Spotted Pod Borer, *Maruca vitrata* Geyer in Legumes: Ecology and Management

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Spotted pod borer is one of the key insect pests of tropical food legumes damaging tender leaf axils, flower buds, flowers and pods by webbing and boring clusters of flowers or pods during cooler parts of the year on about 39 hosts. Short duration, determinate pigeon peas and cowpeas with compact clusters are more susceptible. In cowpea the damage was about 25-40% and in pigeonpea, it was 9-84% across the globe. Female moths laid about 200 flat scaly eggs on floral buds, flowers, leaves, leaf axils, terminal shoots and tender pods. Larvae are photonegative and larval period lasted from 8 to 21 days on different hosts. Pupal period lasted from 6 to 14 days. Longevity of female moths was more (7-10 days) than males (5-6 days). Peak incidence started from 40th (October) to 47th standard week (November). Temperature preferenda ranged from 20 to 28°C for growth and development. For screening pigeon pea genotypes for resistance, a comprehensive methodology (Plant Susceptibility Index) involving webbing damage, larval density and flower damage was attempted. In cowpea and pigeonpea, higher phenol, lower sugar, amino acid and crude fibre contents might contribute for resistance. Qualitative traits such as red petals, pink pod streaks may also supplement for low resistance. A total of 27 parasitoids, 20 predators, two protozoans and two bacteria were reported on egg, larva and pupa. Cultural practices such as removing leguminous weeds, trap cropping with *Crotalaria* spp., intercropping monocots like sorghum, maize, pearl millet or finger millet, mung and urd beans reduced pod damage in main crop. Biocides like Neem Seed kernel extract (NSKE), Neem Oil (NO) and *Bacillus thuringiensis* (Bt) showed varied levels of potency either alone or in combination with insecticides. Due to concealed larval habitat, insecticides showed varied levels of effectiveness. However, Controlled Droplet Application (CDA), strip application and sequential spraying of selected insecticides were effective in reducing pod damage.

**Key words:** Spotted pod borer, *Maruca vitrata* (*M. testulalis*), grain legume pest-damage, hosts, resistance, natural enemies, management.

The legume pod borer, Spotted Pod Borer (SPB) or *Maruca* Pod Borer (MPB), *Maruca vitrata* Geyer. (*M. testulalis*) (Lepidoptera; Pyralidae) was first reported on "Katjan" (bean) in Indonesia (Dietz, 1914) and described by Hubner but the work was posthumously published by Geyer. Normally, larvae feed on anthers, filaments, styles, stigma and ovaries of flowers (Taylor, 1967; Singh and Allen, 1980). Jackai (1981) observed the infestation to start from terminal shoots of cowpea 21 days after planting and then spreading to reproductive parts. Intensity was the highest on flowers followed by flower buds, terminal shoots and pods. Goud and Vastrad (1992) observed young larvae boring the stems of black gram from leaf-axils of branches causing wilting. In pigeon pea, the larvae damaged leaves by rolling, webbing and continued feeding inside the rolled leaves. At flowering and pod formation stages, larvae fed on buds, flowers and pods by webbing them (Sharma, 1998).

**Damage potential**

Larvae damage stems, peduncles, flowers and pods of several tropical and sub-tropical grain legumes. Hence damage was observed from seedling to podding stages (Singh and Taylor, 1978). Singh and Allen (1980) estimated losses to range from 20 to 60 per cent in cowpea. According to Patel and Singh (1976), in pigeon pea the larvae caused 10 per cent damage to fruitlets and pod damage ranged from 25 to 40 per cent. Vishakantiah and Jagadeesh Babu (1980) estimated the infestation levels to range from 9 to 51 per cent under Bangalore conditions in pigeon pea. Karel (1985) also observed more larvae (52.3%) on flowers than on pods (37.8%), and leaves (9.9%). In Sri Lanka, Dharmasena et al. (1992) reported about 84 per cent pod borer damage in pigeon pea. Ganapathy (1996) estimated an avoidable loss of nearly 50.0% and flower drop damage ranging from 9.4 to 12.7% in short, medium and long duration pigeon pea cultivars in Tamil Nadu.
India. In pigeon pea, first-instar larvae prefer flowers over pods and leaves while third instar larvae prefer pods compared to flowers and leaves (Sharma, 1998).

**Host range and suitability**

Legume pod borer is reported to feed on 39 host plants (Akinfenwa, 1975; Atachi and Djihou, 1994) and has been reported to occur throughout the tropics and sub-tropics as summarized below. (Table 1)

<table>
<thead>
<tr>
<th>Place</th>
<th>Host</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Puerto Rico</td>
<td>Common beans</td>
<td>Wolcott (1933)</td>
</tr>
<tr>
<td>USA</td>
<td>Common beans, cowpea, blackgram, greengram</td>
<td>Williamson (1943)</td>
</tr>
<tr>
<td>The Philippines</td>
<td>Cowpea</td>
<td>Djamin (1961)</td>
</tr>
<tr>
<td>India</td>
<td>Dwarf pigeonpea</td>
<td>Srivastava (1964)</td>
</tr>
<tr>
<td>Taiwan</td>
<td>All grain legumes</td>
<td>Lee (1965)</td>
</tr>
<tr>
<td>Australia</td>
<td>Navy bean</td>
<td>Passlow (1968)</td>
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<tr>
<td>Asia</td>
<td>Common beans, vegetable cowpea</td>
<td>Das and Islam (1968)</td>
</tr>
<tr>
<td>Fiji Islands</td>
<td>Pigeonpea, soybean, cowpea, blackgram, green gram</td>
<td>Oel - Dharma (1969)</td>
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<td>Indonesia</td>
<td>Pigeonpea</td>
<td>Subasinghe and Fellowes (1978)</td>
</tr>
<tr>
<td>Papua</td>
<td>Winged beans</td>
<td>Lamb (1978)</td>
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<tr>
<td>New Guinea</td>
<td>Labrador</td>
<td>Lalasangi (1978)</td>
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<tr>
<td>Sri Lanka</td>
<td>Cowpea, lablab and cowpea</td>
<td>Babu (1980)</td>
</tr>
<tr>
<td>East, west and South Africa</td>
<td>Cowpea</td>
<td>Akifenwa (1975)</td>
</tr>
<tr>
<td>Brazil</td>
<td>Soybean</td>
<td>Taylor (1978)</td>
</tr>
<tr>
<td>Kenya</td>
<td>Cowpea, lablab and cowpea</td>
<td>Okeyo - Owuor and Ochieng (1981)</td>
</tr>
</tbody>
</table>

Table 1. Host range of M. vitrata

The most frequent host plants are Cajanus cajan, Vigna unguiculata, Phaseolus lunatus and Pueraria phaseoloides. Growth indices (GI) for larvae were; 4.14 on pigeonpea, 4.63 on cowpea, and 5.17 on hyacinth bean (Ramasubramanian and Sundarababu, 1988 and 1989). Whereas, the GI was 8.1 in cowpea, 6.5 in pigeonpea, 6.3 in green gram and 5.8 in black gram. Howe's Growth Index (Howe, 1971) was also maximum in cowpea (0.07) followed by pigeonpea and green gram (0.06 each) and the least in black gram (0.05). Success index was the highest in pigeonpea (0.92) followed by black gram (0.89) and green gram (0.87) (Ganapathy, 1996).

**Bionomics**

Wolcott (1933) made initial observations on biology on lima beans in Puerto Rico. Later, the biology of this pest on cowpea was well studied by Taylor (1967), Akinfenwa (1975), Okeyo - Owuor and Ochieng (1981) and Jackai and Singh (1983). In India, the details of biology in pigeonpea were described by Vishakantaiah and Jagadeesh Babu (1980) and Lalasangi (1988). Ramasubramanian and Sundarababu (1989) studied its comparative biology on pigeon pea, lablab and cowpea.

**Egg**

Eggs were flat, slightly elongate, pale yellowish, translucent with faint reticulate sculpturing on thin and delicate chorion (Taylor, 1978; Vishakantaiah and Jagadeesh Babu, 1980). Eggs were observed on floral buds, flowers, leaves, leaf axils, terminal shoots and tender pods (Bruner, 1931; Wolcott, 1933; Taylor, 1963). Number of eggs laid by a female moth and incubation period of eggs varied on different hosts. On cowpea, Taylor (1967) recorded a maximum of 140 eggs. Egg numbers ranged from 6 to 189 (Akinfenwa, 1975). Ochieng et al. (1981) and Okeyo-Owuor and Ochieng (1981) observed egg numbers to range from 174 to 194 which hatched in 2.3 days. On artificial diet, eggs hatched in 2.5 days (Ochieng and Bungu, 1983). Lalasangi (1988) recorded as high as 338 eggs per female on pigeonpea flower buds. Whereas, Vishakantaiah and Jagadeesh Babu (1980) observed 5 to 15 egg masses that hatched in 3.3 days. Ramasubramanian and Sundara Babu (1989) recorded an average of 35.3 eggs by a female moth that hatched in about 2.9 days. Arulmozhi (1990) recorded 176 eggs on cowpea, 93 eggs on soybean flour diet and 91 eggs on cowpea flour diet with the egg period ranging from 3.3 to 3.7 days.

**Larva**

Larval stage consisted of five instars (Taylor, 1967; Nyiira, 1971; Akinfenwa, 1975). Singh and Taylor (1978) found that the larvae became active in evenings and fed on the plant throughout night and were photonegative. Larval body is translucent with a pair of dark brown spots on each segment. The intensity of spotting varied with host and sometimes even without spots. Larval period lasted for 8 to 14 days in cowpea (Ochieng et al., 1981; Okeyo - Owuor and Ochieng, 1981). Jackai and Singh (1983) registered a larval period of 7.3 days in cowpea, 16.4 days in pigeonpea, 21 days in Crotalaria juncea, 19.9 days in C. miserensiensis, 16.9 days in C. mucronata, 14.0 days in C. saltiana and a low 13.2 days in C. amazonas. On an artificial diet, the larval period ranged from 13.5 to 14.3 days (Ochieng and Bungu, 1983). Ramasubramanian and Sundara Babu (1988) recorded a larval period of 13.9 days in cowpea, 13.3 days in pigeonpea and a low 12.9 days on hyacinth bean. Larval period lasted for 12.7 days on pigeonpea (Vishakantaiah and Jagadeesh Babu, 1980). According to Arulmozhi (1990), larval period lasted for 11.1 days on cowpea, 16.5 days on cowpea flour diet and 14.4 days on soybean flour diet. Whereas larval period varied from 11.9 days in cowpea to 14.7 days in pigeonpea, 15.4 days in green gram and 16.5 days in black gram (Ganapathy, 1996).
**Pupa**

The pre-pupal period was two days during which larval feeding ceased completely. The spotting on skin also disappeared and the larvae constructed a gauze-like cocoon on dry leaves, flowers and debris, completely concealed (Taylor, 1978; Vishakantaiah and Jagadeesh Babu, 1980; Ramasubramanian and Sundarababu, 1988; Jackai and Singh, 1983; Arulmozhi, 1990). Pupae formed at the time of prepupal stage were green which soon were sclerotized and became brown. Moths emerged in about 6 to 9 days (Taylor, 1978; Jackai and Singh, 1983). Obtect pupae were brown, protected with a gauze-like, matty cocoon. Each pupa measured 12.5 mm in length and 3.0 mm in width. Pupal period lasted for eight to ten days (Vishakantaiah and Jagadeesh Babu, 1980). Ochieng et al. (1981) observed no pupal diapause and the pupal period extended between five to 14 days on cowpea. Jackai and Singh (1983) recorded the mean pupal period on seven legumes and cowpea as, 11.6 days on Crotalaria juncea, 9.3 days on C. miserensiiens, 8.4 days on C. mucronata, 7.4 days on C. saltiana, 7.8 days on C. amazonas, 11.1 days on pigeonpea and 5.6 days on cowpea. According to Ramasubramanian and Sundarababu (1988), pupal period was minimum (6.4 days) in pigeonpea followed by cowpea (6.9 days) and lablab (7.5 days). Arulmozhi (1990) recorded the maximum pupal weight (55.7 mg) coupled with maximum pupal period (5.9 days) on cowpea flower buds.

On artificial diet, the mean pupal period lasted for six to seven days (Ochieng and Bungu, 1983). Jackai and Raulston (1988) recorded the pupal periods as, 6.5 days on soybean flour-wheat germ diet, 6.9 days on cowpea-casein diet, 6.5 days on cowpea-yeast diet and 7.1 days on corn-soymilk diet. Pupal period ranged from 6.4 days in soybean flour diet to 7.1 days in cowpea flour diet (Arulmozhi, 1990).

**Adult**

Moths were medium-sized, with fuscous brown forewings bearing a lunulate black-edged white spot in the end of the cell. A black-edged, semi hyaline band beyond the cell from below the costa was conspicuous. Hind wings were semi-hyaline white, with a basal fuscous area and a spot at the upper angle of the cell. A marginal fulvous brown fuscous band from costa to vein 1c with an inner irregular edge was very distinct. Both sexes were morphologically similar (Hampson, 1976).

Average life-span of sexes varied on different hosts. Ochieng et al. (1981) observed on cowpea that the female moths lived for 9.5 days than males that lived only for 7.7 days but on artificial diet, the longevity was reduced to 7.1 days in females and 6.3 days in males (Ochieng and Bungu, 1983). Ramasubramanian and Sundarababu (1988) observed the longevity periods to vary from 8.6 to 5.9 days in cowpea, 8.5 to 6.1 days on pigeonpea and 10.0 to 6.1 days on lab-lab in both sexes. On soybean flour diet, the female and male moths lived for 8.3 days and 5.8 days respectively while on cowpea flour diet, the periods varied from 9.0 to 6.1 days in both sexes. Moreover, adult emergence was 96.4 per cent when reared on cowpea flower buds (Arulmozhi, 1990).

**Life cycle**

Booker (1965) observed that the total life cycle lasted for about 30 to 35 days while Akinfenwa (1975) recorded 23 to 30 days on cowpea in northern Nigeria. In southern Nigeria, it varied from 18 to 25 days (Taylor, 1978). Okeyo-Owuor and Ochieng (1981) recorded the life cycle to range from 20 to 57 days on cowpea. In pigeonpea, life -cycle extended up to 27 days (Vishakantaiah and Jagadeesh Babu, 1980) and the mean life-cycle ranged from 30.2 days in males to 32.6 days in females (Ramasubramanian and Sundarababu, 1988). Jackai et al. (1990) reported that four or five nights of pairing resulted in highest mating percentage and oviposition. Best mating and oviposition were recorded at 1:1 ratio (10 male : 10 female) and mating occurred between 21.00 h and 05.00 h when temperature ranged from 20 to 25°C and RH more than 80 per cent. Peak mating activity took place between 02.00 h. and 03.00 h.

**Seasonal Incidence**

According to Taylor (1967), initial infestation of spotted pod borer on cowpea commenced from the moths emerging from alternative host plants and from the flowers of early crop, with the peak during June-July. While the first generation moths emerged in June-July, the second generation emerged between July and September. The loss on late crop was more than the earlier crop. Peak larval incidence was recorded in August and the peak adult catches during November in Nigeria (Akinfenwa, 1975), with peak adult catches between 18.40 h and 04.45 h in light traps. In cowpea, major pests reached their peaks during September-October (Nangju et al., 1979). Field damage was heavy in April and May plantings, low in June-July but again high in August-September plantings of cowpea (Akingbouhungbe, 1982). Ezuch (1982) also found that cowpea planted in June and October suffered heavy damage with the maximum in August and least in April plantings. Lalasangi (1988) recorded the peak incidence during July, August and October in cowpea. At ICARISAT, Hyderabad, Srivastava et al. (1992) recorded more moth catches in light traps from early November to mid December with the peak during the 46th and 47th standard weeks in November. A second peak was recorded in September during the 37th and 38th standard weeks. The third and smallest peak occurred in early February (6th standard week).
At Hisar, moth activity was observed from mid September to mid October (37th to 43rd standard weeks) with the peak between mid September to mid October and there were no subsequent peaks. The peaks during 40th to 42nd standard weeks coincided with the flowering of medium and long duration types sown in the first fortnight of June. However, there was no secondary peak (Srivastava et al., 1992). In Sri Lanka, Saxena et al. (1992) studied the population dynamics of pod borer complex in pigeonpea during 1990/91 ‘Maha’ season. Larval population was high in mid-October, gradually decreasing towards mid-November. Grain yield of pigeonpea planted in November was high because of low incidence. Grain yield in ‘Yala’ season was comparatively higher due to low pod borer damage. M. testulalis incidence was high in pigeonpea crop planted with the onset of ‘Maha’ rains in mid-October. A delay in planting pigeonpea to mid-October reduced the damage by pod borers. Development to adult stage was completed only at 22°C and 28°C and temperatures above 34°C were lethal to the larvae (Jackai and Inang, 1992). Kushwaha and Malik (1987) and Kabaria et al. (1993) advocated early sowing during the first week of June to avoid pod borer damage. Akhauri et al. (1994) observed the incidence between mid-October and end of November with the peak at the end of November. Bajpai et al. (1995) also reported the incidence to commence from early September with the peak during mid October and then declining at Pant Nagar. Sharma (1996) opined that the high humidity and low temperatures during the months of November-December might be conducive for the pest build up. Correlation between incidence, RH and rain fall were positive while temperatures had negative influence (Ganapathy, 1996; Sharma et al., 2000). Lower threshold temperature for pupae was 15.6-17.8°C, and upper threshold was 28-34°C. The incidence increased with the initiation of flowering, and the highest population at full podding stage (Imosanen and Singh, 2005).

**Varietal Screening**

Dabrowski et al. (1983) found that the growth stage of cowpea modified the expression of resistance. Five to seven shoot stages was the most suitable for screening in the preflowering period. Echendu and Akingbohungbe (1990) confirmed higher levels of resistance in four cowpea entries and lower levels of resistance in three entries using free choice and no-choice tests. Saxena et al. (1992, 1995) rated the susceptibility levels of pigeonpea cultivars on a 1-9 scale and found that the determinate types recorded a high susceptibility score of 7.09 while the indeterminate types registered a lesser susceptibility score of 5.29 only. Among the determinate types, MPG 359, MPG 531, MPG 532 and MPG 566 recorded a damage rating score of less than 3. Eighteen determinate types suffered maximum damage. During the ‘Yala’ season, MPG 537, MPG 664, MPG 665, MPG 359 and ICPI 88034 gave higher grain yields. However, these suffered 10 to 25 per cent M. testulalis damage in the following ‘Maha’ season under insecticide free conditions. ICP 909 and T21 were found to be tolerant to pod fly and pod borers. Early types that bore compact terminal flower clusters provided the favourable microhabitat. Moreover, since the flowers were closely opposed in early types, each larva could reach and web easily more number of flowers with minimum energy expenditure. Consequently, the magnitude of damage tended to be higher (Shanower, 1995) unlike medium and late types where the racemes were not compact. Saxena (1974b), Lal et al. (1981), Yadava et al. (1988), Ujagir (1989), Lateef and Reed (1991), Sahoo and Patnaik (1993), Bajpai et al. (1995) and Sahoo (1995) reported similar results in the early pigeonpea types of UPAS 120, Ageti, Prabhat, Manak, ICPL 316 and ICPL 87. This pest was the single major factor responsible for heavy loss in early, medium late maturing pigeon pea genotypes (Shanower et al., 1999). Larvae fed by remaining inside the webbed mass of leaves, flowers and pods. This concealed feeding complicates the management of this pest as pesticides and natural enemies have difficulty in penetrating the shelter to reach the larvae (Sharma, 1998).

Pigeon pea genotypes with determinate growth habit, where pods are bunched together at the top of the plant were more prone to damage than in the indeterminate ones (Sharma et al., 1999). During 2005 and 2009, incidence of spotted pod borer was high in early (140-150 days) and late maturing (190-200 days) pigeon pea varieties, moderate in medium duration (170-180 days) and was high in late sown conditions and also in varieties having clustering type of branching habit in Karnataka, India (Gopali et al., 2010). However, Sheldrake et al. (1979) opined that pigeon pea crop generally produces an over abundance of flowers in the first flush. In the event of loss of first flush of flowers due to insect damage or moisture stress, the crop could make good the loss with a succeeding compensatory flush with more yield potential, provided, the compensatory flush was free from insect damage or any stress.

In pigeonpea, *M. testulalis* is more damaging to flowers than pods. Hence, a comprehensive criterion encompassing all the parameters of damage such as webbing damage, larval density, flower damage, seed damage and pod damage will be ideal to assess the levels of resistance. The methodology suggested by Jackai (1982) for screening cowpea was modified and adopted for classifying pigeon pea genotypes by Ganapathy (1996). The classification was based on Plant Susceptibility Index (PSI) from the number of webbings per plant, number of larvae per plant and flower damage per cent. Based on PSI, genotypes were classified as: Highly Resistant
(HR), Resistant (R), Moderately Resistant (MR), Moderately Susceptible (MS), Susceptible (S) and Highly Susceptible (HS) on a rating scale of 0 to 9. Out of 217 pigeon pea genotypes field screened, no entry was free from damage. Eight genotypes, viz., ICP 7954, ICP 8392, ICP 8400, ICP 11059, ICPX 6484, JA 3, JAS and SMR 1258/2 were identified as resistant. The PSI values were low in ICP 8392 (10.7), ICP 8400 (11.7) SMR 1258/2 (12.6) and high in JA 5 (14.9) and HY 3 A (15.8). Replicated trials showed that ICP 8392 was the least damaged with low seed and pod damage levels. Among the qualitative traits of resistance, flower petals with red or reddish streaks were more damaged (PSI=9.6) followed by pink (PSI=8.7) while yellow coloured petals were least damaged (PSI=8.3). Similarly, pink pods or pods with pink streaks were more damaged (PSI=10.06) than green with brown streaks (PSI=8.9), brown (PSI=7.5) or Green streaks (PSI=8.1). The preference towards darker colours like red or pink might be due to the negative phototrophic behavior of larvae that prefer a concealed environment either inside webs, flowers or pods. Red or pink colour would have simulated a favourable darker environment than yellow.

**Mechanisms of resistance**

**Antixenosis**

Ramasubramanian and Sundarababu (1989) showed that oviposition preference of females was more on the inflorescence of hyacinth bean followed by cowpea and pigeon pea. Maximum numbers of eggs were laid three days after mating on the preferred host. In cowpea and pigeon pea, maximum numbers of eggs were laid on the fourth day after mating.

**Antibiosis**

Macfoy et al. (1983) showed that the larvae caused less damage on TVu 946 cowpea than of Ile Brown and VITA-1 cowpeas under field and screen house experiments. VITA-1 cowpea recorded higher concentrations of sugars, amino acids, lower amounts of phenols and crude fibre whereas in resistant TVu 946 the contents were on the reverse. Okech and Saxena (1990) confirmed the resistance level of TVu 946 and VITA-5 cowpeas based on nutritional studies. Later, Oghiakhe and Odulaja (1993a) studied the variations in resistance to 18 cowpea cultivars based on principal component analysis from the damage on floral buds, flowers and sliced pods. Using cluster analysis, Oghiakhe and Odulaja (1993b) found that MRx 6-84F had wider adaptability in the presence of Maruca infestation. TVu 946 performed best, and was in a single cluster. On pigeonpea, the third-instar larvae consumed 27.0 to 47.2 mg food on the flowers, and had growth rates (GR) of 114.7% on ICPL 88020 to 207.3% on ICPL 85010. Approximate digestibility (AD) was lower on ICPL 85010 than on ICPL 90011. Efficiency of conversion (ECI) of ingested food into body matter was lower on ICPL 90011 compared to ICPL 85010 and ICPL 88007. The fifth-instar larvae consumed 52.3 to 80.6 mg of food on pods, and showed growth rates of 30.1 to 41.8%. EC1 was lowest on ICPL 90011, followed by that on ICPL 88020, ICPL 88007, and ICPL 85010 (Sharma, 1998). Higher phenol content in seeds (579 ng/g) might be the cause of low pod damage compared to flowers (167.5ng/g) in pigeonpea (Ganapathy, 1996).

**Tolerance**

Short duration pigeon pea lines, ICPL 88037 and MPG 679 that recorded low damage (10 to 25%) showed excellent recovery from damage when evaluated for recovery resistance to *M. testulalis* on a 1 to 5 scale (Saxena et al., 1992 and 1995). ICPL 88034 and MPG 679 with low *Maruca* damage (0-25%) showed excellent recovery from damage (Saxena et al., 1996).

**Contributing factors for resistance**

In cowpea, pod size and rate of pod growth were important in the susceptibility to pod borer damage (Tayo, 1988). Singh et al. (1976) and Oghiakhe et al. (1991) explained that the resistant cowpea types TVu 946 and TVu 4557 suffered less stem damage because of smaller stem diameter coupled with closely knit interlocking collenchyma cells. As a result, inter-cellular spaces became restricted which blocked free larval movement. Flower and pod damage levels were also low as these varieties possessed abnormally long peduncles which held the pods above plant canopy with wider angles but high in varieties with closely held pods. Pods contacting any plant parts sustained more damage at the point of contact (Singh, 1978). Pod wall toughness had no significant effect on resistance to SPB in cowpea (Oghiakhe et al., 1992). Pods with wide angles (> 89°) were damaged on one side, and rarely on both sides. Erect and profuse flowering contributed to the resistance of TVu 946 (Oghiakhe et al., 1993b). Open canopy, long peduncles, erect pods with wide angles, profuse flowering, pod size, and rate of pod growth can be used to select for resistance to *M. vitrata* (Sharma, 1998). Pigeonpea genotypes with pink/pinkish streaks on pods suffered more damage than green and brown pods with streaks. Similarly, genotypes with red or pinkish streaks on standard petals were more damaged than yellow (Ganapathy, 1996).

**Natural enemies**

The extent of parasitism on larvae ranged from 5.7 to 6.8 per cent by *Phanertoma* sp. and *Braunioa* sp. (Don Pedro, 1983). Parasitoids and pathogens contributed 41% and 36% to the total generation mortality (K) at two sites, respectively. Mortality due to disappearance, which also included predation, accounted for about 60%. Life table data and survival curves revealed high mortality (ca. 98%), most of which occurred in the early life stages (Otiene and...
A total of 27 parasitoids, 20 predators, two protozoans and two bacteria were reported on egg, larva and pupa as listed below. (Table 2)

### Table 2. Natural resources of *M. Vitrala*

<table>
<thead>
<tr>
<th>Natural enemy</th>
<th>Stage</th>
<th>Reference</th>
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<tbody>
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<td><em>Tachinidae</em></td>
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<tr>
<td><em>Exorista xanthaspis</em> (Wiedemann)</td>
<td>Larva</td>
<td>Barrion et al. (1987)</td>
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<td><em>Palexorista solemnis</em> (Walker)</td>
<td>Larva</td>
<td>Barrion et al. (1987)</td>
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<td><em>Peirbaea orbata</em> (Wiedemann)</td>
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<td>Barrion et al. (1987)</td>
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<td><em>Zygobothria atropivora</em> (Rob.Desv.)</td>
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<td>Barrion et al. (1987)</td>
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<td><em>Zygobothria ciliata</em> (Wulp)</td>
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<td>Barrion et al. (1987)</td>
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<td><em>Theilairosoma</em> sp.</td>
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<tr>
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<td>Usua and Singh (1977)</td>
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<td><strong>Hymenoptera</strong></td>
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<td><em>Apanteles</em> sp.</td>
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<td><em>Bracon greeni</em> Ashm.</td>
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<td><em>Bracon</em> sp.</td>
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</table>

**Economic Injury Levels**

In pulses, reports on EIL are very limited. Saxena et al. (1987) fixed an EIL of one egg per 1.72 metre row at flowering and 1 larva per 0.13 metre row at pod formation for Lampiedes boeticus (L.) in mung bean. Arulmozhi (1990) fixed the EIL for M. testulalis in cowpea. A threshold of 40% larval infestation in flowers was established (Ogunwolu, 1990) in cowpea. Ganapathy (1996) enumerated an EIL of 3.0 larvae per plant and a combined threshold of 2 pairs each of M. testulalis and Exelastis atomosa per plant at 50% flowering stage when both occurred together on pigeon pea.

**Management**

**Cultural practices**

Taylor (1977) observed less damage by M. testulalis on cowpea intercropped with maize. Singh and Singh (1978b) also concluded that the changes in crop canopy brought out by intercropping with blackgram, greengram, cowpea, sorghum and pearl millet delayed the incidence of pod borers in...
and inhibited borer damage in pigeon pea cultivar, Asha (Gopali et al., 1993). Flower, seed and pod damage levels were low in pigeonpea intercropped with maize, sorghum, ragi, pearl millet and cowpea (Ganapathy, 1996). Intercropping with sorghum, sowing during the first fortnight of June and removing leguminous weeds reduced pod borer damage in pigeon pea cultivar, Asha (Gopali et al., 2010).

**Biocides**

Neem seed powder and neem kernel extract were also effective against legume pod borer (Singh et al., 1985; Hongo and Karel, 1986; Kareem et al., 1989; Tanzubil, 1991; Jackai et al., 1992) but neem seed kernel extract (NSKE) was less effective than fenvalerate and monocrotophos. Aqueous extracts of neem seed kernels and chilli fruits exhibited high deterrent effects against the pests of common bean (Hongo and Karel, 1986). Among the two antifeedants isolated from *Teprosia elata* (D.), isopongaflavone displayed higher activity than tephrosin on *M. testulalis*. Rottenone was also found to be a good antifeedant (Bentley et al., 1987; Lwande et al., 1986.). Harrison and obacunone had antifeedant activity against the larvae (Hassanali et al., 1986). Cobbinah and Osei-Owusu (1988) reported that defatted neem seed powder applied as dust on soil around the plant reduced the incidence of *M. testulalis* and increased pod yield. Degaonkar et al. (1988) obtained the highest benefit-cost ratio with 5 per cent neem leaf extract. Ibvijaro and Bolaji (1990) also observed that pod borer damage was reduced by four sprays of *Azadirachta indica* or *Piper guinense* extracts. Different concentrations of neem oil emulsifiable concentrate (NOEC) (5, 10, and 20%) exhibited high degree of activity against *M. vitrata* (Jackai and Oyediran, 1991). The effective ness of NSKE and NO against the pod borers of pigeon pea was well-documented by Shambulingappa (1994) and Wanjari (1994). Neem oil slurry emulsifiable concentrate (NOSEC) and 5% NOEC exhibited similar insecticidal activity, but neem oil and NOEC were superior to NOSEC. Flower infestation was not reduced by 5 and 10% neem leaf extracts (Bottenberg and Singh, 1996). Ganapathy (1996) found that Neem Seed Kernel Extract 5% and Neem Oil 3% recorded low larval numbers (1.0 and 1.3/ plant), flower damage (7.7 and 10.4%), webbings (1.6 and 1.5/plant) and pod damage (6.6 and 7.8%). Neem Seed Kernel Extract (5%) + DDVP @ 0.5 ml/liter of water were found next best treatment for the management of spotted pod borer (Gopali et al., 2010). *Bacillus thuringiensis* was effective in controlling pod borers (Karel and Schoonhoven, 1986; Supriyatin, 1990; Otieno and Karikuri, 1991).

**Insecticides**

Chemical control of this pest in cowpea was well studied earlier by Booker (1965), Jerath (1968), Taylor (1968), Koehler and Mehta (1972), Raheja (1974) and Singh and Allen (1980). In pigeonpea, insecticidal spray operations were difficult because of dense crop canopy (Pawar et al., 1983). Ultra Low Volume, Controlled Droplet Application (CDA) was more effective than conventional sprays (Pawar, 1986). Chauhan et al. (1988) proved that spraying operation in pigeonpea was easier in strips upto 7 m width when interspersed with 3m bands of black gram. Spraying two rounds of monocrotophos 0.5 kg a.i./ha starting from pod formation stage and at 14 days later was very effective (Sinha et al., 1977; Mishra and Saxena, 1982, 1984). Bhalani and Parsana (1987) observed the highest larval mortality three days after spraying deltamethrin, cypermethrin and fluvalinate under laboratory conditions and monocrotophos was on par with pyrethroids. Triazophos, cypermethrin and endosulfan gave maximum benefit in controlling pod borers (Chaudhari, 1988). Lal and Yadava (1988) reported that two sprays of dimethoate 0.05 per cent and monocrotophos 0.05 per cent were effective.

According to Rahman and Rahman (1988), four sprays of cypermethrin 0.008 per cent (1st at flower initiation, 2nd at 50 per cent flowering, 3rd at 100 per cent flowering and the 4th at 100 per cent pod set) were effective against *Maruca* with the highest benefit cost ratio of 6.23 in pigeonpea. Singh and Rai (1988) observed that quinalphos 0.5 kg a.i./ha applied three times at fortnightly intervals was very effective. An appropriate spray schedule of either three sprays of monocrotophos 0.04 per cent or two sprays of endosulfan 0.07 per cent was suggested by Sinha and Srivastava (1989). Bhadauria et al. (1991) advocated that spraying three rounds of monocrotophos 0.04 per cent at 170, 190 and 210 days after sowing were very effective in long duration types. Sontakke and Mishra (1991) reported the effectiveness of application of cypermethrin 75 g a.i./ha and quinalphos 300 g a.i./ha. Bhalani and Parsana (1991) recommended sequential spraying of endosulfan 0.07 per cent at pod initiation stage followed by monocrotophos 0.04 per cent at 50 per cent pod set. Sachan et al. (1993) showed the increased effectiveness of strip application of dimethoate 0.03 per cent and endosulfan 0.07 per cent as first and second sprays. Ganapathy and Durairaj (1994) suggested sequential spraying of either monocrotophos (0.04%) - fenvalerate (0.02%) - dimethoate (0.03%) or monocrotophos (0.04%)-Cypermethrin (0.025%)-dimethoate (0.03%) starting from 50 per cent flowering time to pigeonpea.
Kataria et al. (1994) also advocated that a sequential spray of dimethoate (0.03%) - fenvalerate (0.02%) and monocrotophos (0.04%) was very effective. Patnaik and Mishra (1994) also recommended the sequential spraying of endosulfan (0.07%)-endosulfan (0.07%) - monocrotophos (0.04%) at 15 days interval starting from 50 per cent flowering stage in pigeonpea. The efficacy of dust formulations of methyl parathion, fenvalerate, quinapah, hexachlorocyclohexane and endosulfan was well documented earlier (Patil et al., 1990; Kataria et al., 1994; Srivastava and Singh, 1994 and Yazdani et al., 1994). Profenophos 50EC @ 2.0 ml/liter of water in combination with DDVP @ 0.5 ml/liter of water at the time of flowering was found most effective in combating the pest and registered lowest pod damage (6.23 %), highest grain yield and most effective in combating the pest and registered highest yield (45.66%).

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