Pests and diseases

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Greek and Latin terms that most frequently appear in the corpus

Termes latins fréquents : *noxium animal*, (*noxia*) *pestis*, *bestiola*, *pernicies*, *animal maleficum*, *dirum animal*, *animal inimicum*, *animal infestum*, *monstrum*, *uitium*. On notera que le verbe *nocere*, sous diverses formes, est appliqué à certains animaux pour décrire leur caractère nuisible.

Termes grecs fréquents : τὰ *(λυμαινόμενα)* θηρία, τὰ *(φθοροποιὰ)* ἑρπετά, τὰ δηλητήρια. Une grande variété de substantifs et de verbes sont utilisés pour décrire les dommages causés par les animaux nuisibles.

Related themes

animaux nuisibles ; prophylaxie ou remédiation (hors amendements) ; maladies des plantes

Principal references

Pour une liste complète des passages dans les œuvres de Caton, Varron, Columelle et Palladius, voir 1. et Fögen (2022).

1.ANIMAL PESTS IN ANCIENT TEXTS

In **Hesiod**'s *Erga*, there are only four instances where the author draws attention to noxious animals: In *Erga* 420–421 (τῆμος ἀδηκτοτάτη πέλεται τμηθεῖσα σιδήρῳ | ὕλη) and 435 (δάφνης δ' ἢ πτελέης ἀκιώτατοι ἱστοβοῆες), the author refers to wood getting potentially damaged by worms, as indicated by the superlative adjectives ἀδηκτοτάτη (‹least bitten by worms›, derived from the verb δάκνειν: ‹to bite›) and ἀκιώτατοι (‹the least wormy›, derived from the substantive κίς: ‹woodworm› or ‹weevil›; see Frisk [2]1973 [vol. 1]: 858). He recommends that the ploughman be followed by a worker using a mattock to cover up the seed and thus prevent birds from picking it up (*Erga* 469–471: ὁ δὲ τυτθὸς ὄπισθεν | δμωὸς ἔχων μακέλην πόνον ὀρνίθεσσι τιθείη | σπέρμα κατακρύπτων). He also points out the need to remove spider-webs from storage vessels (*Erga* 475: ἐκ δ' ἀγγέων ἐλάσειας ἀράχνια), presumably to be able to use those jars again. But apart from these four passages, Hesiod has nothing else to say on pests and vermin.

With regard to pests and vermin, **Cato** uses various forms of the verb *nocere*, referring to ants (*De agr.* 91: *formicae*), weevils (92: *curculiones*) and moths (98.1: *tiniae*). However, unlike later Roman agricultural writers, he does not have a specific substantive or a combination of substantive and adjective to designate such animals. In *De agricultura*, he discusses methods of pest control regarding the following animals: ants (*formicae*), moths (*teredines*), weevils (*curculiones*), mice (*mures*), caterpillars (*convolvuli*), ticks (*ricini*), snakes (*serpentes*), tapeworms (*taeniae*), stomach-worms (*lumbrici*), moths (*tiniae*) and worms (*vermes*). In comparison with the later tradition, this is a rather small selection of noxious animals; his narrow perspective is to some extent due to the character of *De agricultura* as a treatise that comes across as incomplete and unrevised.

Varro speaks of *animalia quaedam minuta* (*De re rust.* 1.12.2), who are said to occur in marshy regions and transmit diseases. Several times he employs the term *bestiolae* for pests and vermin (*De re rust.* 1.12.3, 2.5.14). There is also the combination *animal maleficum* (3.7.3) and the circumscription *cetera, quae gallinam conquiescere non patiuntur* (3.9.8). He discusses a wide range of noxious animals, e.g. bugs (*cimices*), ants (*formicae*), worms (*vermes*), weevils (*curculiones*), flies (*muscae*), gad-flies (*tabani*), ticks (*ricini*), fleas (*pulices*), lice (*pedes*), mice (*mures*), lizards (*lacertae*), snakes (*serpentes*), weasels (*mustelae*), martens (*faeles*), badgers (*maeles*), ravens (*corvi*), hawks (*accipitres*), eagles (*aquilae*), goats (*caprae*), foxes (*vulpes*) and wolves (*lupi*).

Columella uses the combination *noxium animal* in the singular (*De re rust.* 8.2.11) and in the plural (*De re rust.* 2.9.10, 8.3.4, 8.11.1, 9.7.1, 11.3.63). On one occasion, he refers to *noxiae pestes* (*De re rust.* 8.3.6). The substantive

pestis is repeatedly employed to refer to undesirable animals (*De re rust.* 1.5.6, 2.9.10, 7.4.6, 8.5.18, 9.7.6, 9.14.2; see also 10.357). Furthermore, Columella uses *pernicies* (*De re rust.* 8.14.9), *bestiolae* (*De re rust.* 11.3.61 and 11.3.64), and in a poetic context *dira animalia* (10.351). A detailed discussion of the individual types of pests and vermin in Columella is offered by Fögen (2022).

Palladius uses various forms of the verb *nocere*, referring to a variety of different animals (1.35.2, 1.35.4, 1.35.6, 1.35.7, 1.35.12, 1.35.13, 14.21.1, 14.22.14). He also speaks of *animalia inimica* (1.7.4, 1.24.3), *noxia animalia* (1.19.2, 1.19.3, 1.37.8, 3.12.4), *animalia infesta* (1.35.5; see also 7.3.2) and *monstra noxia* (1.35.11). In addition, there is the substantive *noxa* combined with the pernicious animals added in the subjective genitive (1.37.7: *propter lacertorum ceterorumque animalium noxam*, 14.18.6). In Books 1–12 Palladius ranges the following animals among pests and vermin: lice (*peducli*), fleas (*pulices*), caterpillars (*campae* and *erucae*), worms (*vermes* and *tineae*), bugs (*cimices*), ants (*formicae*), weevils (*gurguliones*), cockroaches (*blattae*), Spanish flies (*cantharides*), gnats (*culices*), moths (*papiliones*), locusts (*locustae*), mole crickets (*prasocoridae*), hornets (*crabrones*), snails (*limaces*), spiders (*araneae*), scorpions (*scorpii*), lizards (*lacerti*), snakes (*serpentes*), birds (*aves*), mice (*mures*), moles (*talpae*), cats (*catti*), ferrets (*mustelae*) and foxes (*vulpes*), but also small cattle (*pecus*). In Book 14, dealing with veterinary medicine, Palladius mentions lice (*peduculi*), ticks (*ricini*), worms (*vermes*) in ulcers of bovines, fleas, gad-flies (*ystri*), snakes (*serpentes*), scorpions (*scorpii*), harmful animals with a sting or poisonous animals (*aculeata vel venenata animalia*), various poisonous animals (*vermiculi*, serpentes, minora animalia, viperae, caeciliae and mures aranei), internal contamination with leeches (*hirudines* and *sanguisugae*), worms (*vermes*) and stomach-worms (*lumbrici*), the excrements of pigs and chickens as a source of danger, and rabid dogs and wolves.

Pliny the Elder devotes Book 18 of his *Naturalis historia* to agriculture and deals specifically with the different types of grain and leguminous plants. To refer to noxious animals, he uses words such as *bestiolae* and *maleficia* (*Nat. hist.* 18.308). More generally, he speaks of vitia (*Nat. hist.* 18.302 and 18.308; see also 18.154: *commune . . . omnium satorum vitium*) or simply of *animalia* (*Nat. hist.* 18.304); in those cases, it is sufficiently clear from the context what type of animals he is thinking of. Methods to repel noxious creatures are described through verbs such as *abigere* (e.g. *Nat. hist.* 18.160) or through substantives such as *remedium* (e.g. *Nat. hist.* 18.156). In Book 18 he mentions worms (*vermes* and *vermiculi*), caterpillars (*uricae* [= *erucae*]), weevils (*curculiones*), a small beetle called ‹kantharis› (*cantharis dictus scarabaeus parvus*), slugs (*limaces*) and small snails (*cocleae minutae*), mice (*mures*), birds (*aves*), in particular sparrows (*passeres*) and starlings (*sturni*), and more generally small quadrupeds (*parvae quadripedes*).

Vergil's *Georgica* are a slightly more complicated case. With his poetic diction, he repeatedly uses a suggestive or even outright negative diction to refer to noxious animals. For example, a goose (*anser*) is called *improbus* (‹bad›, ‹vile›) because it may do harm to seeds (*Georg.* 1.118–121); a viper (*vipera*) is ‹deadly to touch› (*mala tactu*), an adder (*coluber*) is the ‹sore plague of cows› (*pestis acerba boum*), a type of snake occurring in Calabria is simply *malus*, which may be translated not only as ‹bad› or ‹evil›, but also as ‹deadly› (*Georg.* 3.416–419, 3.425). At the beginning of Book 4, Vergil uses several verbs describing the detrimental impact of different animals such as sheep (*oves*), young goats (*haedi*) and heifers (*buculae*): *insultare*, *decutere*, *atterere* and *vastare* (*Georg.* 4.10–17). Equally graphic is a later passage in the same book (*Georg.* 4.245–247), where he refers to the ‹fierce hornet› (*asper crabro*), the ‹pestilent race of moths› (*dirum tiniae genus*) and the ‹spider being hateful to Minerva› (*invisa Minervae . . . aranea*). On one occasion, he even speaks of ‹countless beasts born of the earth› (*Georg.* 1.184–185: *quae plurima terrae monstra ferunt*). In addition to the aforementioned noxious animals, he also refers to cockroaches (*blattae*), weevils (*curculiones*) ants (*formicae*) toads (*bufones*), lizards (*lacerti*), geckos (*steliones*), mice (*mures*), moles (*talpae*), water-snakes (*chelydri*) and birds (*aves*), among them specifically cranes (*grues*), bee-eaters (*meropes*) and swallows (*Procnae*).

In the tenth-century Byzantine Greek farming manual *Geoponica*, noxious animals are usually referred to through the relatively neutral terms τὰ θηρία (‹animals›), τὰ ἑρπετά (‹beasts/animals which go on all fours›, ‹creeping things›, ‹reptiles›, esp. snakes) or even τὰ ζῷα (‹animals›). However, it is usually clear from the context that these animals are to be classified as harmful. In some cases, this is explicitly signalled through words employed to describe their actions or their impact, e.g. through substantives such as ἔφοδος (‹approach›, ‹arrival›, ‹attack›, ‹onslaught›; often used elsewhere as a military term), βλάβη (‹damage›), φθορά (‹destruction›, ‹ruin›) and πληγαί (‹bites›), but also through verbs such as προσιέναι or προσέρχεσθαι (‹to come near›), εἰσέρχεσθαι (‹to go in›, ‹enter›), ἐπέρχεσθαι (‹to come upon›, ‹arrive›), ἅπτεσθαι (‹to fasten oneself to›, ‹grasp›, ‹take hold of›, ‹cleave to›, ‹attack›), ἐπικαθέζεσθαι (‹to sit down upon›), βλάπτειν (‹to damage›, ‹hurt›), ἀδικεῖν (‹to wrong›, ‹injure›, ‹harm›), ὀχλεῖν or ἐνοχλεῖν (‹to trouble›, ‹annoy›, ‹be a nuisance›) and λυμαίνεσθαι (‹to outrage›, ‹maltreat›, ‹harm›, ‹injure›, ‹spoil›, ‹ruin›). In *Geop.* 9.10.9, the expression τὰ λυμαινόμενα θηρία is used, against which a ‹treatment› (θεραπεία) is recommended (similarly *Geop.* 18.2.4: τὰ θηρία τὰ λυμαινόμενα). A parallel is the word τὰ δηλητήρια (*Geop.* 12.30.4), a substantivised form of the adjective δηλητήριος (‹noxious›), which is derived from the verb δηλεῖσθαι (‹to hurt›, ‹do a mischief to›, ‹damage›, ‹spoil›, ‹waste›, ‹violate›). A similar case is *Geop.* 5.26.6 which speaks of τὰ φθοροποιὰ ἑρπετά (φθορο-ποιός: ‹causing destruction›). Slightly more specific is the expression τὰ ἰοβόλα θηρία (*Geop.*

2.47.12), referring to venomous creatures such as adders, widow spiders, poisonous snakes, rats and scorpions; the adjective ἰοβόλος literally means ‹shooting arrows›, but here it denotes animals ‹shedding venom›, envisaged to attack farm workers. Passages discussing the prevention from pests and vermin use verbs such as κωλύειν (‹to hinder›, ‹prevent›) or more explicitly τὴν ἐκ τῶν θηρίων βλάβην κωλύειν (‹to prevent damage caused by animals›), φυλάττειν (‹to watch›, ‹guard›, ‹defend›), εἴργειν (‹to prevent›), ἀπ-είργειν (‹to keep away from›, ‹debar from›, ‹ward off›), ἐκφοβῆσαι (‹to frighten off›) and θηρᾶν (‹to hunt after›, ‹pursue eagerly›). More specifically, the actual removal and killing of noxious animals is described through verbs such as καταλαμβάνειν (‹to catch›, ‹seize›, ‹lay hold of›), ἐλαύνειν (‹to drive away›; also through the compounds ἐξ-ελαύνειν and ἀπ-ελαύνειν), φεύγεσθαι (‹to be expelled›, ‹be driven out›), ἐξάγειν (‹to expel›), διώκειν or ἀπο-/ἐκ-διώκειν (‹to chase away›; see also the substantive ἀποδίωξις in *Geop.* 13.1.1), ἐκβάλλειν (‹to throw out›, ‹expel›), ἀφανίζειν (‹to make unseen›, ‹hide›, ‹remove›, ‹destroy›), ἀποκτείνειν (‹to kill›), κατακτείνειν (‹to kill›), διαφθείρειν (‹to kill›), ἀπόλλυσθαι (‹to kill›), ἀναιρεῖν (lit. ‹take up [sc. and carry off]›, ‹kill›, ‹destroy›) and ἀπόλλυσθαι (‹to be destroyed›). Book 13 of the Geoponica is specifically dedicated to noxious animals and deals with locusts (13.1), βροῦχοι (13.2, a type of locust), weasels (13.3), house mice (13.4), field mice (13.5), cats (13.6), mole rats (13.7), snakes (13.8), scorpions (13.9), ants (13.10), mosquitoes (13.11), flies (13.12), bats (13.13), bugs (13.14), fleas in the house (13.15), beetles (13.16), leeches (13.17) and frogs (13.18); this book offers a wide range of different methods as to how eliminate these animals. In the rest of the work, there are references to (animal) fleas, ticks, lice, flea beetles, borer beetles, caterpillars, grubs, worms, leek moth larva, horseflies, gadflies, gnats, wasps, lizards, adders, vipers, birds (specifically vultures, tits, bee-eaters, swallows and jackdaws), foxes and crocodiles.

Siede (2006: 149–150) has claimed that neither Greek nor Latin has « eine eigene Bezeichnung entsprechend unserem ‹Schädling› ». The evidence presented here speaks very clearly against this hypothesis.

2.ANCIENT AND MODERN TERMINOLOGY

From the above material assembled in the above section « Termes grecs et latins les plus fréquents dans le corpus », it is evident that all four Roman agricultural writers use certain terms to refer to pests and vermin, though to a varying degree. Columella's and Palladius' terminology is more developed in this regard than that of Cato and Varro.

Latin terms such as *noxium animal* or *noxiae pestes* have direct correspondences in modern languages. In French it is ‹animal nuisible› (or ‹espèce nuisible› and ‹organisme nuisible›), in German ‹Schädling› (or ‹Schad¬organismus›, ‹Lästling› and ‹Ungeziefer›), and in English ‹pest› and ‹vermin›. Among similar terms in Slavic languages, one may refer to Czech ‹škůdce› (derived from ‹škoda›, corresponding to the German word ‹Schade›), Slovak ‹škodca›, Polish ‹szkodnik›, Ukrainian ‹шкідник› and Slovenian ‹škodljivec›. In Russian, the word ‹□□□□□□□□› refers to a ‹naughty child› or ‹rascal›; for ‹pest› or ‹vermin›, the word ‹□□□□□□□□□› is used, derived from the substantive □□□□ (‹damage›) and the verb □□□□□□□ (‹to harm›). These modern terms usually designate animal or plant organisms which represent a certain danger for humans and animals in sanitary, economic and ecological respects. Pests and vermin may destroy plants, in particular those that guarantee the sustenance of humans and animals. Furthermore, they can attack and even destroy both human and animal organisms. But they can also affect buildings and ultimately cause their damage. Antonyms in English are ‹working animal› or ‹farm animal› and ‹useful plant› or ‹crop plant›; German has the terms ‹Nützling›, ‹Nutztier› and ‹Nutzpflanze› (for definitions, see e.g. Wolf 2001: 41, Reichholf 2001: 77–80, DeMello 2012: 194–210 and Kompatscher, Spannring & Schachinger 2017: 78–85; specifically with regard to Roman antiquity, see Martini, Küppers & Landfester 2000: 140–141 and Goguey 2003: esp. 9–14).

Pests and vermin may be divided into various different subcategories, usually determined by the area that has been affected by them, e.g. agriculture, forestry, supplies of goods and certain materials, but the exact boundaries are sometimes difficult to define (see e.g. Kemper 1959: 21, Keilbach 1966: 9–10 and Grau 1971: 5–11). Kemper (1959: 10–11) differentiates between Vermes, Mollusca, Crustacea, Insecta, Arachnoidea, Aves and Mammalia; he emphasises that most pests belong to the class of insects (Kemper 1959: 35).

However, there are animals that may cause a great deal of damage without actually being called ‹pests› or ‹vermin›—presumably on the grounds that they are for the most part or at least to some extent useful (see Kemper 1959: 21–22). Moreover, pests and vermin are not necessarily identical with parasites (see esp. Stullich 2013; see also Keilbach 1966: 10–11, further Bodson 1994: 305, 306). For that reason, one may argue that pests or vermin are living beings that are at the wrong place at the wrong time; humans diagnose them as such when they interfere with their environment or influence their existence in a negative way, even in cases where this is only of a short duration. In other words, they are not pests or vermin per se. The use of this kind of terminology is therefore a matter of perspective which must be seen as anthropocentric (see e.g. Kemper 1968: 11, Keilbach 1966: 9, Grau 1971: 4, Kompatscher, Spannring & Schachinger 2017: 48–60, esp. 56–57, and DeMello 2012: 51).

3.THE PROTECTION AGAINST PESTS AND VERMIN IN ROMAN AGRICULTURE

From the ancient Roman agricultural treatises, it is obvious that estate owners and farmers take a strong interest in economic profit. This entails that they must prevent their agricultural products, including their animals, from being affected by any damage or loss. The right choice of a suitable territory for an estate is essential: it needs to guarantee a benign climate, fertile ground, a healthy environment, good water supply and closeness to a flourishing city (see e.g. Cato, *De agr.* 1; Varro, *De re rust.* 1.12.2–3; Pliny the Elder, *Nat. hist.* 18.26–33; Columella, esp. *De re rust.* 1.2.3, 1.5.6; Pliny the Younger, *Epist.* 5.6, esp. 5.6.2–3, 11 and 45; see also *Geop.* 2.3, 5.4, 5.5, 10.1 and 12.2). In addition, farmers need to protect their crops and animals against pests and vermin.

This can be achieved in various different ways. Cato, Varro, Columella and Palladius offer advice as to how to construct farm buildings in an appropriate manner so as to make them as pest-resistant as possible. Of utmost importance is hygiene; this applies to the warehouses as well as the stables for farm animals. The preservation of food, especially through the use of salt and oil, is also practised widely.

The Roman agricultural writers further recommend specific ingredients such as *amurca* (< ἀμόργη: ‹dregs of oil›, ‹watery part which runs out when olives are pressed›; see Bruno ^{2}1969: 213) used for all kinds of purposes, e.g. the impregnation of buildings, vessels, cabinets or materials (such as leather, metal, wood and clay), but also as a remedy for animals, trees and even humans (see e.g. Cato, *De agr.* 91–92, 95–98, 128; Columella, *De re rust.* 1.6.14, 4.24.5–6; Pliny, Nat. hist. 15.33–34, 17.264, 18.157–159, 18.295, 18.301, 18.305; *Geop.* 2.10, 2.18, 2.26, 3.15, 5.21, 5.38, 6.9, 7.17, 7.28, 9.10, 9.19, 10.48, 10.84, 11.18, 12.8, 13.4, 13.10, 13.14–15, 17.14, 17.28, 18.8, 18.15 and 19.3).

Veterinary medicine, including the removal of pests, vermin and parasites, is an important part of ancient agriculture (see Bodson 1984, Fischer 1988 and Goebel & Peters 2014). It provides farmers with therapeutic methods and remedies that they can practise and apply themselves in order to protect the health of their animals. In certain cases, remedies used for animals are suitable for humans as well. The most detailed advice is offered by Columella and Palladius; while the former integrates passages on veterinary medicine into Books 6–9 of his *De re rustica*, the latter has a separate book on the principles of this discipline (Book 14 of his *Opus agriculturae*).

To some extent, ritual and magic play a role for the prevention of pests and vermin (see Ordish 1976: 28–32, Schlütsmeier-Hage 1988: 74 and Siede 2006: 158, 160–161; see also Ager 2019). Their efficiency has been rightly questioned by modern scholars, but also by some of the ancient writers themselves (see e.g. *Geop.* 13.5 on the explicit rejection of a ‘ridiculous’ practice fighting mice). At the same time, it has to be admitted that certain other methods or remedies that were widespread among Roman farmers are still used in agriculture today (or have been used until recently).

4.PARASITE DIVERSITY AND DISEASES POTENTIALLY PRESENT IN GAUL IN ROMAN TIMES

Bad weather and climate variations can damage plants severely and even stimulate the development of parasites on growing plants and of destructive pests in stored products. Some of the pathogens—animal, vegetal, fungal, bacterial, or viral—that have now disappeared from western European fields are still active elsewhere in the world. These “diseases” affecting crops and food stocks present a significant risk factor, because damage to plants causes a reduction in productivity, the loss of stocked seed or a decrease in their germination capacity, and the decline in the sanitary quality of the produce. Written sources suggest that agriculture in the ancient world had to contend with several forms of animal and vegetal destruction, invasion, or infestation, endangering both field crops and stored harvests (Darck and Gent, 2001; Ruas *et al.*, 2016).

Parasites affect plants at different stages of their growth and according to specific modes of development: they may live in the plant’s tissue or organs (endoparasites), or feed on external parts of the plant (ectoparasites). Some parasites produce resistance organs whose maturation occurs at the same time as the plant’s. These parasites are then harvested with the expected produce (grain, fruit, etc.) and put into storage among it. Unless they are eliminated before the next sowing, they will trigger a new infestation cycle in the seedlings.

In addition to parasites, commensal granivores, such as some birds and rodents, are also responsible for the loss of newly sown and stored seeds.

Some ant species, known as harvester ants, are essentially granivorous, and have developed a collective supply system. Most of these ants belong to the *Messor* genus, several species of which are found in France, but they do not feed exclusively on domesticated plants.

Species that target plants useful to humans are more concerning. Several can be identified in evidence from archaeological contexts. Among insects, several types of beetles are ectoparasites of growing plants and of stored seeds. Members of the *Bruchus* genus infest growing pulses and often target a single species (e.g., pea, broad bean).

Adults lay their eggs in young pods (fruits) while their protective tissue is still soft. Each young larva settles inside a seed and grows there until it reaches the nymphosis stage, feeding on the seed's reserves, although this does not necessarily have any impact on the seed's development. The adult beetle (*imago*) emerges from the seed by piercing the tegument, and leaves behind a cavity as evidence of its presence. Usually, each seed contains a single larva, but occasionally a single seed may house several. When cultivated species are infested, the emergence of adult beetles often follows the harvest and occurs while the pods are drying, before threshing, or while the seeds are in storage. Adults of the Bruchus genus do not feed on the seeds, but rather on nectar. Although they may be damaged, the empty, pierced seeds are still edible and easily separated from intact seeds owing to their lower density: by immersing seeds briefly in water before use, it is easy to identify and remove damaged seeds, which float on the surface of the water.

Other insects prefer to target stored seeds or their derivatives, such as semolina and flour. Weevils (*Sitophilus* genus) are among the most common primary insect pests, particularly wheat weevils (*Sitophilus granarius* L.). This wingless species lays eggs directly inside the seed (Rollin, 2016), and its propagation is tightly linked to the circulation of foodstuffs. It favours common wheat, but also targets barley, rye, corn, buckwheat, sorghum, shelled rice, oat, sunflowers, millet, and chickpea (Huchet, 2016). The lesser grain borer *Rhyzopertha dominica* (F.) is another primary insect pest attested in archaeological sources. Both species are responsible for extensive damage, as their larvae develop inside the seeds and feed on their embryo (germ) and albumen. When they emerge from the seed as adults, they consume the inside of the grain until only the pericarp remains. They reproduce in the stored grain, and, from one generation to the next, play in a significant part in destroying harvests. Both species leave behind residue that is in turn targeted by secondary insect pests feeding on grain dust or the waste of previous pests, or preying directly on other pest species. This category contains, to name but a few, sawtooth grain beetles [*Oryzaephilus surinamensis* (L.)], read beetles [*Stegobium paniceum* (L.)], dermestids, larvae of the Staphylinus genus, ptinids, and tenebrionids [mealworm (*Tenebrio molitor*) larvae] (Huchet, 2016).

Animals from other classes can also be a cause for concern, such as nematodes: thin, elongated worms, which are usually between 0.3 and 1.5 mm long. Their life cycle comprises two stages: worms and galls. The latter of these are dormant organs responsible for dissemination; galls are swollen growths that may be cylindrical or misshapen, purplish brown—almost black—in colour, and 3–5 mm long and 3–4 mm wide. As their size is comparable to that of plant macroremains, galls may be identified in archaeological deposits. *Anguina tritici* is the most common seed and leaf-gall nematode in the *Anguina* genus, a common pest of the *Triticum* (wheat) genus. Although it was widespread during the twentieth century, *Anguina tritici* disappeared from western European fields in the 1950s and is now considered an old disease, although it persists in a few countries (e.g., Brazil and India), and has been identified in some organic crops in Brittany.

An infestation of *Anguina tritici* begins on the ground when humidity causes the galls to open. Larvae emerge and migrate into the leaf tissue of the host seedling upon which they feed; they settle in the floral buds of the ears and gather together to form a gall, in which they develop until they reach the adult stage. When the ears are mature, the galls fall on the ground or are harvested with the grain. They are easy to sort by sight owing to their dark colour; if they are ground together with the grain, the resulting flour will be unpleasant to taste, but not toxic. In any case, such parasitism reduces crop yields. In the first century CE, Pliny the Elder mentioned that the presence of "worms" and other diseases in wheat crops seemed to be linked to the humidity of the soil, and he provided the following piece of advice: "if worms are clinging to the roots, the remedy is to sprinkle them with pure, unsalted lees, and then to hoe" (Pliny, *Natural History*, 18, 159).

In addition to animals, several fungi species are common crop parasites; each species targets a specific organ of the plant. Rust and smut fungi are well known and are responsible for the deterioration of leaves, stems, or roots.

Two further pathogens are of interest to archaeobotanists because their remains are sometimes identifiable in habitats, stores, or waste heaps: wheat bunt and rye ergot. They mainly infest the ears of grasses, including cereals. Their life cycle—like that of gall nematodes—includes a stage involving a macroscopic organ, equal or superior in size to the seed, that is released when the ears are ripe. These growths develop when spores infest the floral bud of a spikelet; they may create a deformed seed filled with spores (sorus in wheat bunt), or a swelling replacing the seed (sclerotia in rye ergot). Once the ears are ripe, they are released, fall on the ground, or are harvested with the grain.

Cereal bunts belong to the *Tilletia* genus; they are basidiomycetous fungi and include nearly 175 parasitic species. Wheat bunt infestations [*Tilletia tritici* (Bjerk.) G. Winter] result in decayed grains, in which the starch has been replaced by black spores. These grains burst and release the spores as black dust.

Until the description of the nematode cycle in the nineteenth century by Davaine (1889, 363–64), authors observed that the blackened grains disease seemed to be linked to mists and dews, supposedly emanating from the ground, and falling back on the plants. These sources mention diseased grains, filled with black dust and giving

off a fetid stench, but do not refer to the presence of worms, indicating that these grains may have been infested by wheat bunt. For centuries, the names used to refer to wheat affected by this disease created and maintained confusions between several causes for the blackening of the grains (Ruas *et al*., 2016).

Rye ergot (*Claviceps purpurea* Tul.) belongs to the ascomycetes group. Its sclerotia – vegetative structures of the fungus, composed of compact white mycelium masses—are shaped like dark, curved "fingers"; they are 20–30 mm long and 3–4 mm wide and emerge from the spikelets of grasses or Cyperaceae (e.g., bulrushes and sedges). Although this fungus does not destroy its host, its sclerotia are toxic and therefore dangerous if ground with the grain of infested plants. They contain alkaloids such as lysergic acid from which LSD is derived, and ergotism, or ergot poisoning, causes intense burning sensations inside the body, followed by gangrene. A form of ergotism that developed in Northern Europe featured symptoms including convulsions, spasms, and hallucinations. Outbreaks of this disease, the cause of which was not identified, were reported in France in the tenth and eleventh centuries, and later in the seventeenth and eighteenth centuries, and were referred to as "holy fire", "Saint Anthony's fire", or "Saint Andrew's disease" when including convulsions (Aillaud, 1988).

Another ascomycetous fungus, belonging to the same family as ergots (*Clavicipitaceae*) is indirectly responsible for the toxicity of darnel (*Lolium temulentum* L.) seeds—a self-propagating plant growing in cereal crops—and of tall fescue (*Schedonorus arundinaceus*) seeds—a species of forage grass. These seeds are often infested by Neotyphodium coenophialum [*Epichloe coenophiala* (Morgan-Jones & W. Gams) C. W. Bacon & Schardl], an endophyte that does not interfere with the growth of its host, but produces alkaloids that are toxic to cattle who may ingest it in pastures or in forage, and to humans, if they consume flours made before the infested grains were eliminated.

5.ARCHAEOLOGICAL EXAMPLES AND CONSIDERATIONS CONCERNING THE QUALITY OF PRIMARY FOOD PRODUCTS AND FLOURS

Paleoparasitology, applied to archaeology, focuses primarily on the remains of ancient parasites present in the digestive system of humans and animals as a result of certain hygiene and food conditions (Le Bailly *et al*., 2017). However, archaeological records also contain evidence for some of the above-mentioned parasites and pests infesting stored produce, as traces left in the produce itself, deformations of the affected plant organs, or as the individual parasites or their organs, which can reach several millimetres in size (larvae, adult insects, galls).

Galls produced by Anguina sp. have been identified through high-resolution imaging in French medieval carpological collections (Ruas et al., 2016). Although these galls would not have been recognised in Antiquity, their appearance is, by now, well documented, and they are easily recognised, even in ancient contexts.

Crop parasites may be studied in archaeological contexts as adult specimens carbonised in stored produce and as nymphs trapped inside seeds. Multiple perforations attributable to primary insect pests can sometimes be observed in the epidermis of grains, but severe infestations can cause the destruction of the seeds during carbonisation – and thus the importance of the infestations may have been underestimated (Ruas *et al*., 2019). To reduce infestation risk, barns were kept dry and well ventilated in order to prevent the proliferation of weevils, and the fermentation of the produce. Modern authors recommend storing grain at 11% humidity—at this level, insects are less active and fermentation cannot occur (Diffloth, 1917). Damages (phytophagy) caused by primary insect pests such as weevils can be severe because these insects attack the germ and are able to completely destroy the grain as they consume the endosperm. They also produce dust and waste that may foster further infestations, as secondary pests feed on broken up grain and are themselves targeted by predatorial species. Such a sequence of events took place in the second century CE in a reserve of spelt stored in an urban barn in Amiens/*Samarobriva* (Matterne *et al*., 1998). The storage building, erected on the banks of the river Avre, was affected by ambient humidity and the reserve of grain began to germinate. Several crop pests have been identified there, including primary pests such as the wheat weevil (*Sitophilus granarius*) and grain beetle (*Cryptolestes ferrugineus*), and other detritivore beetles such as *Oryzaephilus surinamensis*, *Palorus ratzburgi*, and *Aglenus brunneus*, as well as large mites. Whole danewort (*Sambucus ebulus*) fruits were also found in unusually large numbers among the stored grain. Seeds were preserved in anatomical connection, although the grain had probably been abandoned for a while, as is suggested by the degree of infestation; this indicates that the fruits had probably dried before carbonisation occurred. J.-P. Pals (1992) observed a similar phenomenon while studying a shipment of starched wheat discovered in Woerden/Laurium in the Netherlands. More recently, a study of four sets of carpological evidence from Northern France revealed that scentless mayweed, stinking chamomile, and danewort may have been added to stored grain to deter pests. Anatomical connections were observed, showing that flowers of plants from the Asteraceae family and whole elder fruits could have been incorporated to deposits after the harvest, during cleaning treatments (Dietsch-Sellami et Pradat, 2016). Ancient sources regularly mention the use of grains and fruits as pest repellents in produce or cloth (Panagiotakopulu *et al*., 1995). Thanks to these precautions, damage to stored grain remained minimal, but consumers of the resulting produce had to tolerate variable degrees of quality in grain affected by the methods of preservation (Gourevitch, 2005). While grain remained theoretically edible, it could not be ground correctly if

germination or pest damage had occurred: during grinding, the rotation of the grindstone rolls out the bran (or epidermis of the grain) to release the endosperm that forms the body of the grain while reducing the starch into flour. However, damaged bran interferes with this process and causes the grain to flatten. Fortunately, although insect infestations were perceived as a threat to domestic plants and stored grain, the means to counter them were available in the fields themselves, and sources attest that farmers, consumers, and cooks did not fail to make use of them.

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