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Excerpt
More information

1

Man and insects

Impact on man

Certain insects, such as flies, lice and locusts have been associated with ill health of humans, sickness in domesticated animals and crop losses from pre-biblical times. However, since man was a hunter-gatherer long before he took up farming, his first experience of insect problems must have been with being bitten by them. A much-quoted biblical passage describes the plague of flies the Lord is said to have despatched to Egypt which entered the house of Pharaoh (Exodus). In spite of this long association, connections between biting insects and disease took many centuries to be made, whereas the depredations of insects on crops were largely instantly recognizable. The eccentric physician Erasmus Darwin, grandfather of Charles, came very close to guessing the truth that lice transmitted typhus, but it was only during the late nineteenth and early twentieth centuries that insects such as mosquitoes were identified as vectors of malaria, yellow fever and other infections, that tsetse flies transmitted sleeping sickness and animal trypanosomiasis, and that ticks spread various infections, such as so-called Texas fever, to cattle (Table 1.1). Similarly the first proof that an insect (the honey bee) transmitted a disease of plants (fireblight) was not obtained until 1892. Although the pace of vector incrimination has slowed down, more recent discoveries have identified ticks as vectors of the spirochaetal organisms causing Lyme disease in humans.

Mosquitoes have had a drastic effect on man's progress. For example, anopheline mosquitoes are responsible for transmitting the best known and most important, and arguably man's oldest, vector-borne disease, namely malaria. It is probable that the disease originated in Africa, and followed

Table 1.1. *Some major infections transmitted by arthropods.*

Vector	Parasite	Disease	Main distribution*
Aphids			
Bird-cherry aphid	Virus	Barley yellow dwarf	Worldwide
Peach-potato aphid	Virus	Beet yellows	Worldwide
	Virus	Potato leaf roll	Worldwide
Brown citrus aphid	Virus	Citrus tristeza	Subtropics
Leafhoppers			
Green rice leafhopper	Virus	Rice tungro	Asia
Maize leafhopper	Virus	Maize streak	Africa
Beet leafhopper	Virus	Beet curly top	Western USA, Mexico, Canada, Mediterranean
Planthoppers			
Brown planthopper	Virus	Rice grassy stunt	Africa, Asia
Maize planthopper	Virus	Rice stripe	Asia
Plant bugs			
Cocoa capsid	Virus	Swollen shoot (cocoa)	Africa
Antestia bug	Fungus	*Nematospora* taint of coffee	Africa
Bees	Bacterium	Fireblight	North and South America, Europe, New Zealand
Bark beetles	Fungus	Dutch elm disease	Asia, Europe, USA, Canada
Mosquitoes			
Anophelines	Protozoa	Malaria	Tropics, subtropics
	Filaria	Filariasis	Tropics
Culicines	Arboviruses	Yellow fever	Africa, South America
		Dengue	Tropics
	Numerous other arboviruses		Worldwide
Tsetse flies	Protozoa	Human and animal trypanosomiasis	Africa

Table 1.1. (*cont.*)

Vector	Parasite	Disease	Main distribution*
Simuliid black flies	Filaria	Onchocerciasis	Africa, South America
Sand flies	Protozoa	Leishmaniasis	Tropics, subtropics
Muscid flies	Protozoa	Enteric infections	Worldwide
	Bacteria etc.	Mastitis	Worldwide
Triatomine bugs	Protozoa	Chagas disease	Central and South America
Fleas	Bacteria	Plague	Worldwide
Body lice	Rickettsiae	Epidemic typhus	Worldwide
	Spirochaetes	Epidemic relapsing fever	Tropics, subtropics
Argasid ticks	Spirochaetes	Tick-borne relapsing fever	Tropics, subtropics
	Rickettsiae	Aegyptianellosis	Worldwide
Ixodid ticks	Arboviruses	Tick-borne encephalitis	Europe
		Colorado tick fever	North America
		Many other arboviruses	Worldwide
	Rickettsiae	Many typhuses	Tropics, subtropics
	Spirochaetes	Lyme disease	Worldwide
	Protozoa	Theileriosis	Worldwide
		Babesiosis	Worldwide

* The distributions are only approximate, for example worldwide indicates the infection spans the tropical, subtropical and temperate regions, but is not necessarily widespread in all or any region.

in the wake of human migrations out of Africa to the Mediterranean, the Indian subcontinent and South-East Asia. Malaria is said to have caused, or aided, the decline of the Roman Empire and fall of Greece; how true this is remains debatable. Nevertheless, malaria has certainly helped defeat armies involved in military campaigns, sometimes causing more deaths than military action. For example, during the First World War (1914–18) malaria outbreaks immobilized armies in Macedonia for three years. During the Vietnam war (1965–73) the American army had as many soldiers suffering from malaria as battle casualties. More recently, in 1988, the anopheline mosquito caused more than 25 000 deaths in Madagascar. Malaria has played a major role in retarding the cartographic exploration of Africa, and inhibiting trade between Africa and Europe. Malaria was mainly responsible for West Africa being known as 'The White Man's Grave', because it claimed so many lives at the beginning of the nineteenth century. Statistics can be notoriously inaccurate, but an educated guess is that malaria currently kills about 2 million people annually, some 90% of this occurring in sub-Saharan Africa.

Because of the so-called yellow fever mosquito, *Aedes aegypti,* construction work on the Panama Canal was abandoned in 1889 due to the devastation this mosquito caused in transmitting yellow fever to the itinerant work force. Some 20 000 workers, comprising young engineers, administrators and labourers were killed. And in 1895–1908 there were at least 28 000 deaths from yellow fever before efficient control measures against *Aedes aegypti* were adopted. These days there is an excellent vaccine that provides 10, or more, years of protection.

In some parts of the world, such as subarctic regions of North America, mosquitoes can be so numerous as to prevent just about all outdoor activities. In fact research on mosquito biology and control has been financed by the Canadian government because their armed forces would find it difficult to defend certain terrain because of the intolerable nuisance caused by mosquitoes.

Tsetse flies, *Glossina* species, are found only in Africa, but they have greatly influenced the development of that continent. They transmit two related protozoal diseases, sleeping sickness (human trypanosomiasis) and animal trypanosomiasis (often called nagana).

The animal disease infects domestic livestock, especially cattle, which become emaciated, sick and often die. Areas where tsetse flies are particularly numerous are often called fly-belts, and cattle owners try to avoid these areas. The disease is found in 37 sub-Saharan countries covering some 11 million km^2 of land, and causes an estimated annual loss of US$ 5000 million. Animal trypanosomiasis has greatly hindered African agricultural development and kept communities poor.

Insects have attacked crops since the dawn of agriculture. Chinese cave paintings dating about 4000 BC and Egyptian artefacts from 2300 BC depict pests attacking crops. The ancient Egyptians were also only too aware that food brought into store was rapidly destroyed by insect and rodent pests. Close on the biblical plague of flies referred to earlier, the Lord visited a plague of locusts on the Egyptians. '. . . and when it was morning, the east wind brought the locusts . . . they covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees . . . ; and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt' (Exodus). Today swarms of locusts still darken the skies of Africa. These swarms may occupy hundreds of square kilometres of air space with 100 million individuals (weighing more than 100 tons) in every km^2. Swarms can travel hundreds of kilometres a day and, as stated in Exodus, they destroy every piece of green vegetation where the swarm lands.

Aphids are another major world problem. They neither swarm nor chew, but drift as isolated individuals in the air and then suck the sap of the plants they attack. Numbers can again be huge (e.g. over 200 million black bean aphids (*Aphis fabae*) per hectare in sugar beet), arrived at by multiplication from perhaps only 500 colonizing individuals.

The great Chinese famine (1958–62), in which 30 million people starved to death, was in large part due to uncontrolled pest populations, following an amazing contrived reduction in their bird predators. In an attempt to control sparrows, huge numbers of Chinese were mobilized to make noises by beating metal pans etc. to prevent sparrows landing till the birds died of exhaustion.

In the spring of 2001 there was a plague of armyworms which again devastated crops in the eastern and southern provinces of Cameroon, threatening a famine like the one that followed a similar event in 1980. One plantation owner was quoted as follows: 'Not a single green plant is spared, from bananas to cocoyams to groundnuts.'

The first succinct treatise on agricultural entomology is again in the Bible, in the book of the prophet Joel. 'That which the palmerworm hath left hath the locust eaten; and that which the locust hath left hath the cankerworm eaten; and that which the cankerworm hath left hath the caterpillar eaten.' Many attempts have been made to measure the overall losses of our crops to insects. These estimates differ considerably. One estimate which several workers have reached is that we grow about a third of our crops to feed insects either in the field or in store, in spite of modern control measures being taken to minimize such losses where we can afford to do so. Put another way, we grow plants as insect food on something approaching the equivalent of 50 million hectares!

Today there are crop pests which take their place alongside mosquitoes and tsetse flies on the world stage as ringleaders on the insect side of what is sometimes called the 'Insect War'. Such are locusts, grasshoppers, armyworms, bollworms of cotton, diamond-back moths (*Plutella xylostella*) of brassicas and brown planthoppers (*Nilaparvata lugens*) of rice. More detail of these major pests will be given elsewhere in this chapter, but the last three are typical of the many pests which have dramatically changed (in this case increased) in importance since the advent of insecticides, the introduction of new crop varieties and more intensive agriculture. They will appear as the targets of pest control measures in other chapters, but would probably hardly have warranted mention had this book been written in the 1950s. Man has created many new pests by his efforts to control others and to strive for ever higher crop yields. Thus insecticides used against one pest of apples destroyed the biological control of others (perhaps most famously the fruit tree red spider mite, *Panonychus ulmi,* in the UK). Similarly, trying to control the one and only pest scale insect of citrus (an imported species) in California at the start of the twentieth century with insecticide has raised the number of scale insect species which now may need control to nearly 100.

Colonization of Africa by Europeans is believed to have caused the spread of sleeping sickness. There have been disastrous epidemics and deaths, due to the opening up of trade routes that allowed African populations to travel into what were formerly hostile areas. David Livingstone and his large entourage of porters, some already infected, are credited with spreading sleeping sickness in parts of eastern Africa. There were dramatic epidemics in the early 1900s. Although sleeping sickness still kills at least 20 000 people a year, the greatest economic burden for Africa is the animal form of trypanosomiasis.

Human travelling and trade have moved crop pests and crop plants around the world and, like the movement of insect-vectored human diseases, many new problems have been caused thereby. Some examples are given later under 'migrant pests'. The colonization of North America by Europeans created a major new pest problem, not because an insect but a new crop was introduced to the USA. In 1824, a British insect collector visited the Rocky Mountains, and returned with an attractively striped beetle which was new to science and which he named *Leptinotarsa decemlineata*. He had found sparse populations of the beetle feeding on a weed (buffalo-bur) on the eastern slopes of the mountain range. Thirty years later, settlers from Europe started growing potatoes (the same plant family as buffalo-bur) on the plains and, when they reached the foothills of the Rockies, the beetle transferred to this new nutritious and almost limitless food resource. The new pest spread eastwards towards the Atlantic seaboard at 140 km a year, and soon travelled in the opposite direction to the human settlers to reach Europe. Today the beetle, under the name 'Colorado beetle' (Fig. 2.6) is a serious pest of potatoes in much of Europe and figures in warning posters on police station notice boards in the company of wanted criminals.

Fleas and lice from time immemorial have changed the demography of the world. Fleas, mainly the tropical rat flea, *Xenopsylla cheopis*, have been responsible for three pandemics of bubonic plague, namely the ancient plague which culminated in the great plague of Justinian's reign (*c.* AD 542), the Black Death of the Middle Ages (1347–55) which killed 30–60% of the population of Europe, and an epidemic which is believed to have originated in China in about 1870, and which in 1895 on reaching India killed an estimated 1 300 000 people. Plague is reputed to have retarded western civilization by about 200 years. In addition to these pandemics there was the Great Plague of 1665–6 which killed more than 68 000 people in the UK, and the plague of Marseilles (1720–1) which killed nearly 40 000 of the city's 90 000 population.

Another ectoparasitic insect that has caused an immense loss of life is the body louse (*Pediculus humanus*). This louse transmits epidemic typhus, also formerly known as jail fever or ship fever because the overcrowded and unsanitary conditions that occurred in jails, ships and in army camps encouraged the spread of body lice. When Thomas à Becket was murdered in Canterbury Cathedral it is said that body lice marched from his cold body like a retreating army. The body louse caused appalling typhus epidemics in the sixteenth and seventeenth centuries. The potato famine in Ireland plus typhus outbreaks resulted in the migration of 1.5–2 million people to the USA from 1845 onwards. As recently as 1917 and 1923 some 30 million people in eastern Europe were infected with typhus; about 3 million of them died. At other times insects have caused nuisances by their sheer numbers. It has been said that the historically poor state of croft farming in western Scotland is due to multitudes of biting midges (*Culicoides* species) hindering farming activities in the evenings. During the eighteenth century the simuliid black fly (*Simulium colombaschense*), known as the Golubatz fly, was such a biting pest along the shores of the River Danube that cattle were killed in their hundreds and even thousands by sheer loss of blood! The last major outbreak of these black flies was in 1951 and killed 801 animals.

In the eighteenth and nineteenth centuries ticks were responsible for many cattle deaths in the USA due to their transmission of a protozoal parasite (species of *Babesia*) causing a disease known as Texas fever or redwater fever.

Famines have been a feature throughout history, and it is likely that crop pests have contributed equally to human misery as have the insects carrying diseases. Yet, although some 350 cases of famine can be found in historical records since Roman times, the records do not distinguish between pests, crop diseases or events such as drought as the cause. However, there are some relatively recent accounts of crop destruction. One of these concerns the total destruction of the first cereal crops established by the Mormons in 1847 when they settled in Utah. The insect was *Anabrus simplex,* now known as the 'Mormon cricket'. When the crop was threatened again the following year, the settlers gathered in church to pray for deliverance and, amazingly so far inland, a huge flock of seagulls appeared and ate up the crickets. This we believe to be the first and only example of biological control by divine intervention. In 2001, a plague of similarly devastating proportions occurred in Utah; this time prayers were replaced by the broadcasting of huge quantities of poisonous bait.

Pests and vectors

What is a pest?

Almost any animal can be a pest. For example, in Kenya many farmers regard elephants as pests because they often destroy crops. Honey bees are regarded as beneficial insects, but the African honey bee (*Apis mellifera scutellata*) can be a serious, and dangerous, pest because of its unprovoked attacks on people and livestock. It can be hard to give an all-inclusive definition of a pest. However, we might define an arthropod pest as any species that is injurious or potentially injurious to humans, their possessions, plants, plant products or domesticated animals. They may do this in a variety of ways, including disseminating diseases (see below).

Crop pests can damage any part of the plant above and below ground by chewing, sucking, tunnelling or causing plant tissue deformations known as 'galls'. Insects (e.g. termites, leaf-cutter ants) may remove parts of plants to build their nests and shelters and/or to take into the nest for food or to use a substrate for growing fungus gardens for later grazing. Insects can also be damaging by cross-fertilizing certain rust (fungal) diseases.

Pests may irritate or injure man and domestic animals by just being present, settling on the skin, by odours they may produce or by entering openings. They may sting, bite, suck blood or cause rashes and other allergies; also they may invade the body and tunnel into tissues (e.g. muscles) or enter organs including the alimentary canal.

What is a vector?

Some pests are such because, more importantly than any direct damage they may cause by their feeding, they are vectors, i.e. organisms that transmit infections. In the broad sense dogs can be vectors! By biting people they can transmit the rabies virus. A distinction is often made between biological vectors and mechanical vectors. Although we distinguish these two types of vectors, the disease rather than the insect determines the type of transmission. Thus the same aphid species may be the biological vector of one plant virus, but the mechanical vector of another. Any one disease is, with a few exceptions of medical and veterinary infections, transmitted in the same way. Among the exceptions is *Trypanosoma vivax*, which is cyclically transmitted by tsetse flies in Africa whereas in South America it is mechanically spread by tabanids and stable flies. The serious barley yellow dwarf virus disease is transmitted by at least ten different aphid species, but always in a biological manner. With biological vectors, the pathogens or parasites undergo a developmental cycle in the vector, or multiplication, or both. Examples are leafhoppers spreading Tungro virus disease of rice in Asia and mosquitoes transmitting malaria parasites. With mechanical transmission there is no multiplication or cyclical development in the vector, the infectious agents being passively carried by the vector. Examples include aphids spreading potato leaf roll virus and house flies transmitting enteric pathogens by their contaminated feet, vomit or faeces. Usually there are more direct methods by which such parasites are transmitted, such as unhygienic handling of food. With plant viral diseases, mechanical transmission can usually be reproduced with the point of a pin.

Some arthropods, especially ticks, can become infected with pathogens during a nymphal stage and transmit the pathogens when any subsequent nymphal stages and adults feed. This is termed transstadial transmission. Even more interesting and of greater epidemiological significance is transovarial transmission. This is when an infection in a tick, or a few other types of arthropods, passes to the ovaries which results in the nymphal and subsequent stages being infected and thus becoming vectors before they have even taken a blood-meal.

Most arthropods of veterinary or medical importance such as mosquitoes, lice, ticks and fleas are regarded as vectors, because of their role in the transmission of diseases such as malaria and plague. However, vectors can sometimes also be pests. For instance, the mosquito *Aedes aegypti* has gained notoriety because it transmits yellow fever and dengue viruses, but in both areas where it is, and is not, a vector it can be a pest because of the distress caused by its bites. Similarly, although house flies can transmit (mechanically) a variety of pathogens and parasites to humans and animals, they can be a greater problem because they can make outdoor recreational pursuits intolerable due to the large numbers landing on people, their food and drink.

Categories of pests and vectors

Major pests and vectors

What makes a major pest? Many things. When environmental conditions are most favourable arthropods can become very common and cause much annoyance or damage, or become important vectors. Major pests and vectors may be widespread or localized, or only important seasonally, such as during the summer or the rainy seasons when their populations are likely to peak.

The world's most dangerous and efficient malaria vector is most probably *Anopheles gambiae*, which is found in sub-Saharan Africa. What makes it so? Firstly, *Anopheles gambiae* is fairly common and is closely associated with man, breeding in aquatic habitats found around houses while adults commonly rest in houses before and after blood-feeding. More importantly adult females feed predominantly on humans in preference to cattle, thus there is a so-called high degree of mosquito–man contact. Adults are also *relatively* long-lived, which increases the chance that the developmental cycle the malaria parasites must undergo in the vector after their ingestion with a blood-meal, before the mosquito can infect a person with malarial parasites (sporozoites) while biting, is successfully completed. Typically the percentage of females that are infective, that is have malarial sporozoites in their salivary glands (called the sporozoite rate), is around 5%. In contrast a common mosquito in the Indian subcontinent, *Anopheles culicifacies*, actually bites cattle more often than man, the average life of adult females is slightly less than that of *A. gambiae*, and the sporozoite rate (% females infective) is usually 0.1% or less, yet in many areas it is the principal malaria vector. How is this possible? The answer is that local populations of *A. culicifacies* can be very large, so that people receive many more bites than Africans get from the more efficient vector, *A. gambiae*. Efficiency is replaced by numbers.

Theileriosis is an important tick-borne protozoal infection of cattle and sheep in Europe, North America and many tropical regions. It causes morbidity and loss of productivity in indigenous breeds, and severe, often fatal, disease in imported livestock breeds. One common form of the disease (caused by *Theileria parva*) in Africa is known as East Coast fever.

Every agricultural crop has its own list of pest problems. Although some pests are very polyphagous (e.g. armyworms), the secondary plant chemicals characteristic of botanical taxa deter the majority of potential herbivores and at the same time attract insects specializing on that taxon. Thus there is an 'allocation of grazing privileges' which means that each crop will have its own cohort of 'major pests'. As different crops are often characteristic of different continents, the concept of what are the major pests will not only differ by crop but also by geographical region (especially tropical, subtropical and temperate). Hill's (1975) lists of pests by crop for the tropics contain well over 300 different major pests of crops in the field and in store. A very restricted selection therefore has to be made here; we have selected a round half-dozen of non-migratory pests (migratory pests are discussed under a separate heading below) on the basis that any course on world agricultural entomology would not be credible without including these.