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Pests, Diseases, Resistance, and Crop Protection in Groundnuts

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Abstract. There is an extensive literature on pests and diseases of stored groundnuts and groundnut products but in this paper we concentrate on field pests and diseases. Many of these have been reported in recent years but few have been shown to be important on a world scale. Current research in many countries now emphasises the integration of chemical control with cultural practices and the use of resistant varieties. While the application of pesticides as high- and medium-volume sprays and as dusts has been economic for groundnut farmers in the USA and elsewhere, this has not been the case in much of the tropics where groundnuts are produced on small plots by traditional farmers. Although advances in controlled droplet application techniques could change this situation in the future, there is no doubt that the greatest benefit for the traditional groundnut farmer would be the availability of varieties resistant to the major fungal and viral diseases. Research towards this end should be encouraged and international cooperation increased.

I. Introduction

The literature on pests and diseases of groundnuts (peanuts) has been reviewed for the USA [14, 76] and worldwide [73]. However, these reviews cover research published up to about 1970 and the work they describe was done primarily in the southern USA. Research into pest and disease problems of groundnuts has developed and increased since 1970, especially in Asia and Africa. Numerous pests and diseases have been recorded but here we shall concern ourselves mainly with those of worldwide importance.

II. Arthropod pests

Insect and other arthropod pests of groundnuts may be placed in three groups according to the parts of the plant upon which they feed.

A. Shoot and foliage feeders

These are mostly polyphagous species, many of which are present throughout the life of the crop but are serious pests of seedlings only. The cowpea or groundnut aphid (*Aphis craccivora*) is the most widely distributed pest of

groundnuts. This sap feeder, when present in large numbers, can cause severe damage or even kill plants but, of greater general importance, is that it vectors rosette disease. All stages of the aphid can transmit the virus but nymphs are more efficient than apterae.

Several species of leafhoppers (genus *Empoasca*) attack groundnuts; the nymphs and adults suck sap from the leaves, inject toxic saliva, and oviposit on the abaxial surfaces. Infected leaves become chlorotic from the tips and margins to produce a characteristic 'hopperburn' effect. *Empoasca fabae* is the dominant species in the Americas [14] and *E. facialis* in Africa [73], while *E. dolichi* is an important pest in Nigeria [157].

Thrips damage can be important, especially when young plants are attacked and the leaflets become scarred or deformed. The main species in the USA is the tobacco thrips, *Frankliniella fusca* [14, 195]. Other troublesome genera include *Caliothrips* (=*Heliothrips*) from India and the Sudan [4, 175, 207], *Taeniothrips* from the Cameroons and Nigeria [157, 164], and *Enneothrips* and *Selenothrips* from Brazil [30, 36, 128]. *Scirtothrips dorsalis* has recently been identified as the vector of the virus which causes groundnut bud necrosis in India (D.V.R. Reddy, pers. comm.).

Some polyphagous species can cause moderate or severe damage. The hairy caterpillars *Amsacta moori, A. albistriga*, and *Diacrisia obliqua*, and the leaf miner *Stomopteryx subsecivella* are important in India [175, 208]. The corn earworm (*Heliothis zea*), fall armyworm (*Spodoptera frugiperda*), granulate cutworm (*Feltia subterranea*), and velvetbean caterpillar (*Anticarsia gemmatalis*) are the more important foliage feeders described from the USA [14]. Cosmopolitan pests such as *Nezara viridula, Heliothis armigera, Spodoptera exigua* and *S. littoralis* may occasionally cause serious damage [73, 135] and some chrysomelid and curculionid beetles can also be important [100, 183].

The spider mites *Tetranychus* spp. are widespread [9, 84, 157, 166], and are now considered as important pests of groundnuts in the USA [33, 193]. The change in their status as pests is attributed to the prolonged overuse of insecticide, particularly as mites have proved very resistant to organophosphorus formulations [193]..

B. Flower feeders

Groundnuts come into flower about 4 weeks after planting and flower production continues throughout the season. Most of the kernel yield is produced from flowers which open between weeks 4 and 8 of reproductive development and any damage to flowers at this stage is obviously important (see also Bunting and Elston, this volume).

Various insects attack buds, flowers and pegs. Blister beetles (family Meliodae) and thrips (*Taeniothrips* spp.) are important in Africa [73, 157]. *Spodoptera littoralis* and *Heliothis armigera* have also been found to attack flowers [135].

C. Root and pod feeders

The arthropods which attack underground parts of the plant are possibly the

most important groundnut pests. Yield losses result from premature plant death and both direct and secondary damage to pods and kernels.

Termites and millipedes are the most important soil pests in Africa. The important termite genera are *Microtermes, Odontotermes* and *Amitermes*. In northern Nigeria *Microtermes* spp. are especially troublesome and population densities greater than 4000 termites per square metre have been recorded in agro-ecosystems [219]. Although they are established as pests of groundnuts in the tropics [73], there are few estimates of termite damage. In Nigeria, yield losses of 10–15% have been recorded, and this may prove to be an underestimate [114].

Millipedes are common pests of groundnuts in Africa; their immature forms feed on young pods. Several species have been identified, the most important belonging to the genus *Peridontopyge* (family Odontopygidae) [58, 174, 181].

The cosmopolitan cutworm, *Agrotis ipsilon*, can sometimes cause serious damage by severing young plants and later by feeding on pods [73]. White grubs, which feed on roots and girdle stems, are serious pests of groundnuts in many parts of the world. Three species, *Lachnosterna consanguinea, L. insularis* and *Anomala bangalensis*, are important in India [175], while *Rhopaea magnicornis* and *Heteronyx* sp. have been reported from Australia [73, 168]. Pests which inhabit the soil and are recognised as important in the USA include the lesser cornstalk borer (*Elasmopalpus lignosellus*), white fringed beetles (*Graphognathus* spp.), southern corn rootworms (*Diabrotica undecimpunctata howardi*), and banded cucumber beetles (*D. balteata*). Furthermore, *Elasmopalpus lignosellus* is widely distributed in the Americas and *Graphnognathus* spp. are found in the Americas, Australia, New Zealand and South Africa. A burrowing bug *Pangeus bilineatus* has recently become a major groundnut pest in Texas [194]: both adults and nymphs feed on pods and produce deformations and undesirable flavour.

Pod-suckers of the family Lygaeidae cause damage to windrowed groundnuts in West Africa and India [45, 82, 157, 175].

Pest control in groundnuts relies at present mostly on the use of chemicals and few attempts have been made to integrate different control methods, although some pest management systems have been developed in the USA [101, 191, 192, 193]. There are only a few reported instances of varietal resistance to pests in groundnuts [25, 32, 33, 44, 112, 130, 132, 176].

III. Virus diseases

Only four virus diseases of groundnuts – rosette, mosaic, ringspot and stunt – have received much attention and only rosette and stunt were regarded as important by growers in the late 1960s [76]. Since then the literature on groundnut virus diseases has expanded greatly but identification has often been based only on visual symptoms. Consequently, the status of most viral diseases is very confused and the viruses involved have not been properly established.

A. Rosette

Groundnut rosette virus (GRV) disease is common in Africa and can seriously reduce yields [220]. Three types of foliar symptoms have been described [120] but most workers describe only two – 'chlorotic' and 'green' rosette [102, 180, 197]. A rosette disease has also been reported from Argentina, Fiji and India [73] but identity with African GRV has not been established. The description and spread of rosette disease in India are similar to those in Africa [121, 122] but host range studies suggest that the virus is of a different strain [75].

Cultural control by early sowing at dense plant populations and/or the use of insecticides have proved effective; both measures are aimed at control of the insect vector *Aphis craccivora* [2, 22, 55, 56, 70, 71, 74, 180].

Extreme resistance to GRV has been found in germplasm from West Africa [16, 17, 54, 181] and very resistant varieties with good agronomic characteristics have been bred [60, 94]. Lines resistant to GRV in Nigeria are also resistant in Upper Volta and in Kenya (C. Harkness, pers. comm.).

B. Stunt

Groundnut stunt virus disease was first identified in the USA [48, 150] and spread rapidly. It causes considerable yield losses [5, 50, 179] and has now been reported from Japan [105] and, possibly, from Senegal [21]. Stunt virus has a wide host range among the Leguminosae [42, 66, 67, 105, 148, 156] – an important factor in the spread and persistence of the disease [214].

Less than 0.1% of stunt virus in groundnuts is seed-borne [217] and although it can be transmitted mechanically, it is normally spread by aphids, particularly *Aphis craccivora* [96]. Aphicide application for vector control has been tested successfully [31]. Several hundred varieties and lines have also been screened for their ability to withstand natural infections and measurable resistance has been identified in some lines [51].

C. Mosaic

At least three different mosaic diseases have been reported. The Indian strain was reported in 1949 and again in 1964 when heavy losses occurred [40, 121, 122, 161]. No vector is known but the virus is graft-transmissible [122].

An entirely different mosaic disease has been described from Java [212], which is transmitted by a leafhopper. Furthermore, a mosaic disease from west Malaysia which is transmitted either by sap or by *Aphis craccivora* [213] can drastically reduce yields [77].

D. Spotted wilt

Tomato spotted wilt virus (TSWV) has been reported from Brazil [49], South Africa [119], Australia [97], India [177], and Texas [85]. Symptoms are variable; they can be mild or severe, and include stunting, chlorosis, ring spots, and bud necrosis. Bud necrosis [177] is caused by TSWV which is

transmitted by *Scirtothrips dorsalis* in India (D.V.R. Reddy, pers. comm.). A disease with symptoms similar to those found in India has just been encountered in Nigeria (S. Subbarayudu, pers. comm.).

E. Mottle

First described in the USA [124], peanut mottle virus (PMV) is now widespread there [59]. The disease has also been found in Japan, Venezuela, Australia, East Africa and India [15, 19, 99, 104; D.V.R. Reddy, pers. comm.). It can infect soyabeans and other legumes and is transmitted by seed [19, 124]. The virus is also transmitted by aphids but in a non-persistent manner, and hence insecticide control is unlikely to be effective. Kuhn *et al.* [125] screened 465 groundnut introductions but failed to find any immunity.

F. Clump

Groundnut clump disease was first reported from Senegal [216] and later found in Upper Volta [78]. Bouhot [20] described symptoms which were similar to those of 'green rosette'. The viral nature of the disease has been established [79, 211] and the virus is mechanically transmissible and soil-borne. No insect vector has been implicated, but application of nematicides to the soil stops spread; hence it is suspected that nematodes, possibly *Trichodorus* spp., may be vectors [79, 147, 210].

A 'clump' disease has been found in India [199] and a similar disease in India is caused by a mechanically transmissible virus (D.V.R. Reddy, pers. comm.).

IV. Fungal diseases

Many fungal diseases of groundnuts have been reported [73, 76, 107] and may attack plants at all stages of development. Some diseases which are capable of severe damage have only a very restricted geographical distribution; e.g. scab, which is incited by *Sphaceloma arachidis*, is found only in a limited area in South America, while others are widely distributed. Three fungal diseases – *Mycosphaerella* leafspots, rust, and the *Aspergillus flavus*/ mycotoxin problem – are all important in almost every area where groundnuts are produced.

A. Mycosphaerella leafspots

Mycosphaerella or *'Cercospora'* leafspots incited by *Cercospora arachidicola* and *Cercosporidium personatum* are serious diseases of groundnuts in most parts of the world. Yield losses of about 10% have been cited in the USA, where fungicide application is widely practised, and losses of 15–50% in other parts of the world [107]. Several recent papers have dealt with the effects of this disease on the quantity and quality of economic yield [52, 68, 86, 89, 143, 144]. Infected crops produce poor yields as fewer pods reach maturity and individual seed weights are reduced. Lesions on pegs may

weaken them, hence pods can be left in the ground when the crop is lifted. Forage yields are greatly reduced by defoliation. Disease symptoms are well described [73, 107] and although the pathogens are widely distributed no hosts other than species of *Arachis* are known.

The diseases are soil-borne and crop rotation is important to reduce the incidence of infection [53, 72, 116, 123, 162]. Unfortunately, rotation is difficult where farmers intercrop, as they commonly do in the tropics.

Fungicide control is an established practice in the USA and very effective formulations have been developed [11, 52, 86, 190]. Research on fungicide control has also been carried out in many other countries, e.g. India [3, 39, 131, 167], Honduras [7], Malawi [113, 144, 145, 146], and the Philippines [172]. The most effective fungicides have been benomyl and related systemic compounds but reports of the appearance of resistant strains [43, 133] have discouraged their use except in mixtures with, or in addition to, other fungicides. Recent developments in ultra-low-volume application technology provide some promise for economic fungicide control of leafspots in the traditional, small-plot systems practised by many farmers in the tropics.

Much effort has recently gone into the search for resistance to leafspot (see also Moss, this volume). Within *Arachis hypogaea* only very limited resistance is available although reports have been cited of differences in resistance between varieties and groups of varieties [80]. Large numbers of varieties were evaluated and only one collection from Peru showed marked tolerance to the disease [1]. Other workers [10, 38, 44, 95] have also tested large numbers of accessions but have isolated only a very limited amount of resistant germplasm which is now being utilised in breeding programmes in various places. As yet, no extremely resistant, commercially acceptable variety is available.

B. Rust

First reported from Paraguay in 1884 [196], the rust disease caused by *Puccinia arachidis* has been well described [107]. For long a serious disease in the Caribbean, Central and South America, rust has recently caused significant damage to crops in the southern USA and yet when the literature was reviewed in 1971 [27] the disease was of little importance outside the Americas. Rust has been reported from the USSR [108], China [202], and Mauritius [188] but has not become established as a serious disease in these areas.

In the period from 1969 to 1972 the situation changed dramatically with reports of rust from India [18, 37, 83, 187], Thailand [115], Indonesia [215], and Papua New Guinea [28]; and, in 1973, from Australia [171].

Rust appeared in Africa in 1974 [182] and spread rapidly. It is now present in South, Central, East, and West Africa [5, 6, 8, 117].

Although in some areas rust does not 'overwinter' [87], the disease is now established in almost all countries where groundnuts are grown. Natural wind dispersal of uredospores must have played an important role in this recent spread and the import of contaminated seed is thought to have introduced the disease into Brunei [169]. The uredinial stage is by far the most common and the telial stage has rarely been found [37, 98, 196].

Some wild *Arachis* species are immune or extremely resistant to rust but there are few sources of resistance within cultivars [29, 87]. Three distinct genotypes within *A. hypogaea* possess marked resistance and these have been used extensively in recent breeding work [87]. Varietal screening has confirmed the limited sources of resistance available [12, 28, 29, 46, 87, 137]. The United States Department of Agriculture has recently released 14 lines which incorporate rust resistance (from a single chance natural hybrid) and these are being used in several breeding programmes.

Considerable research has been done on the control of rust with fungicides [7, 90, 91, 92, 93, 165, 173, 182, 209]. Some systemic fungicides used for leafspot control do not control rust, but several contact fungicides confer reasonable protection against both diseases. As rusts and leafspots normally occur together any fungicides used should be effective against both diseases. Recent developments in ultra-low-volume application of fungicides augur well for economic fungicide control of both diseases [146].

C. *Aspergillus flavus and aflatoxins*

Aspergillus flavus, common in the soil flora, has often been associated with seed and seedling diseases of groundnuts but is especially important because of the ability of certain strains to produce toxic 'aflatoxins' when grown on groundnuts and some other substrates. *Aspergillus flavus* is a common component of the mycoflora of undamaged 'healthy' groundnut pods and seeds [65], and should be considered in this context and not in isolation. Investigations in different parts of the world have shown the mycofloras of pods and seeds to vary considerably between locations but to have a number of component fungi which are almost universal; *A. flavus* is one of these [88, 106, 111, 134, 138, 139, 198]. Most investigators have found that while undamaged pods at maturity have significant infection with *A. flavus* and other fungi, the seeds are normally free from fungi [65]. Most infection of seeds from undamaged pods takes place as they are cured and dried [139, 198] but infection can occur before harvest if the crop is left in the ground beyond maturity [140]. This information has been used to develop harvest and subsequent husbandry methods which minimise the risk of *A. flavus* infection and aflatoxin production. In essence, farmers are advised to lift their crops at optimum maturity and to dry them as rapidly as possible. However, this may present difficulties and much attention has been given in recent years to the search for groundnut varieties with resistance to infection of pods and seeds by *A. flavus*.

Mixon [159] reviewed work on screening, selection, and breeding groundnuts for 'aflatoxin resistance' and noted that some earlier results which had indicated resistance [e.g. 158] had not been confirmed, although two 'resistant' accessions had much less infection than a susceptible line [see also 218]. Barrz *et al.* [13] screened a number of varieties over a period of 4 years and found that harvest procedures did not affect susceptibility, but there were large variations between years. Florunner was most tolerant and Tifspan the most susceptible of the varieties tested, as found also in the USA, India, and Africa [160, 200, 223].

Research has been done to try to link resistance to chemical and physical properties of shells and seed testas [34, 126, 127, 221, 222], but with limited success.

Although resistance to post-harvest infections of seeds with *A. flavus* is an important selection objective, seeds in ostensibly undamaged pods can become infected before the crop is lifted. Factors which encourage such infections include death of the mother plant, over-maturity, water stress, and late season drought [142, 170, 223]. More attention should be paid to resistance to infection before the crop is lifted.

V. Bacterial diseases

The only bacterial disease of any importance on groundnuts is the wilt caused by *Pseudomonas solanacearum*. First recorded in the East Indies in 1905 where it caused significant damage [26], it has subsequently been found in many countries [76]. The pathogen has a wide host range and occurs in several biotypes. It is of potential importance in the southern USA [109] and research has been carried out to isolate sources of resistance [110]. Potentially useful germplasm has been identified and resistance in groundnut germplasm has also been reported from Uganda [189].

VI. Nematode diseases

A Technical Committee [204] in the USA reported species of nine genera of nematodes known to parasitise groundnuts. Ten years later others have reviewed research on the few species considered to be important [73, 76].

A. Root-knot nematodes

Two cosmopolitan species, the peanut root-knot nematode *Meloidogyne arenaria* and the northern root-knot nematode *M. hapla*, attack groundnuts. Both are distributed throughout Europe, Africa, Asia, Australia, and South America; *M. hapla* is more common in colder and *M. arenaria* in warmer regions; both species also occur in the USA [203]. *Meloidogyne arenaria* seems to be the more important pathogen of groundnuts and a number of biotypes of this species are reported to differ in host range and/or pathogenicity [118, 151, 178, 184, 185, 186]. Attack by *M. arenaria* may reduce yields by more than 30% [206] and in combination with fungal pathogens it can be especially severe [62]. Rotation with resistant crops can be beneficial [205] and control with nematicides has been successful [61, 63, 64, 129, 153, 154].

Hardly any resistance has been found in groundnuts to *M. arenaria* in the USA where many introductions have been screened [149, 152]. Netscher [163] in Senegal studied resistance to *Meloidogyne* spp., which probably included *M. arenaria*, and concluded that some lines had resistance conferred by root hypersensitivity. In East Africa, Martin [136] noted only slight damage to groundnuts by *M. arenaria* but in Nigeria, where this species is widespread, no damage has been reported (J.J. Smit, pers. comm.).

Meloidogyne hapla has been known to cause 70% yield reduction of groundnuts [47]. A few lines of *A. hypogaea* have been classified as only moderately susceptible and some *Arachis* species are resistant [35]. However, 22 populations of *M. hapla* were all able to reproduce on groundnuts [203] and this species also encourages infection of infested pods with *A. flavus* [155].

Meloidogyne incognita attacks groundnuts in the Mediterranean area [201] and crops can also suffer depredations by *M. javanica* [103].

B. Lesion nematodes

The root-lesion nematode *Pratylenchus brachyurus* is cosmopolitan, and when present in large numbers can cause significant damage [41, 69]. Roots, pods and pegs are attacked and most loss is occasioned by the number of pods that become detached at harvest. Pod damage may facilitate entry of *A. flavus* (and of pod-rotting fungi), but nematicide applications can prove effective [24].

C. Other nematodes

Several other nematodes have been reported to cause damage to groundnuts. These include the sting nematodes *Belonolaimus longicaudatus* and *B. gracilis* which occur in the USA [76], the ring nematodes *Trichodorus* spp., the reniform nematode *Rotylenchulus reniformis*, and the dagger nematodes *Xiphinema americanum* and *X. diversicaudatum* [73, 76]; also another species, *Aphelenchoides arachidis*, which can attack testas of groundnuts in Nigeria [23].

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