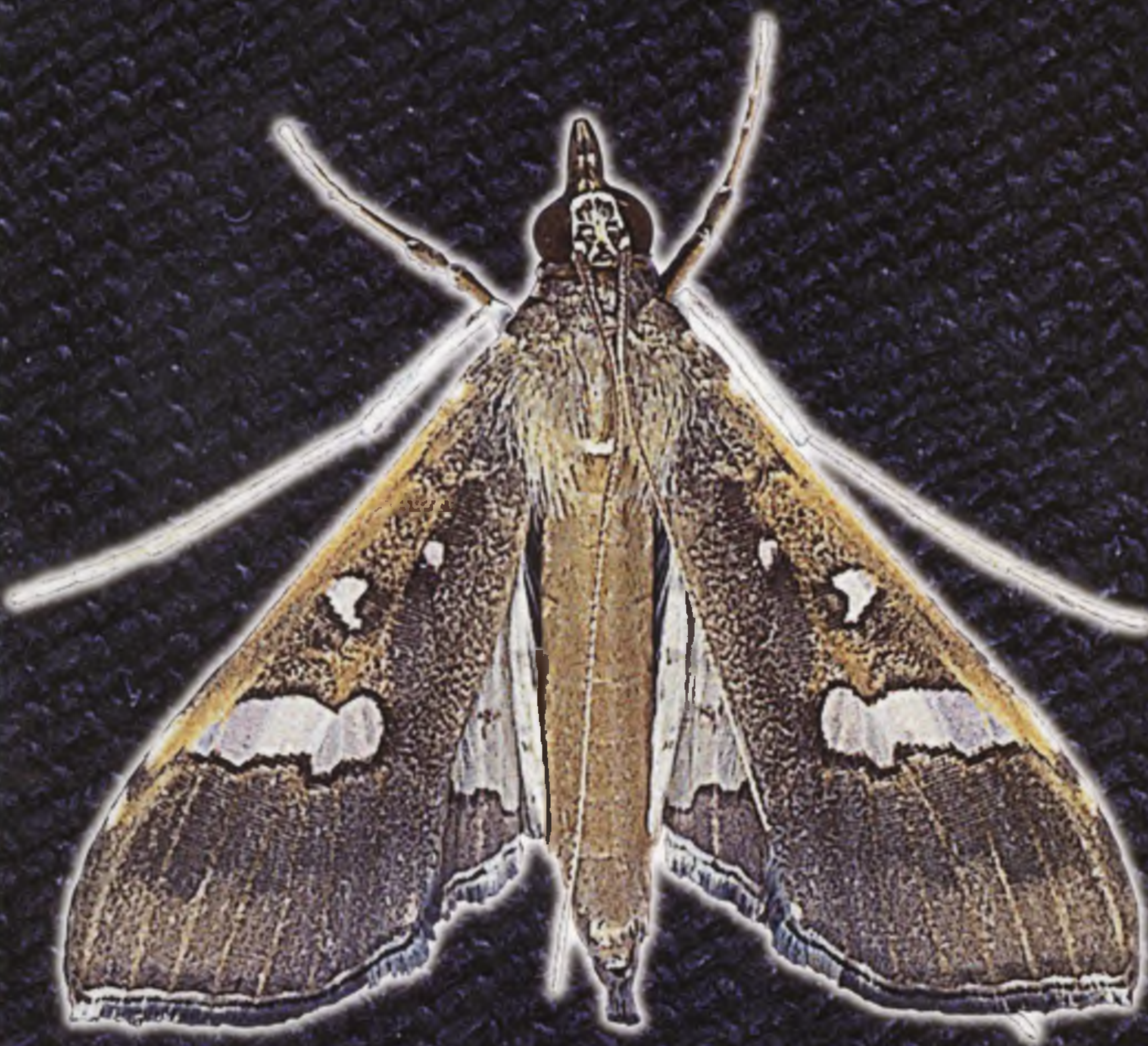
The Legume Pod Borer, *Maruca vitrata*: Bionomics and Management



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Abstract

The legume pod borer, *Maruca (testulalis) vitrata* (Geyer) is one of the major limitations to increasing the production and productivity of grain legumes in the tropics. Bionomics, host-plant resistance, natural enemies, cultural practices, and chemical control of the legume pod borer have been discussed in this bulletin to identify gaps in present knowledge and to help plan future strategies for research on this pest on pigeonpea. While information is available on bionomics and host-plant resistance in cowpea, such information on pigeonpea and other legumes is limited. Several natural enemies have been recorded on *M. vitrata*, and pathogens such as *Bacillus thuringiensis*, *Nosema*, and *Aspergillus* play an important role in regulating its populations under field conditions. Cultural practices such as intercropping, time of sowing, density of sowing, and weeding reduce the pod borer damage. Several insecticides have been found to be effective for controlling this insect. There is a need to focus future research on standardizing the resistance screening techniques, identification and utilization of resistance, and integrated pest management strategies for sustainable agricultural production.

Résumé

Le foreur des gousses: la bionomique et la lutte. Le foreur des gousses *Maruca (testulalis) vitrata* (Geyer) constitue une des limitations importantes à l'augmentation de la production et de la productivité des légumineuses à grain dans les régions tropicales. La bionomique, la résistance des plantes-hôtes, les ennemis naturels, les pratiques culturales, ainsi que la lutte chimique contre le foreur sont exposés dans cet ouvrage dans le but d'identifier les lacunes d'informations, et de permettre la planification des stratégies futures de recherche sur cet insecte ravageur du pois d'Angole. Alors que des informations sont disponibles sur la bionomique et la résistance des plantes-hôtes chez le niébé, de telles informations sur le pois d'Angole et d'autres légumineuses sont limitées. Plusieurs ennemis naturels ont été constatés sur *M. vitrata.* Des agents pathogènes tels *Bacillus thuringiensis, Nosema* et *Aspergillus* jouent un rôle important dans la réduction des populations du ravageur en milieu réel. Des pratiques culturales telles la culture associée, le temps de semis, la densité de semis et le désherbage permettent de limiter les dégâts dus au foreur des gousses. Nombre d'insecticides ont fait preuve de leur efficacité dans la lutte contre cet insecte. Les travaux de recherche futurs doivent mettre l'accent sur la normalisation des techniques de criblage pour la résistance, l'identification et l'utilisation de la résistance, ainsi que sur les stratégies de lutte intégrée contre le ravageur dans le but de réaliser la production agricole durable.

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Contents

Introduction

Pigeonpea, *Cajanus cajan* (L.) Millsp. is an important grain legume in the semi-arid tropics (SAT) in Asia, eastern Africa, and the Caribbean. It is a source of protein for millions of people living in these regions (Nene et al. 1990). In India, it is sown on nearly 4.6 million ha with an annual production of 2.5 million tonnes. It is generally grown on marginal lands with minimal or no inputs in the form of fertilizers and pesticides, and is usually intercropped with cereal and fiber crops. After the harvest of the main crop, pigeonpea plants are generally left in the field to utilize residual moisture and nutrients. Within a season, a pigeonpea crop produces two to three flushes of flowers, but generally only one of them accounts for a major proportion of the total grain harvest; the others being either totally damaged by insects or other biotic and abiotic factors causing a poor retention of flowers and pods.

Area and production of pigeonpea in India have increased by 2% per annum between 1970 and 1990. However, the productivity has only increased at a rate of 0.33% annually. Considerable progress has been made in developing high-yielding cultivars, particularly the short-duration (<150 days to maturity) pigeonpeas, which have considerable potential for increasing pigeonpea production as a monocrop under high planting density (Ariyanayagam and Singh 1994). Short-duration pigeonpea can also play an important role in cropping systems/crop rotations in the traditional rice-wheat cropping system followed in the northern Indian plains, and in rice or rice-fallow systems of Southeast Asia. The short-duration pigeonpea cultivars are less sensitive to photoperiod and temperature, and can be adapted in several newer environments (Singh 1991). However, it has not been possible to exploit the full genetic potential of high-yielding pigeonpea cultivars because of extensive losses due to insects, diseases, and moisture stress. Short-duration cultivars suffer greater loss than the intermediate- and long-duration cultivars due to insect damage because of shorter growing period, and less time available to the plant to compensate for insect damage if the main flush is heavily damaged. The medium- and long-duration pigeonpeas, although equally susceptible to these insects, have enough time to produce additional flushes in case the early flushes are damaged.

Pigeonpea is damaged by over 200 species of insects worldwide (Reed and Lateef 1990); insects damaging the reproductive parts cause the maximum reduction in grain yield. Pod borer [*Helicoverpa (Heliothis) armigera* (Hübner)], pod fly (*Melanagromyza obtusa* Malloch), legume pod borer or spotted caterpillar [*Maruca (testulalis) vitrata* (Geyer)], plume moth [*Exelastis atomosa* (Walsingham)], blister beetles (*Mylabris* spp), pod sucking bugs (*Clavigralla* spp), and bruchids (*Collasobruchus* spp) are the most important pests of pigeonpea. However, the relative importance of different species varies with location, season, and time of flowering of different cultivars.

As flowering of the short-duration pigeonpea cultivars occurs during periods of high humidity and moderate temperatures in Sep-Oct in India, *Maruca* has emerged as an important pest. *Maruca vitrata* is a serious obstacle for introducing pigeonpea into new areas/cropping systems, e.g., in Sri Lanka, where humidity is very high at flowering: its control becomes very difficult because of rapid increase in its population. Therefore, it is important to have a critical look at the basic information on biology, population dynamics, insect density/yield-loss relationships, artificial rearing, resistance screening techniques, sources and mechanisms of resistance, the role of biotic and abiotic factors on population fluctuations, the effect of cultural practices in minimizing the damage, and rational use of insecticides for integrated management of this insect.

Distribution

The legume pod borer, *M. vitrata*, is a serious pest of grain legumes in the tropics and

Figure 1. Geographical distribution of the legume pod borer, Maruca vitrata *(Source: International Institute of Entomology, London, UK, 1996).*

sub-tropics because of its extensive host range, and destructiveness. It is widely distributed in Asia, Africa, Australia, and the Americas (Fig. 1). Its recorded distribution stretches from the Cape Verde Islands in West Africa to Fiji and Samoa in the Pacific, and also includes the West Indies and the Americas (IIE 1996). It is a serious pest of pigeonpea in India (Sharma 1998), Thailand (Buranapanichpan and Napompeth 1982), Bangladesh (Das and Islam 1985), Sri Lanka (Fellows et al. 1977), and Pakistan (Ahmed et al. 1987). It has also been recorded as a pest of pigeonpea in Australia (Sharma, in press), eastern Africa (Nyiira 1971), and West Africa (Taylor 1978).

Nature of damage

The importance of *M. vitrata* as a pest on grain legumes results from its early establishment on the crop. The larvae web the leaves and inflorescence, and feed inside on flowers, flower buds, and pods. This typical feeding habit protects the larvae from natural enemies and other adverse factors, including insecticides. The flower bud stage is preferred most for oviposition, and it is at this stage that the young larvae cause substantial damage, and reduce the crop potential for flowering and fruit setting. The young larvae bore into the flower buds, and cause flower shedding by destroying the young flower parts enclosed in the sepals. The successful establishment of this pest at the flower bud stage is significant in relation to subsequent damage, reduction in grain yield, and efficiency of control. Young larvae feed on the style, stigma, anther filaments, and ovary; besides a limited feeding on the internal components of the corolla (Fig. 2a). Little or no feeding has been observed on the anthers (Sharma, in press). At this stage the damage is largely internal and there is little or no sign of damage externally. Usually more than one larva is present in each flower. These subsequently disperse to other flowers and flower buds on the same or other adjoining peduncles. The larval movement is facilitated by the silken threads, which are used as bridges between flowers. After initial dispersal, larval development is completed on several flowers/pods. The larvae move from one flower to another as they are consumed, and a larva may consume 4–6 flowers before larval development is completed. Third to fifth-instar larvae were capable of boring into the pods (Fig. 2b), and consuming the developing grains (Fig. 3) (Taylor 1967). The moths and larvae of

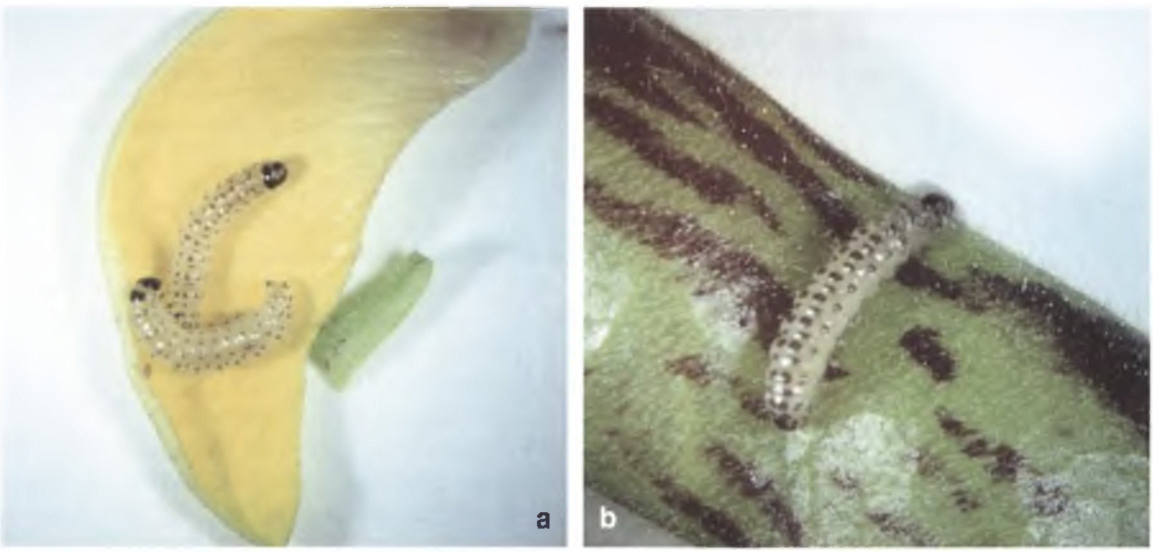

Figure 2. Larvae of **Maruca vitrata** *feeding on pigeonpea petals (a), and on the developing pods (b).*

Figure 3. Pigeonpea pods damaged by the larvae of **Maruca vitrata.**

M. vitrata are nocturnal (Usua and Singh 1979). The larvae, which are photo-negative, emerge early in the evening and feed on the plant throughout the night. In dual-choice assays, the third-instar larvae preferred pods rather than flowers or young leaves, and flowers rather than leaves (Sharma, in press). First-instar larvae showed a strong preference for flowers over pods and leaves.

Extent of losses

Losses in grain yield of 20 to 60% due to *Maruca* damage in grain legumes have been estimated by Singh and Allen (1980). In Bangladesh, pod borer damage has been estimated to be 54.4% during harvest in cowpea, but yield loss was <20% (Ohno and Alam 1989). In Nigeria, loss in cowpea grain yield has been estimated to be 72% in 1985 and 48% in 1986, and the economic threshold is nearly 40% larval infestation in flowers (Ogunwolu 1990).

In pigeonpea, losses due to *M. vitrata* have been estimated to be $US 30 million annually (ICRISAT 1992). Patel and Singh (1977) reported an average of 1.2 larvae per plant, which caused 10% damage to the fruiting bodies, and the pod damage varied from 25 to 40%. Vishakantaiah and Jagadeesh Babu (1980) observed between 9 and 51% infestation at Bangalore, Karnataka. Patnaik et al. (1986) reported 8.2 to 15.9% pod damage, resulting in 3.7 to 8.9% loss in grain yield in Orissa. In Sri Lanka, the pod borer has been reported to cause up to 84% damage in pigeonpea (Dharmasena et al. 1992, Dharmasena 1993).

In plants of pigeonpea cultivar ICPL 88007, infested with 0, 2, 4, 8, and 16 larvae per plant at the podding stage, there was a progressive increase in pod damage with an increase in insect density (Sharma, in press). Pod damage varied from 12.4 to 71.2% (Table 1). There was no

Table 1. Insect density–damage relationships of the legume pod borer, *Maruca vitrata*, on pigeonpea (cultivar ICPL 88007) under greenhouse conditions. Queensland Department of Primary Industries (QDPI), Toowoomba, Australia, 1996.

No. of larvae released per plant	No. of pods per plant	No. of pods damaged per plant	Pod damage (%)	No. of flowers dropped per plant	No. of pupae recovered per plant	Grain yield per plant (g)	Variation in grain yield (%)
0	21.6	–	–	–	–	2.28	–
2	13.8	1.6	12.4	51.2	0.2	2.30	+0.88[1]
4	11.2	3.0	29.7	52.8	1.2	2.52	+10.53
8	14.6	8.2	59.5	41.4	5.0	1.10	–51.75
16	8.8	6.0	71.2	49.6	5.4	0.76	–66.67
Mean	14.0	3.8	34.6	39.0	2.4	1.792	–23.3
SE	±2.15	±1.17	±7.46	±9.84	±1.21	±0.230	±12.3
LSD at 5% t	6.45	3.51	22.39	29.5	3.63	0.688	37.8

1. +, – = Increase (+) or decrease (–) in grain yield over the noninfested control plants.

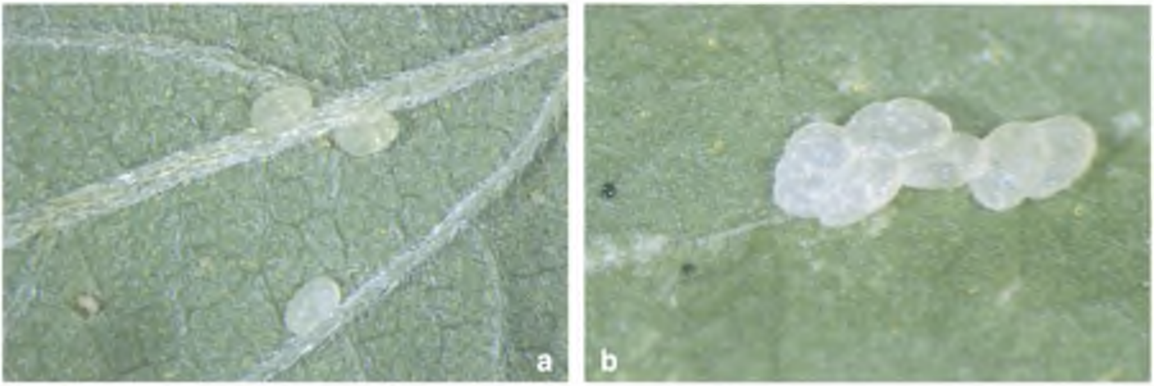

Figure 4. Eggs laid by **Maruca vitrata** *females on the under surface of leaves singly (a), or overlapping (b).*

apparent effect on flower drop with an increase in insect density. With 8 larvae per plant, the loss in grain yield was estimated as 51.75%, and with 16 larvae per plant it was 66.67%.

Bionomics

Eggs are normally deposited on flower buds and flowers although oviposition on leaves, leaf axils, terminal shoots, and pods has also been recorded (Taylor 1967). A female lays between 6 and 189 eggs, although 200–300 ova have been observed per female. Eggs are light yellow, translucent, and have faint reticulate sculpturing on the delicate chorion, and measure 0.65 ↔ 0.45 mm. Eggs are usually deposited singly (Fig. 4a) or in batches of 2 to 16 (Fig. 4b). Females live for 4–8 days. Eggs hatch in about five days. There are five larval instars: I lasts for 3.7±0.2 days, II for 3.2±0.14, III for 2.5±0.16, IV for 2.4±0.15, and V for 4.5±0.16 days (Das and Islam 1985). Total larval development is completed in 8–14 days. The larvae are translucent and shining, and have six rows of black spots running from thorax to abdomen. Because of the prominent black spots on the larva, it is also called a spotted caterpillar. The head is dark brown. The larvae are very active and tend to fall off the webbed flowers and pods with the slightest disturbance, by spinning a silken thread. The prepupal period lasts for two days. Pupation occurs in a silken cocoon amongst webbed leaves/pods or in soil (Fig. 5). The life cycle is completed in 18 to 35 days (Taylor 1967, Akinfenwa 1975, Sharma, in press). Adults are brown to black with a white patch on the wings (Fig. 6). In their normal resting posture, the moths hold the wings in a horizontal position, unlike other moths which rest with folded

Figure 5. Pupa of **Maruca vitrata**.

Figure 6. **Maruca vitrata** *adult.*

wings. There is no diapause in this insect, and the populations during the off-season are maintained on wild hosts such as *Vigna triloba*, *Crotalaria* spp, or *Phaseolus* spp (Taylor 1967).

On pigeonpea, egg incubation lasts 3.13 days, the larval stage 12.65 days, prepupal stage 2.05 days, and pupal stage 8.73 days (Vishakantaiah and Jagadeesh Babu 1980). The total life cycle from egg to adult is completed in 26.53 days. Under laboratory conditions, eggs hatch in 3–4 days. Larval development is completed in 11 to 14 days, and the pupal period lasts for 8 to 11 days. The prepupal period lasts for 1 to 2 days (Table 2). The entire postembryonic development is completed in 21.8 to 22.6 days on pigeonpea and adzuki bean (Sharma, in press). Adults begin to lay eggs after a preoviposition period of 5 days.

Jackai et al. (1990) observed that four or five nights pairing resulted in the highest mating percentage and oviposition. Some males mated more than once; while the majority of the females mated only once. A one-to-one ratio (10 males : 10 females) gave best results for mating and oviposition. Mating took place between 2100 h and 0500 h, when temperatures ranged between 20° to 25°C and relative humidity (RH) over 80%. Peak moth activity has been observed between 0200 and 0300 h.

Population dynamics

Peak infestation in Nigeria has been observed on early-sown cowpea in Jun–Jul. The first generation adults on cowpea emerge in Jul, and the second between Jul and Sep. Adults have been observed in light traps in most months, although the catches are low during the off-season. Possibly the insects migrate from south to north, associated with movements of the inter-tropical convergence zone, and move south in Nov–Dec. Adults have been caught in

Table 2. Postembryonic development of legume pod borer on pigeonpea and adzuki bean under laboratory conditions (QDPI, Toowoomba, 1996).

Genotypes	Larval survival after 2 days (%)	Larval period (days)	Pupal period (days)	Postembryonic development period (days)	Pupal mass (mg)
Pigeonpea					
ICPL 85010	87	11.4	9.6	21.0	0.039
ICPL 88007	70	13.0	7.7	20.7	0.043
ICPL 88020	77	12.5	8.5	21.0	0.046
ICPL 90011	70	12.1	8.6	20.7	0.040
Adzuki bean	60	11.7	8.4	20.2	0.039
Mean	73	12.2	8.5	20.7	0.041
SE	±7.2	±0.48	±0.52	±0.52	±0.004

light traps between 1840 to 0045 h, with a peak between 2000 and 2100 h (Akinfenwa 1975). In Kenya, the legume pod borer abundance was low during the short-rainy season, but infestation was continuous unless flower and pod production ceased (Okeyo-Owuor et al. 1983). Atachi and Ahohuendo (1989) observed maximum larval density 40 days after sowing (DAS) on four cultivars, and 47 DAS on six cultivars (4–17 larvae per 20 flowers) in Benin. Highest infestation in flowers has been recorded on the same sampling date on all cultivars (20–70%).

Populations of *M. vitrata* have been monitored at ICRISAT-Patancheru through light traps (Srivastava et al. 1992) (Fig. 7). Moth catches were greatest between 45 to 50 standard weeks, i.e., from early-Nov to mid-Dec. Maximum numbers of moths were caught during Nov (in standard weeks 46 and 47). Another peak was recorded in Sep in standard weeks 37 and 38. A third and smaller peak occurred in early Feb during the 6th standard week. The peaks during Nov and Feb coincided with the flowering of medium- and long-duration genotypes, whereas the one during Sep may have been from the first generation completed on foliage or early flowering genotypes or of migrant populations. At Hisar, Haryana, India, maximum moth abundance has been observed during 37–43 standard weeks, i.e., from mid-Sep to mid-Oct. Akhauri et al. (1994) observed that larval density increased from mid-Oct to end-Nov at Dholi, Bihar, India, on early-flowering pigeonpeas, and the peak in larval

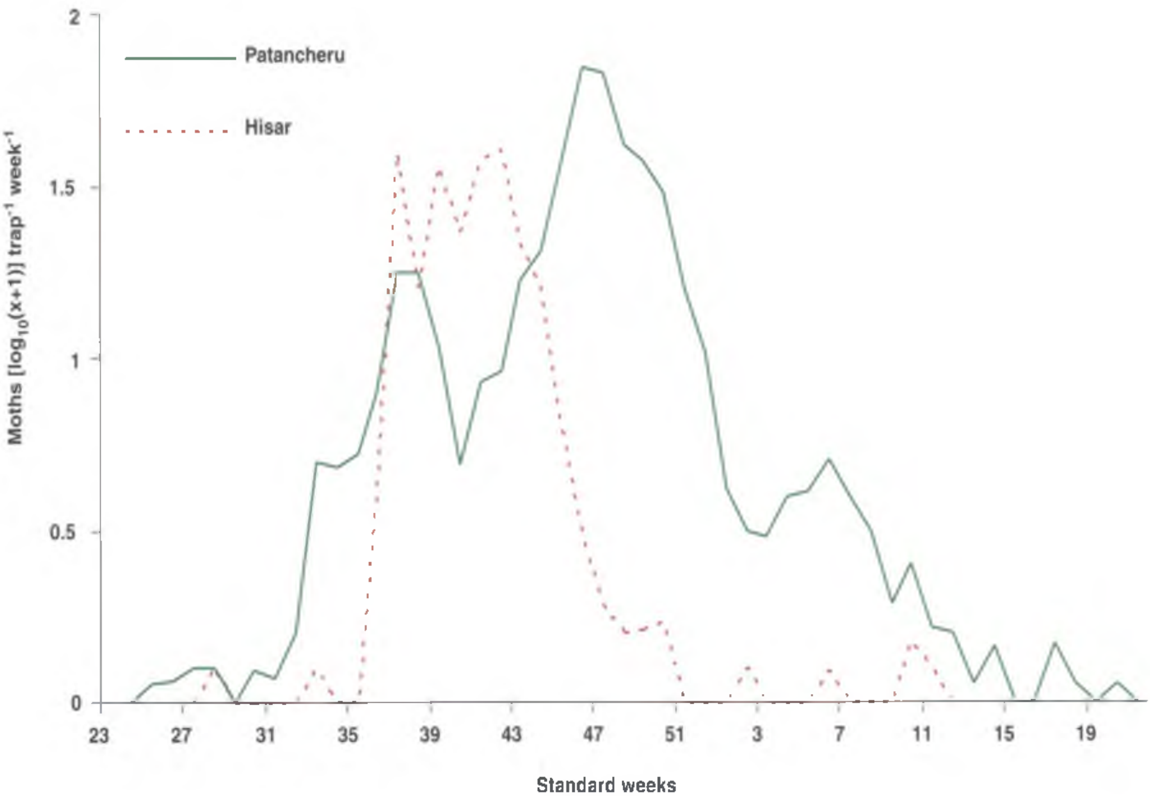

Figure 7. Population dynamics of Maruca vitrata *at ICRISAT-Patancheru, Andhra Pradesh, and at Haryana Agricultural University, Hisar, Haryana, India (Source: Srivastava et al. 1992).*

density occurred during the last week of Nov. In Sri Lanka, high pod borer density has been observed during the *maha* (main season) (Dec–Mar) (Fellows et al. 1977). Larval population was high in pigeonpea crops planted in mid-Oct, and gradually decreased in the crop planted in mid-Nov (Dharmasena et al. 1992). High humidity and low temperatures experienced during this period may be conducive to the build up of *M. vitrata* populations on pigeonpea.

Alghali (1993a) studied the effect of agrometereological factors on population fluctuation of *M. vitrata*. There were smaller peaks in crops planted between 5 May and 1 Jun, and between 24 Jun and 13 Jul, and a larger peak on crops planted between 24 Aug and 7 Sep. These peaks in general coincided with peaks in rainfall. Significant relationships have been observed between pod borer counts and cumulative rainfall, and number of rainy days between crop emergence to 50% flowering.

Host range

Maruca vitrata is an important pest of grain legumes such as cowpea, pigeonpea, mung bean, common bean, soybean, adzuki bean, groundnut, hyacinth bean, field pea, country bean, broad bean, kidney bean, and lima bean (Table 3). It feeds on plant species belonging to 20 genera and six families, the majority of which belong to Papilionaceae (Akinfenwa 1975). Atachi and Djihou (1994) recorded a total of 22 host plants belonging to Papilionaceae, Caesalpiniaceae (Fabaceae), Mimosaceae (Fabaceae), Annonaceae, Malvaceae, Euphorbiaceae, Rubiaceae, and Moraceae. The most frequently recorded food plants were *Cajanus cajan*, *Vigna unguiculata*, *Phaseolus lunatus*, and *Pueraria phaseoloides*. While several eggs were recorded on *Crotalaria retusa*, only one larva was recorded in over 1000 samples observed.

Host-plant suitability

Larvae fed on *V. unguiculata* showed 0 to 30% mortality (Jackai and Singh 1983), while those fed on *Cajanus cajan*, *C. amazonas*, *C. saltiana*, and *C. mucronata* suffered 30 to 50% mortality. Larvae reared on *C. retusa*, *C. juncea*, and *C. misereniensis* suffered 50 to 100% mortality. They suggested that *C. juncea* could be used as a possible trap crop for the pod borer. Ramasubramanian and Sundara Babu (1988, 1989a) studied the suitability of pigeonpea (*Cajanus cajan*), cowpea (*Vigna unguiculata* subsp *cylindrica*), and hyacinth bean (*Dolichos lablab* var *typicus*) as hosts for rearing *M. vitrata*. Rearing of the larvae on different host plants led to significant differences in durations of prepupal, pupal, mating, and preoviposition periods and also in fecundity and percentage egg hatchability. In all cases (except the preoviposition period), pigeonpea was the most suitable host plant. More females than males were produced on all the host plants. On cowpea, there was a significant increase in mating and preoviposition periods, and a concomitant increase in fecundity and egg hatchability. The calculated growth indices were 4.14 on pigeonpea, 4.63 on cowpea, and 5.17 on hyacinth bean. The number of eggs and percentage hatchability were greatest when the larvae were reared on hyacinth bean. The larval period lasted for 13.32 days on pigeonpea, 13.86 days on cowpea, and 12.90 days on hyacinth bean. Pupae from the larvae reared on hyacinth bean were the heaviest, but the pupal period on this host was longest. Female moths from the larvae reared on hyacinth bean had the longest oviposition period, whereas those reared on cowpea had the shortest preoviposition period. Adults emerging from the insects reared on hyacinth bean lived longer than those reared on other host plants. Considering the number of eggs laid, the percentage of eggs hatched, growth index, adult emergence, and sex ratio, hyacinth bean was identified as the most suitable host for culturing *M. vitrata*.

Oghiakhe et al. (1993) reared the legume pod borer larvae successfully on floral buds, flowers, and sliced pods, but not on stems, terminal shoots, or intact pods of cowpea. Sliced pods were most suitable for growth and development,

Table 3. Host range of the legume pod borer, *Maruca vitrata*.

Common name	Scientific name	Reference
	Papilionaceae	
Cowpea	*Vigna unguiculata*	Phelps and Oostihuizen (1958), Taylor (1967)
Green gram	*Vigna aureus*	Visvanathan et al. (1983)
Black gram	*Vigna mungo*	Taylor (1978), Das and Islam (1985)
Mung bean	*Vigna radiata*	Venkaria and Vyas (1985), Das and Islam (1985)
	Vigna triloba	Taylor (1967)
Pigeonpea	*Cajanus cajan*	Taylor (1967), Patel and Singh (1977)
	Cajanus indicus	Taylor (1978)
Hyacinth bean	*Dolichos lablab*	Ramasubramanian and Sundara Babu (1988)
Country bean	*Lablab purpureus*	Das and Islam (1985)
Kidney bean	*Phaseolus vulgaris*	Rejesus (1978), Taylor (1978)
Lima bean	*Phaseolus lunatus*	Leonard and Mills (1931), Atachi and Djihou (1994)
Adzuki bean	*Phaseolus angularis*	Katayama and Suzuki (1984), Passlow (1966)
Broad bean	*Vicia faba*	Siddig (1992)
Yard long bean	*Vigna sinensis*	Satsijati et al. (1986)
Fusi-sasage	*Vigna vexillata*	Oghiakhe et al. (1992c)
Long bean	*Vigna sesquipedalis*	Ibrahim (1980)
Winged bean	*Psophocarpus tetra-gonolobus*	Taylor (1978)
Soybean	*Glycine max*	Das and Islam (1985)
Groundnut	*Arachis hypogaea*	Taylor (1978), Traore (1983)
African yam bean	*Sphenostylis stenocarpa*	Taylor (1978)
	Gliricidia sepium	Taylor (1978)
Grass pea	*Lathyrus sativus*	Das and Islam (1985)
Pea	*Pisum sativum*	Das and Islam (1985)
	Pueraria phaseoloides	Atachi and Djihou (1994)
	Stizolobium sp	Taylor (1978)
Velvet bean	*Mucuna sp*	Taylor (1978)
	Tephrosia candida	Taylor (1978)
	Tephrosia purpurea	Taylor (1978)
	Crotalaria juncea	Jackai and Singh (1983)
	Crotalaria amazonas	Jackai and Singh (1983)
	Crotalaria saltiana	Jackai and Singh (1983)
	Crotalaria mucronata	Jackai and Singh (1983)
	Crotalaria incana	Jackai and Singh (1983)
	Crotalaria retusa	Atachi and Djihou (1994), Jackai and Singh (1983)
	Crotalaria misereniensis	Jackai and Singh (1983)
	Caesalpiniaceae	
Poinciana	*Poinciana* sp	Taylor (1978)
	Pedaliaceae	
Sesame	*Sesamum* sp	Taylor (1978)
	Malvaceae	
Hibiscus	*Hibiscus* sp	Taylor (1978)
	Mimosaceae	
	Escelerona dolabriformis	Taylor (1978)

Table 4. Growth and development of *Maruca vitrata* on leaves, flowers, and pods of pigeonpea under laboratory conditions. ICRISAT-Patancheru, 1997.

	Larvae		Pupae		Adults
Plant part	Mass (mg)	Period (days)	Mass (mg)	Period (days)	Longevity (days)
Leaves	9.5	14.1	31.7	8.0	18.9
Flowers	17.5	12.3	48.4	7.2	19.5
Pods	33.3	11.8	54.0	7.0	22.3
Mean	25.0	12.1	51.1	7.2	19.2
SE	±0.81	±0.04	±1.29	±0.05	±0.06

followed by flowers, and flower buds. Development and survival of the larvae were greater on pods, followed by flowers and leaves of pigeonpea and cowpea (Table 4). Larvae completed development on cowpea leaves but not on pigeonpea leaves. Larval and pupal periods were prolonged considerably when the larvae were reared on the leaves. In another study, Bhagwat et al. (1998) observed that the pod borer females preferred pigeonpea to cowpea for oviposition. Maximum oviposition was recorded on leaves, followed by tender pods (24%) on ICPL 87 (Fig. 8). Moths reared as larvae on flowers produced more eggs than those reared on pods. However, hatching percentage was higher in eggs laid by females reared on pods than in those reared on flowers.

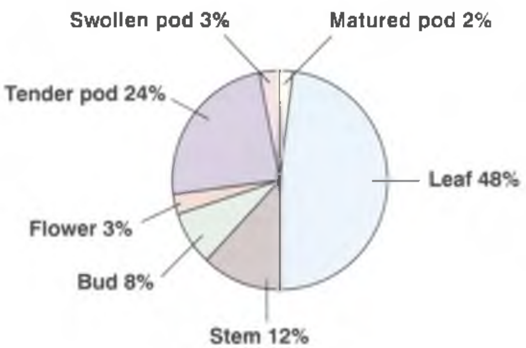

Figure 8. Ovipositional preference by Maruca vitrata *on different plant parts of pigeonpea (ICRISAT-Patancheru, 1997).*

The suitability of four pigeonpea genotypes and adzuki as hosts of *M. vitrata* has also been studied under laboratory and greenhouse conditions (Sharma, in press). Larval development was completed in 11.7 days on adzuki bean, and 11.4 to 13.0 days on pigeonpea (Table 2). Postembryonic development was completed in 20.2 days on adzuki bean, and 20.7 to 21.0 days on pigeonpea under laboratory conditions. Under greenhouse conditions, the postembryonic development was completed in 22.4 to 22.6 days, and the pupal mass ranged from 0.051 to 0.053 g on the ratooned crop infested at the flowering stage. In the crop infested at the podding stage, the postembryonic development varied from 21.8 to 22.6 days, and the pupal mass from 0.051 to 0.057 g. The development period was prolonged by 1.4 days and the pupal weight was lower by 0.003 g on the ratooned crop, possibly because of increased production of secondary plant substances in the ratooned crop as a result of physical damage.

Screening for resistance

Field screening techniques

Infester rows of a susceptible cultivar planted two weeks earlier than the test material increased the pod borer abundance for resistance screening under field conditions (Jackai 1982). Infester rows running parallel to the test material can be uprooted six weeks after crop emergence. Keeping the greenhouse or field plots moist also improved the efficiency of screening for resistance to this insect (Singh and Jackai 1988). Flower, pod, and seed damage measurements give the most reliable assessment of pod borer resistance. The larval population in flowers shows marked differences in infestation levels between cultivars, and has been suggested as a means of comparing the genotypes. Wooley and Evans (1979) suggested that flower damage and the ratio of grain yield under protected and unprotected conditions could also be used as selection criteria to evaluate cowpea genotypes for resistance to pod borer. The percentage flower and pod infestation and the total number of larvae in flowers and the pods were equally effective for evaluating cowpea resistance to the pod borer (Valdez 1989).

In India, maximum abundance of the legume pod borer has been observed during Oct–Nov. The test material should be grouped according to maturity, and the planting times adjusted such that flowering and podding occur during periods of maximum abundance of the legume pod borer. Suitable resistant and susceptible controls should be included in each group for valid comparisons. Mid-Oct plantings were suitable to screen pigeonpeas for resistance to *M. vitrata* in Sri Lanka (Dharmasena et al. 1992). Sowing infester rows of a susceptible cultivar such as ICPL 87 in the first week of Oct has been found to be effective in increasing *Maruca* damage on the test material (Saxena et al. 1998). However, infester rows did not increase the pod borer damage when the plantings were delayed.

Greenhouse and laboratory screening techniques

Screening under field conditions is often difficult due to lack of uniform infestation or low levels of infestation. Because of the staggered flowering of pigeonpea cultivars and variation in pod borer population density over time, lines flowering at the beginning and end of the cropping season may escape insect damage while those flowering in mid-season are exposed to heavy infestations. Thus, it becomes difficult to select lines with repeatable resistance under field conditions unless the material is tested over several seasons and locations. Also, insect abundance varies over space and time, and this makes it difficult to compare the results across seasons and locations. This problem can be avoided through artificial infestation of the test plants under field or greenhouse conditions. Mass rearing and infestation techniques can be utilized to screen for resistance to this insect under uniform insect density. Levels of resistance to the pod borer are low. Therefore, research efforts should be focussed on the development of resistance screening techniques that are sufficiently sensitive to separate lines possessing small differences in susceptibility to the legume pod borer.

A procedure for mass rearing of *M. vitrata*, which allows production of over 75 000 eggs per month has been developed by Ochieng et al. (1981). Thirty moths should be placed in the oviposition cage containing potted cowpea plants. Fifty larvae are optimum for each rearing box. The larval survival declines sharply above a density of 50 larvae per box.

Jackai and Raulston (1982, 1988), and Ochieng and Bungu (1983) attempted rearing of *M. vitrata* on an artificial diet, but the performance of the laboratory reared insects declined after some generations. A semi-synthetic diet, composed of soybean and cowpea flour as basic ingredients, has been developed by Onyango and Ochieng-Odero (1993). On this diet, fecundity of the females from the larvae reared on the artificial diet increased with advancing generations. The pupae from the artificial diet were lighter than those collected from the field. However, fecundity, fertility, adult life span, and sex ratio did not differ between the insects reared on the artificial diet and those collected in the field from natural hosts. On the artificial diet, adult emergence ranged between 70 and 90%. One liter of diet produced nearly 400 pupae or adults, and a female laid >200 eggs. Atachi and Ahounou (1995a) described another diet for rearing *M vitrata*. The biological parameters (intrinsic rate of increase, net reproductive rate, finite rate of increase, capacity for increase, mean length of generation, mean age of moths in a cohort at birth of female offspring, sex-ratio, and mortality) of the insects reared on this artificial diet, cowpea, and those collected from the field were different (Atachi and Ahounou 1995b). Longevity and fecundity of the insects were affected when the larvae were fed on 10% sucrose, glucose, or honey.

Dabrowski et al. (1983) developed a methodology to screen cowpea for resistance to *Maruca* under artificial infestation under greenhouse conditions. Plant growth stage modified the expression of cowpea resistance to *Maruca*. The five to seven shoots stage (not younger) was most suitable for screening for resistance in the preflowering period. By using five eggs per plant at the preflowering stage, it was possible to differentiate between the resistant and susceptible lines. The standard error between plants infested with 10 eggs per plant was lower than those infested with five eggs per plant. Therefore, it is appropriate to use 10 eggs per plant to screen for resistance to *Maruca*. Using 10 or 20 eggs per plant at flowering differentiated cowpea lines for resistance and susceptibility based on larval survival and damage to the flower buds, flowers, and pods.

Echendu and Akingbohungbe (1990) employed free-choice and no-choice tests for evaluating cowpea resistance to *M. vitrata*. The results confirmed the levels of resistance of different genotypes observed under field conditions. In another study, Jackai (1991) used two resistance screening techniques to evaluate cowpea lines for resistance to *M. vitrata*. In the first assay, the dual-choice arena test (DCAT) provided a choice of two varieties to the larva for 72 h. A preference hierarchy representing the resistance ranking of test varieties was obtained using a preference ratio. The relative resistance of a given test line when compared with either the susceptible or resistant check or another test line was determined using a feeding index. In the second assay, the intact pod test (IPT) (a no-choice test) was conducted in the greenhouse. About 2 weeks were needed to complete this test, but conclusive information on seed damage was obtained after 72 h of feeding exposure. The two assays were complementary

Figure 9. Pigeonpea plants at the flowering (a) and podding stages (b), which can be infested with 10 eggs or 10 first-instar larvae for resistance screening.

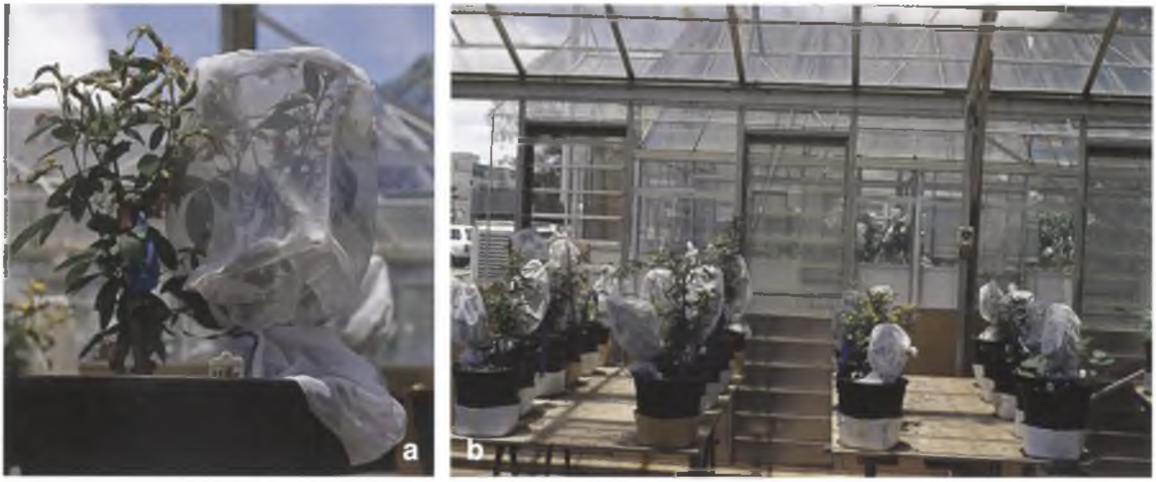

Figure 10. Wire-framed cage (diameter 40 cm, length 45 cm) to screen for resistance to the legume pod borer under uniform insect density (a). A view of the pigeonpea genotypes being screened for resistance to the legume pod borer using the cage technique under greenhouse conditions (b).

and provided useful information on antixenosis and antibiosis components of resistance, and can therefore be used in sequence.

Sharma (in press) described a cage technique to screen pigeonpeas for resistance to the pod borer under greenhouse conditions using uniform insect pressure at the flowering (Fig. 9a) and podding stages (Fig. 9b) of the crop. The plants were infested with 10 first-instar larvae, and covered with a cloth bag placed around a wire-framed cage (diameter 40 cm, length 45 cm) (Figs. 10a,b). Infested plants were evaluated for insect damage 15 days after releasing the insects inside the cages. In the crop infested at 50% flowering, the number of pods per plant ranged from 8.7 in ICPL 90011 to 13.3 in ICPL 88007, and the insect damaged pods from 4.3 in ICPL 90011 to 8.3 in ICPL 88007 (Table 5). Percentage pod damage and reduction in the number of pods was relatively lower in ICPL 90011

Table 5. Relative susceptibility of four pigeonpea genotypes to the legume pod borer, *Maruca vitrata*, at the flowering stage (10 larvae per plant in a ratooned crop). QDPI, Toowoomba, Australia, 1996.

Genotype	No. of pods per plant	No. of pods damaged	No. of flowers per plant	No. of flowers dropped	No. of pods in noninfested plants	No. of flowers in noninfested plants	Grain yield (g plant^{-1})	
							Infested	Noninfested
ICPL 85010	10.3	5.7	5.7	63.3	12.3	30.0	1.24	2.82
ICPL 88007	13.3	8.3	11.7	123.0	18.0	29.0	1.39	3.79
ICPL 88020	9.0	6.3	12.3	102.0	19.0	9.3	1.93	4.11
ICPL 90011	8.7	4.3	11.3	47.0	12.3	29.3	1.31	2.71
Mean	10.3	6.2	10.3	83.8	15.4	24.4	1.46	3.36
SE	±3.0	±2.7	±7.3	±9.6	±2.8	±10.0	±0.56	±0.79
LSD at 5% t	NS[1]	NS	NS	33.4	9.6	NS	NS	NS

1. NS = F-test nonsignificant at $P < 0.05$.

Table 6. Relative susceptibility of pigeonpea and adzuki bean to the legume pod borer, *Maruca vitrata*, at the podding stage under greenhouse conditions (10 larvae per plant). QDPI, Toowoomba, Australia, 1996.

Genotype	No. of pods per plant	No. of pods damaged per plant	No. of flowers at 15 DAI[1]	Flowers dropped per plant	No. of pods in noninfested plants	No. of flowers in noninfested plants	Grain yield (g $plant^{-1}$)	
							Infested	Non-infested
Pigeonpea								
ICPL 85010	15	5	0	45	17	0	2	4
ICPL 88007	19	4	5	84	19	2	2	5
ICPL 88020	16	6	2	42	22	40	2	4
Adzuki bean	5	3	0	0	6	0	0	3
Mean	13.6	4.4	1.7	42.6	15.8	10.4	1.8	3.8
SE	±3.9	±1.1	±1.8	±11.4	±3.8	±7.9	±0.61	±0.81
LSD at 5% t	12.6	NS[2]	NS	36.4	12.0	25.2	1.96	NS

1. DAI = Days after infestation.
2. NS = F-test nonsignificant at $P < 0.05$.

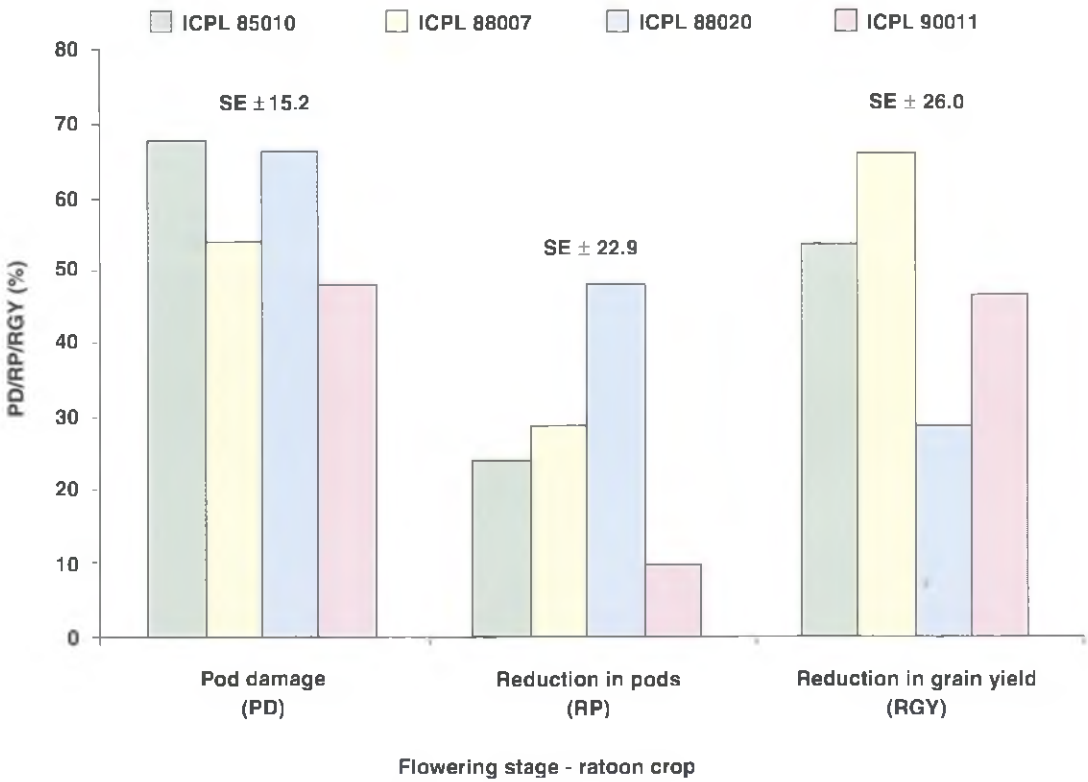

Figure 11. Pod damage (PD%), reduction in number of pods (RP%), and grain yield (RGY%) in four pigeonpea genotypes infested with 10 first-instar larvae of Maruca vitrata *at flowering (Queensland Department of Primary Industries (QDPI), Toowoomba, Australia, 1996).*

compared with ICPL 88020 (Fig. 11). However, percentage reduction in grain yield was lowest in ICPL 88020, followed by ICPL 90011. The former possibly has tolerance as one of the components of resistance to pod borer damage. In the crop infested at the podding stage, there were 15 pods per plant in ICPL 85010 compared with 19 pods in ICPL 88007 (Table 6). Percentage pod damage was 30 to 42% in pigeonpea, and 60% in adzuki bean. Reduction in grain yield was over 60% in adzuki bean, and 50 to 55% in ICPL 85010 and ICPL 88020, while ICPL 88007 showed only 20% reduction in grain yield (Fig. 12). This technique can be used to test the material under uniform insect pressure and the genotype response can be studied both at the flowering (Fig. 13) and podding (Fig. 14) stages. This technique can be used to confirm the resistance observed under field conditions, and also determine the levels of resistance in different sources of resistance.

Sources of resistance

Early-maturing pigeonpea varieties suffer greater pod borer damage than the late-maturing varieties such as CC 11 and Berhampur local (Sahoo and Patnaik 1993). Patnaik et al. (1986) did not observe any significant differences in the susceptibility to pod borers of

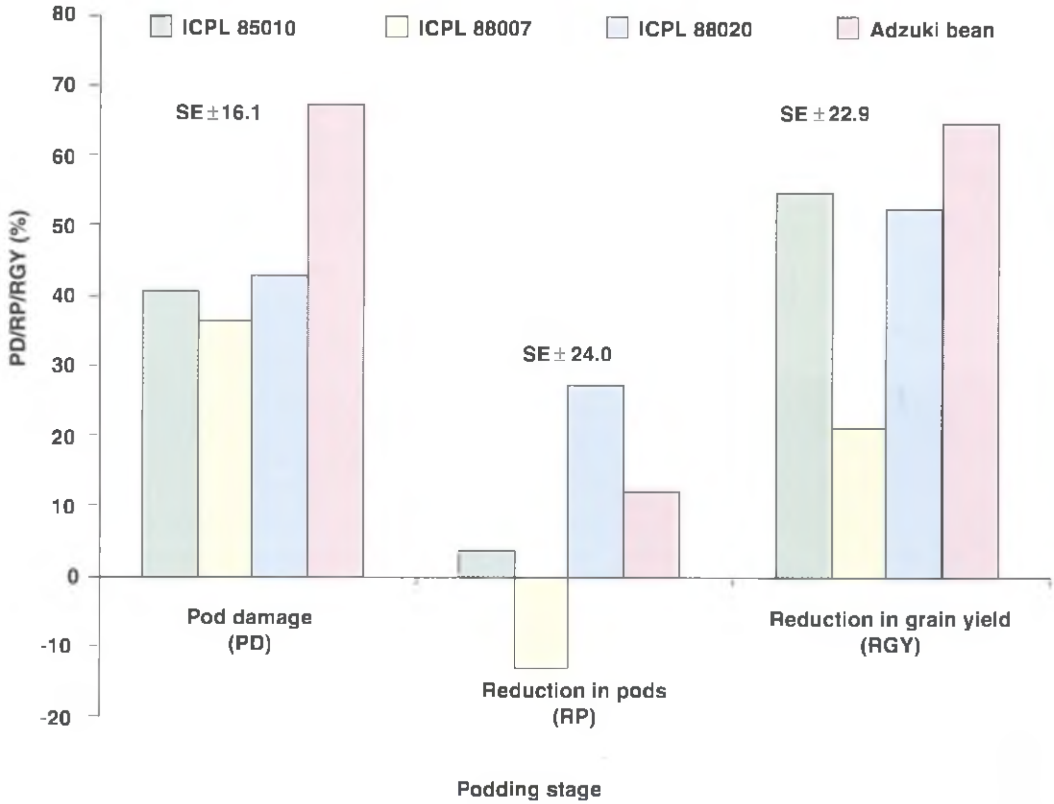

Figure 12. Pod damage (PD%), reduction in number of pods (RP%), and grain yield (RGY%) in three pigeonpea genotypes and adzuki bean infested with 10 first-instar larvae of Maruca vitrata *at 50% podding stage (QDPI, Toowoomba, Australia, 1996).*

Figure 13. Legume pod borer damage in pigeonpea plants infested with first-instar larvae at flowering. All the flowers in the infested plant have been destroyed by the larvae. The plant on the left is a noninfested control.

Figure 15. Pigeonpea lines showing resistant (left) and susceptible (right) reaction to Maruca vitrata *damage.*

early-maturing pigeonpeas. However, ICPL 81, Pusa 33, and H 76-208 had lower infestation (8.2 to 10.7%) compared with ICPL 1 and ICPL 151 (15.7 to 15.9%). Prasad et al. (1989a) reported that Pusa 855 had the lowest pod borer damage (36.3%) over two seasons, followed by Phule T 14 (43.7%), and ICPL 106 (46%). In another trial, MTH 8 suffered low pod borer damage, and this was at par with Phule T 17 and MTH 9; BR 65 being the most susceptible (Prasad et al. 1989b).

Figure 14. Reaction of pigeonpea to Maruca vitrata *when infested at the podding stage. The plant on the left is a noninfested control.*

Under unsprayed conditions, the highest grain yield has been recorded in MPG 537 (2.261 t ha^{-1}). Lines MPG 664, 665, 359, and ICPL 88034 also gave higher yields than the control cultivar ICPL 2 (Saxena et al. 1996). These lines suffered 10 to 25% *Maruca* damage under unsprayed conditions in the preceding *maha* season. In another trial, ICPL 89038 and MPG 662 recorded yields similar to that of ICPL 2, and were less susceptible to *Maruca*. Similarly, ICPL 87115, ICPL 90037, ICPL 89016, ICPL 85045, and ICPL 86020 also gave high yields and suffered low damage. ICP 909 and T 21, which are comparatively tolerant to pod fly and pod borer, are also less susceptible to *Maruca*.

Saxena et al. (1998) reported the development of *Maruca*-resistant lines through pedigree selection in Sri Lanka (Fig. 15). Differences in larval numbers and percentage pod damage were not significant between the test entries and the control cultivars, both under sprayed and unsprayed conditions (Table 7). However, percentage pod damage was lower in MPG 537-M1-2 (13%) as compared with the susceptible control, ICPL 87 (22%). Under unsprayed conditions, the pod borer-resistant lines showed significant yield advantage over the control cultivars. Reduction in grain yield was nearly 25% in the *Maruca*-resistant cultivars (MPG 537-M1-2-1B, MPG

Table 7. Larval abundance at pod filling, and percentage pod damage at maturity in pigeonpea genotypes. Maha Illuppallama, Sri Lanka, 1996/97 rainy season.

	Larval counts[1]			Pod damage (%)[2]		
Genotype	Sprayed		Unsprayed	Sprayed		Unsprayed
Determinate						
MPG 537-M1-2-1B	0		15	7		19
MPG 537-M1-2-5B	0		18	4		19
MPG 537-M1-2-M4	0		15	5		18
MPG 537-M1-2-M13	0		16	6		21
MPG 537-M1-2-M16	0		16	5		22
ICPL 87 (control)	0		16	5		22
Mean (n = 15)	0		16	6		20
SE (var)		±1.0			±1.4	
SE (spray)		±0.6			±1.5	
SE (var ↔ spray)		±1.4			±1.4	
Nondeterminate						
MPG 664-M1-2-M2	4		12	9		19
MPG 664-M1-2-M13	4		12	12		18
MPG 664-M1-2-M22	4		12	10		19
MPG 664-M1-2-M23	2		12	12		21
MPG 664-M1-2-M27	4		9	12		18
UPAS 120 (control)	3		10	15		20
Mean (n = 15)	4		11	11		19
SE (var)		±1.4			±3.1	
SE (spray)		±0.6			±1.8	
SE (var ↔ spray)		±2.0			±4.4	

1. Larval count: mean of 5 plants.
2. Pod damage: mean of 10 plants.

537-M1-2-5B, MPG 537-M1-2-M4, and MPG 537-M1-2-M16 - determinate types; MPG 664-M1-2-M2, MPG 664-M1-2-M13, MPG 664-M1-2-M22, and MPG 664-M1-2-M27 - nondeterminate types) compared with >74.6% reduction in ICPL 87 and 68.9% in UPAS 120 (Table 8). Cultivars MPG 537-M1-2-1B, MPG 664-M1-2-M2, and MPG 664-M1-2-M13 yielded nearly 2 t ha^{-1} compared with 0.6 t ha^{-1} of ICPL 87 under unprotected conditions. Under protected conditions, MPG 537-M1-2-1B, MPG 537-M1-2-M13, MPG 664-M1-M2, MPG 664-M1-M13, and MPG 664-M1-M23 yielded more than the control cultivars ICPL 87 and UPAS 120.

MPG 537 has shown consistent superiority over the control cultivar, ICPL 87, over three years of testing. Genotypes MPG 537-(bulk), MPG 533-M1-2-M5, ICPL 84023, ICPL 4, MPG 664-M1-2-M 20, and ICPL 90036 M2(C) have also shown oviposition nonpreference, reduction in larval / pupal mass, and / or reduced fecundity under laboratory conditions.

Table 8. Performance of pigeonpea lines selected for resistance to the legume pod borer, *Maruca vitrata*. Maha Illuppallama, Sri Lanka, 1996/97 rainy season.

Genotype	Days to flower[1]	Days to maturity[1]	Seed yield (t ha^{-1})		Yield loss
			Sprayed	Unsprayed	(%)
Determinate					
MPG 537-M1-2-1B	62	109	2.39	2.01	15.9
MPG 537-M1-2-5B	59	108	2.07	1.83	11.6
MPG 537-M1-2-M4	60	107	2.09	1.86	11.0
MPG 537-M1-2-M13	57	107	2.37	1.53	35.4
MPG 537-M1-2-M16	58	107	2.09	1.62	22.5
ICPL 87 (control)	63	119	2.36	0.60	74.6
Mean (n = 15)	60	108	2.12	1.52	28.3
SE (var)	±1.4	±1.4		±0.23	
SE (spray)	-	-		±0.08	
SE (var ↔ spray)	-	-		±0.32	
Nondeterminate					
MPG 664-M1-2-M2	63	109	2.41	1.99	17.4
MPG 664-M1-2-M13	65	110	2.64	2.19	17.1
MPG 664-M1-2-M22	69	111	2.25	1.67	25.8
MPG 664-M1-2-M23	69	110	2.90	1.68	42.1
MPG 664-M1-2-M27	67	110	2.22	1.92	13.5
UPAS 120 (control)	66	115	2.32	0.70	68.9
Mean (n = 15)	66	110	2.50	1.42	
SE (varieties)	±1.5	±1.1		±0.20	
SE (spray)	-	-		±0.08	
SE (var ↔ spray)	-	-		±0.29	

1. Under unsprayed conditions.

Mechanisms of resistance

Nonpreference

Females of *M. vitrata* showed oviposition preference for hyacinth bean, followed by cowpea and pigeonpea (Ramasubramanian and Sundara Babu 1989b). The maximum number of eggs was laid three days after mating on the preferred host, while on cowpea and pigeonpea the highest number of eggs was laid on the fourth day after mating. Greenhouse experiments in a choice situation have clearly shown nonpreference for oviposition as a component of resistance in cowpea (Macfoy et al. 1983). However, Valdez (1989) did not observe any oviposition nonpreference in cowpea cultivars. Nonpreference for larval feeding has been observed by Echendu and Akingbohungbe (1990). Attraction and arrest-stay of first-instar larvae contributed to the resistance of TVu 946 and VITA 5 to the legume pod borer (Okech and Saxena 1990).

Significant differences in oviposition preference have been observed under multi-choice conditions on different pigeonpea cultivars (Table 9). Maximum egg numbers (108.4) were laid on ICPL 90011 and the lowest number (0.2) on cowpea. Under no-choice conditions, maximum oviposition was recorded on ICPL 87 and least on ICPL 90036-M1-2. Genotypes MPG

Table 9. Oviposition preference by *Maruca vitrata* females on nine pigeonpea genotypes and on cowpea under laboratory conditions. ICRISAT-Patancheru, 1997/98.

Genotype	Number of eggs laid per female	
	Multi-choice	No choice
Pigeonpea		
MPG 537 (Bulk)	38.6	9.8
MPG 537-M1-2-M5	10.7	3.4
ICPL 90011	108.4	35.4
ICPL 84023	22.7	11.0
ICPL 88034	22.1	5.8
ICPL 4	35.4	7.0
MPG 664-M1-2-M20	38.4	18.8
ICPL 90036-M1-2(C)	26.7	0.8
ICPL 87 (susceptible control)	28.2	68.8
Cowpea	2.9	0.0
Mean	33.4	16.1
SE	±15.82	±18.57

537-M1-2-M5 (nondeterminate), ICPL 84023, ICPL 84034, and ICPL 90036-M1-2(C) (determinate) have shown nonpreference for oviposition both under multi- and no-choice conditions. Trends in genotypic preference for oviposition were dissimilar under choice- and no-choice conditions.

Antibiosis

Larval survival in cowpea is low on TVu 946, and this has been attributed to nutritional and antibiotic factors (Macfoy et al. 1983). Valdez (1989) observed only a slight effect of the host on larval survival. Okech and Saxena (1990)

Table 10. Growth and development of *Maruca vitrata* on nine short-duration pigeonpea cultivars under laboratory conditions. ICRISAT-Patancheru, 1997.

Genotype	Larva		Pupa		Adult
	Mass (mg)	Period (days)	Mass (mg)	Period (days)	Longevity (days)
Pigeonpea					
MPG 537 (Bulk)	25.3	12.1	48.3	6.7	18.7
MPG 537-M1-2M5	19.6	12.5	48.9	6.7	18.8
ICPL 90011	18.9	12.0	49.4	7.0	19.4
ICPL 84023	10.3	13.2	43.1	7.5	18.5
ICPL 88034	22.6	12.4	50.9	7.0	19.4
ICPL 4	24.0	11.7	54.4	7.4	19.1
MPG 664-M1-2-M20	31.7	11.6	52.2	7.1	18.7
ICPL 90036-M1-2	40.6	11.6	56.9	6.9	20.6
ICPL 87	26.4	11.6	54.4	7.5	19.1
Cowpea	29.6	12.2	50.9	7.3	19.3
Mean	25.0	12.1	51.1	7.2	19.2
SE	±2.26	±0.11	±2.78	±0.11	±0.14

indicated that antibiosis was a component of resistance in TVu 946 and VITA 5 stems and pods. Highest larval weight gain has been recorded on TVu 3 and least in CES 15-27. Consumption index (CI) was higher on TVu 1248 and TVu 1 compared with CES 15-27, TVu 161-1-2, TVu 461, TVu 946, TVu 1016-1, and TVu 1499-1.

In pigeonpea, larvae reared on ICPL 84023 had lower larval and pupal mass than those reared on ICPL 90036-M1-2 (Table 10). Moths emerging from the larvae reared on ICPL 960036-M1-2 produced the maximum number of eggs, followed by those reared on ICPL 90011. Fecundity was low when the larvae were reared on the pods of *Maruca*-resistant cultivar MPG 537-M1-M5 (Table 11).

There are significant differences in consumption and utilization of flowers by the third-instar larvae and pods by the fifth-instar larvae. Third-instar larvae consumed 27.0–47.2 mg food on the flowers, and had growth rates of 114.7% on ICPL 88020 to 207.3% on ICPL 85010 (Sharma, in press) (Table 12). The consumption index was greater on ICPL 90011 compared with that on ICPL 88020, ICPL 85010 and ICPL 88007. Approximate digestibility was lower on ICPL 85010 than on ICPL 90011 (Fig. 16). Efficiency of conversion of digested food into body matter was lower on ICPL 90011 and ICPL 88020 as compared with ICPL 85010 and ICPL 88007. The fifth-instar larvae consumed between 52.3 and 80.6 mg of food on pods, and showed growth rates of 30.1 to 41.8% (Table 13). Food consumption was lowest on ICPL 85010, and maximum on ICPL 90011. Approximate digestibility was lower on ICPL 85010 compared with that on ICPL 88020, ICPL 90011, and ICPL 88007 (Fig. 17). Efficiency of conversion of ingested food into body matter was lowest on ICPL 90011, followed by that on ICPL 88020, ICPL 88007, and ICPL 85010.

Tolerance

The ability of plants to recover from insect damage is an important component of resistance to insects in crop plants. There is no relationship

Table 11. Fecundity (number of eggs laid per female) of *Maruca vitrata* females reared as larvae on flowers and pods of pigeonpea genotypes under laboratory conditions. ICRISAT-Patancheru, 1997.

Genotype	Flowers		Pods	
	Eggs	Eggs hatched (%)	Eggs	Eggs hatched (%)
Pigeonpea				
MPG 537(Bulk)	76.8	41.8 (40.1)[1]	31.8	55.5 (48.2)
MPG 537-M1-2-M5	43.4	23.1 (28.1)	22.4	35.2 (32.7)
ICPL 90011	118.4	52.4 (46.4)	132.8	77.9 (62.6)
ICPL 84023	95.2	36.2 (36.1)	42.0	58.4 (50.1)
ICPL 88034	99.6	34.8 (35.8)	52.8	65.0 (55.0)
ICPL 4	51.4	37.6 (36.3)	58.2	53.5 (47.4)
MPG 664-M1-2-M20	81.2	40.9 (39.7)	37.0	60.2 (51.0)
ICPL 90036-M1-2	230.2	60.3 (51.1)	189.0	79.6 (64.5)
ICPL 87	100.6	51.0 (45.4)	116.4	63.2 (52.8)
Cowpea	79.2	42.0 (39.9)	72.2	76.5 (62.4)
Mean	97.6	42.0 (39.89)	75.5	62.5 (52.7)
SE	±28.32	±8.86 (5.79)	±27.35	±9.12 (6.25)

1. Numbers in parentheses are Arc-sine transformed values.

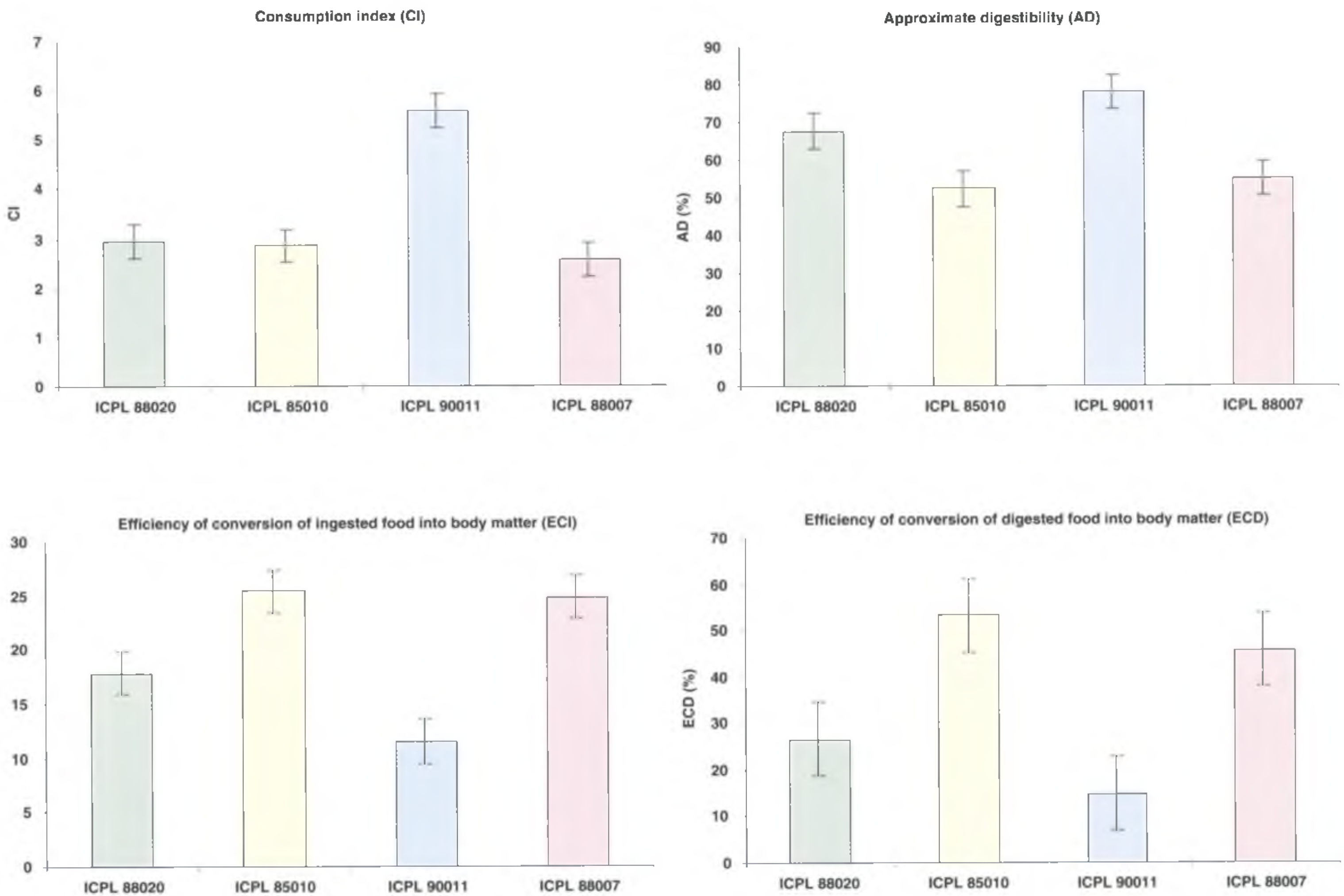

Figure 16. Consumption, digestion, and utilization of flowers of four pigeonpea genotypes by the fifth-instar larvae of **Maruca vitrata** *(QDPI, Toowoomba, Australia, 1996). CI = Consumption index, AD = approximate digestibility, ECI = efficiency of conversion of ingested food into body matter, and ECD = efficiency of conversion of digested food into body matter.*

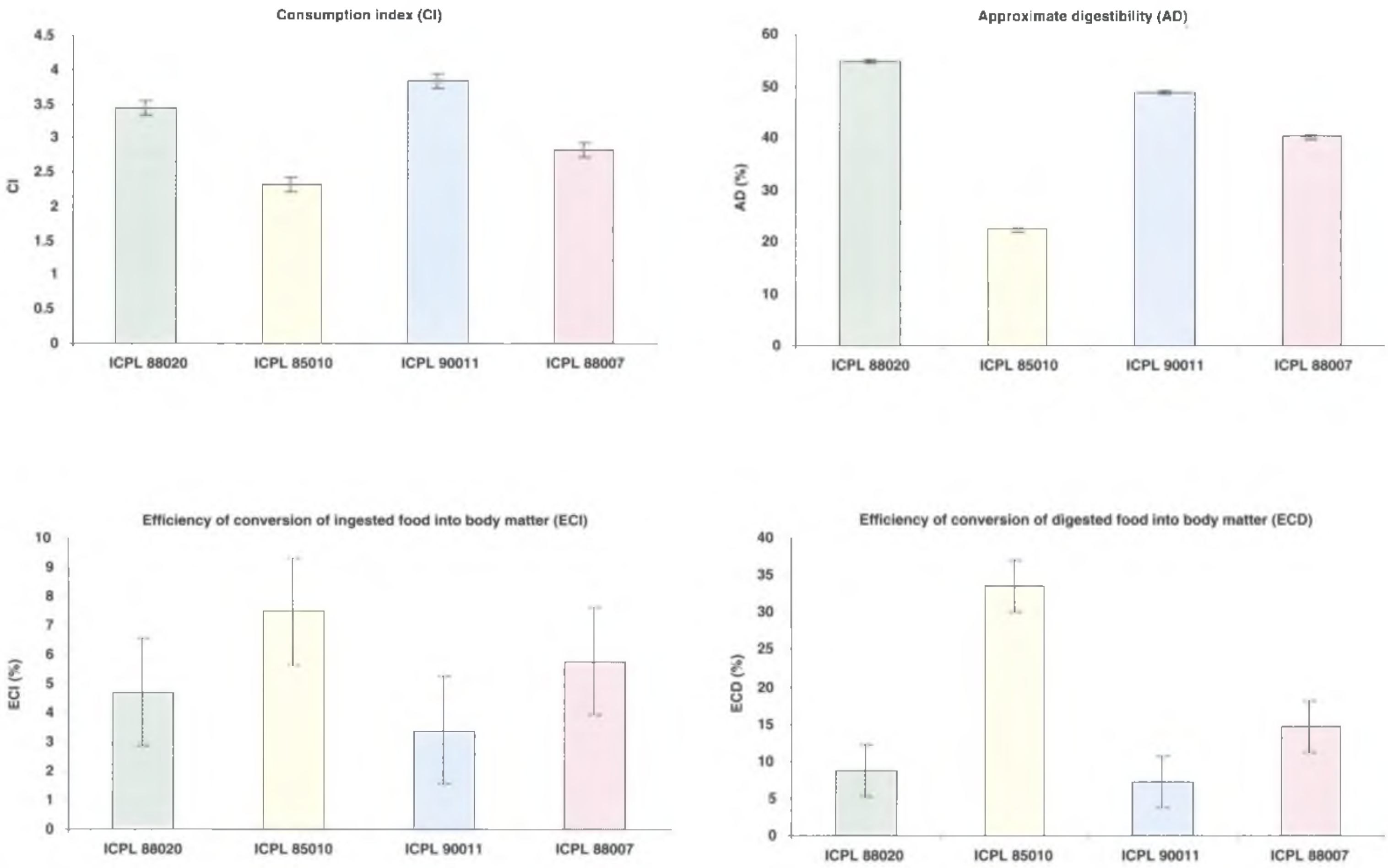

Figure 17. Consumption, digestion, and utilization of pods of four pigeonpea genotypes by the fifth-instar larvae of Maruca vitrata *(QDPI, Toowoomba, Australia, 1996). CI = Consumption index, AD = approximate digestibility, ECI = efficiency of conversion of ingested food into body matter, and ECD = efficiency of conversion of digested food into body matter.*

Table 12. Consumption and utilization of flowers of four pigeonpea genotypes by the third-instar larvae of *Maruca vitrata* (dry mass basis). QDPI, Toowoomba, Australia, 1996.

Genotype	Mass of food consumed (mg)	Mass of faeces (mg)	Mass of larvae before feeding (mg)	Mass of larvae after feeding (mg)	Increase in mass (mg)	Growth rate (%)
ICPL 88020	27.0	9.2	2.1	7.0	4.9	114.7
ICPL 85010	29.3	13.2	1.7	8.7	7.0	207.3
ICPL 90011	47.2	10.5	1.6	6.9	5.3	173.4
ICPL 88007	34.0	16.1	2.5	11.0	8.5	173.9
Mean	34.4	12.23	1.97	8.39	6.4	167.3
SE	±5.78	±2.49	±0.36	±1.54	±1.2	±12.41
LSD at 5% t	20.00	8.63	1.23	5.33	NS[1]	42.94

1. NS = F-test nonsignificant at $P \leq 0.05$.

between *Maruca* damage and recovery resistance (Table 8). However, ICPL 88034 and MPG 679, which recorded low *Maruca* damage (10 to 25%), showed excellent recovery. Although larval counts and pod damage were similar on resistant and susceptible cultivars, the grain yield was significantly greater in the *Maruca*-resistant cultivars than the susceptible ones (Saxena et al. 1998). This suggests that some genotypes recover quickly following *Maruca* damage.

Factors associated with resistance

Plant architecture

Infestation and damage by *M. vitrata* in cowpea is influenced by plant architecture. Canopy structure and pod position together or independently exert a profound effect on cowpea resistance to the pod borer. Cultivars with pods held within the canopy suffer significantly greater

Table 13. Food consumption, mass of larvae, increase in mass, and growth rates of *Maruca vitrata* fifth-instar larvae on the pods of four pigeonpea genotypes (dry mass basis). QDPI, Toowoomba, Australia, 1996.

Genotype	Mass of food consumed (mg)	Mass of faeces (mg)	Mass of larvae before feeding (mg)	Mass of larvae after feeding (mg)	Increase in mass (mg)	Growth rate (%)
ICPL 88020	80.6	36.4	9.8	13.6	3.8	39.0
ICPL 85010	62.7	48.7	11.2	15.9	4.7	41.8
ICPL 90011	59.3	30.8	6.7	8.8	2.1	30.1
ICPL 88007	52.3	30.9	7.7	10.7	3.0	38.9
Mean	63.7	36.7	8.86	12.2	3.34	37.4
SE	±6.19	±3.58	±0.62	±0.91	±0.40	±4.26
LSD at 5% t	21.41	12.38	2.13	3.15	1.37	NS[1]

1. NS = F-test nonsignificant at $P \leq 0.05$.

Table 14. Yield (t ha^{-1}) of *Maruca vitrata* - resistant line MPG 537 and the susceptible control, ICPL 87, under different spray regimes. Maha Illuppallama, Sri Lanka, 1994/96.

No. of sprays	Season	MPG 537	ICPL 87	Superiority of MPG 537 (%)
3[1]	1994/95	1.56	0.33	-
	1995/96	1.14 (9.5)[2]	0.81 (10.9)	-
	Mean	1.35	0.57	137
2	1994/95	1.30	0.37	-
	1995/96	1.19 (11.4)	0.77 (10.4)	-
	Mean	1.25	0.57	119
0	1994/95	0.65	0.06	-
	1995/96	0.81 (16.3)	0.68 (13.5)	-
	Mean	0.73	0.37	97

1. Recommended practice.
2. Pod damage at maturity.

damage than the cultivars where the pods are held in the normal position. Selection and breeding cowpea cultivars with less dense foliage and long peduncles holding the reproductive structures above the canopy may increase resistance to *M. vitrata* (Oghiakhe et al. 1991a, Usua and Singh 1979). A negative relationship has been observed between pod angle and percentage pod damage, as well as the seed damage index in two cowpea cultivars (Oghiakhe et al. 1992a). Pods with wide angles (>89°) were damaged on one, but rarely on both sides. The eventual pod size and rate of pod growth appeared to be important factors in cowpea susceptibility to the pod borer (Tayo 1988).

Tall and intermediate type cultivars (nondeterminate type) of pigeonpea have fewer flowers per cluster than shorter cultivars (determinate type), and a disproportionately lower number of pod borer larvae per 100 flowers. Genotypes with branching and loose flower arrangements were less susceptible to legume pod borer damage (Fellows et al. 1977). Saxena et al. (1996) also observed that nondeterminate type pigeonpea lines were less susceptible to *Maruca* damage than the determinate types (Fig. 18). The average score of the determinate lines was 7.1, while the corresponding value for the nondeterminate group was 5.3. This suggests that, in general, the determinate lines having a clustered inflorescence are more prone to *Maruca* damage than the nondeterminate genotypes which have long fruiting branches and a loose inflorescence. Lateef and Reed (1981) also suggested that determinate types suffered greater pod borer damage than the nondeterminate types. In the case of cowpea, lines having clustered pods have been found to be more susceptible (Usua and Singh 1979). Similarly, pigeonpea genotypes with clustered pods may be more susceptible than genotypes with a nonclustered podding habit (Fig. 19). However, there was a large variation for *Maruca* damage within each growth type. In the determinate group, only four lines (MPG 359, 531, 532, and 566) suffered a damage rating of <3, while in the nondeterminate group, 12 lines showed a damage rating of <3. None of the nondeterminate types showed 100% *Maruca* damage. On the contrary, 18 determinate types suffered complete damage. In the nondeterminate group, 56% of the lines tested showed <50% damage, while in the determinate group, 85% of the lines had >50% damage.

Figure 18. Determinate (left) and nondeterminate (right) growth habit of pigeonpea genotypes. The lines with nondeterminate branching habit are less susceptible to **Maruca vitrata** *damage.*

Therefore, factors other than the flowering habit may also be important in pigeonpea resistance to *Maruca*.

Anatomical characteristics

Anatomical features of the stem and pod wall were associated with resistance to *M. vitrata* in cowpea (Oghiakhe et al. 1991b). The anatomical micro-environment of the area immediately beneath the stem epidermis seemed to impose severe limitations on larval movement and feeding within the tissue. Although stem anatomy was considered to be an important factor, this did not appear to be the case in pod wall resistance to *M. vitrata*. The toughness of nonintact and intact pod walls increased with age, but the rate varied at different growth stages of the pod as well as between cultivars (Oghiakhe et al. 1992b). Jackai and Oghiakhe (1989) observed that in two wild cowpea (*Vigna vaxillata*) accessions (TVNu 72 and TVNu 73), feeding and development were deterred on the pods with or without trichomes compared with the susceptible variety IT 84E-124. A similar effect has also been observed on seeds and flowers. *Maruca* larvae fed and developed better when the trichomes were removed. The growth index was 13x less when the trichomes were left intact both on TVNu 72 and TVNu 73. It appears that the resistance of these lines is based on trichomes and phyto-chemicals. Thick and compact collenchyma cells in the stems and fibrous tissues on the petal surface contributed to resistance. Trichomes varied in length and density, but not in type on different plant parts

Figure 19. Clustered (left) and nonclustered (right) podding habit of pigeonpea. Genotypes with clustered podding habit are more susceptible to **Maruca vitrata.**

(Oghiakhe et al. 1992c). Trichome density decreased with plant age. Significant correlations have been observed between trichome density and pod borer damage, but trichome length may be less important than density.

In pigeonpea, trichomes have been shown to be associated with resistance to *H. armigera* (Shanower et al. 1996). However, there is no information on the role of trichomes in pigeonpea in imparting resistance to *M. vitrata*.

Biochemical factors

There are no specific studies on biochemical mechanisms of resistance to legume pod borer in pigeonpea. However, the secondary plant substances present in pigeonpea, which affect the plant suitability to other insects, are likely to affect the growth and development of *M. vitrata*. Sugar and protein content of different genotypes may also influence the nutritional value of different genotypes for the growth and development of larvae.

Sugar content in the pod walls of cowpea cultivar TVNu 72 was greater than in IT 82D-716, and phenol content was lower in the pod wall of TVNu 72, but the reverse was true for fresh and dry seeds. Neither sugars nor phenols seemed to be involved in the resistance of TVNu 72 to *M. vitrata* (Oghiakhe et al. 1993). Phenol concentration varies significantly between different plant parts, and generally decreases with an increase in plant age. Otieno et al. (1985) indicated that an ethyl-acetate soluble fraction of methanol extracts of stems of TVu 946 showed greater feeding inhibition than the extract from ICG 1.

Components of integrated pest management

Natural enemies

Several parasites and predators have been recorded on *M. vitrata* by Agyen-Sampong (1978), Barrion et al. (1987), Usua and Singh (1977), Okeyo-Owuor et al. (1991), ICRISAT (1978, 1981), Subasinghe and Fellows (1978), and Odindo et al. (1989); and summarized by Sharma (1998). Parasites recorded on larvae/pupae include tachinids [*Aplomya metallica* (Wiedemann), *Exorista xanthaspis* (Wiedemann), *Palexorista solennis* (Walker), *Peirbaea orbata* (Wiedemann), *Zygobothria atropivora* (Robineau-Desvoidy), *Zygobothria ciliata* (Wulp), *Thelairosoma* sp, *Pseudoperichaeta laevis* (Villeneuve), *Pseudaperichaeta* sp, and *Thecocarcelia incedens* (Rondani)], braconids [*Apanteles teragamae* Vierek, *Apanteles* sp, *Bracon greeni* Ashmead, *Bracon* sp, *Braunsia* sp, *Cardiochiles philippinensis* Ashmead, *Chelonus* sp, *Snellenius manilae* Ashmead, *Phanerotoma handecasisella* Cameron, and *Phanerotoma* sp], chalcidids [*Antrocephalus* sp nr *subelongatus* Kohl, *Antrocephalus* sp, and *Brachymeria* sp], eulophids [*Nesolynx thymus* (Girault), *Tetrastichus sesamiae* Risbec, and *Tetrastichus* sp], ichneumonids [*Caenopimpla arealis* (Cushman), *Charops nigrita* Gupta and Maheswary, *Meloboris sinicus* (Holmgren), and *Metopius rufus browni* Ashmead], pteromalids [*Trichomalopsis* sp], scelionids [*Telenomus* sp], mites [*Dinothrombius* sp], nematodes, protozoa [*Mettesia* sp, *Nosema marucae* sp n and *Nosema* sp], and bacteria [*Bacillus* sp and *Clostridium* sp].

Predators include dermapterans [*Diaperastichus erythrocephala* Olivier], mantids [*Polyspilota* sp and *Spodromantis* sp], carabids [*Chlaenius* sp and *Cicindela lacrymosa* (Fabricius)], coccinellids [*Coccinella repanda* (Thunberg), *Menochilus sexmaculatus* (Fabricius), and *Synharmonia octomaculata* (Fabricius)], anthocorids [*Orius tantillus* Motschulsky], formicids [*Camponotus sericeus* Fabricius and *Camponotus rufoglaucus* (Jerdon)], vespids [*Ropalidia flavopicta flavobrunnea* van der Vecht], selenopids [*Selenops* sp], araneids [*Nephila maculata* (Fabricius)], oxyopids [*Oxyopes javanus* Thorell], salticids [*Evarcha* sp, *Marpissa bengalensis* Tikader, and *Marpissa calcutaensis* Tikader], and sparassids [*Heteropoda venatoria* (Linnaeus)].

Okeyo-Owuor and Oloo (1991) carried out key-factor analysis of *M. vitrata* populations in Kenya. The total mortality from egg to adult stage was nearly 98 to 99%, and highest mortality occurred between the egg stage and the third-instar larvae, whilst the fourth-instar larvae suffered lowest mortality. The causes of mortality were disappearance, followed by disease. Parasitism contributed minimally to *M. vitrata* mortality. There was no correlation between population density and mortality at the same stage (Okeyo-Owuor et al. 1991). A pupal endoparasitoid, *Antrocephalus* sp, was the predominant natural enemy, while *Nosema* sp and *Bacillus* sp caused the highest natural mortality. Parasitoids and pathogens contributed 40.7% to the total generation mortality (*K*) at site 1 and 35.6% at site 2. Parasitism only contributed 3.3% of the total generation mortality at site 1 and 3.8% at site 2. Mortality due to disappearance, which also included predation, accounted for 59.4 and 64.8% of *K* at the respective sites. Life table data and survival curves for the pest revealed high generation mortality (about 98%), most of which occurred in the early life stages of the pest. The results suggested a high potential for utilizing biocontrol agents for the management of this pest.

Information on the role of various natural enemies in regulating the legume pod borer populations is scanty or unavailable. Published information indicates that parasitoid contribution to the total natural mortality is very low. Pathogens seem to play a major role in the control of pod borer populations under field conditions. This area of research needs to be pursued in future to exploit natural enemies for the management of this pest.

Cultural practices

Pod borer populations tended to build up over the season, and the pod borer infestation increased on the late sown crops (Alghali 1993a). Grain yield also decreased in late-sown crops. Simultaneous sowings of maize and cowpea increased pod borer infestation in cowpea (Ezueh and Taylor 1984), whereas sowing cowpea 12 weeks after maize reduced the legume pod borer damage.

Pod borer damage in monocrops was greater than the maize – cowpea – sorghum inter/mixed crops (Amoako-Atta and Omolo 1982, Omolo et al. 1993). Pod borer incidence was significantly lower in intercropped, and at higher plant populations than in pure stands, and in lower plant populations of common bean, *Phaseolus vulgaris* (Karel 1993). Flower and pod damage was significantly lower in an intercrop combination of one third bean – two thirds maize. However, Alghali (1993b), Natarajan et al. (1991), and Patnaik et al. (1989) reported no effect of intercropping on *M. vitrata* damage. Cowpea weeded 2, 3, or 4 times had less flower infestation by *M. vitrata* than the nonweeded plots (Ofuya 1989). However, effects of weeding frequency on pod damage by *M. vitrata* are not consistent.

Chemical control

Effective control of the pod borer on cowpea has been achieved with endosulfan (applied at 35 DAS twice at weekly intervals) (Jackai 1983); one spray of cypermethrin, biphenthrin, cyhalothrin, and in combination with dimethoate (Amatobi 1994); a mixture of cypermethrin + dimethoate using an Electrodyn sprayer (Jackai et al. 1987); or two applications of cypermethrin + dimethoate at 10-day intervals (beginning at bud formation) (Amatobi 1995). Atachi and Sourokou (1989) reported that a sequence of deltamethrin - dimethoate - deltamethrin sprays resulted in the highest grain yield (1.37 t ha^{-1}). Spray regimes which terminated early offered better protection against the pod borer, but were inadequate for controlling sucking insects. Calendar-based sprays resulted in less borer infestation than when sprays were based on economic thresholds (Afun et al. 1991). However, differences in grain yield between the calendar-based sprays and those based on economic thresholds were not significant. Crop monitoring reduced the number of sprays by half compared with those based on calendar schedules.

Decamethrin, cypermethrin, and fluvalinate caused the highest mortality of the legume pod borer larvae three days after spraying under laboratory conditions (Bhalani and Prasana 1987). Plots sprayed with synthetic pyrethroids, except fenvalerate at 0.01%, showed least damage to the pods at harvest. Significantly greater grain yield was recorded in plots treated with fluvalinate, followed by those treated with cypermethrin, decamethrin, and fenvalerate at higher dosages. Samolo and Patnaik (1986) reported that of the six insecticides tested, monocrotophos and endosulfan (0.5 kg a.i. ha^{-1}) were most effective, and three applications of endosulfan starting at flower initiation (at 20 days interval) were most effective. Foliar application of cypermethrin (0.008%) or dimethoate (0.07%) at flowering or when egg numbers reached 2 per meter row, and then repeated at 10–15 days interval provided effective protection against *M. vitrata* (Rahman 1991). Cypermethrin (75 g a.i. ha^{-1}) sprayed three times, has been found to be effective against pod borers, followed by decamethrin (12.5 g a.i. ha^{-1}), fenvalerate (150 g a.i. ha^{-1}), and endosulfan (400 g a.i. ha^{-1}) (Sontakke and Mishra 1991). The latter showed the highest cost-benefit ratio. Sprays of 0.07% traizophos or endosulfan, and 0.04% monocrotophos resulted in maximum reduction in pod borer damage (Sundara Babu and Rajasekaran 1984). Dust formulations of phoxim, endosulfan, and phosalone (4%) also gave effective control of the legume pod borer. Venkaria and Vyas (1985) reported that the least number of pods were damaged in plots treated with fenvalerate (0.01%), endosulfan (0.07%) + miraculan (a plant growth stimulant), followed by those treated with fenvalerate (0.01%), endosulfan (0.07%) + miraculan, and monocrotophos (0.04%). Thiodicarb (613 ppm) and ethofenprox (125 ppm) were as effective as methamidophos (200 ppm) for the control of legume pod borer on pigeonpea in Sri Lanka (Dharmasena 1993). Insecticide application increased the grain yield by 28%. Thiodicarb sprays resulted in maximum increase (43%) in grain yield over two seasons.

Four sprays of cypermethrin 0.008% (1st spray at initiation of flowering, 2nd spray at 50% flowering, 3rd spray at 100% flowering, and 4th spray at 100% pod setting) were effective for protecting the pigeonpea crop against *Maruca* (Rahman and Rahman 1988). This schedule also offered the highest benefit-cost ratio (6.23). Dimethoate was not as effective as cypermethrin. The number of flowers, pods, and seeds per plant was significantly greater in plots treated with insecticides based on the economic threshold level of 10 larvae per 100 flowers (3 insecticide applications) than in the untreated plots. The differences in the number of flowers, pods, and seeds per plant were not significant between plots sprayed 3 and 4 times. It has been concluded that 10 larvae per 100 flowers can be considered as a tentative threshold for *M. vitrata* on pigeonpea (Dharmasena et al. 1992).

Natural/biopesticides

Bacillus thuringiensis (Bt) (Karel and Schoonhoven 1986) and neem seed powder and neem kernel extract (Singh et al. 1985, Jackai et al. 1992) are effective against legume pod borer. Flower infestation was not influenced by 5 and 10% neem leaf extracts in cowpea, except in 1994 (Bottenberg and Singh 1996). Neem leaf extract applied four times on Cv 715 resulted in less pod borer damage than on Cv 941. Neem application reduced pod damage by 12% in Cv 715, and by 16% in Cv 941. In pigeonpea, trials conducted to assess the utility of *Maruca*-resistant cultivars for managing this pest revealed that pod borer-resistant lines can reduce the number of insecticide sprays at least by one under certain conditions (Table 14) (Saxena et al. 1998).

Conclusions

Information on the biology of *M. vitrata* has been generated for cowpea, and to a limited extent for pigeonpea. Comprehensive information is needed on the population dynamics of this insect, and the factors that lead to rapid population build up. This information will be useful to screen for resistance under natural infestation, development of resistance screening techniques, and appropriate management strategies for controlling this pest. Such information can be generated through light traps, and sequentially planted crops. A few susceptible and resistant cultivars may be included in such studies to quantify the role of plant resistance in minimizing the damage by this pest.

Some information is available on insect density-yield loss relationships. This will be useful for estimating economic thresholds, the level of insect infestation needed to screen for resistance, and the desirable levels of resistance needed in the commercial cultivars to minimize losses due to this insect.

Screening for resistance has been carried out using natural infestation, and multi- and no-choice tests under greenhouse and laboratory conditions. Laboratory/greenhouse tests are useful for confirming the resistance observed under field conditions. Ten eggs per plant are adequate to screen for resistance to this insect in cowpea. The larvae can be reared on natural hosts/artificial diet in the laboratory. Procedures for infestation and evaluation of resistance under field and greenhouse conditions should be standardized and adopted across locations in crop improvement programs.

Considerable information has been generated on genotypic resistance/susceptibility to *M. vitrata* in cowpea, while such information on pigeonpea and other pulse crops is scanty. Levels of resistance seem to be repeatable across seasons. Important sources of resistance to other yield-reducing traits should be evaluated for resistance to the pod borer to identify lines with multiple resistance to insects and other yield-reducing factors.

Several plant characteristics such as stem and pod wall thickness, and podding habit (clusters versus spread out pods, pod angle, etc.) contribute to decreased susceptibility to *Maruca*. Some of these characteristics such as growth habit, pods exposed above the foliage, days to complete flowering, and time required for pod maturity can be used to select genotypes as possible candidates for resistance to *Maruca*. The relative contribution of these traits should be assessed in a diverse array of genotypes with resistance to *Maruca*. This material can also be used to quantify the contribution of nonpreference, antibiosis, and tolerance mechanisms of resistance. This will also help to identify lines with different mechanisms of resistance, which can be used in the resistance breeding program to increase the levels and diversify the bases of resistance to *M. vitrata*.

Several natural enemies have been reported on *M. vitrata*. Pathogens have been reported to be most important as population regulating factors in the field. In this regard, the usefulness and effectiveness of *Bacillus thuringiensis*, *Nosema*, and *Aspergillus* may be explored for integrated management of this pest.

Cultural practices such as intercropping, weeding, time of sowing, density of sowing, and pruning have been shown to reduce the damage by the legume pod borer. However, the results are not consistent over seasons or locations. Such studies should be repeated involving large plots, and possibly including genotypes that are less susceptible to this insect.

Several insecticides have been evaluated for the control of this insect. Future studies should focus on insecticide application based on economic thresholds, and timing of insecticide application. Emphasis should also be placed on using the biorational pesticides for integrated management of this insect. Various control options for minimizing the losses due to *M. vitrata* should be tested in farmers' fields in collaboration with the NARS and other organizations. A network of IARCs working on *Maruca* may be established to share the information and technology for integrated management of *M. vitrata*.

References

Afun, J.V.K., Jackai, L.E.N., and **Hodgson, C.J.** 1991. Calendar and monitored insecticide application for the control of cowpea pests. Crop Protection 10:363-370.

Agyen-Sampong, A. 1978. Pests of cowpea and their control in Ghana. Pages 85-92 *in* Pests of grain legumes: ecology and control (Singh, S.R., van Emden, H.F. and Taylor, J.A., eds.). London, UK: Academic Press.

Ahmed, K., Khalique, F. and **Bashir, M.** 1987. Insect pests of pulse crops and their control. Pages 240-252 *in* Integrated Pest Management, 22 Nov-3 Dec 1987, Islamabad, Pakistan (Inayatullah, C., ed.). Islamabad, Pakistan: Pakistan Agricultural Research Council.

Akhauri, R.K., Sinha, M.M. and **Yadav, R.P.** 1994. Population build-up and relative abundance of pod borer complex in early pigeonpea, *Cajanus cajan* (L.) Millsp. Journal of Entomological Research 18:121-126.

Akinfenwa, S. 1975. Biological study of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in the Zaria area of northern Nigeria. M. S. thesis, Ahmadu Bello University, Zaria, Nigeria.

Alghali, A.M. 1993a. The effects of some agrometereological factors on fluctuation of the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae), on two cowpea varieties in Nigeria. Insect Science and its Application 14:55-59.

Alghali, A.M. 1993b. Intercropping as a component for insect pest management for cowpea *Vigna unguiculata* Walp. production in Nigeria. Insect Science and its Application 14:49-54.

Amatobi, C.J. 1994. Field evaluation of some insecticides for the control of insect pests of cowpea (*Vigna unguiculata*) in the Sudan savannah of Nigeria. International Journal of Tropical Pest Management 40:13-17.

Amatobi, C.J. 1995. Insecticide application for economic production of cowpea grain in the northern Sudan savannah of Nigeria. International Journal of Tropical Pest Management 41:14-18.

Amoako-Atta, B., and **Omolo, E.O.** 1982. Yield losses caused by the stem-/pod-borer complex within maize-cowpea-sorghum intercropping systems in Kenya. Insect Science and its Application 4:39-46.

Ariyanayagam, R.P., and **Singh, N.B.** 1994. Pigeonpea breeding: accomplishments and challenges. Plant Breeding Abstracts 64:773-782.

Atachi, P., and **Ahohuendo, B.C.** 1989. Comparison of some parameters characteristic of the population dynamics of *Megalurothrips sjostedti* (Trybom) and *Maruca testulalis* (Geyer) on a single plant host (*Vigna*). Insect Science and its Application 10:187-197.

Atachi, P., and **Ahounou, M.** 1995a. Laboratory rearing of *Maruca testulalis* (Geyer) on simple artificial media (Lepidoptera: Pyralidae). Bulletin de la Société Entomologique de France 100:25-28.

Atachi, P., and **Ahounou, M.** 1995b. Experimental study of the biological control potential of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) on some food substrates under laboratory conditions. Bulletin de la Société Entomologique de France 120:25-45.

Atachi, P., and **Djihou, Z.C.** 1994. Record of host plants of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in the republic of Benin. Annals of the Entomological Society of France 30:169-174.

Atachi, P., and **Sourokou, B.** 1989. Use of Decis and Systoate for the control of *Maruca testulalis* (Geyer) in cowpea. Insect Science and its Application 10:373-381.

Barrion, A.T., **Bandong, J.P.**, **De la Cruz, C.G.**, **Apostol, R.F.**, and **Litsinger, J.A.** 1987. Natural enemies of the bean pod-borer, *Maruca testulalis* in the Philippines. Tropical Grain Legumes Bulletin 34:21-22.

Bhagwat, V.R., **Shanower, T.G**, and **Ghaffar, M.A.** 1998. Ovipositional preference of *Maruca (testulalis) vitrata* (Geyer) (Lepidoptera: Pyralidae) in short maturing pigeonpeas. International Chickpea and Pigeonpea Newsletter 5:45-46.

Bhalani, P.A., and **Prasana, G.J.** 1987. Relative toxicity of certain newer insecticides to *Maruca testulalis* (Geyer) attacking pigeonpea. Pesticides 21(4):23-25.

Bottenberg, H., and **Singh, B.B.** 1996. Effect of neem leaf extract applied by broom method on cowpea pests and yield. International Journal of Tropical Pest Management 42:207-209.

Buranapanichpan, S., and **Napompeth, B.** 1982. Insect pests of pigeonpea in Thailand. Bangkok, Thailand: Kasetsart University. 19 pp.

Dabrowski, Z.T., **Bungu, D.O.M.**, and **Ochieng, R.S.** 1983. Studies on the legume pod-borer, *Maruca testulalis* (Geyer) – 3. Methods used in cowpea screening for resistance. Insect Science and its Application 4:141-145.

Das, G.P., and **Islam, M.A.** 1985. *Maruca testulalis* (Lepidoptera: Pyralidae): an important pest of country bean in Bangladesh. Bangladesh Journal of Agriculture 10:57-66.

Dharmasena, C.M.D. 1993. Efficacy of insecticides on cowpea pod borer *Maruca testulalis* Geyer (Lep: Pyralidae). Tropical Agriculturist 149:101-108.

Dharmasena, C.M.D., **Subasinghe, S.M.C.**, **Lateef, S.S.**, **Menike, S.**, **Saxena, K.B.**, and **Ariyaratne, H.P.** 1992. Entomology research. Pages 104-108 *in* Pigeonpea Varietal Adaptation and Production Studies in Sri Lanka. Report of Work. Department of Agriculture, Sri Lanka. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

Echendu, T.N.C., and **Akingbohungbe, A.E.** 1990. Intensive free-choice and no-choice cohort tests for evaluating resistance to *Maruca testulalis* (Lepidoptera: Pyralidae) in cowpea. Bulletin of Entomological Research 80:289-293.

Ezueh, M.I., and **Taylor, A.T.** 1984. Effects of time of intercropping with maize on cowpea susceptibility to three major pests. Tropical Agriculture 61:82-86.

Fellows, R.W., Subasinghe, S.M.C., and **Amarsena, J.** 1977. Re-assessment of insect pest problems on pigeonpea (*Cajanus cajan*). Tropical Agriculturist 83:91-97.

Ibrahim, A.G. 1980. Some aspects of the ecology of four insect pests of long beans in Malaysia. Pages 251-257 *in* Proceedings, Legumes in the Tropics. Serdang, Selangor, Malaysia: Faculty of Agriculture, University Pertanian.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1978. Pulse Entomology (Pigeonpea) Report of Work (June 1977 to May 1978). Progress Report 1. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1981. Contribution of Cropping Systems (Entomology) (1974-81). Farming Systems Research Program. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1992. The Medium Term Plan. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

International Institute of Entomology (IIE). 1996. Distribution maps of pests. Series A: map no 351, December 1996. *Maruca vitrata* (Lepidoptera: Pyralidae), bean pod borer, mung moth, legume pod borer = *Maruca testulalis* (Geyer). 56 Queens Gate, London, UK: IIE.

Jackai, L.E.N. 1982. A field screening technique for resistance of cowpea (*Vigna unguiculata*) to the pod-borer *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). Bulletin of Entomological Research 72:145-156.

Jackai, L.E.N. 1983. Efficacy of insecticide applications at different times of day against the legume pod-borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae), on cowpea in Nigeria. Protection Ecology 5:245-251.

Jackai, L.E.N. 1991. Laboratory and screenhouse assays for evaluating cowpea resistance to the legume pod borer. Crop Protection 10:48-52.

Jackai, L.E.N., Franks, P.C., and **Alghali, A.M.** 1987. Development of an insect pest control strategy for cowpea using the Electrodyn sprayer [Nigeria]. *In* International Congress of Plant Protection, 5-7 Oct 1987, Manila, Philippines.

Jackai, L.E.N., Inang, E.E., and **Nwobi, P.** 1992. The potential for controlling post-flowering pests of cowpea, *Vigna unguiculata* Walp. using neem, *Azadirachta indica* A. Juss. Tropical Pest Management 38:56-60.

Jackai, L.E.N., Ochieng, R.S., and **Raulston, J.R.** 1990. Mating and oviposition behavior of the legume pod borer, *Maruca testulalis*. Entomologia Experimentalis et Applicata 59:179-186.

Jackai, L.E.N., and **Oghiakhe, S.** 1989. Pod wall trichomes and resistance of two wild cowpea, *Vigna vaxillata*, accessions to *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) and *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae). Bulletin of Entomological Research 79:595-605.

Jackai, L.E.N., and **Raulston, J.R.** 1982. Rearing of the maize stem borers and a legume pod borer on artificial diet. IITA Research Briefs 3:1-6.

Jackai, L.E.N., and **Raulston, J.R.** 1988. Rearing of legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) on artificial diet. Tropical Pest Management 34:168-172.

Jackai, L.E.N., and **Singh, S.R.** 1983. Suitability of selected leguminous plants for development of *Maruca testulalis* larvae. Entomologia Experimentalis et Applicata 34:174-178.

Karel A.K. 1993. Effects of intercropping with maize on the incidence and damage caused by pod borers of common beans. Environmental Entomology 22:1076-1083.

Karel A.K., and **Schoonhoven, A.V.** 1986. Use of chemical and microbial insecticides against pests of common beans. Journal of Economic Entomology 79:1692-1696.

Katayama, J., and **Suzuki, I.** 1984. Seasonal prevalence of pod borers [*Ostrinia scapulalis, Maruca testulalis* and *Matsumuraeses* sp.] in azuki-beans and injury caused by larval infestation. Bulletin of Kyoto Prefectural Institute of Agriculture 12:27-34.

Lateef, S.S., and **Reed, W.** 1981. Development of methodology for open field screening for insect resistance in pigeonpea. Pages 315-322 *in* Proceedings of the International Workshop on Pigeonpea, 15-19 Dec 1980, ICRISAT Center, India. Vol. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Leonard, M.D., and **Mills, A.** 1931. A preliminary report on the lima pod borer and other legume pod borers in Puerto Rico. Journal of Economic Entomology 24:466-473.

Macfoy, C.A., **Dabrowski, Z.T.**, and **Okech, S.** 1983. Studies on the legume pod-borer, *Maruca testulalis* (Geyer) – 4. Cowpea resistance to oviposition and larval feeding. Insect Science and its Application 4:147-152.

Natarajan, N., **Rao, P.V.S.**, and **Gopal, S.** 1991. Effect of intercropping of pulses in cereals on the incidence of major pests. Madras Agricultural Journal 78:59-67.

Nene, Y.L., **Hall, S.D.**, and **Sheila, V.K.** (eds.). 1990. The Pigeonpea. Wallingford, UK: CAB International. 490 pp.

Nyiira, Z.M. 1971. The status of insect pests of cowpea (*Vigna unguiculata*) and their control. PANS 17:194-197.

Ochieng, R.S., and **Bungu, M.D.O.** 1983. Studies on the legume pod borer, *Maruca testulalis* (Geyer) – IV. A model for mass rearing. Rearing on artificial diet. Insect Science and its Application 4:83-88.

Ochieng, R.S., **Okeyo-Owuor, J.B.**, and **Dabrowski, Z.T.** 1981. Studies on the legume pod-borer, *Maruca testulalis* (Geyer) – 2: Mass-rearing on natural food. Insect Science and its Application 1(3):269-272.

Odindo, M.O., **Otieno, W.A.**, **Oloo, G.W.**, **Kilori, J.**, and **Odhiambo, R.C.** 1989. Prevalence of microorganisms in field-sampled borers on sorghum, maize, and cowpea in Western Kenya. Insect Science and its Application 10:225-228.

Ofuya, T.I. 1989. Effect of weed removal regimes on post-flowering insect damage and grain yield of cowpea, *Vigna unguiculata* (L.) Walp. in a rain forest area of Nigeria. Tropical Agriculture 66:142-144.

Oghiakhe, S., **Jackai, L.E.N.**, and **Makanjuola, W.A.** 1991a. Cowpea plant architecture in relation to infestation and damage by the legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae)-1. Effect of canopy structure and pod position. Insect Science and its Application 12:193-199.

Oghiakhe, S., **Jackai, L.E.N.**, and **Makanjuola, W.A.** 1991b. Anatomical parameters of cowpea, *Vigna unguiculata* (L.) Walp. Stem and pod wall resistance to the legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae). Insect Science and its Application 12:171-176.

Oghiakhe, S., **Jackai, L.E.N.**, and **Makanjuola, W.A.** 1992a. Cowpea plant architecture in relation to infestation and damage by legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae)-2. Effect of pod angle. Insect Science and its Application 13:339-344.

Oghiakhe, S., Jackai, L.E.N., and **Makanjuola, W.A.** 1992b. Pod wall toughness has no effect on cowpea resistance to the legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae). Insect Science and its Application 13:345-349.

Oghiakhe, S., Jackai, L.E.N., Makanjuola, W.A., and **Hodgson, C.J.** 1992c. Morphology, distribution, and the role of trichomes in cowpea (*Vigna unguiculata*) resistance to the legume pod borer, *Maruca testulalis* (Lepidoptera: Pyralidae). Bulletin of Entomological Research 82:499-505.

Oghiakhe, S., Makanjuola, W.A., and **Jackai, L.E.N.** 1993. Antibiosis mechanism of resistance to the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) in cowpea. Insect Science and its Application 14:403-410.

Ogunwolu, E.O. 1990. Damage to cowpea by the legume pod borer, *Maruca testulalis* Geyer, as influenced by infestation density in Nigeria. Tropical Pest Management 36;138-140.

Ohno, K., and **Alam, M.Z.** 1989. Ecological studies on cowpea borers. I. Evaluation of yield loss of cowpea due to the pod borers. Page 12 *in* Annual Research Review, 29 Jun 1989. Salna, Gazipur, Bangladesh: Institute of Postgraduate Studies in Agriculture. (Abstract).

Okech, S.O.H., and **Saxena, K.N.** 1990. Responses of *Maruca testulalis* (Lepidoptera: Pyralidae) larvae to variably resistant cowpea cultivars. Environmental Entomology 19:1792-1797.

Okeyo-Owuor, J.B., Agwaro, P.O., and **Simbi, C.O.J.** 1983. Studies on the legume pod-borer *Maruca testulalis* (Geyer) – V. Larval population. Insect Science and its Application 4:75-81.

Okeyo-Owuor, J.B., and **Oloo, G.W.** 1991. Life tables, key factor analysis and density relations in natural population of the legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) in Western Kenya. Insect Science and its Application 12:423-431.

Okeyo-Owuor, J.B., Oloo, G.W., and **Agwaro, P.O.** 1991. Natural enemies of legume pod-borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) in small farming systems of western Kenya. Insect Science and its Application 12:35-42.

Omolo, E.O., Niyambo, S., Simbi, C.O.J., and **Ollimo, P.** 1993. The role of host plant resistance and intercropping in integrated pest management (IPM) with specific reference to Oyugis project. International Journal of Tropical Pest Management 39:265-272.

Onyango, F.O., and **Ochieng-Odero, J.P.R.** 1993. Laboratory rearing of the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) on a semi-synthetic diet. Insect Science and its Application 14:719-722.

Otieno, D.A., Hassanali, A., and **Nijorogen, P.W.** 1985. Chemical basis of TVu 946 stem resistance to *Maruca testulalis* Geyer. Insect Science and its Application 6:259-262.

Passlow, T. 1966. Navy bean pests. Queensland Agricultural Journal 94:762-763.

Patel, R.K., and **Singh, D.** 1977. Serious incidence of pod-borer *Maruca testulalis* Geyer on red gram at Varanasi. Science and Culture 43(7):319.

Patnaik, N.C., Dash, A.N., and **Mishra, B.K.** 1989. Effect of intercropping on the incidence of pigeonpea pests in Orissa, India. Pigeonpea Newsletter 9:24-25.

Patnaik, H.P., Samolo, A.P., and **Samolo, B.N.** 1986. Susceptibility of some early varieties of pigeonpea for pod borers under protected conditions. Legume Research 9:7-10.

Phelps, R.J., and **Oostihuizen, M.J.** 1958. Insects injurious to cowpea in Natal region. Journal of the Entomological Society of South Africa 21:286-295.

Prasad, D., Premchand, and **Haque, M.F.** 1989a. Incidence of pod boring insects in different cultivars of pigeonpea. Journal of Research, Birsa Agriculture University 1:79-80.

Prasad, D., Premchand, and **Haque, M.F.** 1989b. Relative susceptibility of different cultivars of redgram. Journal of Research, Birsa Agriculture University 1:179-181.

Rahman, M.M. 1991. Control measures for important insect pests of major pulses. Pages 139-146 *in* Advances in pulses research in Bangladesh: Proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Rahman, M.M., and **Rahman, M.S.** 1988. Timing and frequency of insecticide application against *Maruca testulalis* Geyer infesting short-duration pigeonpea in Bangladesh. Legume Research 11:173-179.

Ramasubramanian, G.V., and **Sundara Babu, P.C.** 1988. Effect of host plants on some biological aspects of spotted pod-borer, *Maruca testulalis* (Lepidoptera: Pyralidae). Indian Journal of Agricultural Sciences 58:618-620.

Ramasubramanian, G.V., and **Sundara Babu, P.C.** 1989a. Comparative biology of the spotted pod-borer, *Maruca testulalis* (Geyer) on three host plants. Legume Research 12(4):177-178.

Ramasubramanian, G.V., and **Sundara Babu, P.C.** 1989b. Ovipositional preference of spotted pod-borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). Legume Research 12(4):193-195.

Reed, W., and **Lateef, S.S.** 1990. Pigeonpea: pest management. Pages 349-374 *in* The Pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds.). Wallingford, UK: CAB International.

Rejesus, R.S. 1978. Pests of grain legumes and their control in the Philippines. Pages 47-52 *in* Pests of grain legumes: ecology and control (Singh, S.R., van Emden, H.F., and Taylor, J.A., eds.). London, UK: Academic Press.

Sahoo, B.K., and **Patnaik, N.C.** 1993. Susceptibility of pigeonpea cultivars to pod borers in Orissa. International Pigeonpea Newsletter 18:31-33.

Samolo, A.P., and **Patnaik, H.P.** 1986. Efficacy of different insecticides and their frequency of application on the pod borers infesting pigeonpea. Madras Agriculture Journal 73:352-354.

Satsijati, Sunaryono, H., and **Darliah** 1986. Effect of pruning the tops of some varieties of "bush sitao" yardlong bean (*Vigna sinensis*) on their yield. Buletin Penelitian Hortikultura 14:85-92.

Saxena, K.B., Hettiarachchi, K., Chandrasena, G.D.S.N., Iqbal, Y.B., Shanower, T.G., Bhagwat, V.R., Fonseka, H.H.D., and **Joseph, K.D.S.M.** 1998. Breeding pigeonpeas for resistance to *Maruca vitrata.* Paper presented at the National Symposium on Management of Biotic and Abiotic Stresses in Pulse Crops, 25-28 Jun 1998. Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India.

Saxena, K.B., Lateef, S.S., Ariyaratne, H.P. Fonseka, H.H.D., and **Dharmasena, C.M.D.** 1996. *Maruca testulalis* damage in determinate and indeterminate lines of pigeonpea. International Pigeonpea Newsletter 3:91-93.

Shanower, T.G., Romeis, J., and **Peter, A.J.** 1996. Pigeonpea plant trichomes: multitrophic level interactions. Pages 76-88 *in* Biotechnological perspectives in chemical ecology of insects (Ananthakrishnan, T.N., ed.). New Delhi, India: Oxford and IBH.

Sharma, H.C. 1998. Bionomics, host plant resistance, and management of the legume pod borer, *Maruca vitrata* - a review. Crop Protection 17:373-386.

Sharma, H.C. (In press). Legume pod borer, *Maruca vitrata*: Insect plant relationships. Insect Science and its Application.

Siddig, S.A. 1982. Major pests of faba beans in Sudan. Pages 277-283 *in* Proceedings of the

Faba Bean Conference, 7-11 Mar 1981, Cairo, Egypt (Hawtin, G., and Webb, C., eds.). Den Haag, Netherlands: Martinus Nijhoff Publishers.

Singh, L. 1991. Production aspects of pigeonpea and future prospects. Pages 121-127 *in* Uses of tropical grain legumes: Proceedings of a Consultants Meeting, 27-30 Mar 1989, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Singh, R.P., Singh, Y., and **Singh, S.P.** 1985. Field evaluation of neem (*Azadirachta indica* A. Juss) seed kernel extracts against the pod borers of pigeonpea, *Cajanus cajan* (L.) Millsp. Indian Journal of Entomology 47:111-112.

Singh, S.R., and **Allen, D.R.** 1980. Pests, diseases, resistance, and protection in cowpea. Pages 419-443 *in* Advances in legume science (Summerfield, R.J., and Bunting, A.H., eds.). Kew, Richmond, Surrey, UK: Royal Botanic Gardens.

Singh, S.R., and **Jackai, L.E.N.** 1988. The Legume pod-borer, *Maruca testulalis* (Geyer): past, present and future research. Insect Science and its Application 9:1-5.

Sontakke, B.K., and **Mishra, P.R.** 1991. Comparative efficacy and economics of synthetic pyrethroids in the management of pod borer complex of pigeonpea. Indian Journal of Plant Protection 19:167-170.

Srivastava, C.P., Pimbert, M.P., and **Jadhav, D.R.** 1992. Monitoring of adult population of *Maruca testulalis* (Geyer) with light traps at Patancheru and Hissar in India. Pigeonpea Newsletter 15:27-28.

Subasinghe, S.M.C., and **Fellows, R.W.** 1978. Recent trends in grain legume pest research in Sri Lanka. Pages 37-41 *in* Pests of grain legumes: ecology and control (Singh, S.R., van Emden, H.F., and Taylor, J.A., eds.). London, UK: Academic Press.

Sundara Babu, P.C., and **Rajasekaran, B.** 1984. Studies on the control of pod borers and pod fly on redgram (*Cajanus cajan* L.). Pesticides 18:24-26.

Taylor, T.A. 1967. The bionomics of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae), a major pest of cowpeas in Nigeria. Journal of West African Science Association 12:111-129.

Taylor, W.E. 1978. Recent trends in grain legume pest research in Sierra Leone. Pages 93-98 *in* Pests of grain legumes: ecology and control (Singh, S.R., van Emden, H.F., and Taylor, J.A., eds.). London, UK: Academic Press.

Tayo, T.O. 1988. Flower and pod development in three cowpea (*Vigna unguiculata* (L.) Walp.) varieties with varying susceptibility to the pod-borer, *Maruca testulalis* (Geyer). Insect Science and its Application 9:249-253.

Traore, S. 1993. Inventory and distribution of groundnut insect pests in Burkina Faso. Pages 51-52 *in* Summary Proceedings of the third ICRISAT Regional Groundnut Meeting for West Africa, 14-17 Sep 1992, Ouagadougou, Burkina Faso. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Usua, E.J., and **Singh, S.R.** 1977. Parasites and predators of the cowpea pod-borer, *Maruca testulalis* (Lepidoptera: Pyralidae). Nigerian Journal of Entomology 1:100-102.

Usua, E.J., and **Singh, S.R.** 1979. Behavior of cowpea pod borer, *Maruca testulalis* Geyer. Nigerian Journal of Entomology 3:231-239.

Valdez. P.C. 1989. Host Plant Resistance in Cowpea, *Vigna unguiculata* (L.) Walp. var. *unguiculata,* to the Pod Borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). Los Baños, Laguna, Philippines: Philippines University College. 112 pp.

Venkaria, M.V., and **Vyas, H.N.** 1985. Chemical control of pod borer complex in greengram, *Vigna radiata* (L.) Wilczek with certain insecticides alone and in combination with Miraculan – a plant growth stimulant. Legume Research 8:111-113.

Vishakantaiah, M., and **Jagadeesh Babu, C.S.** 1980. Bionomics of the tur webworm, *Maruca testulalis* (Lepidoptera: Pyralidae). The Mysore Journal of Agricultural Sciences 14:529-532.

Visvanathan, T., Sasitharan, P., and **Kareem, A.A.** 1983. Compatibility studies with monocrotophos (corophos) 36 WSC and diammonium phosphate in terms of bioefficacy against pod borers on green gram (*Vigna radiata* L.). Indian Journal of Farm Chemicals 1:8-20.

Wooley, J.N., and **Evans, A.M.** 1979. Screening for resistance to *Maruca testulalis* (Geyer) in cowpea (*Vigna unguiculata* (L.) Walp.). The Journal of Agricultural Sciences 92:417-425.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

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ICRISAT was established in 1972. It is one of 16 nonprofit research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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