662

# Limits Imposed by Biological Factors: Pests

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THE palatibility and high protein content of some food legumes make them desirable to a wide variety of insects. Although most have developed resistance by natural selection to many potential pests, as for example the chickpea with its acid exudate (Rembold and Winter 1982), almost all food legumes suffer severe losses. A possible exception to this is *Lathyrus*; however, the plant and seed itself is toxic to man, unless properly cooked.

Pests can damage legumes from the seedling (e.g. cutworms) through the vegetative (e.g. defoliators) and reproductive stages (e.g. pod borers) and in the stored seed (bruchids). Many insects can act as pests (e.g. over 200 insect species have been recorded damaging pigeonpea in India). A comprehensive account of the pest problems will not be presented, but rather the account will be restricted to the major food legumes — peanuts, chickpeas, mungbeans, soybeans, pigeonpeas, and cowpeas — that are widely grown in Southeast Asia. This paper will concentrate upon the general aspects of the pests, and their management.

### Losses from Insect Pests

There have been few, if any, realistic assessments of crop losses caused by food legume insect pests. Such assessments should include not only the losses caused to the crops in the farmers' fields, but also the lost opportunity to grow crops in some areas. Flower- and pod-boring insects have nearly stopped the cultivation of pigeonpea in Sri Lanka (Subasinghe and Fellows 1978). Farmers have, through trial and error over generations, found which crops will produce a reasonable return in their fields. They have abandoned crop production of those species which insects destroy in their area. However, with the advent of modern insecticides, it is now possible to protect crops from damaging pests. There are several examples of 'new crop' introductions or high-yielding varieties of established crops, which do well when intensively protected, but yield nothing when left unprotected. We must add the cost of such lost opportunities to the debit account.

Crop loss assessment is difficult. It is more often discussed than practiced. Most data of crop loss are from research station fields, where the ecology and pest complexes are often atypical of those found in farmers' fields. A good example of this is provided by data from pigeonpea on the ICRISAT Centre farm. Here, pigeonpea is severely damaged by a hymenopteran pest, *Tanaostigmodes cajaninae*. More than 80% of the pods of late maturing pigeonpea can be destroyed by this insect. However, in a survey of farmers' fields across India in collaboration with national scientists, the damage to pods caused by this pest averaged less than 2% (Lateef et al. 1985). Clearly, *T. cajaninae* is a research station nuisance rather than a real pest in farmers' fields.

The ICRISAT surveys of pest damage in farmers' pigeonpea and chickpea fields across India provide us with data that are rarely available. Table 1 shows the percentage of pods damaged by the major pests in these surveys. In collecting such data, ICRISAT scientists visited more than 1200 farms, talking to farmers and collecting pod samples that were later analysed. Few national research organisations afford their scientists the opportunity or facilities to conduct such surveys. Most have no transportation, so their research is restricted to the atypical conditions of their research farm.

Even the extensive and expensive ICRISAT surveys did not provide direct data on crop loss. The percentage of damage caused to pods is obviously an important factor in crop loss, but the survey did not reveal the losses of pods caused by insects feeding on vegetation, buds, flowers, and young pods. Perhaps the easiest means of estimating crop

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TABLE 1. The percentages of pigeonpea pods, sampled from farmers' fields just before harvest, that were damaged by pests in India in 1975-81 (after Lateef et al. 1985).

| Pests | Northern India (above 23°N) | Central India (20-23°N) | Southern India (below 20°N) |
|---|---|---|---|
| Lepidopterous borers | 15.2 | 24.3 | 38.6 |
| *Melanagromyza obtusa* | 20.1 | 22.1 | 11.7 |
| *Callosobruchus* spp. | 0.2 | 2.2 | 6.3 |
| *Tanaostigmodes cajaninae* | 0.4 | 1.6 | 2.4 |
| No. of fields sampled | 407 | 446 | 444 |

loss is to compare the yields of plots that are left unprotected and those that are adequately protected by appropriate pesticide use. It is impractical to eliminate all damage, so the difference between the yields of the protected and unprotected plots is generally referred to as the 'avoidable loss'. Such data from replicated trials in farmers' fields would be very valuable for research and extension planning. Unfortunately, such data did not appear to exist for the food legume crops of Southeast Asia.

As a result, no realistic estimate of the losses caused by pests to these legumes can be made. However, the economic estimates that do exist, e.g. the ICRISAT estimate that *Heliothis armigera* causes losses of pigeonpea and chickpea to the value of $300 million per year in India, and the frequent reports of these crops being devastated by insect pests are sufficient to convince us that the food legume [illegible] alternate pest management [illegible]

## Major Pests

Pest problems vary from crop to crop, area to area and season to season. More than 500 insects were listed as pests of food legumes in the book edited by Singh et al. (1978). Many predators and parasites prey on these destructive pests and help maintain the balance of nature and reduce pest outbreaks. Hundreds of species of insects and mites were collected in Cambodia from many crops, including the food legumes, during 1961–1963 and identified in an annotated list by Nickel (1979). This review lists only the major widespread pests on each crop. These are shown in Tables 2 and 3. In general, the most damaging pests are those that attack the pods, for most legumes can compensate substantially for damage caused to leaves and flowers. For example, some peanut genotypes can lose up to 50% of their leaves to insects prior to pod formation without a significant loss of yield (Campbell, unpubl.). Pigeonpea can lose all of its first flush of flowers and pods to insects, but still produce a second flush which will give a good yield, if climate and the pests allow.

Some of the major pests are common to most of the food legumes. *Heliothis armigera, Maruca testulalis, Aphis craccivora* and *Nezara viridula* attack almost all of these crops and in most areas. Others, such as the pigeonpea podfly *Melanagromyza obtusa* and the soybean stemfly *M. sojae* are relatively crop specific. Details of the major pests follow.

### *Heliothis armigera*

The larvae of *H. armigera* damage all food legumes. They are particularly damaging to pigeonpea and chickpea in Asia. The female moths can each lay more than 2000 eggs. The moths move from plant to plant laying their eggs separately. The small white eggs hatch after 2–5 days, depending on temperature, and the young larvae initially feed on the surface of green tissue of leaves or buds. The [illegible] can complete their development on leaves if fruiting bodies are not available. On most hosts, eggs are primarily laid during the flowering period and most damage is confined to the flowers and pods or fruits. However, chickpea is an exception for it attracts ovipositing moths while in the seedling stage (Table 4) and it can lose most of its leaves to this pest. On peanuts, *H. armigera* feeds on leaves and flowers and can cause substantial yield loss, but normally the plants compensate for most of the damage.

### *Maruca testulalis*

This pest, which is variously known as the bean pod borer, spotted borer or mung moth, attacks many legumes across Asia and Africa. The moth can lay more than 100 eggs in small batches (2-16). These are usually found on flower buds, but are also found on shoots, leaves, flowers, and pods. The larva, which is easily recognised by the two pairs of black spots on each segment of its white body, produces silk which is used to stitch plant parts together to form a web within which it feeds on leaf, flower or pod tissue. Alternatively, it can bore into pods or stems. It is particularly common on cowpea, mungbean, pigeonpea and soybean. In Thailand, it

**TABLE 2. Damaging pests of food legumes in South and Southeast Asia**

| Legume | Pest Type | Order | Family | Gen. & sp. | Common Name |
|---|---|---|---|---|---|
| Mungbean | Pod borers | Lepidoptera | Pyralidae | *Maruca testulalis* | Legume pod borer |
| | | | Noctuidae | *Heliothis armigera* | Bollworm |
| | | | Noctuidae | *Spodoptera litura* | Cutworm |
| | | | Lycaenidae | *Lampides boeticus* | Long tailed blue |
| | | | Lycaenidae | *Euchrysops cnejus* | Blue butterfly |
| | Stem borers | Diptera | Agromyzidae | *Ophiomyia phaseoli* | Stem fly |
| | | | Agromyzidae | *O. centrosematis* | Stem fly |
| | Sucking pests | Hemiptera | Pentatomidae | *Nezara viridula* | Green stinkbug |
| | | | Cicadellidae | *Empoasca* sp | Potato leafhopper |
| | Defoliators | Lepidoptera | Arctiidae | *Amsacta* sp | Red hairy caterpillar |
| | | Coleoptera | Chrysomelidae | *Madurasia obscurella* | Leaf beetle |
| | Virus vectors | Homoptera | Aleyrodidae | *Bemisia tabaci* | White fly |
| | | | Aphididae | *Aphis craccivora* | Cowpea aphid |
| Peanut | Pod borers and root feeders | Hymenoptera | Formicidae | *Dorylus orientalis* | Subterranean ant |
| | | Dermaptera | | | Earwigs |
| | | Diplopoda | | | Millipedes |
| | | Coleoptera | Scarabaeidae | *Lachnosterna* spp. | White grub |
| | | Isoptera | Termitidae | *Odontotermes* spp. | Termite |
| | | | Termitidae | *Microtermes* spp. | Termite |
| | Defoliators | Lepidoptera | Noctuidae | *Heliothis armigera* | Bollworm |
| | | | Noctuidae | *Spodoptera litura* | Cutworm |
| | | | Arctiidae | *Amsacta* spp. | Red hairy caterpillar |
| | | | Lymantriidae | *Orgyia* spp. | Hairy caterpillar |
| | | | Gelechiidae | *Aproaerema modicella* | Leaf miner |
| | | | Tortricidae | *Archips micacaeana* | Leaf roller |
| | | | Pyralidae | *Lamprosema* spp. | Leaf roller |
| | Sap suckers and mycoplasma vectors | Hemiptera | Cicadellidae | *Empoasca* spp. | Potato leafhopper |
| | Virus vectors | Homoptera | Aphididae | *Aphis craccivora* | Cowpea aphid |
| | | Thysanoptera | Thripidae | *Frankliniella schultzei* | |
| | | | | *Scirtothrips dorsalis* | |
| Pigeonpea | Pod borers | Lepidoptera | Noctuidae | *Heliothis armigera* | Bollworm |
| | | | Pyralidae | *Maruca testulalis* | Legume pod borer |
| | | | Pyralidae | *Etiella zinckenella* | Lima bean pod borer |
| | | | Pterophoridae | *Exelastis atomosa* | Plume moth |
| | | | Pterophoridae | *Sphenarches anisodactylus* | Plume moth |
| | | | Lycaenidae | *Lampides boeticus* | Long tailed Blue |
| | Podfly | Diptera | Agromyzidae | *Melanagromyza obtusa* | Podfly |
| | Pod sucking insect | Hemiptera | Coreidae | *Clavigralla spp.* | |
| | Leaf binder | Lepidoptera | Tortricidae | *Cydia critica* | |
| | Sterility mosaic vector | Acarina | Eriophyidae | *Aceria cajani* | Eriophyid mite |
| Soybean | Pod borers | Lepidoptera | Noctuidae | *Heliothis armigera* | Bollworm |
| | | | Pyralidae | *Etiella zinckenella* | Lima bean pod borer |
| | Stem borers | Diptera | Agromyzidae | *Melanagromyza sojae* | Stem fly |
| | | | Agromyzidae | *Ophiomyia phaseoli* | Stem fly |
| | | Coleoptera | Cerambycidae | *Oberia brevis* | Girdle beetle |
| | Stem feeder | Lepidoptera | Noctuidae | *Agrotis* spp. | Cutworm |
| | Defoliators | Lepidoptera | Noctuidae | *Spodoptera litura* | Cutworm |
| | | | Noctuidae | *S. exigua* | Cutworm |
| | | | Arctiidae | *Diacrisia obliqua* | Jute hairy caterpillar |
| | | | Gelechiidae | *Aproaerema modicella* | Leaf miner |
| | | | Pyralidae | *Lamprosema* spp. | Leaf roller |
| | | | Tortricidae | *Archips micacaeana* | Leaf roller |
| | | Acarina | Tetranychidae | *Tetranychus urticae* | Twospotted spider mite |

| Legume | Pest Type | Order | Family | Gen. & sp. | Common Name |
|---|---|---|---|---|---|
| Soybean | Sucking pest | Hemiptera | Pentatomidae | *Nezara viridula* | Green stinkbug |
| | Virus vector | Homoptera | Aleyrodidae | *Bemisia tabaci* | White fly |
| | | | Aphididae | *Aphis craccivora* | Cowpea aphid |
| Chickpea | Pod borer | Lepidoptera | Noctuidae | *Heliothis armigera* | Bollworm |
| | Stem, pod and foliage | Lepidoptera | Noctuidae | *Agrotis* spp. | Cutworm |
| | Virus vector | Homoptera | Aphididae | *Aphis craccivora* | Cowpea aphid |
| | Root and stem | Isoptera | Termitidae | *Odontotermes* spp | Termites |
| Cowpea | Pod borers | Lepidoptera | Pyralidae | *Maruca testulalis* | Legume pod borer |
| | | | Noctuidae | *Heliothis armigera* | Bollworm |
| | | | Lycaenidae | *Lampides boeticus* | Long-tailed blue |
| | Stem feeder | Diptera | Agromyzidae | *Melanagromyza phaseoli* | Bean fly |
| | Pod sucking | Hemiptera | Pentatomidae | *Nezara viridula* | Green stinkbug |
| | Defoliators | Lepidoptera | Noctuidae | *Spodoptera litura* | Cutworm |
| | | | Noctuidae | *S. exigua* | Cutworm |
| | Sap feeder | Hemiptera | Cicadellidae | *Empoasca* sp. | Potato leafhopper |
| | Virus vector | Homoptera | Aphididae | *Aphis craccivora* | Cowpea aphid |

**TABLE 3.** Postharvest pests of beans, peas and peanuts

Coleoptera
- Adzuki Bean Seed Beetle -- *Callosobruchus chinensis* (Bruchidae)
- Cowpea Seed Beetle -- *Callosobruchus maculatus* (Bruchidae)
- Ground nut seed beetle -- *Caryedon serratus* (Bruchidae)
- Bean Seed Beetle -- *Acanthoscelides obtectus* (Bruchidae)
- Khapra Beetle -- *Trogoderma granarium* (Dermestidae)
- Lesser Grain Borer — *Rhizopertha dominica* [illegible]
- [illegible]
- Merchant Grain Beetle [illegible] (Cucujidae)

Lepidoptera
- Rice Moth -- *Corcyra cephalonica* (Galleridae)
- Almond Moth -- *Ephestia cautella* (Phycitidae)
- Warehouse Moth -- *Ephestia elutella* (Phycitidae)
- Indian Meal Moth – *Plodia interpunctella* (Phycitidae)

...is found in the stems of groundnuts, but this appears to be unusual. It has not been reported from chickpeas.

### *Aphis craccivora*

Of the many aphids that feed on the food legumes in the region, the cowpea aphis is the most common and widespread. These black aphids can build up to

**TABLE 4.** Mean numbers of eggs laid on chickpea and pigeonpea plants grown in pots and exposed to *Heliothis armigera* moths in field cages at ICRISAT 1978–79 (after Bhatagar et al. 1982).

| Stage | Mean no. of eggs laid/plant: Chickpea | Pigeonpea |
|---|---|---|
| Seedling | 12.5 (120)[a] | 2.3 (134) |
| Flowering | 1.2 (113) | 18.5 (105) |

[a] Figures in parentheses are number of plants examined

[illegible] and petioles. However, [illegible] vectors of various viruses that can cripple or kill the hosts.

### *Nezara viridula*

The green stink bug is a common pest of most food legumes, but it causes little damage to peanuts and has not been reported from chickpea. The shield-shaped green or green and gold adult female lays several batches of 10–100 green eggs on leaves or pods. The newly hatched black nymphs disperse over the plant, feeding on the shoots and pods. The feeding causes necrosis, and heavy populations can greatly reduce yields. Very young pods are particularly susceptible. When the stink bug pierces young seeds, they shrink, become distorted and wither. Older beans, when pierced, will show a discolored and slightly sunken spot.

***Bemisia tabaci***

The common whitefly whose immature stages (scales) feed on the underside of several legumes, particularly mungbean, can build up to heavy populations causing wilting and defoliation. However, this pest causes most damage as the vector of yellow mosaic on mungbean and other legumes.

***Agromyzids***

The agromyzid flies are particularly important on food legumes in the region. Some, such as the pigeonpea pod fly, *Melanagromyza obtusa* and the soybean stem fly, *M. sojae* are host-specific, but others such as the bean flies, *Ophiomyia phaseoli* and *O. centrosematis* attack the stems of a wide range of food legumes across the region. The plants may be killed if the stem feeding larvae attack the seedlings, but older plants can usually compensate for the damage. The pigeonpea pod fly is the most damaging pest of pigeonpea in central and northern India. ICRISAT surveys found 21% of the pods sampled from farmers' fields were damaged by this pest. The losses caused may amount to 250 000 tonnes, worth more than $US60 million per year.

***Aproaerema modicella (= Stomopteryx subsecivella)***

The peanut leafminer occurs throughout India and Southeast Asia. Peanut and soybean are the major host, but it also feeds on pigeonpea and mung bean (Mohammad 1981). Females lay an average of 186 eggs. Eggs hatch within 3 days and the larvae tunnel into the leaflet near the midrib. After feeding for about one week, the larva emerges from the mine, folds the leaflet or webs together several leaflets. The destructive larval stage lasts 9-17 days. Young larvae are cream colored and as they age, they turn green to brown with a black head. The life cycle from egg to adult lasts from 15 to 28 days. Adults live only 5-20 days. Keerati-Kasikorn and Hiranyasaree (1975) reported 15-65% leafminer damage to peanuts in Thailand. Arunin (1978) reported 85% soybean seedling stand loss in Thailand. Heavy rain and high humidity results in a decrease in the leaf miner population. Multiple cropping of susceptible legumes, especially soybean and peanut in rotation, should be avoided (Feakin 1973).

***Bruchids***

*Callosobruchus* spp. occur worldwide. They are particularly destructive to cowpea, but pigeonpea and soybean pods are also attacked. *Callosobruchus* larvae bore through the green pod to attack the developing bean. Although field infestations may only be 1%, the weevils increase rapidly in storage, so that what starts as a minor field problem blooms into a destructive storage problem. Southgate (1978) reported that damage increased to 33% in six months and 87% after nine months storage. Losses in quality as well as weight loss occur in bruchid-damaged legumes. *Callosobruchus* spp. do not attack peanuts, but *Caryedon serratus* can attack the pods after harvesting in the fields or in storage, causing substantial losses.

## Pest Management

Insecticides are useful in limiting the losses caused by the insect pests to food legumes, however experience has shown that there are problems and danger in relying solely upon insecticides for insect pest control. There are many examples of prolonged or intensive insecticide use inducing resistance in pests so that the insecticide is no longer effective. There are also examples of insecticides killing the natural control elements and so promoting populations of pests. In the southeastern United States, Bradley and Van Duyn (1979) reported an outbreak of *Heliothis zea* after predators were severely reduced by the incorrect timing of an insecticide application. Spider mite outbreaks occur frequently on peanuts following fungicide and fungicide-insecticide application intended to control lepidopteran pests and prevent plant diseases (Campbell 1978). Some of the food legumes are not high value crops and many farmers in the region have limited capital. Insecticides are expensive and pollute the environment. Hence, there are many good reasons for using alternative means of pest management.

Alternatives to insecticide use are host plant resistance, biocontrol and the use of cultural practices that reduce pests or allow the plant to escape damage.

### Host Plant Resistance

The benefits from host plant resistance have been obvious in plant disease control. There have been very successful efforts to breed food legumes that are resistant to the major diseases, and many new cultivars that have been released have resistance to one or more of the locally damaging diseases in Asia. Unfortunately, the entomologists have not made as much progress, partly because screening and breeding for insect resistance is usually more difficult than for disease, and also because there has been less effort until recently. Good progress is now being reported from ICRISAT, where peanuts, pigeonpeas and chickpeas are being bred for resistance to a variety of pests, and from AVRDC and several national research centres. Lateef (Table 5) evaluated 12 000 chickpea germplasm lines and recorded that very many of these had no insect damage, but it was obvious that most were simply

TABLE 5. Screening chickpea germplasm for susceptibility to *Heliothis armigera*. Plots found to be free from damage in harvested samples, ICRISAT Centre during 1976–77 (after Lateef 1985).

| | No. of entries harvested | No. without *H. armigera* damage | % without *H. armigera* damage |
|---|---|---|---|
| Germplasm lines | 8629 | 955 | 11.1** |
| Check BEG-482 | 221 | 43 | 19.5* |
| Check C-235 | 219 | 61 | 27.9* |

Differences significant at *P<0.05, **P<0.001

escapes. However, subsequent replicated screening of these lines showed that several were less preferred by *Heliothis armigera* for egg laying and larval feeding. Campbell and Wynne (1980) identified peanut plant introductions and breeding lines with low to high resistance to a complex of insects and mites. Resistance to *Spodoptera litura*, thrips, jassids, aphids and pod borers (including termites) has been identified at ICRISAT and is being incorporated into breeding lines for Asia. Wild species of peanut (*Arachis*) exhibited resistance approaching immunity to thrips, potato leafhopper and *Heliothis* (Amin 1985). Rogers (1982) reviewed the literature on screening legumes for resistance to *Heliothis* spp. Singh [illegible] evaluated cowpea for insect [illegible]

[illegible]

[illegible] beanflies in tests conducted in Indonesia, Taiwan and Thailand. Among the nearly 1200 accessions, 24 were selected as moderately resistant (Chiang et al. 1977). Mungbean seeds were exposed to the destructive weevil *Callosobruchus chinensis* in the laboratory in the Philippines and 11 of the 60 accessions were resistant (Epino and Morallo-Rejesus 1982).

Soybean breeding lines were registered as multiple insect resistant in tests conducted in North Carolina (Hinton et al. 1986). These selected soybean lines suffered 40–60% less damage from defoliators than the standard susceptible check.

Litsinger (1982) suggested priorities for breeding for insect resistant legumes. On mungbean and cowpeas he placed high priority on the pod borers *Maruca* and *Heliothis* and on the preflowering pests, beanfly, thrips and leafhopper. On soybean *Etiella*, beanfly and stink bug were considered to be important. Pigeonpea breeding priorities were for resistance to *Heliothis*, *Maruca* and the podfly. Peanut pest priorities included the leafminer, leafhopper, *Aphis* and *Heliothis*. For chickpea, only *Heliothis* was rated as a priority.

There is great diversity of pest susceptibility among germplasm lines of the legume crops that have been adequately studied. It is therefore probable that useful levels of pest resistance can be identified and incorporated into the breeding programs for each food legume in South and Southeast Asia.

### Biocontrol

Biological control, involving the introduction of exotic parasites and predators and the breeding and release of these and endemic species, has been most successful on islands and in perennial crops. It has not been very successful on long-established annual crops. However, there are many natural enemies of pests on these crops, without which the losses due to pests would be much greater. We must at least protect these natural enemies and if possible, augment their effects. For example, in central India *Heliothis armigera* is known to be attacked by at least 26 parasites and many predators (Bhatnagar et al. 1982). Injudicious insecticide use can destroy parasites and predators and lead to greater pest attacks.

Many scientists are investigating the potential for biological control on crops, including food legumes, in Southeast Asia. However, most of this research has not yet reached the economic evaluation stage and it is doubtful whether the production and [illegible]

[illegible] The production and dissemination of viruses to control some lepidopteran pests including *Spodoptera* spp. and *H. armigera* is already at the pilot stage of testing at some centres in India (Nagarkatti 1982).

### Cultural Practices

Changes in the cultural practices, particularly in sowing dates, can have a great effect on the incidence of most insects. By the adroit manipulation of crop proximities and rotations, it is possible to reduce the damage caused by some insects. The traditional systems that have built up over generations, particularly the careful observance of seasons, have evolved partly in response to pest threats. When farmers in an areas sow synchronously, the pests are diluted across crops. If one sows earlier or later or uses a shorter or longer duration cultivar than his neighbors, then he is likely to experience a more or less concentrated pest attack on his crop. Bradley and Van Duyn (1979) reported that early planted soybeans in southeastern United States escaped *Heliothis zea* damage while 79% of the soybeans planted three to four weeks later

**TABLE 6.** Percentages of pods damaged by *Tanaostigmodes cajaninae* in samples taken from trials of short, medium and long duration genotypes of pigeonpea at ICRISAT (after Lateef et al. 1985).

| Genotype duration | Month harvested | 1981-82 n | 1981-82 Mean % (ranges) | 1982-83 n | 1982-83 Mean % (ranges) |
|---|---|---|---|---|---|
| Short | Nov.-Dec. | 9 | 16.3 (6.2-32.6 ± 4.46) | 12 | 10.3 (0.4-19.3 ± 2.82) |
| Medium | Jan.-Feb. | 25 | 22.9 (1.9-83.2 ± 3.88) | 18 | 25.9 (5.4-62.9 ± 7.01) |
| Long | March | 24 | 49.7 (19.0-68.7 ± 5.23) | 15 | 32.6 (11.3-57.2 ± 4.45) |

n = number of genotypes tested.

required insecticide treatment for *H. zea* control. At ICRISAT, short-duration pigeonpea suffered less damage from *Tanaostigmodes cajaninae* than medium or long duration genotypes (Table 6). The many advantages of traditional systems are not well understood and will probably be fully elucidated only when changes in such systems result in major problems.

Food legumes are often grown as intercrops or in sequential-multicrop systems. Ruhendi 1979 (MS thesis, Entomology, Univ. of Philippines) found insect pests on cowpea plants, that had been sown after flooded rice, were affected by the height of the rice stubble. The maximum rice stubble effect on insect reduction occurred at 41-54 cm high for beanfly, 54 cm for thrips, and 44-48 cm for leafhopper. Rice straw mulch reduced thrips and leafhopper numbers but not beanfly. In the United States, Campbell (Table 7) found that peanuts planted after wheat in the stubble (no-till) had significantly less thrip damage than peanuts planted in conventionally tilled land. Campbell (Table 8) reported also that leafhopper damage was reduced on peanuts planted in rye stubble (no-till) compared with conventionally planted peanuts. Irrigation or flooding may have positive or negative effects on insects depending on their environmental requirements. It is therefore possible to take advantage of cultural practices to reduce or manage the complex of pests.

**TABLE 7.** Comparison of thrips damage on two peanut cultivars planted in wheat stubble (no-till) and conventionally tilled land, North Carolina, USA (Campbell, unpubl.)

| Peanut cultivar | Avg. % thrips/damage: No-till planting | Avg. % thrips/damage: Conventional planting |
|---|---|---|
| NC 6 | 3.3 | 14.0 |
| Florigiant | 16.7 | 33.3 |

LSD at 0.05 level is 8.9 for NC 6 vs. Florigiant and 11.5 for no-till vs. conventional.

### Insecticide Use

Insecticides are now widely available in this region, and most farmers in the region have made some use of these, if only for their household pests. In most cases, the high costs of pesticides will ensure that farmers do not overuse these chemicals on their crops. As a whole, insecticides are still relatively underutilised in Southeast Asia. There are, of course, striking exceptions to this, particularly on high-value crops such as cotton and vegetables near urban markets. Most farmers are still at the stage of making tentative, experimental use of insecticides. Unfortunately, most apply insecticides far too late. They wait until they see pest damage and then buy insecticides. The recipe for successful insecticide use is simple; apply the correct insecticide in the right amount at the right time. Unfortunately, few people know the ingredients for this recipe!

**TABLE 8.** Comparison of potato leafhopper damage on two peanut cultivars planted in winter rye stubble (no-till) and cultivated land (conventional). North Carolina, USA. (Campbell, unpubl.)

| Peanut Cultivar | Carbaryl kg/ha | % Leaflets with hopperburn[a]: No-till | % Leaflets with hopperburn[a]: Conventional |
|---|---|---|---|
| NC 6 | 1.1 | 2.3 | 2.3 |
| | Check | 8.0 | 19.0 |
| Florigiant | 1.1 | 3.0 | 4.7 |
| | Check | 17.0 | 40.7 |

[a] Based on 200 leaflet random sample.
LSD at 0.05 level is 7.8 for treated vs. check and 8.6 no-till vs. conventional

Insecticides should be applied when the pest population is such that substantial damage will occur unless the insecticide is applied. Most pest species cause little damage when small or when few are present. Thus, the crops should be regularly monitored and the farmer should be ready to spray whenever counts, particularly of eggs or small larvae or nymphs, threaten to exceed the 'economic threshold'. This threshold is the level of population (or damage) at which the application of insecticide will be profitable.

### Thresholds

Economic thresholds are more often discussed than calculated. It is not possible to give a simple economic threshold for a pest on a crop that will be valid for all seasons and all regions. Economic thresholds must take into account the following factors: crop potential, pest damage potential, cost of the treatment and market value of the crop. These factors vary greatly across areas and time. Crude thresholds can be constructed that will be generally applicable to at least prevent gross over-use or under-use of pesticides. We may have to rely on crop stage and calendar date for treatment guidelines until realistic crop losses are established for farmers' fields.

TABLE 9. Reproductive stages of peanut for Spanish (Starr) and Runner (Florunner) varieties (after Boote 1982)

| Reproductive stage | Days after planting (DAP) | |
|---|---|---|
| | Starr | Florunner |
| [illegible] | | |
| [illegible] | | |
| [illegible] | | |
| [illegible] | | |
| R5 Beginning seed | [illegible] | [illegible] |
| R6 Full seed | 67 | 74 |
| R7 Beginning maturity | 80 | 93 |
| R8 Harvest maturity | 119 | 129 |

An important step is a knowledge of the crop phenology in relation to the insect and its damage potential. In the United States, Boote (1982) described phenological stages for the peanut. A comparison of the reproductive stages of the Spanish and Runner peanut is shown in Table 9.

Thresholds for foliage loss that affect peanut yield also vary with the stage of plant development. Yield reduction occurred at 50% defoliation for the R2 stage, 10% for the R3 and R4 stages, 20% for the R5 stage and 50% for the R6 stage (Table 10). Sathorn Sirisingh (unpublished 1984) found 60-day peanuts were more susceptible to defoliation than earlier phenological stages at Ra Young, Thailand. E.P. Cadapan (Univ. of Philippines, unpubl.) also reported that the R3 to R5 phenological stages of the peanut were the most susceptible to defoliation. In spite of differences in plant duration of 120-150 days, the most susceptible stages for leaf loss occurred at the R3 to R5 stage in North Carolina, Thailand and the Philippines. This is apparently a critical period when pods and young seed are developing. Fehr and Caviness (1977) described growth stages of the soybean. The pod fill stage of the soybean is the most sensitive to foliage loss. Thomas et al. (1974) reported the threshold for soybean defoliator was 40% when pods were just visible, but the defoliation threshold was only 6% when the beans were beginning to develop.

While the economics of pesticide treatment will change, the damage-yield loss relationship remains more stable and will serve as a guide to 'on demand' or 'as needed' treatment. However, the threshold will vary greatly across geographical areas, genotypes and agronomic systems, so it will be [illegible]

[illegible] the pest complexes on peanuts, using the established sampling methods and thresholds. The results show (Tables 11a, 11b) that insecticide application, based on thresholds applied when needed, resulted in

TABLE 10. Effect of foliage loss and date of foliage loss on the yield of NC 5 peanuts North Carolina, USA (Campbell, unpubl.)

| Defoliation date | Plant stage[a] | DAP[b] | Yield kg/20 m row after defoliation | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 0% | 10% | 20% | 30% | 50% | 75% |
| July 1[illegible] | R2 | 61 | 5.87 | 5.90 | 5.75 | 5.79 | 5.45 | 5.22 |
| Aug 1 | R3 | 82 | 6.17 | 5.57 | 5.16 | 5.60 | 3.56 | 4.32 |
| Aug 15 | R4 | 96 | 6.30 | 5.68 | 5.98 | 5.30 | 4.47 | 2.69 |
| Sept 1 | R5 | 113 | 5.79 | 5.79 | 5.26 | 5.22 | 4.96 | 3.44 |
| Sept 15 | R6 | 127 | 5.94 | 5.79 | 5.94 | 5.87 | 5.34 | 4.54 |
| LSD at 0.05 | | | | | | | | 0.39 |

[a] Phenological stage according to Boote (1982)

[b] DAP = Days after planting. NC 5 is late maturing (140-150 days).

**TABLE 11a.** Summary of insect damage in a preventive vs. on-demand control program in a peanut IPM project, North Carolina, USA, 1984. (W.V. Campbell, H.D. Cole and J.E. Bailey, unpubl.).

| Cultivar and treatment | % Thrips damaged leaves | % Leafhopper damaged leaves | % Corn earworm damage | % Southern corn rootworm damage | Average yield kg/65m |
|---|---|---|---|---|---|
| *NC 6* | | | | | |
| Preventive | 1.0 | 1.0 | 2.3 | 0.8 | 23.7 |
| On demand | 20.0 | 6.7 | 5.0 | 1.3 | 24.4 |
| *Florigiant* | | | | | |
| Preventive | 1.2 | 1.5 | 9.8 | 2.7 | 22.6 |
| On demand | 33.7 | 28.7 | 12.3 | 6.7 | 22.5 |
| *Florigiant* | | | | | |
| Check | — | — | — | — | 18.3 |
| LSD 0.05 | | | | | 0.9 |
| LSD 0.01 | | | | | 1.2 |
| Threshold | >25% damage | >25% damage | >10% damage | >3% damage | |

**TABLE 11b.** Comparative cost for each hectare for on-demand (as needed) vs. preventive insect control program, North Carolina, USA, 1984. (Campbell, unpubl.)

| Cultivar | Preventive $ US | On demand $ US |
|---|---|---|
| NC 6 | 47 | 0 |
| Florigiant | 96 | 22 |

yields equivalent to the preventive program and saved the grower money. The NC 6 cultivar has multiple insect resistance (Campbell and Wynne 1980) and insect damage did not exceed established thresholds on this cultivar in this trial. The thresholds used are currently being refined. It is better to use an approximate threshold or plant development stage as a basis for insecticide treatment, rather than treat at the first sign of insect damage or after the insect has caused economic damage.

## Conclusions

Pests of food legumes need to be monitored and their damage potential established with reference to the phenology of the crop. Thresholds should be determined for the most important pests, and the most pest-resistant and acceptable cultivar should be utilised according to the most damaging pests for the particular legume. The identification and development of pest-resistant food legumes offers the most reliable, long-term method of pest management. Cultural practices may be incorporated to reduce the pest potential so long as they fit into the accepted cropping practices for the crop and region. Preservation of natural enemies of our crop pests is possible by the judicious use of well-timed minimum rates of pesticides. Finally, best pest management packages will be put together as interdisciplinary team research expands.

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