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Pest management practices in cowpea: a review

L.E.N. Jackai[1] and C.B. Adalla[2]

Abstract

Cowpea yields are known to be low in most parts of the tropics because of heavy insect pest problems. In Africa, cowpea growers do not generally use synthetic insecticides; however, in most parts of Asia, dependence on the use of insecticides is common, often with serious environmental consequences. Such misuse of insecticides on cowpea, coupled with low yields, has led to an intensive search for pest control options that will increase yields with little or no input from insecticides, or biointensive integrated pest management (IPM). The major elements of this strategy include host plant resistance, use of beneficial organisms, agronomic practices, and (where adequate results are not obtained) some insecticide input, preferably from plant-based insecticides. This paper reviews the status of each of these interventions in cowpea production and discusses new initiatives in cowpea pest management. We also identify gaps in research and discuss options for developing IPM on cowpea.

Introduction

Much has happened in the art and science of insect control since a paper with a similar title (Jackai et al. 1985) was presented at the 1st World Cowpea Research Conference. People have become wiser, and grown more sensitive to environmental problems; research on nonchemical control has been intensified, and the clamor for system sustainability has reached unprecedented levels. Along with these events, and the new visions for pest management, cowpea production has undergone changes, but these are inadequate to address the more difficult pest problems.

Pest problems on cowpea persist, at least in part because of a lack of diversity in research interests in the control of pests. Much effort is devoted to the easier problems (aphids, bruchids, leafhoppers, etc.), while the major problems (e.g., thrips, pod borer, and pod bugs) remain unsolved. The pest problem on cowpea is complex, and requires diversified efforts. Without a major breakthrough in the control of the more recalcitrant postflowering field pests of this crop, bridging the gap between present and potential production of cowpea will be a slow and frustrating process. This notwithstanding, the future of cowpea production looks brighter today than ever before for two main reasons:

1. New advances in biotechnology have provided enormous impetus to host plant resistance research. Recombinant DNA and other molecular techniques are being used to seek answers to pest problems that do not lend themselves to conventional solutions (see later in this volume).

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1. International Institute of Tropical Agriculture (IITA), Oyo Road, PMB 5320, Ibadan, Nigeria.
2. University of the Philippines, Los Baños, the Philippines.

2. The renewed interest in basic ecological research as the foundation for sustainable pest management, and the drive to understand and sustain the system as a whole rather than an individual crop is bound to provide greater insight into pest bionomics.

Cowpea is a popular—and nutritionally important—legume crop in many parts of the tropical world. Despite this, it is considered too risky an investment by many growers, because of the numerous pest problems associated with it. Insect pests damage cowpea from seedling emergence to storage. The pest complex (Table 1) ranges from two to four key pests, often including as many as four minor or sporadic pest species. Different pest guilds specialize on every cowpea plant part, and in the worst cases these pests overlap in their incidence and damage (Fig. 1). It is not unusual to find four or more pests on the crop at the same time.

The most damaging of all pests are those that occur during flowering and podding (i.e., the postflowering pests or PFPs). They include flower thrips (Fth), dominated by *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae); the legume pod borer, *Maruca vitrata* Fabricius (syn. *M. testulalis*) (Lepidoptera: Pyralidae), known more commonly as maruca pod borer (MPB); and a complex of pod and seed suckers, of which *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae) is the dominant species in tropical Africa, where 70–80% of the world crop is grown (Jackai and Daoust 1986; Singh et al. 1990). These pod sucking bugs (PSBs), as they are called, cause similar damage to cowpea and can be controlled using the same methods. To this list can be added the cowpea curculio, *Chalcodermus* spp., and leafhoppers found in South America (Daoust et al. 1985) and parts of southern US (Chambliss and Hunter 1997), and the beanfly, *Ophiomya* spp., which occurs in Asia and parts of Africa. These are the most important pests associated with cowpea in much of its geographical distribution. However, it is not uncommon to encounter specialized, location-specific, pest species such as *Amsacta moorei* (Butler) (Ndoye 1978), *Apion* species (Nonveiller 1984), and *Alcidodes leucocephalus* (Erichson).

Storage pest species of cowpea are more cosmopolitan (Southgate 1978), and they are discussed in greater detail later in this book (Murdock et al. 1997).

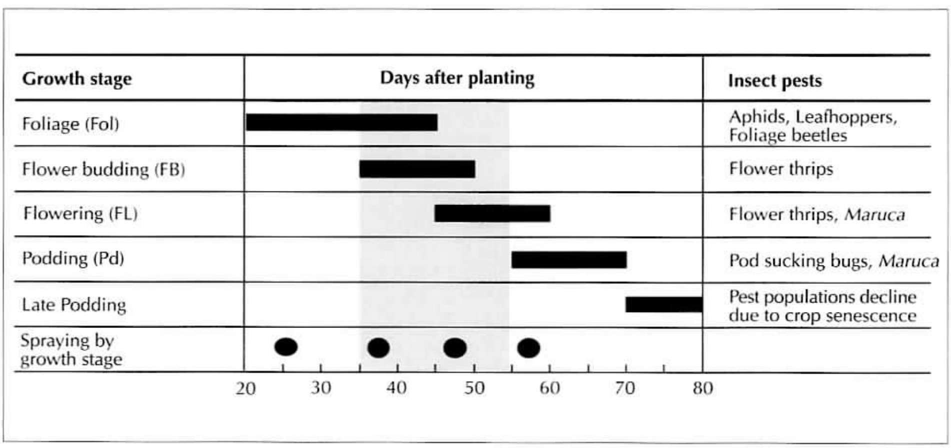

Figure 1. Cowpea growth stages and pest incidence.

Table 1. Major insect pest species found on cowpea worldwide.

Pest species (Order: family)	Geographical distribution	Plant part attacked	Importance
Aphis craccivora Koch (Homoptera:Aphididae)	Cosmopolitan	Foliage, flowers, pods	Key
Empoasca kraemeri, Ross & Moore (Homoptera: Cicadelidae)	S. America	Leaves	Key
Empoasca dolichi Paoli (Homoptera: Cicadelidae)	Africa	Leaves	Sporadic
Empoasca biguttula (Shiraki) (Homoptera: Cicadelidae)	Asia	Leaves	Unknown
Ophiomyia phaseoli (Trybon) (Diptera: Agromizidae	Asia Africa	Stem Stem	Key Sporadic
*Amsacta moore*i (Butler) (Lepidoptera: Arctiidae)	Africa (Senegal)	Leaves	Sporadic
*Megalurothrips sjostedt*i (Trybon) (Thysanoptera: Thripidae)	Africa Asia Americas	Floral structures Floral structures Floral structures	Key Not important Unknown
Thrips palmi (Thysanoptera: Thripidae)	Asia	Floral structures	Sporadic
Thrips tabaci Lindeman (Thysanoptera: Thripidae)	Asia, S. America	Floral structures	Sporadic
Maruca vitrata (Fab.) (Lepidoptera: Pyralidae)	Cosmopolitan (rare in S. America)	Stem, flowers, pods	Key
Elasmopalpus lignosellus (Zeller) (Lepidoptera: Pyralidae)	S. America	Stem	Key
Etiella zinckenella (Treitschke) (Lepidoptera: Pyralidae)	Asia	Pods, flowers	Sporadic
Clavigralla tomentosicollis Stal (Hemiptera: Coreidae)	Africa Asia S. America	Pods Pods Pods	Key Minor Minor
Leptoglossus sp. (Hemiptera: Coreidae)	USA	Pods	Sporadic
Crinocerus sanctus (Fab.) (Hemiptera: Coreidae)	S. America	Pods	Key
Riptortus dentipes (Fab.) (Hemiptera: Alydidae)	Africa	Pods	Sporadic

Table 1. continued.

Pest species (Order: family)	Geographical distribution	Plant part attacked	Importance
Lygus hysperus (Hemiptera: Miridae)	USA	Pods, leaves	Key
Nezara viridula Linnaeus (Hemiptera: Pentatomidae)	USA	Pods	Key
	Africa	Pods	Sporadic
	Asia	Pods	Sporadic
	S. America	Pods	Sporadic
Chalcodermus spp. (Coleoptera: Curculionidae)	USA, S. America	Pods	Key
Callosobruchus spp. (Coleoptera: Bruchidae)	Cosmopolitan	Seeds (storage)	Key

The pest problem on cowpea is clearly more severe in Africa than elsewhere, probably because many of the pests are considered indigenous to the continent and/or have had ample time to co-evolve with the crop in its center of origin and domestication (Ng and Maréchal 1985). Other views on the origin of cowpea pests have recently been expressed (Tamo et al. [in press]; see also Tamo et al. 1997).

Pest management philosophy

Insects are considered pests because of the socioeconomic and medical threat they pose to man and his property. Biologically, an insect is a pest because its population density and/or damage level exceeds a preestablished or conceptualized threshold (the economic injury level, EIL) below which the insect does not constitute an economic threat (Horn 1986). This is defined as the lowest population or damage level capable of causing economic impact (Poston et al. 1983). If the population of an organism exceeds the EIL, the organism becomes a pest. When an insect is introduced into a favorable environment, its population density tends to increase to the carrying capacity, K, of the resource. This is not usually exceeded because of the balance in environmental stress factors (e.g., predation, competition, and other natural mortality factors), constituting the environmental resistance. The EIL is usually below the carrying capacity of the resource. In order to maintain a pest population below this level may require some manipulation using one or more of the interventions at the disposal of growers (e.g., resistant cultivars, beneficial organisms, insecticides, etc.). Usually, we do not let the damage or population density of the pest reach levels that would result in economic loss before action is taken. This resource damage level, or pest population density prior to the EIL, is the economic or action threshold (ET or AT) (Stern et al. 1959), or damage boundary (Pedigo et al. 1986). This is when control measures must be introduced, augmented, or applied to the system. (Horn 1986; Metcalf and Luckmann 1994). Alterations in crop-pest dynamics, for instance by many of man's agricultural activities, dictate how pest management proceeds and the tools that can be used.

Identifying control interventions for cowpea pests

The ecology of most tropical insect pests has been inadequately studied. As a result, many control programs are *ad hoc* activities driven by crises resulting from perceived insect pest outbreaks. In cowpea the situation is somewhat different, though far from perfect, thanks to research at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, and many national research programs (Singh et al. 1978).

Cowpea pest incidence and diversity dictate that a single control strategy is unlikely to produce satisfactory results. Even if this were chemical control, the pests respond differently to different insecticides. As a result, the "best mix" approach is currently advocated. This involves the most logical combination of different compatible tactics for the control of pests on cowpea, as for other crops, in what might be termed, very simply but appropriately, intelligent pest management.

Chemical control using synthetic insecticides

Insecticide use on cowpea has a long history (Booker 1965; Jackai 1983; Jackai et al. 1985; Singh et al. 1990). It is the most widely known form of pest control on this crop. Traditional cowpea growers in Africa do not habitually use insecticides, as reflected in the poor yields they obtain. In many countries in Asia, pest control is mainly insecticide based, and for many commercial growers it is the only way. It is not surprising that insecticide resistance is already evident in certain areas (M. Tamo, personal communication). However, insecticides are the fire-fighting analog in cowpea pest control, a function for which they remain unrivaled (National Academy of Sciences 1969).

The landscape of insecticide use has changed over the years from dependence on the highly toxic and/or persistent insecticides (e.g., DDT, endosulfan, monocrotophos, etc.) of the 1960s and 1970s to an era of great skepticism and reduced usage in the 1980s, typified by a shift towards less toxic and more environmentally friendly and narrow spectrum, target-specific technology (e.g., Electrodyn sprayers). Currently, economic necessity and sensitivity to environmental destruction have rendered insecticide use socially unacceptable, although somewhat unrealistically so. There is also increased advocacy for monitored rather than calendar-based insecticide application, if insecticides must indeed be used (Afun et al. 1991).

The insecticides used on cowpea can be grouped into seed dressings, foliar sprays, storage sprays, and dusts.

Seed treatments. Getting a good crop stand is paramount to getting good yield. Damage from beetles, leafhoppers, beanfly, and birds can cause poor stands. One way this can be avoided is by treating seeds with an insecticide dust or slurry before they are planted (Breniere 1967). Even though poor stands are a persistent problem in a great many locations, it is surprising how little use is made of seed dressings. Detailed studies conducted with carbosulfan (Marshal® 25 ST, FMC, Pa, USA) (Jackai et al. 1988) show that as little as 10 g/kg of seed is required to protect cowpea seedlings from aphids, foliage beetles, and tunneling herbivores such as beanfly for up to 3 weeks in the screenhouse, and for longer periods under field conditions. More recently, another seed dressing, Apron Plus®, was also evaluated using two cowpea cultivars, one susceptible (Vita 7) and the other resistant (IT84S-2246) to *Aphis craccivora* (Koch) (Fig. 2). The results show that

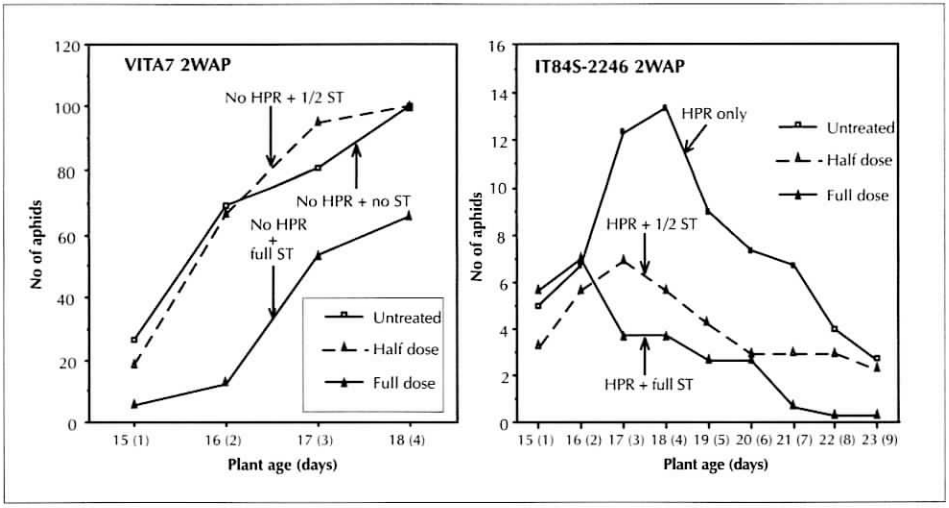

Figure 2. Evaluation of Apron Plus as a seed treatment for the control of seedling pests in cowpea. Vita 7 is susceptible to aphids. Half dose (2.5 g/kg seed) did not reduce aphid infestation after 2 weeks. On the aphid-resistant cultivar, IT845S-2246, there was a marked reduction in the number of aphids even by half dose. This demonstrates how plant resistance and insecticides can be used additively, and safely.

when varietal resistance is combined with seed treatment, the effects are additive and extend over considerable periods.

Other seed dressings that were popular in the past, such as Fernasan-D® (25% Thiram + 20% Lindane) and Aldrex-T®, are no longer recommended because of their organochloride content. They are nonetheless found on sale in the open market in many developing countries. Liquid seed dressing formulations are usually more toxic than dusts, and require special devices for mixing. Dust formulations such as carbosulfan can be applied to seed in small amounts (less than 1 kg), using paper bags or in covered cans. These are suitable for use by small farmers. Medium- to large-scale growers also use seed dressing, the only difference being one of scale. An additional advantage of seed dressing is that it has minimal impact on parasitoids and predators, and it can, therefore, be used in conjunction with biological control. Proper use of seed dressing ensures good initial plant stands, which are critical to successful farming, and many farmers would adopt this technology without too much difficulty. Its major drawback is the potential danger posed to people who consume cowpea leaves. Seed dressing should, therefore, not be recommended in areas where leaves are consumed.

Foliar sprays. Many insecticides used on cowpea are foliar sprays, either of emulsifiable concentrates (EC) or wettable powders (WP). Several of these chemicals are effective against most cowpea pests, although there is greater specificity in some cases against specific groups, a distinction related to the feeding behavior of the different pests.

The most commonly used insecticides include endosulfan, Lambda cyhalothrin, cypermethrin, permethrin, and dimethoate (Table 2). A more complete list is given by Jackai (in press). Despite their differential efficacy, most of these chemicals will increase

Table 2. Most commonly used insecticides for pest control on cowpea in the tropics.

Common name (chemical group)	Trade name†	Target pest
Lambda-cyhalothrin (Synthetic pyrethroid)	Karate	*Maruca vitrata*, foliage beetles, flower thrips, pod bugs
Cypermethrin (Synthetic pyrethroid)	Cymbush Sherpa	*M. vitrata*, flower thrips, pod bugs
Deltamethrin (Synthetic pyrethroid)	Decis	*M. vitrata*, flower thrips, pod bugs
Cypermethrin + Dimethoate (Synthetic pyrethroid + organophosphate)	Sherpa Plus Cymbush Super	All cowpea pests
Monocrotophos (Organophosphate)	Azodrin Nuvacron	Beanfly, leafhopper, aphid (only in Asia), flower thrips, pod bugs
Endosulphan (Organochloride)	Thiodan Perfekthion	*M. vitrata*, pod bugs, beetles, leafhoppers
Carbofuran (Carbamate)	Furadan	Flower thrips, leafhopper, aphid, beetles, beanfly
Carbosulphan (Carbamate)	Marshal	Flower thrips, leafhopper, aphid, beetles, beanfly
Carbaryl	Sevin	*M. vitrata*, other lepidoptera
Aluminum phosphide (Carbamate)	Phostoxin Detia, Gastoxin	Storage pests
Permethrin (Synthetic pyrethroid)	Coopex	Storage pests
Pirimiphos methyl + Permethrin (Organophosphate)	Actellic Actellic Super	Storage pests
Deltamethrin (Synthetic pyrethroid)	K-othrin	Storage pests

† The list is not exhaustive. Use of a trade name is not necessarily an endorsement of the product.

cowpea yields by at least tenfold with 2–4 applications (Franks et al. 1987; Afun et al. 1991).

The introduction of the more target oriented electrostatic (Electrodyn®) sprayer was a significant innovation in the control of cowpea pests in the early 1980s, capturing the interest of many cowpea growers in northern Nigeria (Coffee 1979; Gowman and Durand 1986). However, the popularity of this spray technology was relatively shortlived because of its high cost and the limited number of insecticides that could be used with it.

Consequently, the more versatile, and less expensive, low volume knapsack sprayer has remained the dominant sprayer although it is clearly less suitable (because of the water needed) for use in the drier savannas, where most cowpea is grown.

Insecticide use on cowpea will always have an element of controversy, but its use on cowpea may never be completely eliminated without a substitute that gives comparable results; right now, there is none. In the end, it is perhaps those farmers (the medium- and large-scale growers) that can afford the cost of chemical control who will influence the future of insecticide use on cowpea. Their influence creates a market for chemicals, thereby making insecticide use by others inevitable. To counter this, scientists must make the use of chemicals less attractive by providing viable and realistic alternatives. Our observations in Asia and several African countries indicate that the number of growers who use chemical control is on the increase (Bernardo and Adalla 1992), despite the escalating costs of spraying and nonavailability of appropriate products.

Insecticide use in storage. Use of insecticides to protect cowpea grain in storage is probably more commonplace and controversial than their use on the field crop, because chemical residues are erroneously feared to persist in the bean after cooking. This is a common misconception. If the right insecticides are used in the appropriate manner, there should be little or no concern about residues in cooked food.

The most commonly used insecticides for the protection of cowpea in storage are pirimiphos methyl (Actellic® and the formulation synergized with permethrin, Actellic Super®), aluminum phosphide (Phostoxin®, Gastoxin®, Detia®), malathion, permethrin (e.g., Coopex®, Kaothrin®), deltamethrin, etc. (Table 2). Those available in dust formulations or as liquid-based sprays usually do not pose the same degree of danger as do fumigants (gastoxin, phostoxin, etc.). However, despite the greater risks posed by fumigation, especially if used close to living quarters, fumigants are among the most effective products for disinfesting stored cowpea. Furthermore, the relative ease with which they can be dispensed (as tablet or pellet formulations) has greatly expanded the use of fumigants. In general, most clean and uninfested cowpea sold in the marketplace 3 months or more after the end of the growing season is generally treated with insecticides.

Use of insecticides invariably raises questions about resistant pest strains. Fortunately, this has really not been an issue in the case of cowpea, probably because compared to other crops such as cotton, the use of insecticides on cowpea is small. Reducing insecticide use on cowpea as currently advocated will make the development of pest resistance to insecticides less likely. Unfortunately, many research institutions which conducted research on insecticides have either shifted emphasis or completely abandoned work on this subject in favor of topics that attract more funding. As a result, we may never know if, or when, resistance to insecticides ever develops.

Plant-derived insecticides

Jackai (1993) reviewed the current status of the use of neem (*Azadirachta indica* A. Juss) on cowpea. Research in this area has intensified, possibly because of the high cost and/or the unavailability of conventional insecticides. Neem is only one of the many plants in the African landscape that are being investigated as a source of pest control on food crops (Olaifa et al. 1987; Saxena 1989; Schmutterer 1990). Although most research work on this aspect of plant protection has dwelled on storage protection of cowpea (Ivbijaro 1983; Sowumni and Akinnusi 1983) and maize (Kossou 1989), there has been increasing interest in the application of plant-based insecticides (PBIs) against field pests (Schmutterer 1990). For instance, extensive use has been made of neem extracts to control field pests of rice in Asia (see Saxena 1989, for review), cassava in West Africa (Olaifa and Adenuga 1988) and a few cases on cowpea (Cobbinah and Osei-Owusu 1988; Tanzubil 1992). The main groups of insects that show sensitivity to PBIs, especially neem, include Lepidoptera, Coleoptera, Agromyzidae, and Orthoptera (Schmutterer 1985).

Current work on the use of PBIs on cowpea is dominated by neem; different extracts from neem are under investigation on field pests in Nigeria. The impetus for this work came from the results of laboratory research at IITA and elsewhere, which showed high activity against two of the major pests of the crop, *M. vitrata* and *C. tomentosicollis* (Jackai and Oyediran 1991; Jackai et al. 1992). In Ghana, Cobbinah and Osei-Owusu (1988) and Tanzubil (1992) have also shown that neem has great potential as a field insecticide for use on cowpea. Whereas the emphasis in the past was on using the kernel and seed, ongoing work at IITA has included leaf extracts, to utilize the abundance of leaves. The active principles are, however, known to be more concentrated in the seed and bark of the tree (Saxena 1989; Schmutterer 1990). There is evidence of growth disruption, feeding inhibition, deterrence, and outright mortality associated with neem-based insecticidal products (Table 3) (G. Forjoe and L.E.N. Jackai, unpublished). A number of neem-based commercial insecticides are now available in many countries, especially in India, USA, and Germany. In the Philippines, other plants including *Vitex negundo, Derris* sp., and *Tinospora rumphi* have shown varying levels of toxicity against a wide range of field pests.

The interest in neem is driven mostly by need and economics. There is a gap created by the inaccessibility of conventional insecticides. An additional incentive to explore this and protectants such as vegetable oils (e.g., groundnut oil and dinnetia oil, etc.) (Osisiogu and Agbakwuru 1978; Singh et al. 1979) is their perceived compatibility with the environment and other pest management interventions (Schmutterer 1985, 1990). PBIs are generally not as effective as their synthetic counterparts, but their use can be augmented with other controls, such as natural enemies and entomopathogens, to provide acceptable levels of protection. These plants are grown or grow locally; therefore, educating farmers and the

Table 3. Effect of neem extracts on the hatchability of *Maruca vitrata* eggs†.

Concentration (%) of neem extracts	Egghatch (% ± SE)			
	Leaf extract		Seed extract	
	24 h fermentation	48 h fermentation	24 h fermentation	48 h fermentation
0	81.8(±6.08)a	81.8(±6.08)a	81.8(±6.08)a	81.8(±6.08)a
5	57.4(±13.14)b	50.6(±5.35)bc	35.6(±58.26)b	34.3(±4.36)b
10	40.1(±1.25)bcd	40.7(±10.7)bcd	25.9(±1.61)bc	26.1(±3.15)bc)
20	30.6(±6.72)d	34.8(±3.13)cd	19.8(±0.91)cd	16.0(±4.96)d

† Analysis of observed differences was based on transformed data (Arcsine transformation). Means within a column followed by the same letter are not significantly different at $P < 0.01$ (Student-Newman-Keul test).

general public on their use in plant protection should lead to an increase their use. Farmers in many parts of the tropics use botanicals for grain protection in storage as well as against field pests (Schmutterer 1990). Neem is also useful as a fertilizer and nematicide (Radwanski and Wickens 1981; Cobbinah and Osei-Owusu 1988; Colin and Pussimier 1992; Krishnamurthy 1993).

Plant resistance

A decade ago (Jackai et al. 1985), the emphasis was on chemicals and habitat modification. Mention was made of plant resistance as the focus for future sustained control. The story is now different, for two main reasons: (1) chemical control cannot be sustained by the fragile economies of most African states; and (2) despite the recalcitrance of certain pests, there is greater readiness to exploit the benefits of low or partial resistance to cowpea pests, given the knowledge that these can be used in conjunction with botanicals for a greater payoff. In addition, the traditional cowpea grower appears somewhat better informed of the existence of resistant cultivars, particularly to aphids and bruchids, with the result that there is a marked increase in demand for these cultivars (B.B. Singh, personal communication).

Preflowering pests. Resistance to seedling pests was first reported after evaluating a few hundred germplasm accessions from the gene bank at IITA. Resistance to aphids was identified in TVu nos. 36, 408, 801, 3000, to mention only the most prominent (Singh 1980). According to Ansari (1984), resistance in these accessions is due to antibiosis, but we believe other modalities are involved. Most of the aphid-resistant cowpea cultivars (e.g., IT83S-728-5, IT84S-2246-4, IT85D-3577, IT87S-1394, and KVx 426-1, among others) were developed from crosses involving either TVu 3000 or TVu 36. This narrow resistance base is a potential weakness in these cultivars, particularly since it is controlled by a single dominant gene (Singh and Ntare 1985). Fortunately, as far as we know, only US strains of *A. craccivora* have been reported to survive on some of these resistant lines. Clearly, the potential exists for more of this to happen.

The resistance to aphids identified at IITA was assessed only at the seedling stage (Singh and Jackai 1985). In a recent study to determine the reaction of these resistant cultivars to aphid challenge at different growth stages of the plant, it became clear that some cultivars were susceptible to infestation at the postflowering stage, thus suggesting stage-specific rather than a generalized form of resistance. This finding confirms reports from several colleagues in national programs (e.g., Burkina Faso) that a number of aphid-resistant cowpea cultivars developed at IITA were susceptible to this insect at the reproductive phase. Because of this, a study has been initiated to determine the mechanisms of resistance in known resistant germplasm accessions. This exercise could lead to a wider genetic base for resistance to aphids.

Cowpea growers no longer need to spray their crop against aphids if they plant the right cultivars. Among the best of these is IT84S-2246, a brown-seeded cultivar recommended for release in Nigeria and other countries. This recommendation notwithstanding, many farmers do not grow this cultivar, for reasons unknown to us which deserve investigation.

Leafhoppers present a similar success story (Rahman 1975). In addition, cowpea seedling resistance to the beanfly has been studied in the Philippines (Adalla 1994) and in Taiwan (IITA 1986).

Postflowering pests. While plant resistance can presently provide adequate protection for cowpea against seedling pests, the same cannot be said of the postflowering pests. The gravity of this situation is better understood when one realizes that except where the beanfly is a problem, the fate of cowpea production in many parts of the tropics hinges on what happens during the reproductive phase of the crop. Many insects that attack the crop at this stage are either oligophagous or sternophagous in their host range, with a few being (narrowly) polyphagous. The development of resistant varieties against these pests has eluded efforts over for several years. The most recalcitrant pests are the flower thrips, the maruca pod borer, the pod and seed sucker, *C. tomentosicollis,* and the cowpea curculio. Against this background, the progress achieved in the development of resistance to this group of insects, and the increase in our understanding of the phenomena that are involved in cowpea resistance to this group, becomes quite significant. After screening over 10,000 germplasm accessions of cultivated cowpea, a few were found to possess low to moderate levels of resistance. This has not solved the problem, but clearly represents significant progress in the long-term objective of developing cowpeas resistant to PFPs.

In multilocational trials conducted from 1990 to 1993 on a north-south axis in Nigeria, to evaluate a range of cultivars for their performance under varying intensities of the pod borer, *M. vitrata,* at different sites, it was evident that the pest pressure became less from south (Ibadan) to north (Kano). Under no-spray conditions, most genotypes performed better in the drier northern locations than in the more humid southern sites, as measured by the pod evaluation index (Ipe) (Table 4; see also Jackai 1995). MPB develops and reproduces better under high relative humidity and low to moderate temperatures (Jackai et al. 1990; Oghiakhe et al. 1992). Therefore, its population density tends to be lower in drier weather. Low levels of resistance would be most useful at such locations. Similar information is needed for all other important pests associated with cowpea. Resistance should be tailored to suit different locations (and needs) where possible, rather than seeking to develop varieties that can be planted everywhere.

Table 4. Performance of selected cowpea cultivars for *Maruca vitrata* resistance across three locations on a north–south axis in Nigeria†.

Variable	Location mean (±SE) Ibadan (n = 37)	Mokwa (n = 36)	Kano (n = 30)
Pod evaluation index (Ipe)	28.59 (±0.14)	31.76 (±1.72)	44.3 (±1.88)
Plant resistance index (Ipr)	23.76 (±0.68)	22.76 (±1.76)	37.9 (±2.03)
Relative performance ratio			
Ipe	1.0	1.1	1.6
Ipr	1.1	1.0	1.7

† Ipe = pod load x (9–Pod damage) (see Jackai 1995 for more details)
Ipr = $(FP_{w1} + MF_{w2} + N_{w3} + Z_{w4})/\Sigma_{wi})$, where FP = full protection; MF = spray at midflowering; N = Nuvacron spray; Z = no spray; wl–w4 = different weights in monocrotophos spray; Z = no insecticide protection.

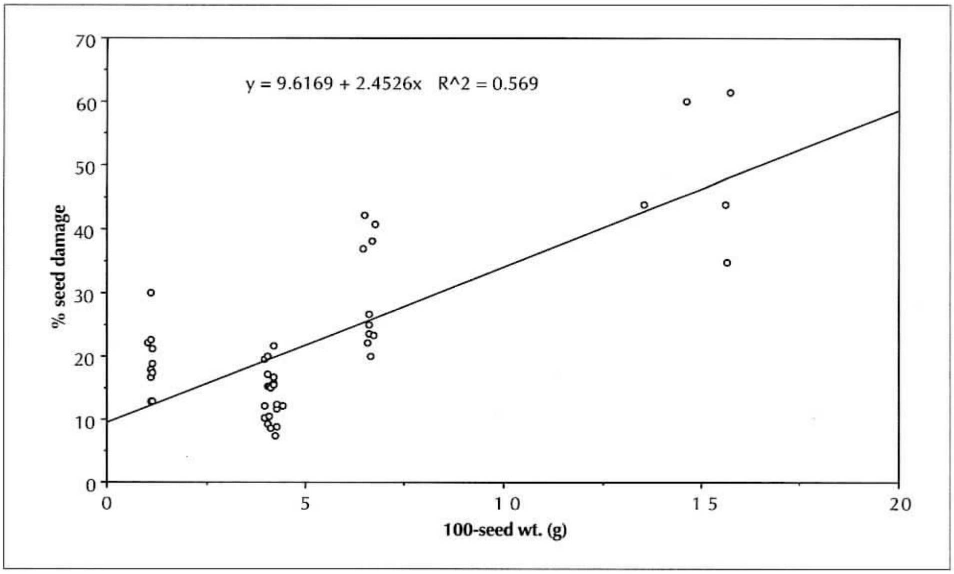

Figure 3. Regression of percentage seed damage by *Clavigralla tomentosicollis* per 100-seed weight of cowpea.

Several of the newly identified resistant germplasm have small seeds, or seed colors that are unacceptable to many consumers. This is important, because seed size is directly related to damage by the pod borer and pod bugs (Fig. 3). Although we need to keep consumer requirements in focus, researchers must recognize that consumers in different regions of the world have different preferences.

With the recent emphasis on the wild relatives of cowpea, intensive and systematic screening has resulted in the identification of good levels of resistance among the wild *Vigna* species. Those that can be easily crossed to cultivated cowpea have already been used in hybridization programs that seek to pyramid the genes for partial resistance, both in the cultivated group, on the one hand, and the uncultivated group in the *V. unguiculata* ssp. *dekindtiana,* on the other.

The resistance mechanisms seem to be quite variable, and they include the disruption of physiological growth processes of the insects, resulting in less crop damage than in the commonly grown cultivars (Jackai et al. in press). Unfortunately, some of these attributes appear to be associated with undesirable features, such as small seed size.

Use of biological control

Natural stress factors have obviously played an important part in ensuring that cowpea pests are contained as much as possible. Unfortunately, until recently, not much was studied about these agents and their impact on cowpea pests. Two papers in this volume (Tamo et al. 1997; Bottenberg et al. 1997) confirm that more attention is being directed towards this important subject. Given the status quo, we know of no case where biological control agents, either arthropods or pathogens, have been deliberately introduced for the control of cowpea pests. However, according to Tamo and his colleagues (Tamo et al. in press; 1997), the future landscape of pest control on cowpea will include the introduction, conservation, and augmentation of natural enemies. By implication, the overall equation of pest control on this important crop will also change, and thus promote biodiversity and sustain environmental quality.

Environmental management practices

Pest control tactics on cowpea that involve manipulating the insect's environment are well-known among traditional cowpea growers. They have practiced these tactics for ages, usually for different reasons than those proposed by scientists (Richards 1985). Several of these agronomic or cultural interventions are used in different parts of the tropics, but the greatest diversity is in the African tropics (Okigbo and Greenland 1976). One of the most common is intercropping, which will be discussed in some detail. Others include date of sowing, tillage, mulching, crop residue management (e.g., rice stubble management in rice fields in the Philippines [Litsinger and Ruhendi 1984]), and trap cropping.

The scientific basis for intercropping as a tactic in the management of insect pests was brought into focus by the work of Tahvanainen and Root (1972) and Root (1973) on *Brassica* sp. In a nutshell, their work indicated that with an increase in vegetational diversity in the agroecosystem, there is usually a corresponding decrease in pest species density, which generally leads to stability of the system.

Intercropping does not necessarily reduce the pest load in any given situation, as is often assumed; it depends on the crop(s) and pest(s) in question. Unfortunately, assessment of the impact of intercropping on pest populations is usually conducted on only one of the associated crops (Ezueh and Taylor 1983). Insects not present on that crop may indeed be found on the associated crop. This leads to an underestimation of the pest density in the whole system, and of the amount of damage caused by a given pest in a mixture, compared to that in the monocrop. Another misconception is that some cowpea pests can be controlled simply by intercropping. This view persists, despite insufficient experimental evidence to support it. Intercropping can reduce damage (or the rate of damage accumulation) on a crop; it can certainly contribute to the control of a pest in an integrated control context. However, in the final analysis, and with a few incidental exceptions, damage to intercropped cowpea is generally no less than that of the monocrop at the time of harvest.

Cowpea is generally intercropped with cereals, root crops, coffee, plantains, and cotton. Millet/sorghum-cowpea mixtures are perhaps the most prevalent form of intercropping involving cowpea in West Africa. Other forms are found in other parts of the tropics. Different patterns of intercropping are used in different locations. One common feature of most studies on intercropping of cowpea, irrespective of the associated crop or intercropping pattern, is the lack of response by the pod borer, *M. vitrata* (Matteson 1982; Lawson and Jackai 1987; Agbo-Noameshie et al. unpublished). Notable exceptions to this assertion were reported by Seshu Reddy and Masyanga (1987) who claimed to have got a 46% reduction of *M. vitrata* in a 1:3 sorghum/cowpea intercrop. Karel et al. (1980) working in Tanzania also reported less damage by flower thrips and the maruca pod borer on cowpea intercropped with maize. In fact, simultaneous sowing of cowpea and maize appears to increase infestation by the borer (Ezueh and Taylor 1983). This is perhaps because higher humidity and relatively lower temperatures, typical of intercropped cowpea, are generally favorable to the borer (Oghiakhe et al. 1992).

Several studies have shown that the population density of flower thrips is consistently lower in cowpea intercropped with maize, or sorghum (Matteson 1982), cassava (Lawson and Jackai 1987), and beans (Kyamanywa and Ampofo 1988), for exactly the same reasons that foster increase in the borer population. Kyamanywa and Ampofo (1988) have shown convincingly that shade, high humidity, and lower temperatures keep the population of thrips down in intercropped cowpea and field beans. Interestingly, in the same ecosystem, we find opposing requirements for two major pests of cowpea. Although this is not a genuine case of intercropping, leafhoppers and the beanfly are also effectively controlled by proper management of rice stubble in the Philippines (Litsinger and Ruhendi 1984).

Despite such evidence, we know of no case where the farmer intercrops for the sole purpose of pest control. We, therefore, consider this benefit as "incidental pest control." Further, the merits and demerits of intercropping are not necessarily dependent on numerical changes of the pests (Helenius 1991). Spatial and temporal changes of pest distribution may result in significant changes in crop damage, even if pest population densities remain unchanged.

Even though plant species diversity (crop-crop and weed-crop diversity) results in a reduction of pest populations (Ballidawa 1985), not all intercropping with cowpea confers entomological advantage. For example, blister beetles (Meloidae) and pod and seed sucking bugs (Coreidae) increased in population when cereals and cowpea were intercropped in Nigeria (Ochieng 1977; Matteson 1982). It is worth noting, however, that other agronomic tactics have been adopted because they help reduce damage by pests, sometimes because of increase in natural enemy activity (Letourneau 1990). Risch (1983) provides a commendable review on intercropping.

Other pest control interventions, which could appropriately be referred to as "cultural controls," vary from one ethnic group to another, and are truly culture-dependent. They include use of wood ash, fine sand, orange peels, various spices, and vegetable oils for the preservation of cowpea grain. Generally, these interventions have no adverse effects on the environment or their user. Their efficacy is quite variable, but they should work well in combination with resistant cultivars.

Future directions of pest control in cowpea

Pest control on cowpea is still primarily centered around the use of insecticides and resistant cultivars. And worse, the decision to spray is not based on pest threshold levels, despite the increasing body of knowledge on this subject. In parts of Asia, the effect of such misuse of insecticides is already being felt as more cases of resistance are reported yearly (Adalla 1994). Unless this trend is stopped, we can expect the same problems of the insecticide treadmill that characterized agricultural systems in the developed world (Edwards 1985). Bio-intensive pest management should be advocated for cowpea, regardless of its subsidiary status in the farming system. A good first step is to strive to reduce the number of insecticide sprays to the barest minimum (usually 2). This has been accomplished in some countries, and is an initial target in many projects on pest control on cowpea. However, the success of this reduction will depend largely on the existence of alternative control options for the farmer. Landmark studies on the cost-effectiveness of monitored insecticide applications show a 50% reduction in costs and clearly unquantifiable benefit to the environment (Afun et al. 1991). In the end, the reduction in synthetic insecticides should be balanced by an increased use of plant-based insecticides, where this input is essential.There is already a reduction in the use of agrochemicals as a result of the poor economic health of these countries.

Ecological studies are necessary for all control interventions to be meaningful. Several gaps exist in our knowledge of the interactions between insect pests and their environment, especially with respect to farmers' fields in the varying ecological zones where cowpea is grown. As more information is obtained, new ideas should be developed and control interventions modified accordingly.

Conclusions

Clearly, several sustainable pest control interventions are available for use in cowpea production. Except for the use of chemicals (synthetic and botanical), there is insufficient evidence to show, or suggest, that growers apply these measures deliberately for the control of cowpea pests. Research workers should be interested in determining why this is so, and try to change the status quo.

The socioecological tenets of pest control require that we apply those control measures we can influence or manipulate only if, or when, pest densities exceed a tolerable threshold and threaten to destabilize natural equilibria or threaten man's welfare more directly. So far, this philosophy does not seem to have been internalized by those involved in tropical agriculture, perhaps on account of ignorance. The use of "incidental controls" and biologically driven, self-sustaining tactics, such as host plant resistance and the use of natural mortality factors, needs to be encouraged in efforts to inculcate the norms of "alternative pest management" (APM), as this approach can be aptly described.

With the exception of chemical control, the different methods of intervention discussed in this paper comprise the basic components of "bio-intensive pest management". Pest control must be sustainable if long-term impact is expected or desired. Every crop has peculiarities, which should be addressed in designing control measures. For cowpea, control strategies need to be neutral in both access and scale, particularly because the target end-user is not expected to remain a small peasant farmer for life, and also because certain areas are better suited than others for larger scale farming. This scenario imposes an enormous challenge on research workers to develop technology that is focused on the small-scale farmer, yet sufficiently flexible to be adapted to other scales of farming, farming systems, and income levels. Tactics such as host plant resistance and the use of beneficial organisms clearly meet these criteria.

Finally, it must be pointed out that insecticides are not necessarily bad, and they can be intelligently integrated in cowpea pest management without the destruction of the environment that has characterized their use on other crops. Their use should be considered only if, or when, other controls fail to provide the desired protection. In the end, only IPM strategies with a sound economic foundation (Mumford and Norton 1984) will succeed. No one wants to grow a crop at a loss!

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