LR-4412
[1-8]

RESEARCH ARTICLE Legume Research- An International Journal, Volume Issue : ()

Habitat Manipulation: An Important Component of IPM in the Management of Webbing Caterpillar, *Maruca vitrata* (Geyer) in Pigeonpea

Zadda Kavitha[1], C. Vijayaraghavan[2]

10.18805/LR-4412

ABSTRACT

Background: *Maruca vitrata* is an economically important cryptic insect pest in pigeonpea. Caterpillar, the damaging stage hides in the webs thus escapes the contact with insecticides thus making an effective insecticide also ineffective. Hence, the role of some tall statured intercrops in the manipulation of pigeonpea crop environment for reducing the incidence of this webbing caterpillar was studied.

Methods: Studies were conducted at NPRC, Vamban, Pudukottai dt., Tamil Nadu to study the effect of different intercrops in reducing the incidence of *Maruca vitrata*. During kharif 2016-17 and 2017-18, *M.vitrata* incidence was compared among the intercropping systems (pigeonpea with pearlmillet, sorghum and maize in 1:6 ratio) and sole pigeonpea crop. IPM modules were formulated in which botanical spray (NSKE 5% at bud initiation stage) and spray of recommended insecticide (indoxacarb 15.8 EC-0.7 ml/lt at flowering and 15 days later) were integrated with intercropping practice and tested for efficacy against this borer pest.

Result: Intercropping of pigeonpea with pearlmillet was effective in managing the spotted pod borer. Coccinellids and spiders were more in intercropped pigeonpea than the sole pigeonpea crop. Synchronized flowering times of short duration pigeonpea and intercrops would have facilitated the transfer of natural enemies from intercrops to pigeonpea and this may be the one of the reasons for the lower insect population. IPM module I (pigeonpea intercropped with pearlmillet, NSKE and indoxacarb sprays) was effective in reducing the spotted pod borer damage. In IPM module I, yield of 770 kg/ha was obtained as against 550 kg/ha in sole pigeonpea crop. Among the IPM modules, high B:C ratio of 1:1.66 was recorded with IPM module I.

Key words: IPM, Maize, *Maruca vitrata,* Pearlmillet, Pigeonpea, Sorghum.

INTRODUCTION

Among the insect pests that cause economic loss by attacking the pigeonpea crop at flowering and pod development stages, spotted pod borer, *Maruca vitrata* Geyer (Crambidae: Lepidoptera) is the most important one. *M. vitrata* larvae feed by remaining inside the webbed flowers and mass of flowers and pods. *M. vitrata* became a predominant insect pest in recent years in all the pigeonpea growing areas of India. This pest is the major factor responsible for heavy loss in early, medium and late maturing pigeonpea genotypes (Sahoo, 1995; Shanower *et al*., 1999). 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). *M.vitrata* became a persistent pest in pigeonpea. It establishes early on the crop, young larvae cause substantial damage at flower bud stage itself and reduces the crop potential for flowering and fruit setting. Due to it's cryptic habitat, this insect remains unnoticed in the field by the farmers and management is also difficult because the insecticide sprayed could not reach the insect inside the flowers and webbed mass. So, it is imperative to search the alternative strategies to manage this insect effectively other than the chemical insecticides. Moreover, insecticides pose several health hazards due to their neurotoxicity, reproductive toxicity, carcinogenic nature (Aman *et al*., 2018). Integrated pest management does not exclude the use of insecticides but restricts their use as there is a growing awareness of the negative impact of the chemical insecticides. As an alternative to the application of chemical insecticides, practice of growing more than one crop simultaneously on the same field *i.e.*, intercropping can be explored as a management method. Efficiency of intercropping in insect management is the direct result of

National Pulses Research Centre, Tamil Nadu Agricultural University, Vamban-622 303, Pudukottai, Tamil Nadu, India.
[1]Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625 001, Tamil Nadu, India.
[2]Regional Research Station, Vridhachalam, Cuddalore-606 001, Tamil Nadu, India.

Corresponding Author: Zadda Kavitha, Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625 001, Tamil Nadu, India.
Email: zaddakavitha@gmail.com

How to cite this article: Zadda Kavitha and Vijayaraghavan, C. (2021). Habitat Manipulation: An Important Component of IPM in the Management of Webbing Caterpillar, *Maruca vitrata* (Geyer) in Pigeonpea. Legume Research. DOI: 10.18805/LR-4412.

Submitted: 05-05-2020 **Accepted:** 30-03-2021 **Online:** 07-08-2021

increase of biological control agents in the field and complex volatile interactions that result in the failure of insect in proper identification of host plant. In this background, the present study was undertaken to evaluate the role of different intercrops in the manipulation of pigeonpea crop environment for reducing the incidence of webbing caterpillar, *Maruca vitrata* in an eco-friendly manner.

MATERIALS AND METHODS

Experiments were conducted at National Pulses Research Centre, TNAU, Vamban, Pudukottai District, Tamil Nadu during 2016 to 2019 to investigate the role of intercropping and it's integration with other integrated pest management components in reducing the incidence of legume pod borer, *Maruca vitrata.* In this study, field trials were laid out during kharif 2016-17 and kharif 2017-18 with the pigeonpea variety, VBN 3 in which pearlmillet, sorghum and maize were intercropped in 1:6 ratio. Pigeonpea sole crop was maintained for comparison (control). Five replications were maintained for each treatment. During the flowering period, observations on number of *M.vitrata* flower webs/50 rachis (inflorescence of 30 cm length) were taken at weekly intervals during the peak incidence of *M.vitrata* in both intercropped and sole pigeonpea. Starting from the early pod formation stage to maturity, observations on number of *M.vitrata* damaged pods per 300 pods in each treatment were taken at weekly intervals in both intercropped and sole pigeonpea crops. Per cent pod damage was calculated for each treatment. During each observation, natural enemy population was also recorded in all the treatments. In this experiment, comparatively pearlmillet was found to be the best in reducing the spotted pod borer infestation when intercropped with pigeonpea. With regard to the other intercrops evaluated i.e., maize and sorghum, mixed results were obtained with no significant difference. So, for testing and comparison, all the three intercrops were taken in to consideration. Three IPM modules were formulated in which intercropping practice was combined with the spray of botanicals (NSKE 5%) and need based spray of recommended insecticide (indoxacarb 15.8 EC - 0.7 ml/lt). details of IPM modules are as following.

Particulars	Intercrop	Spray details
IPM module I	Pearlmillet	NSKE (5%) spray at bud initiation stage and spray of indoxacarb 15.8 EC (0.7 ml/lt) at full flowering stage.
IPM module II	Sorghum	
IPM module III	Maize	
Pigeonpea sole crop	-	-

Five replications were maintained for each treatment. During the flowering period, number of *M.vitrata* flower webs/50 rachis was counted at weekly intervals in all the IPM modules and sole pigeonpea plots. During pod formation stage, observations were taken on per cent pod damage of *M.vitrata* in various IPM modules and sole pigeonpea crop (300 pods/treatment) at weekly intervals and observations were continued upto maturity. During each observation, natural enemy population was also recorded in all the treatments. At harvest, yield data of both main and inter crops were recorded and cost benefit ratio was calculated. Crop equivalent yield (CEY) was calculated for each intercropping system by using the following formula

$$\text{CEY} = \frac{\text{Yield of the intercrop (kg/ha) x Price of intercrop yield (Rs./kg)}}{\text{Price of main crop (Rs./kg)}}$$

RESULTS AND DISCUSSION

Evaluation of the efficacy of intercrops for the management of *Maruca vitrata* (Kharif 2016-17)

At first week after flowering, no. of *M.vitrata* webs/50 rachis ranged from 5.0 (Pigeonpea + pearlmillet) to 9.0 (Pigeonpea sole crop) (Table 1). At second week after flowering, natural infestation of spotted pod borer has increased and 23 *M.vitrata* webs/50 rachis was recorded in pigeonpea sole crop. During this period, among the intercropped pigeonpea crops, comparatively less number of webs was observed in pigeonpea+pearlmillet intercropping system (18/50 rachis) and pigeonpea+sorghum intercropping system was on par with this with 20 *M.vitrata* webs/50 rachis. This is in accordance with the general opinion that arthropod pests out breaks were more likely to occur in monocultures than in polycultures. Similarly, Nath and Singh (1998) stated that, intercropping with non-host plants reduced the incidence of insect pests whereas intercropping with similar plant type increased the pest problems.

Observations recorded at third week after flowering revealed significantly less number of webs (16/50 rachis) in pigeonpea+pearlmillet intercropping system as against 25/50 rachis in pigeonpea sole crop. Pigeonpea + sorghum and Pigeonpea + maize intercropping systems were on par with each other with 20 to 21 webs/50 rachis. The same trend was observed at fourth and fifth weeks after flowering also. The mean no. of *M.vitrata* webs/50 rachis was less in pigeonpea intercropped with pearlmillet (10.4) followed by pigeonpea intercropped with maize (13.4) and pigeonpea intercropped with sorghum (13.0) while in pigeonpea sole crop, it was 16.2. Shravankumar *et al.* (2018) reported low relative abundance of pigeonpea insect pests when pigeonpea was intercropped with sorghum followed by pearl millet when compared to the sole crop of pigeonpea. Per cent pod damage by spotted pod borer was also significantly reduced in pigeonpea + sorghum than in other treatments. Mohammed and Rao (1998) reported 15.0 to 9.7 per cent reduction in *H. armigera* pod damage in pigeonpea + sorghum intercropped plots than the sole crop.

At early pod development stage, comparatively less pod damage (8%) was observed in pigeonpea+pearlmillet intercropping system, while in pigeonpea sole crop it was 13 per cent. Pigeonpea + sorghum and Pigeonpea + maize intercropping systems were on par with each other with 10

Table 1: Effect of intercropping on the incidence of *Maruca vitrata* (kharif 2016-17).

Intercropping system	Mean no. of *M. vitrata* webs/50 rachis						Per cent pod damage					Mean no. of natural enemies/10 plants	
	I WAF*	II WAF	III WAF	IV WAF	V WAF	Mean	Early pod dev. stage	Pod dev. stage	Pod maturity stage	At harvest	Mean	Cocci nellids	Spiders
Pigeonpea + pearlmillet	5.0	18.0	16.0	8.0	5.0	10.4±5.5	8.0	11.0	13.0	11.0	10.8±1.8	15.0	6.0
	(2.24)^{a}	(4.24)^{a}	(4.00)^{a}	(2.83)^{a}	(2.24)^{a}		(16.43)^{a}	(19.37)^{a}	(21.13)^{a}	(19.37)^{a}		(3.87)^{a}	(2.45)^{a}
Pigeonpea + sorghum	7.0	20.0	20.0	10.0	8.0	13.0±5.8	10.0	15.0	17.0	13.0	13.8±2.6	14.0	5.0
	(2.65)^{b}	(4.47)^{ab}	(4.47)^{b}	(3.16)^{b}	(2.83)^{b}		(18.44)^{b}	(22.79)^{c}	(24.35)^{b}	(21.13)^{b}		(3.74)^{a}	(2.24)^{a}
Pigeonpea + maize	6.0	21.0	21.0	11.0	8.0	13.4±6.4	11.0	13.0	16.0	14.0	13.5±1.8	15.0	5.0
	(2.45)^{ab}	(4.58)^{bc}	(4.58)^{b}	(3.32)^{b}	(2.83)^{b}		(19.37)^{b}	(21.13)^{b}	(23.58)^{b}	(21.97)^{b}		(3.87)^{a}	(2.24)^{a}
Pigeonpea sole crop	9.0	23.0	25.0	14.0	10.0	16.2±6.6	13.0	18.0	20.0	18.0	17.3±2.6	12.0	2.0
	(3.00)^{c}	(4.80)^{c}	(5.00)^{c}	(3.74)^{c}	(3.16)^{c}		(21.13)^{c}	(25.10)^{d}	(26.57)^{c}	(25.10)^{c}		(3.46)^{b}	(1.41)^{b}
CD (.05%)	0.2847	0.2378	0.2233	0.3258	0.3197		1.2687	1.3691	1.1679	1.3210		0.2308	0.3487
SEd	0.1307	0.1091	0.1025	0.1495	0.1467		0.5823	0.6284	0.5360	0.6063		0.1059	0.1600

* WAF – weeks after flowering

to 11 per cent pod damage. This is in agreement with the reports of Sule Hassan (2018) who reported less population of aphids (*Aphis craccivora* Koch.) and thrips (*Megalarothrips sjostedi* Trybom) and less incidence of cowpea pod borer, *Maruca vitrata* in cowpea + sorghum intercropping system. Ampong-Nyarko *et al.*, 1994 also confirmed the importance of intercropping as a method of reducing pest attack in cowpea. In contrast, Nampala *et al.* (2002) reported increased pod borer and pod sucking bug populations in cowpea when mixed cropped with sorghum. At pod development stage, minimum pod damage of 11% was recorded in pigeonpea+pearlmillet intercropping system followed by pigeonpea + maize (13%) and pigeonpea + sorghum (15%). In pigeonpea sole crop, 18 per cent pods were damaged by this borer. At pod maturity stage in pigeonpea+pearlmillet intercropping system, 13 per cent pod damage was observed and this was significantly less than the pod damage (20%) observed in pigeonpea sole crop. In pigeonpea + sorghum and pigeonpea + maize intercropping systems, 17% and 16% pod damage was recorded respectively and both were on par with each other. Same trend was observed with the observations at pod harvest stage. Sekhar *et al.* (1997) and Rao *et al.,* (2003) reported that sorghum intercroping with pigeonpea reduced pigeonpea sucking insect pest, leaf hopper infestation significantly than the sole crop. When the mean per cent pod damage values from early pod development stage to harvest were observed, reduction in *M. vitrata* pod damage (10.8%) was very clear due to the intercropping of pearlmillet while mean pod damage in sole crop was 17.3 per cent. The present findings were in agreement with the statement of Ahoaka-atta *et al.*, 1993 that damage by pod borers on cowpea was less when intercropped with maize. However, Ezueh (1991) reported increased infestation by spotted pod borer in cowpea when intercroped with cereals. Singh (2002) observed maximum pod borers damage in sole pigeonpea crop than the intercropped pigeonpea. He reported that the intercrops in pigeonpea *i.e.*, sorghum, rice, pearlmillet and maize were on par with each other in reducing the pod borer damage however, significantly superior to sole crop. He has also recorded minimum per cent damage of tur pod fly, *Melanagromyza obtuse* in pigeonpea + sorghum intercropping system.

Coccinellid beetle population was more in intercropped pigeonpea (14-15/10 plants) than the sole crop (12.0). Spider population ranged from 5 to 6 in intercropping systems and in sole crop 2 spiders per 10 plants were observed. In intercropping systems, less spotted pod borer damage and more natural enemy population were observed during this study. Synchronized flowering times of short duration pigeonpea and sorghum would have facilitated the transfer of natural enemies from intercrops to pigeonpea and this may be the one of the reasons for the lower insect population.

Evaluation of the efficacy of intercrops for the management of *Maruca vitrata* (*Kharif* 2017-18)

At first week after flowering among the different treatments,

Table 2: Effect of intercropping on the incidence of *Maruca vitrata* (kharif 2017-18).

Intercropping System	Mean no. of *M.vitrata* webs/50 rachis						Per cent pod damage					Mean no. of natural enemies/10 plants	
	I WAF*	II WAF	III WAF	IV WAF	V WAF	Mean	Early pod dev. stage	Pod dev. stage	Pod maturity stage	At harvest	Mean	Coccinellids	Spiders
Pigeonpea + pearlmillet	3.0 (1.73)^{a}	3.0 (1.73)^{a}	4.0 (2.00)^{a}	2.0 (1.41)^{a}	3.0 (1.73)^{a}	3.0±0.6	5.0 (12.92)^{a}	7.0 (15.34)^{a}	8.0 (16.43)^{a}	7.0 (15.34)^{a}	6.8±1.1	4.8 (2.19)^{a}	0.6 (0.77)^{a}
Pigeonpea + sorghum	5.0 (2.24)^{b}	6.0 (2.45)^{c}	6.0 (2.45)^{b}	4.0 (2.00)^{b}	5.0 (2.24)^{b}	5.2±0.7	7.0 (15.34)^{b}	9.0 (17.46)^{b}	12.0 (20.27)^{b}	9.0 (17.46)^{b}	9.3±1.8	3.4 (1.84)^{a}	0.0 (0.00)^{b}
Pigeonpea + maize	5.0 (2.24)^{b}	4.0 (2.00)^{b}	6.0 (2.45)^{b}	4.0 (2.00)^{b}	3.0 (1.73)^{a}	4.4±1.0	5.0 (12.92)^{a}	10.0 (18.44)^{b}	13.0 (21.13)^{b}	9.0 (17.46)^{b}	9.3±2.9	2.8 (1.67)^{b}	0.8 (0.89)^{a}
Pigeonpea sole crop	6.0 (2.45)^{b}	7.0 (2.65)^{c}	8.0 (2.83)^{c}	6.0 (2.45)^{c}	8.0 (2.83)^{c}	7.0±0.9	10.0 (18.44)^{c}	14.0 (21.97)^{c}	16.0 (23.58)^{c}	11.0 (19.37)^{c}	12.8±2.4	0.8 (0.89)^{c}	0.0 (0.00)^{b}
CD (.05%)	0.3581	0.2779	0.1905	0.2961	0.3029		1.0030	1.7905	1.3613	0.9321		0.1215	0.1414
SEd	0.1644	0.1275	0.0874	0.1359	0.1390		0.4603	0.8218	0.6248	0.4278		0.3746	0.4358

* weeks after flowering

no. of *M.vitrata* webs/50 rachis ranged from 3.0 (pigeonpea + pearlmillet) to 6.0 (pigeonpea sole crop). No significant difference in spotted pod borer incidence was observed among pigeonpea+maize, pigeonpea+sorghum and pigeonpea sole crop systems. At second week after flowering, pigeonpea+pearlmillet intercropping system recorded less number (3.0) of *M.vitrata* webs/50 rachis and pigeonpea + maize intercropping system was on par with this with 4.0 webs/50 rachis (Table 2). In pigeonpea sole crop, 7 webs were recorded per 50 rachis. At third week after flowering, significant difference was observed in the infestation of spotted pod borer between pigeonpea +pearlmillet intercropping system (4/50 rachis) and pigeonpea sole crop 8/50 rachis. Same trend was noticed during fourth week after flowering also. At fifth week after flowering, pigeonpea+pearlmillet and pigeonpea + maize intercropping systems were found to be on par with each other with 3.0 *M.vitrata* webs/50 rachis while in pigeonpea sole crop, it was 8.0.

At the end of the trial, pigeonpea intercropped with pearlmillet was found to be effective in reducing the infestation of spotted pod borer by recording a mean number of 3.0 webs per 50 rachis followed by pigeonpea intercropped with maize (4.4). In pigeonpea sole crop, mean number of webs per 50 rachis was 7.0. Reduced incidence of cowpea aphid when intercropped with maize than on sole cropped cowpea was reported by Sinthananthem *et al.* (1990) and Ogenga-Latigo *et al,* (1992). At early pod development stage in pigeonpea sole crop, 10 per cent pod damage was observed. When compared to this, pigeonpea+pearlmillet and pigeonpea + maize intercropping systems recorded 5 per cent pod damage and were found to be effective in reducing the damage by this borer. At pod development stage, pearlmillet intercropped pigeonpea recorded less pod damage of 7 per cent as against 14 per cent in pigeonpea sole crop. Pigeonpea + sorghum and pigeonpea + maize intercropping systems were on par with each other with 9 to 10 per cent pod damage.

Intercropping showed positive influence in reducing the insect infestation. This suggests that pest migration after initial establishment was possibly inhibited by the non host plants as physical barriers to inter or intra row migration within intercrop treatment. The conspicuous pest reduction in sorghum – pigeonpea dicrop combination may be because sorghum made inter row migration very difficult for spotted pod borer, *Maruca vitrata* during later stages of pigeonpea crop development. The reduction of *H.armigera* infestation due to sorghum as intercrop can be attributed to two factors. The simultaneous flowering of pigeonpea and sorghum might have caused distribution of *H. armigera* population on main crop pigeonpea and intercrop, leading to less incidence of the pest on main crop. Overlapping of pod formation and flowering of pigeonpea with ear-head formation of sorghum might have reduced the feeding damage to main crop pigeonpea by the pest (Srinivasa Rao *et al*., 2006).

Same trend was observed with the observations at pod maturity and pod harvest stages. With regard to mean per cent pod damages in various treatments, intercropping pigeonpea with pearlmillet was effective in managing the infestation of spotted pod borer and recorded a mean per cent of 6.8 while in sole pigeonpea crop it was 12.8 per cent. Intercropping sorghum in cowpea reduced the damage of legume pod borer on cowpea (Omalo *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). In intercropping systems, low insect infestations are reported due to many factors that include physical protection from wind, shading (Litsinger and Moody, 1976), prevention of dispersal (Kayumbo, 1975) production of adverse stimuli, olfactory stimuli camouflaged by main crop (Aiyer, 1949), presence of natural enemies (Tonhasca, 1993) and availability of food (Fukai and Trenbath, 1993). Lowered resource concentration, other diversionary mechanisms, trap cropping, plant density factors and plant physical obstruction account for 22.5 per cent reduction in insect population. Increase in natural control agents *i.e.*, predators and parasites account for 15 and 10 per cent respectively. Masking, camouflage and repellency account for 12.5 per cent each. Overall natural enemy action controlled about 30 per cent of crop pests and the remaining known cases were controlled by other factors (Baliddawa, 1985).

Due to the presence of intercrop in between the main crop, crop microclimate variables *i.e.,* canopy temperature (Tc), canopy - air temperature differential (CATD) and relative humidity in crop canopy (CRH) were altered. Tc was higher in pigeonpea with intercrops than in sole crop of pigeonpea. Sorghum as intercrop increased the Tc to 32.5°C compared to 30.5°C in sole pigeonpea (30.5°C). High CRH values were recorded in pigeonpea with sorghum (Srinivasa Rao *et al*., 2006). The higher relative humidity under tall canopy together with shading is likely to favour the activity of insects in intercrops also (Srinivasa Rao *et al.,* 2004).

Natural enemy population (coccinellid beetles and spiders) were more in intercropped pigeonpea than the sole pigeonpea crop. Flowering crops can be used as attractant plants to encourage coccinellids such as *C. sexmaculata*, *C. septempunctata* and *Brumoides suturalis* in and around pulses (NIPHM, 2014). Studies by Ogenga-Latigo *et al.*, 1992 and Kyamanywa *et al*., 1993 have shown that in crop mixtures, variations were observed in herbivore load which inturn increased the abundance of natural enemies. Duffield and Reddy, 1997 stated that the generalist predators belonging to major taxa including anthocorids, coccinellids, chrysopids, spiders etc. are more common on sorghum.

Evaluation of the efficacy and economics of IPM modules for the management of *M.vitrata* (*Kharif* 2018-19)

At first and second weeks after flowering, in IPM module I

Table 3: Evaluation of the IPM modules for the management of *M.vitrata.*

IPM Module	Mean no. of *M.vitrata* webs/50 rachis					Per cent pod damage				
	I spray (NSKE) at bud initiation stage		II spray (Indoxacarb) at flowering stage		Mean	II spray (Indoxacarb) at 15 days after II spray		Pod maturity stage	At harvest	Mean
	IWAF*	IIWAF	7DAS**	14DAS		7DAS	14DAS			
IPM module I	23.0 (4.80)^{a}	21.0 (4.58)^{a}	19.0 (4.36)^{a}	15.0 (3.87)^{a}	19.5±3.0	10.0 (18.43)^{a}	6.0 (14.18)^{a}	5.0 (12.92)^{a}	6.0 (14.18)^{a}	6.8±1.9
IPM module II	29.0 (5.89)^{b}	28.0 (5.29)^{b}	24.0 (4.90)^{b}	21.0 (4.58)^{b}	25.5±3.2	15.0 (22.79)^{b}	11.0 (16.43)^{b}	8.0 (16.43)^{b}	10.0 (18.44)^{b}	11.0±2.5
IPM module III	30.0 (5.48)^{b}	29.0 (5.39)^{b}	26.0 (5.10)^{c}	20.0 (4.47)^{b}	26.3±3.9	16.0 (23.58)^{b}	13.0 (21.13)^{c}	10.0 (18.44)^{c}	9.0 (17.46)^{b}	12.0±2.7
Pigeonpea sole crop	35.0 (5.92)^{c}	38.0 (6.16)^{c}	45.0 (6.71)^{d}	43.0 (6.56)^{c}	40.3±4.0	22.0 (27.97)^{c}	18.0 (25.10)^{d}	19.0 (25.84)^{d}	16.0 (23.58)^{c}	18.8±2.2
CD (.05%)	0.1266	0.1656	0.1795	0.2127		1.4234	1.3793	1.7711	1.3894	
SEd	0.0581	0.0760	0.0824	0.0976		0.6533	0.6330	0.8129	0.6377	

(pigeonpea and pearlmillet intercropping, NSKE (5%) spray at bud initiation stage and need based spraying of indoxacarb 15.8 EC - 0.7 ml/lt), less number of *Maruca* webs were recorded *i.e.*, 23 and 21 respectively as against pigeonpea sole crop (35 and 38 respectively) (Table 3). IPM module I was followed by IPM module II (pigeonpea and sorghum intercropping, NSKE (5%) spray at bud initiation stage and need based spraying of indoxacarb 15.8 EC - 0.7 ml/lt) and IPM module III (pigeonpea and maize intercropping, NSKE (5%) spray at bud initiation stage and need based spraying of indoxacarb 15.8 EC - 0.7 ml/lt) and both were on par with each other. The study of Nath and Singh (2006) also confirmed the efficacy of pigeonpea + sorghum intercropping system when integrated with the spray of NSKE (5%) in reducing the damage by pigeonpea gram pod borer, *Helicoverpa armigera*.

At 7 days after second spray, considerable reduction in number of webs in IPM modules was observed. As against 45 webs/50 rachis in pigeonpea sole crop, IPM module I was found to be effective by recording 19 webs/50 rachis. This was followed by IPM module II (24/50 rachis) and IPM module III (26/50 rachis). The same trend was noticed at 14 days after second spray and 7 days after third spray except IPM module II and IPM module III were on par with each other.

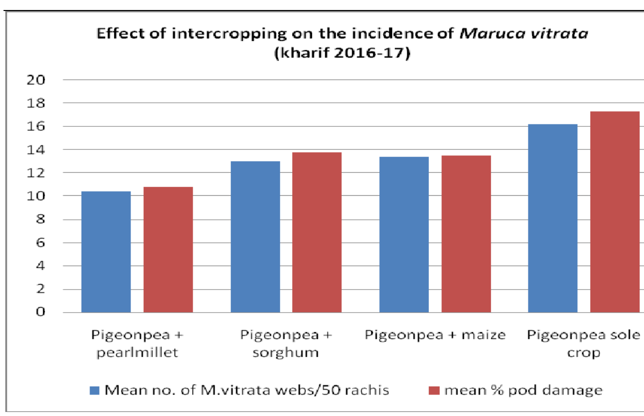
At 14 days after third spray, minimum pod damage of 6 per cent was recorded in IPM module I while in pigeonpea sole crop pod damage was 18 per cent. At pod maturity stage and at harvest, IPM module I was proved to be effective by recording minimum number of webs/50 rachis. When compared to sole pigeonpea crop, IPM modules II and III were proved to be effective in minimizing the spotted pod borer damage. However, among the three modules, IPM module I in which pearlmillet was intercropped with pigeonpea was found to be best. Spraying of eco-friendly biopesticides *i.e*., *B. thuringiensis,* NSKE 5% and nimbecidine at flowering or pod formation stage and 20 days later were found to be effective in reducing the pigeonpea pod damage, grain damage and grain weight loss due to *H.armigera* (Nath and Singh, 2006).

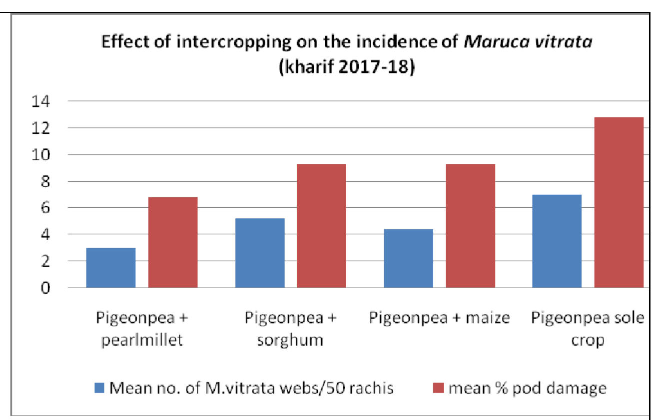
With regard to the natural enemy population, coccinellid beetles were more in IPM module I, IPM module III and untreated control and all were on par with each other (9-10/10 plants) (Table 4). IPM module II recorded comparatively less number of coccinellids (8/10 plants) but was on par with the IPM modules I and III. This mixed result may be due to the spraying of chemical insecticides in the IPM modules. No significant correlation was observed with the abundance of spider population in various treatments. In IPM module I, yield of 770 kg/ha was obtained as against 550 kh/ha in sole pigeonpea crop. Among the IPM modules, high B:C ratio of 1:1.66 (Table 4) was recorded with IPM module I.

Many authors reported the efficacy of the IPM packages including various insect management components in pigeonpea ecosystem. Yelshetty *et al.* (2003) reported the highest benefit-cost ratio of 2.30 in biointensive module (*Ha*NPV - 250LE/ha, hand collection, *B. thuringiensis* - 1 kg/ha, NSKE 5% followed by *Ha*NPV - 250LE/ha) over the recommended package of practice (1.76) during heavy pest

Table 4: Evaluation of the biosafety and economics of IPM modules for the management of *M.vitrata.*

IPM Module	Mean no. of natural enemies/10 plants		Plant population (/ha)	Yield (kg/ha)	Crop equivalent yield (kg/ha)	C:B ratio
	Coccinellids	Spiders				
IPM module I	9.0(3.00)[ab]	6.0(2.45)	42000	770[a]	82.0	1:1.66
IPM module II	8.0(2.83)[b]	7.0(2.65)	42000	730[b]	84.0	1:1.57
IPM module III	9.0(3.00)[ab]	8.0(2.83)	42000	720[b]	91.0	1:1.50
Pigeonpea sole crop	10.0(3.16)[a]	7.0(2.65)	49000	550[c]	-	1:1.28
CD (.05%)	0.1819	NS		4.7056		
SEd	0.0835			10.2528		





load in pigeonpea ecosystem. Bird perches (50/ha), mechanical collection, spray of neem based insecticides at 50% flowering and *Ha*NPV at early pod set and need based spraying of insecticides at flowering and podding stage against pod borer complex on early sown pigeonpea (3rd week of June) recorded less damage by pod borer (14.6 - 26.6%), pod wasp (1.8- 3.0%) and pod fly (2.4- 4.0%) with a grain yield of 362-530 kg/ha and benefit cost ratio of 1.73 to 1.91 (Gajendran *et al.*, 2006). Samiayyan and Gajendran (2009) reported that the IPM package comprising of bird perches (50 nos./ha), collection and destruction of pod borer larvae, pheromone traps (12 nos./ha), spray of *Ha* NPV (1.5 x 10^{12} POB/ha), spraying of indoxacarb 14.5 SC (0.75 ml/l) at 50 per cent flowering or monocrotophos 36 WSC (2 ml/l) at the time of flowering/early pod formation stage recorded minimum cumulative pod borer damage (16.27 to 31.51%) compared to farmers' practice (30.56 to 47.50 %) with higher grain yield (655 to 1397 kg/ha) and C:B ratio (1:1.7 to 1:2.5).

CONCLUSION

In the present study, when pigeonpea crop was intercropped with pearlmillet at 1:6 ratio, *Maruca vitrata* incidence was less from flowering to maturity stages. Coccinellid beetles and spiders were also abundant in intercropped pigeonpea with pearlmillet, sorghum and maize than the sole pigeonpea crop. IPM module (intercropping with pearlmillet, NSKE @ 5% spray at bud initiation stage and indoxacarb spray at flowering and 15 days later were integrated) was effective in reducing the *Maruca vitrata* damage in pigeonpea. In this IPM module, comparatively high yield (770 kg/ha) was obtained as against 550 kg/ha in sole pigeonpea crop and high B:C ratio of 1:1.66 was recorded. Crop equivalent yield was high in IPM module III (91.0 kg/ha) followed by IPM module II (84.0 kg/ha) and IPM module I (81.0 kg/ha).

ACKNOWLEDGEMENT

The authors are grateful to the Professor and Head, National Pulses Research Centre, Vamban, Pudukottai district for extending necessary facilities for carrying out this research work.

REFERENCES

Ahoaka Atta, S., Jackai, L.E.N. and Makanjuola, W.A. (1993). Cowpea plant architecture in relation to infestation and damage by the legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae). Insect Science and its Applications. 12: 171-176.

Aiyer, A.K.Y.M. (1949). Mixed cropping in India. Indian Journal of Agricultural Sciences. 19: 439-443.

Aman, S., Bhuvnesh, Y., Shipra, R. and Baljeet, Y. (2018). Cypermethrin Toxicity: A Review. Journal of Forensic Science and Criminal Investigation. 9(4): 555-767.

Ampong Nyarko, K., Reddy, K.V., Nyangor, R.A. and Sexena, K.N. (1994). Reduction of pest attack on sorghum and cowpea by intercropping. Entomologia Experimentalis et Applicata. 70: 179-184.

Baliddawa, C.W. (1985). Plant species diversity and crop pest control -an analytical Review. Insect Science and its Application. 6: 479-487.

Duffield, S.J. and Reddy, Y.V. (1997). Distribution and movement of predators of *Helicoverpa armigera* in intercropped sorghum and short-duration pigeonpea. Crop Research. 14: 315-35.

Ezueh, M.I. (1991). Prospects for cultural and biological control of cowpea pests. Insect Science and its Applications. 12: 585-592.

Fukai, S. and Trenbath, B.R. (1993). Processes determining intercrop productivity and yields of component crops. Field Crops Research. 34: 247-271.

Gajendran, G., Chandrasekaran, M., Ganapathy, N. and Jeyaraj, S. (2006). Evaluation of pigeonpea integrated pest management module in rainfed ecosystem. Agricultural Science Digest. 26(1): 57-59.

Ganapathy, N. (1996). Bioecology and management of spotted pod borer, *Maruca testulalis* Geyer. (Pyralidae: Lepidoptera) in pigeonpea. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore, India. 171p.

Gopali, J.B., Raju Teggelli, Mannur, D.M. and Suhas Yelshetty. (2010). Web-forming lepidopteran, *Maruca vitrata* (Geyer): an emerging and destructive pest in pigeonpea. Karnataka Journal of Agricultural Science. 23(1): 35-38.

Kayumbo, H.Y. (1975). Ecological background to pest control in mixed crop ecosystem in East Africa. In: AAAS / ford foundation workshop on cropping system in Africa. Monogoro, Tanzania.

Kyamanywa, S., Balidawa, C.W. and Ampofo, K.J.O. (1993). Effect of maize plant on colonization of cowpea plant by bean flower thrips, *Megalurothrips sjostedti.* Entomologia Experimentalis et Applicata. 69: 61-68.

Litsinger, J.A. and Moody, K. (1976). Integrated pest management in multiple cropping systems In: Multiple Cropping. ASA Special Publication. 27: 293-316.

Mohammed, G. and Rao, A.S. (1998). Influence of intercrops on the incidence of *Helicoverpa armigera* (Hubner) in post rainy season in pigeonpea. International Pigeonpea Newsletter. 5: 46-48.

Nampala, P., Ogenga-Latigo, M.W., Kyamanywa, S., Adipala, E., Oyobo, N. and Jackai, L.E.N. (2002). Potential impact of intercropping on major cowpea field pests in Uganda. African Crop Science Journal. 10(4): 335-344.

Nath, P. and Singh, A.K. (1998). Effect of intercropping of groundnut with millets and pigeonpea on the relative incidence of insect pests. Annals of Plant Protection Sciences. 6: 151-154.

Nath, P. and Singh, R.S. (2006). Effect of bio-rational approaches on pigeonpea pod and grain damage by *Helicoverpa armigera* (Hub.). Annals of Plant Protection Sciences. 14(1): 56-61.

National Institute of Plant Health Management. (2014). The AESA based IPM in Brinjal.

Ogenga Latigo, M.W., Ampofo, J.K.O. and Balidawa, C.W. (1992). Influence of maize row spacing on infestation and damage of intercropped beans by beans aphids (*Aphis fabae* Scop.) 1. Incidence of Aphids. Field Crop Resarch. 30: 111-121.

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

Rao, M.S., Reddy, K.D. and Singh, T.V.K. (2003). Impact of intercropping on *Empoasca kerri* of pigeonpea in rainy and post rainy season. Indian Journal of Entomology. 65(4): 506-512.

Sahoo, B.K. (1995). Extent of damage by web-forming lepidopteran pod borers in pigeon pea. Indian Journal of Pulses Research. 8: 195-196.

Samiayyan, K. and Gajendran, G. (2009). Evaluation and demonstration of pigeonpea IPM module for pod borer management. Madras Agricultural Journal. 96(7-12): 401-403.

Sekhar, J.C., Singh, K.M., Singh, R.N., Singh, Y. and Malik, K.S. (1997). Impact of intercropping on the incidence of green jassid, *Empoasca kerri* on pigeonpea. Indian Journal of Entomology. 59(1):119- 123.

Shanower, T.G., Romeis, J. and Minja, E.M. (1999). Insect pests of pigeonpea and their management. Annual Review of Entomology. 44: 77-96.

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

Shravan Kumar, R., Paras Nath and Raju, S.V.S. (2018). Relative abundance of insect pests and pod damage by pod borers in short duration pigeonpea under intercropping systems. International Journal of Current Microbiology and Applied Sciences. 7(12): 267-280.

Singh, R.S. (2002). Study on the management of insect pests associated with pigeonpea [*Cajanus cajan* (L.) Millsp.] pods through intercropping system. Ph.D. thesis submitted to B.H.U., Varanasi.

Sinthananthem, S., Sohati, P.H., Kaunatyan, J. and Haciwa, H.C. (1990). Preliminary studies of bean aphids management in Zambia. Proceedings of the 9th Bean Research Workshop Held Between 17-22 September at Sokoine University of Agriculture, Morogora Tanzania.

Srinivasa Rao, M., Dharma Reddy, K., Srivastava, N.N., Singh, T.V.K., Subba Reddy, G. and Ramakrishna, Y.S. (2004). Effect of change in microclimate on insect pests and their predators in pigeonpea (*Cajanus cajan* L.). Indian Journal of Agricultural Sciences. 74(7): 399-402.

Srinivasa Rao, M., Rama Rao, C.A., Ramakrishna, Y.S., Srinivas, K., Sreevani, G. and Vittal, K.P.R., (2006). Crop-crop diversity as a key component of IPM in pigeonpea. Research Bulletin 2006. Central Research Institute for Dryland agriculture (ICAR), Hyderabad. 24 p.

Sule Hassan. (2018). Effect of variety and intercropping on two major cowpea [*Vigna unguiculata* (L.) Walp] field pests in Mubi, Adamawa State, Nigeria. International Journal of Horticulture and Floriculture. 6 (7): 001-003.

Tonhasca, Jr. A. (1993). Effects of agro ecosystem diversification on natural enemies of soybean herbivores. Entomologia Experimentalis et Applicata. 69: 83-90.

Yelshetty, S., Patil, B.V. and Lingappa, S. (2003). Evaluation of integrated pest management modules against pod borer, *Helicoverpa armigera* (Hubner) in pigeonpea ecosystem. Karnataka Journal of Agricultural Science. 16(1): 54-60.