were killed using an infusion of bay and black hellebore in milk or sweet wine. Similarly, hellebore and arsenic when macerated in milk were known to be fatal to flies.

In addition to the above methods fumigation procedures, similar to those described for the control of mildew and blight, were carried out. Both Pliny (XVII, 47) and Palladius (I, 127) remark that the smoke from the boiling mixture of amurca, bitumen, and sulfur (cf. Cato, XCV) was successful in preventing caterpillars from attacking vines. Gnats infesting damp gardens could be driven away by the fumes of burning galbanum resin (Pliny, XIX, 58). Reputedly locusts and ants would be killed, or kept away, by the smell from their burning kind, while burning animal feces, bones, horns, ivory, garlic, cedar gum, and various plants and roots were considered to be useful against a variety of insect pests ("Geoponika", cf. XIII).

Finally, it should be mentioned that certain forms of nonchemical crop protection were practiced. Theophrastus noted (VII, 5) that radishes could be protected from spi-

ders by sowing vetch among the crop. The planting of bitter vetch with turnips, and chick peas among cabbages, were also thought to be beneficial against crop damage from caterpillars (Pliny, XIX, 58). A method for the protection of young trees from worms was to plant the shoots in the bulb of a squill (Theophrastus, VII, 13; Pliny, XVII, 16).

NONINSECT PEST CONTROL

Besides all the diseases, weeds, and insect pests already mentioned, the crops of the Greek and Roman farmers suffered as well from the depredations of mice, moles, and rats. Weasels, bats, scorpions, and snakes were also considered to be undesirable, but more to farm animals and man than to crops. Against such pests the practices of seed and crop treatment, fumigation, and the use of poisons were all tried as methods of protection.

Many of the seed treatments previously mentioned were, in all probability, used for protection against pests in general including rats and mice. As a specific safeguard against mice, seed was sprinkled with the ashes of a weasel or a cat, or smeared with ox gall before sowing (Pliny, XVIII, 45; "Geoponika", XIII, 5; Palladius, I, 132). Small pests and vermin could also be kept from a variety of crops by regularly sprinkling the plants with the water in which crabs or crayfish had been allowed to rot ("Geoponika", V, 50).

The fumes of burning ivy were reputedly effective against bats, while several fumigants, including origanum, parsley seed, and calocanthus, were used to drive away mice ("Geoponika", XIII, 4, 13). Burning cedar, galbanum, and stag antler supposedly kept snakes from farm buildings (Virgil, III, 415; Varro, III, 9; Palladius, I, 134). Various fumigations were also used against scorpions, with the smell of their burning brethren considered to be a successful deterrent, although the burning of sandarach (an arsenical compound) may have been more so ("Geoponika", XIII, 9).

The use of poisoned bait around the house and granaries to kill rats and mice was also recommended with various preparations being described in the "Geoponika" (cf. XIII). Hellebore, hyocyamus, hemlock, and wild cucumber were all considered to be poisonous to small animal pests and used in such remedies. Iron filings when mixed with bread were held to be fatal to mice while radish juice was thought to be deadly to scorpions.

DISCUSSION

The foregoing represents some of the methods known to be available to the Greek and Roman agriculturalists for crop protection, though it is impossible to decide how extensively such practices were used. Nothing is known regarding the success of these remedies, for if comparisons were made between treated and control crops, there appears to be no mention made.

The writings of Xenophon, Theophrastus, Virgil, Cato, Varro, and Columella imply that these authors knew something about agriculture and had studied its practice, whereas those of Pliny and Palladius seem to be based chiefly on the writings of others and hearsay. An added difficulty is that famous writings were often rewritten and appeared under new authorship, while even more common was the attributing of new works to a famous author as seems to be the case in the "Geoponika". This work contains numerous remedies collected from many sources, together with such a variety of spells, hearsay, and folk magic that one wonders how much this reflected the farming of the age.

Even more difficult is to look back almost 2000 years and try to assess how successful the various crop protection methods might have been. As already intimated certain difficulties must arise as to exactly which insect, grub, caterpillar, plant, plant disease, or compound the ancient authors were referring. Throughout this text all such names given are those designated by the translators.

Seed treatments against fungal infections could have been slightly effective, especially the use of wine, as the alcohol would have had some antiseptic qualities. Burnt ashes are a source of lye (impure potassium carbonate), while stale or old urine would contain ammonia. Such alkaline seed treatments were shown by Tillet in 1752 to be effective in reducing the incidence of the fungal disease of wheat now known as bunt (cf. Large, 1962). For similar reasons vines, figs, and other plants when sprinkled with a mixture of ashes in water could have been given a small measure of protection against certain diseases. This protection would have been more marked with the applications of sandarach, considered to be a sulfide of arsenic, for arsenical compounds possess both fungicidal and insecticidal properties.

In a Greek and Latin version of the "Geoponika", edited by Niclas, and published in Leipzig in 1781, "sandarach" appears as σανδαράχη and sandaracha respectively; thus, the Latin name seems to be a direct transcription from the Greek. Pliny describes (XXXV, 22) some of its properties, such as its red color and that it occurred in gold and silver mines. Modern sources, which include the Shorter Oxford English Dictionary (1933 edition), the Encyclopaedia Britannica (1973 edition), and the Greek–English Lexicon of Liddell and Scott (1901 edition) all consider sandarach (or sandarac) to be a sulfide of arsenic.

For crop protection against insects and small mammals the impression is gained that many of the remedies were used as a means of driving the creatures away, as there are few actual references to the killing of pests. Many of the materials applied to the seeds and crops were evil smelling or otherwise obnoxious to man and would, therefore, be assumed to be repugnant to other animals by men of this period. Such preparations described may, indeed, have had pest repelling qualities or may have masked the scent of the crop, or otherwise disguised it, thus making the plants more difficult for the pests to find.

It is now known that certain plants do have insecticidal properties and some of those mentioned in the text may have contained such principles, especially the hellebore, if *Veratrum album* Linn. was being used. The ground rhizome of this plant contains several alkaloids active against insect pests (Frear, 1948, p 181). Certain species of lupin also contain insecticidal ingredients (Frear, 1948, p 186), while hemlock, hyocyamus, and squill contain poisonous compounds which could have been fatal to insects, larvae, and small animals.

Whether hemlock juice and bitter lupins in conjunction would prove fatal to trees seems doubtful, but oil of hemlock, which contains the alkaloid coniine, was known by the ancient Greeks to be toxic to man since they used it in executions. The most famous use of hemlock in this instance was the forced suicide of Socrates in 399 B.C.

Certain animal fats do have some insecticidal properties (Martin, 1940, p 214) so that the use of bear's and goat's fat, when applied in large amounts to the crops, may have afforded some measure of protection from insects. The rubbing of pruning knives with these preparations might have reduced the incidence of some diseases, since in horticulture the pruning knife can be a dangerous carrier of bacterial, fungal, and viral infections.

The use of olive oil could have proved beneficial by making the leaves sticky and thus repellant to insects, or by masking the scent of the fruits, though olive oil, in common with other vegetable oils (Frear, 1948, p 196; Martin, 1940, p 152), does possess some fungicidal, insecticidal, and ovicidal properties. Oils and greases also impart phytotoxic properties, usually by affecting the stomata and thus transpiration, so the observation that olive oil was detrimental to trees, and specifically young ones, could be valid. A fur-

ther component of ripe olives is oleic acid (Diez, 1971) which has been shown to be phytocidal in small amounts (Martin and Salmon, 1933).

The role of amurca is difficult to assess though it does seem to have been a universal remedy against insects, weeds, and plant diseases. The composition of amurca is unfortunately difficult to deduce. According to Columella (XII, 52) and Cato (LXVI) the olive pits were not to be crushed during the pressing since this was considered to spoil the flavor of the oil. Pliny mentioned (XV, 4) that amurca was a bitter, watery liquid and this bitterness is now known to be chiefly due to the easily hydrolyzable glycoside oleuropine (Diez, 1971) whose structure has been elucidated (Inouye et al., 1970). It is not known whether this glycoside possesses any pesticidal properties. The amurca would also have contained traces of phytocidal, insecticidal, and fungicidal glyceride oils as well as oleic acid. Salt was sometimes added to the olives prior to pressing which may have resulted in additional phytotoxic properties. A further and complicating factor was that during the preparation of amurca as described by Varro (I, 64) the liquid was boiled to about two-thirds of its original volume in a copper vessel. In this way not only would the amurca become contaminated with traces of copper, but a number of extra products could be formed by hydrolytic processes. As copper salts are now known to be extremely effective against certain fungal diseases it is possible that the amurca prepared in this manner contained fungicidally active amounts of the metal.

The principles of fumigation involving evil smelling compounds may have had some temporary effects in driving away insects, small mammals, and snakes, but its effectiveness in mildew and rust control would have been limited. Also it is not too clear from the various texts whether it was the diseases themselves or the causal "fogs and dews", or both, which were to be dispelled by such measures. Sulfur is now known to have both insecticidal and fungicidal properties and the use of sulfur containing fumigations could be expected to have lethal effects against adult insects and their larvae. Such fumigants may also have resulted in some protection against fungal diseases.

Application of bitumen and sulfur to the trunks of trees is an example of what is now called grease banding and should have been very successful in preventing wingless pests from crawling up the vine and tree trunks to deposit eggs on the buds and twigs. The bitumen used may even have contained insecticidal principles of its own.

The use of arsenic as a fumigant and in bait (sandarach being a derivative of arsenic) would have almost certainly had fatal effects on the recipients and many of the toxic baits used against mice and rats should have proved effective.

References to the use of plants sown mixed with turnips and cabbages are somewhat vague, though the sowing of trap crops to attract the pest from the important crop may have been the intent. The growing of tree shoots in the bulb of a squill, whose toxicity to insects has already been mentioned, seems also to have been an ingenious concept.

Although it is very difficult to assess the success of the various products and methods mentioned by the classical writers or even to guess whether they were commonly used by agriculturalists throughout the era, the principles of seed treatment, fumigation, tree banding, and of using certain preparations to kill unwanted plants, insects, larvae, and animal pests were well established and must be considered to be the forerunners of modern crop protection practice.

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For the citations to the works of Columella, Palladius, Pliny, Theophrastus, Varro, Virgil, and the "Geoponika" the Roman numeral refers to the book number and the arabic number to the chapter. In the case of the writings of Palladius and Virgil the arabic numerals are to the stanzas and paragraphs, respectively. The works of Cato and Xenophon are not divided into books; thus the Roman numbers associated with these references are to the numbered sections. As these sections are very long in Xenophon's "Oeconomicus" the arabic numerals have been added to indicate the paragraph. For the citations to references to the remaining modern books, the arabic numbers are for the year and pages.

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