Insect Damage to Groundnut in Semi-Arid Tropical Africa

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Abstract

This paper reviews arthropod damage to groundnut in semi-arid tropical (SAT) West Africa in relation to plant phenology and drought stress, and presents preliminary results of groundnut insect research at the University of Ouagadougou, Burkina Faso. Research in Africa and the United States has shown that arthropod damage, drought stress, and delayed harvest increase Aspergillus flavus *and aflatoxin contamination in groundnut. The interaction of arthropod damage and the types of arthropod damage are important criteria for potential aflatoxin contamination in groundnut. Methods to reduce aflatoxin contamination are being investigated.*

Résumé

Dommages causés à l'arachide par les insectes dans les régions tropicales semi-arides africaines : *Cet article passe en revue les dommages causés par les arthropodes à l'arachide dans les zones tropicoles semi-arides de l'Afrique de l'Ouest, en fonction de la phénologie de la plante et des contraintes hydriques. Il présente les résultats préliminaires des recherches sur les insectes de l'arachide conduites à l'Université de Ouagadougou, au Burkina Faso. Des recherches faites en Afrique et aux Etats-Unis ont montré que les dégâts causés par les arthropodes, les contraintes hydriques et le délai de la récolte cause une augmentation de l'*Aspergillus flavus *et de la contamination par l'aflatoxine. L'interaction entre les dégâts causes par les arthropodes et les types de dégâts par les arthropodes sont un critère important du potentiel de contamination par les aflatoxines. Les méthodes permettant de réduire la contamination par les aflatoxines sont étudiées.*

Introduction

World hunger is an ever-increasing problem—a problem that requires the immediate cooperation of researchers around the world. Mass starvation, such as recently experienced in Ethiopia, occurs all too frequently and is, in part, due to erratic food production. Thus, stability in crop production has been recognized as the primary goal of the developing countries (Gibbons 1980). An example of the instability in food production is given by the groundnut-production reports of Niger from 1968-1978 (Mounkaila 1980). Yield ranged from 270000 t in 1968-69 to 42000 t ha^{-1} in 1975. Much of this instability can be attributed to the drought and the insect-borne rosette virus epidemic in 1975.

Groundnuts are recognized as one of the major cash crops, as well as a high-quality, protein-rich food for local consumption in SAT Africa. Groundnuts represent from one-third to one-half of the

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exports from Senegal (Jackson et al. 1981). In Niger, groundnuts accounted for almost 45% of the exports in 1972, but declined to only 5% in 1975 as a direct result of the rosette epidemic (Mounkaila 1980). In many of the West African countries, groundnuts are also one of the most important cultivated domestic and commercial crops. However, in many of these countries, groundnut production has declined due to the extreme yield variability from year to year.

Plant protection from damaging infestations of insect and related arthropod pests is vitally important for stabilized production. Over 450 species of insect pests have been recorded on groundnut (Smith and Barfield 1982, Redlinger and Davis 1982). Only a few of these pests are economically important worldwide, but many are severe pests in localized regions of the world (Feakin 1973). Damage by these insects may be devastating, as evidenced by the rosette virus epidemic spread by *Aphis craccivora* Koch in 1975 (Gibbons 1977, Rossell 1977, Yayock et al. 1976), or may be rather insidious, producing small, unnoticed losses that accumulate throughout production and storage. In either instance, insects and related arthropods should be recognized as a major constraint in peanut production in both developed and developing countries.

Developing countries in West Africa offer a tremendous potential for expanded food production. These countries have vast arable lands suitable for increased agricultural production. However, in these countries, most agriculture is characterized by small farms with little mechanization or advanced technology. Minor improvements, such as higher-yielding, disease- or insect-resistant varieties, or the implementation of pest-control strategies can have a tremendous impact on production and the local economy. Crop production can be improved through cooperative research and the practical application of this research on the small farms characteristic of this region.

One area that offers such potential is the development of an integrated pest management (IPM) program for insects. IPM can be readily adapted to the normal agricultural practices of these developing countries, since it integrates all components of the agricultural system into one program that offers potential for increasing stability in crop production through proper management of the insect pests that often cause the instabilities.

Integrated pest management can be defined as a "pest management system that, in the context of the total environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury (Glass 1975). The objectives of pest management are to create and maintain situations that prevent insects from causing significant problems—in other words, to provide stability in the insect ecosystem. These objectives may be achieved by preventing the establishment or spread of insect pests, controlling established infestations, or maintaining pest infestation levels at which little or no damage occurs (Subcommittee on Insect Pest Control 1969). Insect pests can be managed by using knowledge of pest ecology in relation to the phenology of the host, and integrating this knowledge with cultural, physical, mechanical, biological, microbial, and chemical control; insect-resistant plants; and other means of managing insect pest populations.

The pest-management concept is based on the precept that insects should be managed to maintain their populations below an economic level. Paramount in this concept is the determination of an economic insect. An economic insect is one that causes enough yield or quality loss to justify the expense to manage that insect. The basic concepts regarding the relationship between insect populations and economics of control were advanced by Stern et al. (1959) and Stern (1966). The authors pointed out the necessity for determining economic damage in agricultural crops. Economic damage is the amount of damage that, if prevented, will equal or exceed the cost of using artificial control measures. Two concepts are related to economic damage. First, for IPM programs to work effectively, the economic injury level (the lowest number of insects that will cause economic damage) must be determined for the host, i.e., the minimum number of insects required to reduce yield or quality equal to or greater than the cost of applying artificial control. Second, after the economic injury level is determined for a particular crop, the economic threshold or action threshold (the insect population level when action is taken to prevent insect numbers from reaching the economic injury level) must be established.

Stern et al. (1959) categorized insect pests in relation to their economic significance as "noneconomic pests, occasional pests, and severe pests". Most insect pests of groundnuts could probably be classified in the first two categories.

Noneconomic pests are characterized by an average density that only rarely, if ever, reaches the economic injury level. They are most common in crops with relatively low market values. In ground-

nuts, some of the minor defoliators would probably fit into this category.

Occasional insect pests are those whose average densities are generally below the economic injury level, but whose highest population-level fluctuations occasionally exceed the economic injury level. With these pests in particular, knowledge of the insect biology, prediction of future population trends, and knowledge of the economic injury level are vitally important. Awareness of these aspects of pest bionomics allows a preventive outlook rather than a curative one. Treatment of crops unnecessarily, without regard to the economic injury level for the occasional pest species, may be the difference between profit and loss in marginal operations. Also, the unnecessary use of chemical insecticides can produce undesirable side effects, such as resurgence of the pest, development of pest resistance to insecticides, or harmful levels of pesticide residues on the crop. Most insect pests of groundnuts are occasional pests; they are not economic in every generation of every year.

The severe pest is characterized by an average population density that exceeds the economic injury level. With this type of pest, insecticides are required almost continually and usually on schedules. This type of pest problem is generally associated with high-value crops. In all likelihood, groundnuts are not attacked by this type of pest in the developing countries. In certain areas, however, termites may inflict levels of damage that would characterize them as severe pests.

The basis for managing pests, such as the occasional pest, is the planned manipulation of the various processes that prevent pest populations from becoming economic, and thus minimize the economic impact of the pests (Southwood and Way 1970). These principles can be implemented in the developing countries to aid in the management of pests and thus aid in reducing the dramatic fluctuation in crop productivity. Four elements are basic to successful IPM programs for these countries:

- the development of reliable sampling procedures for estimating population density,
- the determination of economic levels for the various pests,
- an estimation of the influence of natural control agents, and
- a good knowledge of the insect biology and ecology (Moore 1978).

These four basic elements form the research core for the development of IPM programs for SAT Africa.

Groundnut Pests in SAT Africa

Over 400 arthropod species are reported as preharvest pests of groundnuts, of which 188 species attack groundnuts in SAT Africa (Smith and Barfield 1982). In addition, over 80 species are reported as pests of postharvest groundnuts (Redlinger and Davis 1982). The most frequently encountered arthropod pests are the beetles (*Coleoptera*), with 120 species that damage postharvest groundnuts, 49 of which are found in SAT Africa, and 70 species that damage postharvest groundnuts. The second most prevalent group of pests includes the leptidopterous larvae; 68 species are reported from preharvest and 6 species from postharvest groundnuts. The true bugs (Homoptera-Hemiptera) represent the third most frequently encountered group of insects, with 43 and 39 species, respectively, that attack preharvest groundnuts. Other major groups that attack preharvest groundnuts include the grasshoppers and locusts (Orthoptera), with 36 species; the termites (Isoptera), with 25 species; the thrips (Thysanoptera), with 19 species; the mites (Acarina), with 17 species; and the millipedes (Julida), with 13 species (all from SAT Africa).

Recent reviews by Amin and Mohammad (1980) and Wightman (1985) discussed major groundnut pests for the SAT. In Africa, 10 arthropods are considered as major pests of groundnuts (Amin and Mohammad (1980). These include the groundnut aphid, *Aphis craccivora* Koch; leafhoppers, *Empoasca dolichi* Paoli and *E. facialis* Jacobi; an armyworm, *Spodoptera littoralis* (Boisduval); the groundnut hopper, *Hilda patruelis* Stal; a termite, *Microtermes thoracalis* Sjöstedt; the "Wang," *Aphanus (Elasmolomus) sordidus* (F.); millipedes of the genus *Peridontopyge*; and the groundnut bruchid, *Caryedon serratys* (01.). In addition to these, Wightman (1985) lists an earwig, *Anisolabis stali* (Lucas); white grubs, *Eulipida mashona* Arrow (appears to be the most important in Africa); and several species of thrips.

Several other species of insects are listed by Hill (1979), Feakin (1973), and Mercer (1977, 1978a, 1978b) as groundnut pests in SAT Africa. These include the African bollworm, *Heliothis armigera* (Hübner); a semilooper, *Achae finita* (Guenee); the beet armyworm, *S. exigua* (Hübner); the black cutworm, *Agrotis ipsilon* (Hufnagel); the brown leaf beetle, *Ootheca mutabilis* Sahlberg; the striped sweet potato weevil, *Alcidodes dentipes* (Oliver);

chafer grubs, *Schizanycha* spp.; and systates weevils, *Systates* spp.

Wightman (1985) lists the order of research importance for arthropod pests of groundnuts in Africa as: (1) termites, (2) aphids and the transmission of rosette virus, (3) *Hilda patruelis*, and (4) jassids. Millipedes were also listed at a lower priority.

Several minor pests of groundnuts become of prime importance when their ability to transmit virus diseases is considered. Amin and Mohammad (1980), Smith and Barfield (1982), and Wightman (1985) list 13 virus diseases of groundnuts and the insects that transmit the viruses. Aphids, thrips, and leafhoppers are the most common vectors of the virus diseases in groundnuts.

Termites appear to be the most destructive insect pests in SAT Africa. Harris (1971) lists 10 species and Feakin (1973) lists 14 species of termites that damage groundnuts in Africa. However, two genera *Microtermes* and *Odontotermes*, are reported to produce the majority of groundnut damage (Wightman 1985, Johnson et al. 1981, Johnson and Gumel 1981). Yield losses of up to 40% have been reported in Nigeria (Johnson et al. 1981). These authors noted that *Microtermes lepidus* Sjöstedt damaged the tap root, tunneled into the stems, and scarified and invaded the pods. They also noted a linear relationship between tap root invasion and yield loss. Johnson and Gumel (1981) noted that pod scarification by *M. lepidus* is restricted to the more mature pods and that it is much greater (40.9-87.9%) in dead stands where the tap root is invaded, than in healthy stands (7.9-31.6%) without tap root damage. They also reported that 85-91% of the kernels from scarified pods were infected with fungi while only 67% of the kernels from unscarified pods were infected with fungi.

Groundnut pod damage by termites is accentuated by irregular maturity and delayed harvest (Feakin 1973). Planting a single variety rather than a mixture of varieties and selecting optimum harvest dates reduces termite damage. Mechanical cultivation for successive years may reduce termite populations and thus reduce damage, but hand or shallow cultivation has no effect on termite damage. Feakin (1973) also suggested that groundnuts should not be planted on newly prepared ground. Johnson et al.(1981) noted that in farmland that is cultivated continuously every year, the only food available to termites is the crops, their residues, and litter. This, according to the authors, combined with the restricted foraging of termites during the dry season, poses a serious threat to the survival of *Microtermes*, particularly in the drier areas. Thus, substantial food reserves, i.e., fungal combs, have to be built up rapidly during the wet season. This foraging occurs at the expense of susceptible crops, such as groundnuts, and is an important factor in explaining the pest status of *Microtermes*. Johnson et al. (1981) also reported that the initiation of severe groundnut damage by termites, particularly the invasion of the tap root, coincided with the depletion of water in the top soil, which forces the termites to restrict their foraging to levels below the soil surface. They hypothesized that the highest levels of damage would occur in locations with a short rainy season and with well-drained soils.

The groundnut aphid, *Aphis craccivora*, as well as other aphids that feed on groundnuts, is important primarily because of its ability to transmit virus diseases to groundnuts. *A. craccivora* was the major cause of the rosette virus epidemic that devastated groundnut yields in 1975 (Gibbons 1977). Seven viral diseases are known to be transmitted to groundnuts by aphids (Wightman 1985); *A. craccivora* is the only aphid that is known to transmit all seven of these viruses.

Several thrips species are reported to attack groundnuts. Okwakpam and Youdeowei (1980) reported that four species of thrips attack groundnuts and other edible legumes in Nigeria, and Smith and Barfield (1982) listed an additional six species of thrips that attack groundnuts. Lynch et al. (1984) evaluated four systemic insecticides for control of thrips, primarily *Frankliniella fusca* (Hinds), on groundnuts in the southeastern U.S. They found that controlling thrips did not significantly increase yields, that high thrips populations occurred too early in the season to be of economic significance, and that thrips control was primarily cosmetic. Similar results were reported by Tappan and Gorbet (1979, 1981). In Africa, however, high thrips populations occur throughout the growing season.

Demange (1975) reported 13 species of millipedes that damage groundnuts in Senegal. During the rainy season, over 50% of the millipedes are found in the upper 10 cm of the soil, whereas in the dry season, 90% of the millipedes are below the 10-cm soil level (Gillon and Gillon 1979a, 1979b). Populations of millipedes tend to be higher around or under stumps, and around and in termitaries. Six species, *Graphidostreptus tumuliporus* Karsh, *Haplothysanus chapellei* Demange, *Peridontopyge conani* Brölemann, *P. rubescens* Attems, *P. spinosissima* Silvestri, and *Syndesmogenus minmeuri* Brölemann, are the most frequently encountered (Rossion 1976,

Masses 1981). *P. rubescens* and *S. mimeuri* are the dominant species, with one-third of the population of these two species occurring in groundnut fields. Millipedes are the most important pests of groundnuts in central Senegal (Masses 1981, personal communication, H. Masses, Station ISRA de Darou, B.P. 75 Kaolack, Senegal). They damage young groundnuts just after plant emergence, reducing plant density up to 20%. They also feed on developing pods, reducing yields by 30-40%. Millipedes primarily attack immature, developing pods, while termites attack the more mature pods (Johnson et al. 1981, IRHO 1982).

In many parts of Africa, the groundnut bruchid, *Caryedon serratus*, tends to be the most important insect pest of groundnuts, especially after the pods are dug (Davey 1958, Green 1959). Losses may approach 10% in each of the 4.5 generations during the dry season; after 3 generations of infestations by this insect, the groundnuts are unmarketable. Damage is greater on unshelled groundnuts where the insect egg is laid on the pod surface and the emerging larva tunnels through the pod and feeds on the kernel. Populations often reach economic levels when the crop is left in open storage for a prolonged period. Mature fruits of several native trees, *Piliostigma thonningi*, *P. reticulatus*, *Tamarindus indica*, and *Cassia sieberiana*, provide a continuous source for infestation throught the year (Conway 1983). Groundnut infestations from insects that emerge from primary tree hosts in the field are of major importance, with residual infestations in storage facilities of little consequence. Allowing groundnuts to remain in the field to dry for extended periods increases infestation. Damage during storage is related to the degree of infestation while the groundnuts are drying in the field. Jute bags for storing groundnuts restrict entry or exit of bruchid adults and thus reduce infestation from one bag to the next.

The "Wang" *Aphanus sordidus*, also attacks groundnut pods while they are drying in the field. This lygaeid bug pierces the groundnut pod with its mouthparts and feeds on the oil in the kernel. Such feeding causes the seed to become wrinkled and darker, and reduces germination (Thomas 1983, Conway 1976).

Delbosc (1966), Gillier and Bockelee-Mowan (1979), Mbata and Osuji (1983), and Thomas (1983) discussed most of the principal insect pests of stored groundnuts in Africa. Two orders of insects, Coleoptera and Lepidoptera, are of primary importance. The major coleopteran pests of stored groundnuts are the red flour beetle, *Tribolium castaneum* (Herbst); the confused flour beetle, *T. confusum* Jacquelin duVal; the khapra beetle, *Trogoderma granarium* Everts; the merchant grain beetle, *Oryzaephilus mercator* (Fauvel); and the sawtoothed grain beetle, *O. surinamensis* (L.). The major lepidopteran pests of stored groundnuts include the rice moth, *Corcyra cephalonica* (Stainton); the almond moth, *Ephestia cautella* (Walker); and the Indian meal moth, *Plodia interpunctella* (Hübner).

Peanut CRSP Research in SAT Africa

Collaborative research between the University of Ouagadougou and the University of Georgia to develop IPM strategies for reducing insect damage to groundnuts in SAT Africa is conducted in Burkina Faso. The major goal of this collaborative research is to develop research information and procedures based on sound IPM principles that will help stabilize and/or increase groundnut yield. Specific goals of the Peanut CRSP-Entomology Project in Burkina Faso are to:

1. Identify the major economic pests of groundnuts.
2. Determine the relationship between level and type of arthropod damage and aflatoxin contamination in both preharvest and postharvest groundnuts.
3. Develop economic injury levels for major arthropod pests by quantifying pest density with groundnut yield.
4. Develop reliable sampling procedures to estimate population densities of the major pests.
5. Determine arthropod abundance as related to groundnut developmental phenology and season.
6. Provide training opportunities for Burkina Faso students.
7. Develop bait attractants or other control strategies for major insect pests.
8. Evaluate promising breeding lines developed by the CRSP Breeding Project for resistance/susceptibility to major arthropod pests.

Research addressing objectives 1, 5, and 6 was initiated in 1984. Surveys of groundnut pests were conducted in the major groundnut-growing areas of Burkina Faso and included locations near the cities of Po, Fada, Boromo, and Niangoloko. During three survey trips in 1984, the following insect groups were collected on groundnuts: Orthoptera, Thysanoptera, Homoptera, Hemiptera, Lepidoptera, Coleoptera, Diptera, Hymenoptera, Isoptera, and Julida. Insects collected during the surveys are cur-

rently being identified by taxonomic specialists. It appears from these results that four groups of these insects are of potential economic importance (Table 1). Thrips (apparently three species) populations were relatively high on groundnuts during all three surveys. Lynch et al. (1984) showed that in Georgia (USA), control of thrips with systemic insecticides did not significantly increase yield. However, in Georgia, damaging thrips populations occur primarily during the first 30 days after emergence (DAE). Once groundnuts begin to flower, thrips move from the leaf terminals to the flowers, the plant growth rate increases logarithmically, and thrips populations decline. However, thrips in SAT Africa may be of much greater importance since high populations are maintained during the critical pod-set and pod-filling stages of growth.

Jassids are another group of insects that are of potential importance to groundnuts in Burkina Faso. Two species, *Empoasca dolichi* and *E. facialis*, are major pests in Africa (Amin and Mohammad 1980). Populations of jassids showed a drastic increase from July to September, especially at Boromo and Niangoloko. These extremely high jassid populations occurred during the latter portion of the pod-filling stages when the kernels are rapidly developing. Reduction in photosynthetic area and/or production of photosynthate that is partitioned for development of kernels during the critical physiological stages could substantially reduce groundnut yield.

Termites are a third group of insects that have economic importance to groundnut production in Burkina Faso. Although surveys in July to September showed limited populations and damage, their damage to groundnuts at harvest on the Gampala Research Station plots was substantial; 50-80% of the pods were scarified. Thus, these preliminary observations on termite damage confirm the ranking of termites as the first research priority by Dr. John Wightman, Principal Groundnut Entomologist, ICRISAT. Collaborative research between ICRISAT and the Peanut CRSP is planned to evaluate the termite-resistant genotypes reported by Amin et al. (In press).

Millipedes are the most important groundnut pests in the major growing region of Senegal (Masses 1981; personal communication, H. Masses, Station ISRA de Darou, B.P. 75, Kaolack, Senegal). Millipede populations were relatively low in the surveys in Burkina Faso, but millipedes should still be considered of potential economic importance until additional data are collected.

Damage to groundnut pods by millipedes and termites has certain similarities to damage caused by the lesser cornstalk borer (LCB) *Elasmopalpus lignosellus* (Zeller), a major groundnut pest in the USA. Lynch (1984) reported that damage to groundnut pods by LCB is determined by the stage of pod development (Williams and Drexler 1981) at the initiation of attack. Groundnut pods in stages 1-3 are preferred and penetrated by LCB larvae that then feed on the developing kernel. This is similar to the preference of millipedes for immature pods (Johnson et al. 1981). Conversely, pods in stages 4-6 were not penetrated by LCB larvae, but were scarified externally, resulting in damage similar to that reported for termites (Johnson et al. 1981). The LCB

Table 1. Arthropod abundance on groundnuts in Burkina Faso in 1984.

Location	Survey date	Thrips/ 10 terminals (10 sweeps)	Jassids/ 10 sweeps	Termites m^{-1}	Millipedes m^{-1}
Po	7/7/84	-	-	-	-
Fada		67	72	0	0
Boromo		72	12	4	10
Niangoloko		36	9	0	0
Po	19/8/84	83 (4)	14	0	8
Fada		27	0	0	0
Boromo		32	0	0	0
Niangoloko		59 (32)	134	0	4
Po	25/10/84	9 (53)	150	37	0
Fada		97 (166)	87	0	21
Boromo		30 (433)	657	0	0
Niangoloko		0 (94)	606	0	0

is considered a dryland insect in the U.S., primarily because economic damage by the LCB is associated with drought. Johnson et al. (1981) and Johnson and Gumel (1981) also reported that termite damage was greatest in periods of inadequate rainfall during the latter portion of the growing season, and they obtained a significant correlation of -0.76 between the percentage of groundnuts with the tap root invaded by termites, and rainfall. Lynch and Wilson (1984) demonstrated that the LCB was an excellent vector of *Aspergillus flavus* (Link) and that pod penetration and delayed harvest increased *A. flavus* and aflatoxin contamination. Similar results have been suggested for termites (Diener 1973, McDonald and Harkness 1963, 1964, McDonald et al. 1964) and millipedes (personal communication, H. Masses, Station ISRA de Darou, B.P. 75, Kaolack, Senegal). The number of similarities between the LCB, millipeds, and termites in their damage to groundnuts and probable enhancement of aflatoxin formation under dry conditions warrants continued research. Methods to reduce aflatoxin contamination in groundnuts through proper harvest dates, short- season varieties, and chemical control of soil pests are currently being investigated in Burkina Faso and the U.S. by the Peanut CRSP-Entomology Project.

References

Amin, P.W., and Mohammad, A.B. 1980. Groundnut pest research at ICRISAT. Pages 158-166 *in* Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Amin, P.W., Singh, K.N., Dwivedi, S.L., and Rao, V.R. (In press.) Sources of resistance to the jassid, *Empoasca kerri* Pruthi, thrips, *Frankliniella schultzei* Trybon, and termites, *Odontotermes* sp., in groundnut, *Arachis hypogaea* L. Peanut Science.

Conway, J.A. 1983. Notes on the biology and ecology of the groundnut seed beetle *Caryedon serratus* (01.) (Coleoptera: Bruchidae) under field conditions in Senegambia. Tropical Stored Products Information 45:11-13.

Conway, J.A. 1976. The significance of *Elasmolomus sordidus* (F.) (Hemiptera: Lygaedae) attacking harvested groundnuts in the Gambia. Tropical Science 18:187-190.

Davey, P.M. 1958. The groundnut bruchid, *Caryedon gonargra* (F.). Bulletin of Entomological Research 49:385–404.

Delbosc, G. 1966. Les parasites des stocks d'arachide. (In Fr.) Oléagineux 21:293-296.

Demange, J.M. 1975. [Millipedes (Diplopoda) harmful to groundnuts in Senegal.] Les Myriapodes Diplopodes nuisibles à l'arachide au Sénégal. (In Fr. Summaries in En, Es.) Oléagineux 30:19-24.

Dienier, U.L. 1973. Deterioration of peanut quality caused by fungi. Pages 523-527 *in* Peanuts—culture and uses. Stillwater, Oklahoma, USA: American Peanut Research and Education Association.

Feakin, S.D. (ed.). 1973. Pest control in groundnuts. 3rd edn. PANS Manual no. 2, London, UK: Center for Overseas Pest Research.

Gibbons, R.W. 1977. Groundnut rosette virus. Pages 19-21 *in* Diseases, pests and weeds in tropical crops (Kranz, J., Schumlteres, H., and Kock, W., eds.) Berlin, Federal Republic of Germany: Verlag Paul Parey.

Gillier, P., and Bockelee-Morvan, A. 1979. [Protection of groundnut stocks against the insects.] La protection des stocks d'arachide contre les insectes. (In Fr. Summaries in En, Es.) Oléagineux 34:131-137.

Gillon, D., and Gillon, Y. 1979a. Distribution spatiale des principales espèces d'iules (Myriapodes Diplopodes) dans une zone cultivée au Sénégal. (In Fr.) Bulletin d' Ecologie 10:83-93.

Gillon, D., and Gillon, Y. 1979b. Estimation du nombre et de la biomasse des iules (Myriapodes Diplopodes) dans une zone cultivée au Sénégal. (In Fr.) Bulletin d' Ecologie 10:95-106.

Glass, E.H. (ed.). 1975. Integrated pest management: rationale, potential, needs, and implementation. College Park, Maryland, USA: Entomological Society of America. 141 pp.

Green, A.A. 1959. The control of insects infesting groundnuts after harvest in the Gambia. 1. A study of the groundnut borer *Caryedon gonagra* (F.) under field conditions. Tropical Science 1:200-205.

Harris, W.V. 1971. Termites: their recognition and control. London, UK: Longman. 165 pp.

Hill, D.S. 1975. Agricultural insect pests of the tropics and their control. Cambridge, UK: Cambridge University Press. 516 pp.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1980. Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, Patancheru, A.P. 502 324, India: ICRISAT.

IRHO (Institut de Recherches pour les Huiles et Oléagineux), Départément Oléagineux Annuels. 1982. Synthesis of studies presented on control of predators and groundnut diseases. Synthèse des travaux présentés sur la lutte contre les prédateurs et maladies de l'arachide. (In En, Fr.) Oléagineux 37:25-28.

Jackson, C.R., Okezie, O.B., and Wheelock, G.C. 1981. Peanut collaborative research support program—request for proposals for implementation of a global program. Athens, Georgia, USA: University of Georgia. 46 pp.

Johnson, R.A., and Gumel, M.H. 1981. Termite damage and crop loss studies in Nigeria—the incidence of termite-scarified groundnut pods and resulting kernel contamination in field and market samples. Tropical Pest Management 27:343-350.

Johnson, R.A., Lamb, R.W., and Wood, T.G. 1981. Termite damage and crop loss studies in Nigeria—a survey of damage to groundnuts. Tropical Pest Management 27:325-342.

Lynch, R.E. 1984. Damage and preference of lesser cornstalk borer (Lepidoptera: Pyralidae) larvae for peanut pods in different stages of maturity. Journal of Economic Entomology 77:360-363.

Lynch, R.E., and Wilson, D.M. 1984. Relation of lesser cornstalk borer damage to peanut pods and the incidence of *Aspergillus flavus*. Proceedings of American Peanut Research and Education Society 16:35.

Lynch, R.E., Garner, J.W., and Morgan, L.W. 1984. Influence of systemic insecticides on thrips damage and yield of Florunner peanuts in Georgia. Journal of Agricultural Entomology 1:33-42.

Masses, H. 1981. [Control of millipedes (Diplopodes, Spirostreptoidea) in groundnut crops in Senegal.] Lutte contre les iules (Diplopodes, Spirostreptoidea) en culture arachidière au Sénégal. (In Fr. Summaries in En, Es.) Oléagineux 36:555-562.

Mbata, G.N., and Osuji, F.N.C. 1983. Some aspects of the biology of *Plodia interpunctella* (Hubner) (Lepidoptera: Pyralidae), a pest of stored groundnut in Nigeria. Journal of Stored Products Research 19:141-151.

McDonald, D., and Harkness, C. 1963. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. Part II. Tropical Science 5:143-154.

McDonald, D., and Harkness, C. 1964. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. Part IV. Tropical Science 6:12-27.

McDonald, D., Harkness, C., and Stonebridge, W.C. 1964. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. Part VI. Tropical Science 6:131-154.

Mercer, P.C. 1977. Pests and diseases of groundnuts in Malawi. I. Viruses and foliar diseases. (Summaries in Es, Fr.) Oléagineux 32:483-488.

Mercer, P.C. 1978a. Pests and diseases of groundnuts in Malawi. II. Disorders of pods, kernels and seedlings. (Summaries in Es, Fr.) Oléagineux 33:119-122.

Mercer, P.C. 1978b. Pests and diseases of groundnuts in Malawi. III. Wilts, post-harvest, physiological and minor disorders. (Summaries in Es, Fr.) Oléagineux 33:619-624.

Moore, L. 1978. Implementation of integrated pest management programs. Pages 97-104 *in* Pest management in transition with a regional focus on the interior west: proceedings of the Pest Control Strategies Conference, 30-31 Mar 1978, Denver, Colorado, USA. Washington, D.C., USA: Environmental Protection Agency.

Mounkaila, A. 1980. Groundnut production research and research problems in Niger. Pages 262-263 *in* Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

NAS (National Academy of Sciences), Subcommittee on Insect Pest Control. 1969. Principles of plant and animal pest control, Volume 3, Insect-pest management and control. Washington, D.C.: National Academy of Sciences. 508 pp.

Okwakpam, B.A., and Youdeowei, A. 1980. The annotated key to four species of thrips (Thysanoptera) attacking edible legumes in Nigeria. Bulletin de l'Institut Fondamental d'Afrique Noire 42:157- 165.

Redlinger, L. M., and Davis, R. 1982. Insect control in postharvest peanuts. Pages 520-570 *in* Peanut science and technology (Pattee, H.E., and Young, C.T., eds.). Yoakum, Texas, USA: American Peanut Research and Education Society.

Rossion, J. 1976. [Millipedes, depredators of groundnuts in Senegal: recent results in chemical control]. Les iules, déprédateurs de l'arachide au Sénégal: résultats récents obtenus en matière de lutte chimique. (In Fr. Summary in En.) Oléagineux 31:327-333.

Rossell, H.W. 1977. Some observations and experiments on groundnut rosette virus and its control in Nigeria. Miscellaneous Paper no. 71. Samaru, Nigeria: Institute of Agricultural Research.

Smith, J.W., Jr., and Barfield, C.S. 1982. Management of preharvest insects. Pages 250-325 *in* Peanut science and technology. (Pattee, H.E., and Young, C.T., eds.). Yoakum, Texas, USA: American Peanut Research and Education Society.

Stern, V.M. 1966. Significance of the economic threshold in integrated pest management. Pages 41-56 *in* Proceedings of the FAO Symposium on Integrated Pest Control, Vol 2. Rome, Italy: FAO.

Stern, V.M., Smith, R.F., van den Bosch, R., and Hagen, K.S. 1959. The integrated control concept. Hilgardia 29:81-101.

Southwood, T.R.E., and Way, M.J. 1970. Ecological background to pest management. Pages 6-29 *in* Concepts of pest management. Raleigh, North Carolina, USA: North Carolina State University.

Tappan, W.B., and Gorbet, D.W. 1979. Relationship of seasonal thrips population to economics of control on Florunner peanuts in Florida. Journal of Economic Entomology 72:772-776.

Tappan, W.B., and Gorbet, D.W. 1981. Economics of tobacco thrips control with systemic pesticides on Florunner peanuts in Florida. Journal of Economic Entomology 74:283-286.

Thomas, P. 1983. Conditioning and conservation of groundnut seed. Conditionnement et conservation des semences d'arachide. (In En, Fr.) Oléagineux 38:131-139.

Wightman, J.A. 1985. Groundnut entomology in the semi-arid tropics: current status and formulae for future research. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

Williams, E.J., and Drexler, J.S. 1981. A non-destructive method for determining peanut pod maturity. Peanut Science 8:134-141.

Yayock, J.Y., Rossell, H.W., and Harkness, C. 1976. A review of the 1975 groundnut rosette epidemic in Nigeria. Presented at the African Groundnut Symposium on Pests of Groundnuts and Millet in the Field, 21-23 Apr 1976, Koalak, Senegal. Samaru Conference Paper no. 9. Samaru, Zaria, Nigeria: Institute for Agricultural Research.