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Seasonal Abundance of Spotted Pod Borer, *Maruca vitrata* Fabricius in Early Pigeonpea [*Cajanus cajan* (L.) Millsp.] and its Management through Farmscaping in Uttar Pradesh

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ABSTRACT

Field experiments were carried out in pigeonpea during *Kharif* 2014 to *Kharif* 2017 for *Maruca vitrata* Fabricius management through farmscaping approach with 7 different border crops (5 leguminous crops; 2 non-leguminous crops) and a sole crop. The *M. vitrata* larval webbing per plant was lowest and per cent decrease in webbing/plant over sole crop was highest in sorghum (2.05 and 60.95) as border crop followed by pearl millet (3.29 and 37.39). The highest mean number of *Coccinella septumpunctata* per plant (0.77), *Cheilomenes sexmaculata* per plant (0.85/plant) and spiders (0.76/plant) was recorded from sorghum as border crop with pigeonpea. The highest percent increase in above said natural enemies over sole crop was also recorded from sorghum as border crop treatment (755.6, 844.4 and 660). The highest pigeonpea yield (730.72 kg/ha) and per cent yield gain (65.81%) was also recorded with sorghum treatment. Among 5 weather parameters tested, day length (1.53) and relative humidity (-0.12) were found to influence the *M. vitrata* population significantly and its incidence was recorded from 41st SMW to 47th SMW.

Key words: Bio-intensive IPM, Crop diversification, Eco-friendly management, IPM, Legume pod borer, Population dynamics.

INTRODUCTION

India is one of the leading producers of pigeonpea in the world with a production of 41.80 Lac tonne during 2017-18. Among the major pigeonpea producing states, Uttar Pradesh occupies fifth position (7.25%), with a production of 3.03 Lac tonne during 2017-18 (Anonymous, 2018). The national productivity of pigeonpea is 937 kg/ha. Developing early maturing varieties / hybrids with high yielding potential is the prerequisite for increasing the productivity. The spotted pod borer, *Maruca vitrata* Fabricius is a key insect pest that causes severe yield loss of up to 68 per cent in early maturing pigeonpea genotypes (Sharma and Franzmann, 2000). Singh (1999) has reported a yield loss of 70-80 per cent in pigeonpea at Bangalore, India. A similar loss in pigeonpea was also reported from Dindigul, Tamil Nadu also (Kumar and Pavviya, 2018). Short duration pigeonpea recorded higher pod damage by *M. vitrata* (32%) than gram pod borer, *Helicoverpa armigera* (Hubner) Hardwick (4%), pod bugs and blister beetle in Uttar Pradesh (Sujayanand and Saxena, 2013). The *M. vitrata* larvae have a typical habit of feeding inside webs. The larva produces a silken web for spinning the leaves, flower-buds, developing flowers and pods and it starts feeding the reproductive parts of the plant. Often, the larva pupates inside the web. Thus, the entire larval and pupal stage is protected from the external environment and insecticides by the silken web (Sharma, 1998). Some of the insecticides like methomyl failed to control *M. vitrata* population in soybean at Brazil (Grigolli *et al*., 2015). Hence there is a need to have sustainable management through Farmscaping approach. Pigeonpea genotypes having determinate and cluster flowering habit is found to be highly susceptible to *M. vitrata* infestation (Sunitha *et al*., 2008; Saxena *et al*., 1996). *M. vitrata* is a serious pest in many leguminous crops like cowpea, black gram, green gram, field bean *etc* (Sonune *et al*., 2010; Randhawa and Saini, 2015). This insect pest has a wide geographic distribution with a prominent occurrence in Semi-arid tropical countries (Margam *et al*., 2011). Hence, there is a need to understand the pest population dynamics, micro-climatic requirements and its natural enemies for devising a sustainable management technique through integrated pest management. In order to modify the microfauna and microclimate of cropping environment, farmscaping strategy was chosen in the present investigation. Border crops were selected based on its ability to perform as refugia plant *i.e*. it will enhance the natural enemy activity and thereby suppress the pest. Further, knowledge of *M. vitrata* incidence

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and the weather factors favouring the population flare up or abundance is very much essential for planning the prophylactic spray schedule to control *M. vitrata* population and its damage. The present study was devised to identify a suitable border crop which can modify the micro-climate in such a way that enriches natural enemies and concurrently diminishes the pest population in sustainable way. Further, the present investigation was also designed to identify the weather factors that influence the population build up of *M. vitrata*. So, that prophylactic spray with suitable biopesticide can be done before onset of the favourable weather.

MATERIALS AND METHODS

A field trial on early pigeonpea (variety ICPL67B) was conducted in ICAR-Indian Institute of Pulses Research, Kanpur for management of spotted pod borer, *M. vitrata* by deploying 7 different border crops (Cluster bean, Green gram, Black gram, Cowpea, Daincha, Sorghum and Pearl millet) during *Kharif* 2014 to 2017. The individual plot size measured, 7 x 5 m and it was laid out in randomized block design with 8 treatments replicated thrice. Each block was separated by 2 m apart and 1 m alley was present between the plots. The pigeonpea variety ICPL67B was sown in *Kharif* season (23rd to 24th standard meteorological week (SMW)) during four consecutive years (*Kharif* 2014 to 2017) with spacing of 60 X 30 cm. Two rows of border crops (60 cm distance between rows) either cluster bean (*Cyamopsis tetragonoloba* L. Taub.) or green gram [*Vigna radiata* (L.) Wilczek.] or black gram [*Vigna mungo* (L.) Hepper] or cowpea [*Vigna unguiculata* (L.) Walp.] or daincha [*Sesbania aculeate* (Willd.) Pers.] or pearl millet [*Penisettum glaucum* (L.) R.Br.] or sorghum [*Sorghum bicolour* (L.) Moench] was sown in all 4 sides of pigeonpea during 29th to 30th SMW of every year. Recommended agronomic package of practices were followed to raise a healthy crop. The entire experimental plot was exposed to natural infestation of insect pest and natural enemies by not spraying any insecticides during the entire crop growing period. Fixed-plot sampling technique was followed for recording the incidence of *M. vitrata* larval webbings and its major natural enemies in different plots. Ten pigeonpea plants were randomly selected and tagged in each plot for recording insect population at weekly intervals. Yield data were recorded plot wise and mean was calculated for each year. Data analysis was done by using SAS 9.1 software.

To find out the role of different weather parameters that influence the seasonal abundance of *M. vitrata* in Kanpur and to assess its contribution, multiple regression was performed by considering the *Maruca* larval population (ML) as dependent variable (Y) and the six weather parameters [day length (h), maximum temperature T max (°C), minimum temperature T min (°C), rainfall (mm) and relative humidity (RH %)] as independent variable (X) for the corresponding years. The weather data during four years (*Kharif* 2014 to 2017) were recorded from the automatic weather station [AWS, Field Climate METOS® Pessl Instruments GmbH, Austria] maintained at Division of Basic sciences, ICAR-IIPR and weekly mean for each weather parameter was calculated.

$$ML = b_0 + a\,(\text{Day length}) + b\,(\text{Rainfall}) + c\,(\text{T min}) + d\,(\text{T max}) + e\,(\text{RH})$$

Where

b_0 is intercept; a, b, c, d and e are regression coefficients of respective weather parameter mentioned above.

RESULTS AND DISCUSSION

Incidence of spotted pod borer webbing

The pooled mean of *M. vitrata* larval webbing per plant in pigeonpea (ICPL67B) during *Kharif* 2014 to 2017, ranged from 2.05 to 5.78 (Table 1). The highest (5.78) larval webbing per plant was recorded from cowpea (T_4) as border crop with pigeonpea which was on par with sole crop (T_8:5.25) while the lowest (2.05) was recorded from sorghum (T_7) as border crop with pigeonpea. Among the four years, two years *i.e. Kharif* 2017 (8.81) and 2015 (2.49) had recorded highest larval webbing from T_8; while *Kharif* 2016

Table 1: Effect of different border crops on spotted borer larval incidence in ICPL67B.

Treatments (border crop deployed with pigeonpea)	Larval webbings/plant*					
	2014$^{\$}$	2015$^{\$}$	2016$^{\$}$	2017$^{\$}$	Pooled	% decrease over sole crop
T_1-Cluster bean	4.29(1.95)^{bc}	1.91(1.52)^{bc}	4.13(1.96)^{bc}	4.51(2.23)^{c}	3.71(2.03)^{ab}	29.35
T_2-Green gram	4.19(1.89)^{bc}	2.19(1.58)^{ab}	4.92(2.08)^{bc}	6.05(2.50)^{b}	4.34(2.17)^{ab}	17.40
T_3-Black gram	4.90(2.03)^{bc}	1.73(1.44)^{c}	6.12(2.37)^{ab}	3.72(2.03)^{c}	4.12(2.11)^{ab}	21.52
T_4-Cowpea	7.09(2.71)^{a}	1.98(1.52)^{bc}	6.83(2.67)^{a}	7.23(2.72)^{b}	5.78(2.46)^{a}	-10.16
T_5-Daincha	4.33(2.05)^{bc}	1.91(1.50)^{bc}	5.00(2.20)^{b}	4.26(2.14)^{c}	3.88(2.07)^{ab}	26.15
T_6-Pearl millet	5.10(2.05)^{bc}	1.24(1.27)^{d}	5.00(2.07)^{bc}	1.81(1.51)^{d}	3.29(1.89)^{bc}	37.39
T_7-Sorghum	3.01(1.70)^{c}	1.19(1.26)^{d}	2.83(1.68)^{c}	1.17(1.28)^{d}	2.05(1.57)^{c}	60.95
T_8-Sole crop	4.52(2.13)^{b}	2.49(1.66)^{a}	5.17(2.27)^{ab}	8.81(3.01)^{a}	5.25(2.35)^{a}	
S.Em. ±	0.13	0.09	0.12	0.11	0.12	
C.V. %	15.16	7.14	18.58	11.34	12.84	

*****Values inside parenthesis are square root transformed (√x+0.5). In a column means followed by same letter are not significant different from each other by DMRT (α =0.05); $^{\$}$Average of 7 weeks observation.

had recorded highest larval webbing from T_4 (6.83) which was on par with T_8(5.17). Similarly, during *Kharif* 2014, T_4(7.09) has recorded highest larval webbing. The lowest, *M. vitrata* larval webbing per plant was recorded from the treatment having sorghum as border crop with pigeonpea (T_7) during all the four years (3.01, 1.19, 2.83 and 1.17) and also in pooled mean (2.05). The *M. vitrata* larval webbing per plant in pigeonpea with pearl millet as border crop (T_6:3.29) was on par with sorghum as border crop (T_7:2.05) and also it was significantly lower than sole crop (T_8:5.25). Hence it was considered as second best treatment among the eight treatments. The present finding is in congruence with Hassan (2009) who had reported that cowpea (variety kanannado white), intercropped with sorghum had recorded significantly lower *Maruca* population (p>0.05) than sole cowpea crop at Nigeria. Similarly, Sandeep *et al*. (2013) also reported that summer ploughing accompanied by mixed cropping of pigeonpea with sorghum (300 g/ha) as bird perches had increased the average production of pigeonpea and controlled the pod borers and pod fly up to 85 per cent. Singh *et al*. (2013a) have reported that pigeonpea variety *Bahar* when intercropped with pearl millet or sorghum or black gram resulted in significantly lower *Lampides boeticus* larval population and grain damage than monocrop. The present result is in line with findings of Soundararajan and Chitra (2012). They had reported lowest *Maruca* larval population in black gram (3.18/plant) when it is intercropped with sorghum.

Activity of Coccinellids

The activity of *Cheilomenus sexmaculata* Fabricius per plant in pigeonpea for 4 years was the highest (0.85) with sorghum as border crop (T_7) followed by cowpea (T_4:0.66) and pearl millet (T_6:0.65) (Table 2).The above said three treatments were on par with each other and it was significantly different from the remaining treatments (T_1 to T_3, T_5 and T_8). The lowest *C. sexmaculata* activity per plant was recorded from sole crop (T_8:0.09). Sorghum as border crop recorded the highest *C. sexmaculata* per plant in pigeonpea during *Kharif* 2017 (1.36), *Kharif* 2016 (1.13) and *Kharif* 2015 (0.78) while cowpea as border crop has recorded the highest in *Kharif* 2014 (0.73). Both of these treatments recorded significantly higher *C. sexmaculata* activity per plant than sole crop treatment. Pearl millet as border crop has recorded second highest activity of *C. sexmaculata* per pigeonpea plant during *Kharif* 2017 (0.81) and *Kharif* 2016 (0.72) while it was on par with sorghum and cowpea during *Kharif* 2015 (0.67) and *Kharif* 2014 (0.42), respectively. The percent increase in *C. sexmaculata* activity over sole crop was highest for sorghum (844.4) followed by cowpea (633.3) and pearl millet (622.2). The present finding corroborates with that of Rao (2008) and Kavitha *et al*. (2013), wherein they had reported that coccinellids population in pigeonpea was enhanced by intercropping with sorghum.

The four years pooled mean of *Coccinella septempunctata* Linnaeus activity per plant was the highest with sorghum (T_7:0.77) followed by cowpea (T_4:0.59) and pearl millet (T_6:0.49) as border crop and all the three were on par with each other (Table 3). The lowest activity of *C. septempunctata* per plant was recorded from sole crop (T_8:0.07). The highest activity of *C. septempunctata* per plant during the 4 years was recorded from sorghum as border crop (T_7:0.30, 0.67, 0.80 and 1.32). The pearl millet as border crop has recorded second highest *C. septempunctata* population per plant during *Kharif* 2015 (0.47) and 2016 (0.53). The per cent increase in *C. septempunctata* activity over sole crop was highest for sorghum (755.5) as border crop followed by cowpea (555.6) and pearl millet (444.4). The present result is in accordance with findings of Parthiban *et al*. (2018). They had reported a higher activity of *C. septempunctata* and *C. sexmaculata* from groundnut + maize (8.11/10plants) followed by groundnut + pearl millet (7.39/10 plants) and groundnut + sorghum (7.11/10 plants). Lokesh *et al*. (2017) observed the highest per cent increase in coccinellids population from black gram + cowpea (161.97) among the 6 different border crops tested. In the present study, pigeonpea + sorghum (755.6) recorded the

Table 2: Effect of different border crops on *Cheilomenus sexmaculata* activity in ICPL67B.

Treatments (border crop deployed with pigeonpea)	*C. sexmaculata*/plant*					
	2014$	2015$	2016$	2017$	Pooled	% increase over sole crop
T_1-Cluster bean	0.21(0.86)^{bc}	0.22(0.83)^{bcd}	0.20(0.82)^{d}	0.21(0.81)^{c}	0.21(0.84)^{b}	133.3
T_2-Green gram	0.27(0.93)^{bc}	0.44(0.95)^{abc}	0.33(0.89)^{cd}	0.22(0.83)^{c}	0.32(0.90)^{b}	255.6
T_3-Black gram	0.03(0.74)^{c}	0.08(0.76)^{d}	0.18(0.82)^{d}	0.18(0.81)^{c}	0.12(0.78)^{b}	33.3
T_4-Cowpea	0.73(1.18)^{a}	0.50(0.97)^{ab}	0.59(1.02)^{bc}	0.83(1.33)^{a}	0.66(1.08)^{a}	633.3
T_5-Daincha	0.18(0.85)^{bc}	0.17(0.81)^{bcd}	0.13(0.78)^{d}	0.22(0.81)^{c}	0.17(0.82)^{b}	88.9
T_6-Pearl millet	0.42(1.02)^{ab}	0.67(1.05)^{a}	0.72(1.07)^{b}	0.81(1.14)^{b}	0.65(1.07)^{a}	622.2
T_7-Sorghum	0.15(0.82)^{bc}	0.78(1.09)^{a}	1.13(1.25)^{a}	1.36(1.33)^{a}	0.85(1.15)^{a}	844.4
T_8-Sole crop	0.00(0.71)^{c}	0.11(0.77)^{cd}	0.15(0.80)^{d}	0.11(0.77)^{c}	0.09(0.77)^{b}	-
S.Em. ±	0.06	0.05	0.05	0.05	0.07	
C.V. %	21.77	22.27	20.53	10.55	9.75	

*****Values inside parenthesis are square root transformed (√x+0.5). In a column means followed by same letter are not significant different from each other by DMRT (α =0.05); $Average of 12 weeks observation.

highest *C. septumpunctata* followed by cowpea (555.6). The possible reason may be due to high incidence of aphids in sorghum compared to cowpea.

Activity of spider

The predominant spiders found in different treatments were *Oxyopus* sp, *Clubiona* sp, *Thomisus* sp and *Araneu* sp. The highest (0.76) spider population per plant was recorded from pigeonpea having sorghum as border crop (T_7) followed by pearl millet (0.45) (Table 4). Further, the sorghum (T_7) has recorded significantly highest spider population among the 8 treatments studied. The sorghum as border crop has recorded significantly higher spider population per pigeonpea plant during 2015 (0.69), 2016 (0.78) and 2017 (1.2). The present result supports the findings of Gopali *et al*. (2010) where they reported that spider population was the highest in sorghum intercropped pigeonpea (1.25/plant) followed by bajra intercropped pigeonpea (1.05/plant). The sole crop (T_8:0.10) has recorded the lowest spider population per plant and was on par with treatments (T_1:0.30; T_2:0.35; T_3:0.14; T_4:0.16 and T_5:0.07). Singh *et al*. (2013b) also reported that spider population (0.75/plant) was more in pigeonpea + rice intercrop than sole crop and other treatments. The present finding is in agreement with Solanki and Kumar (2015). They found highest spider diversity in maize crop followed by pigeonpea. In the present study the sorghum and pearl millet belongs to same family (Poaceae) and crop geometry as that of maize which in turn might have enhanced spider population in those treatments. The present result is in agreement with Khajuria *et al*. (2015); wherein the occurrence of predatory spider was reported in pigeonpea agro-ecosystem.

Yield

The sorghum as border crop with pigeonpea has recorded significantly highest pooled yield of pigeonpea (730.72 kg/ha) among the 8 treatments. The second highest yield was recorded from green gram as border crop with pigeonpea (517.79 kg/ha) followed by cluster bean (494.25 kg/ha) and pearl millet (487.58 kg/ha). Also, similar trend was observed in per cent increase in yield over sole crop. The highest percent increase in yield (Fig 1) was recorded from sorghum (65.81%) followed by green gram (17.49%), cluster bean

Table 3: Effect of different border crops on *Coccinella septempunctata* activity in ICPL67B.

Treatments (border crop deployed with pigeonpea)	*C. septempunctata*/plant*					
	2014$	2015$	2016$	2017$	Pooled	% increase over sole crop
T_1-Cluster bean	0.00(0.71)^{c}	0.19(0.81)^{bc}	0.17(0.80)^{b}	0.16(0.84)^{cd}	0.13(0.79)^{b}	44.4
T_2-Green gram	0.06(0.74)^{bc}	0.36(0.90)^{abc}	0.17(0.81)^{b}	0.18(0.85)^{c}	0.19(0.83)^{b}	111.1
T_3-Black gram	0.24(0.85)^{ab}	0.06(0.74)^{c}	0.08(0.76)^{b}	0.16(0.82)^{cd}	0.13(0.80)^{b}	44.4
T_4-Cowpea	0.18(0.81)^{abc}	0.36(0.90)^{abc}	0.53(1.03)^{a}	1.31(1.15)^{b}	0.59(1.03)^{a}	555.6
T_5-Daincha	0.00(0.71)^{c}	0.08(0.76)^{c}	0.14(0.79)^{b}	0.17(0.84)^{cd}	0.10(0.77)^{b}	11.1
T_6-Pearl millet	0.15(0.80)^{abc}	0.47(0.96)^{ab}	0.53(0.97)^{a}	0.81(1.13)^{b}	0.49(0.98)^{a}	444.4
T_7-Sorghum	0.30(0.87)^{a}	0.67(1.04)^{a}	0.80(1.11)^{a}	1.32(1.35)^{a}	0.77(1.11)^{a}	755.6
T_8-Sole crop	0.06(0.74)^{bc}	0.08(0.76)^{c}	0.14(0.79)^{b}	0.09(0.77)^{d}	0.09(0.77)^{b}	-
S.Em. ±	0.04	0.05	0.05	0.05	0.07	
C.V. %	15.36	22.22	22.20	8.43	11.06	

*Values inside parenthesis are square root transformed (√x+0.5). In a column means followed by same letter are not significant different from each other by DMRT (α =0.05); $Average of 12 weeks observation.

Table 4: Effect of different border crops on spiders activity in ICPL67B.

Treatments (border crop deployed with pigeonpea)	Spider/plant*					
	2014$	2015$	2016$	2017$	Pooled	% increase over sole crop
T_1-Cluster bean	0.21(0.84)^{a}	0.44(0.94)^{ab}	0.42(0.92)^{bc}	0.12(0.79)^{d}	0.30(0.89)^{bcd}	200.0
T_2-Green gram	0.36(0.92)^{a}	0.55(0.99)^{ab}	0.39(0.91)^{bc}	0.09(0.77)^{d}	0.35(0.92)^{bc}	250.0
T_3-Black gram	0.27(0.86)^{a}	0.03(0.73)^{c}	0.19(0.81)^{bc}	0.06(0.74)^{d}	0.14(0.80)^{cd}	40.0
T_4-Cowpea	0.06(0.75)^{a}	0.06(0.74)^{c}	0.11(0.78)^{c}	0.41(0.94)^{c}	0.16(0.81)^{cd}	60.0
T_5-Daincha	0.06(0.75)^{a}	0.03(0.73)^{c}	0.08(0.76)^{c}	0.09(0.77)^{d}	0.07(0.75)^{d}	-30.0
T_6-Pearl millet	0.15(0.80)^{a}	0.33(0.88)^{bc}	0.53(0.98)^{ab}	0.77(1.12)^{b}	0.45(0.97)^{b}	350.0
T_7-Sorghum	0.36(0.89)^{a}	0.69(1.06)^{a}	0.78(1.10)^{a}	1.2(1.30)^{a}	0.76(1.11)^{a}	660.0
T_8-Sole crop	0.15(0.80)^{a}	0.06(0.74)^{c}	0.11(0.77)^{c}	0.08(0.76)^{d}	0.10(0.77)^{cd}	
S.Em. ±	0.05	0.05	0.05	0.05	0.07	
C.V. %	22.94	23.60	23.67	8.21	11.39	

*Values inside parenthesis are square root transformed (√x+0.5). In a column means followed by same letter are not significant different from each other by DMRT (α =0.05); $Average of 12 weeks observation.

(12.15%) and pearl millet (10.64%). The pulse intercropping with monocots such as sorghum always enhances the yield. The present finding is in accordance with Prasad *et al*. (2011) wherein they had reported pigeonpea + sorghum cropping system as most remunerative cropping system among the four different intercropping systems they had evaluated. A similar report of the lowest per cent fruit damage in brinjal by *L. orbonalis* was found when it is planted with maize as border crop and coriander as intercrop as reported by Sujayanand *et al*. (2015). Thus, the graminaceous crops (like sorghum or maize or pearl millet) act as wind shield and it restrict the movement of adult moths by mechanical means. Apart from mechanical hindrance some of the plants like sorghum, maize, etc offers pollen and nectar for the predaceous coccinellids that act as refugia for them, the predators, in turn, suppress the neonate larvae present in main crop. Thus, indirect biological control service and mechanical hindrance provided by these refugia crops results in the lowest pod damage and thereby increases the pod yield.

Influence of abiotic factors on seasonal abundance of M. vitrata larvae

The *Maruca* larval population was noticed from 41st SMW to 47th SMW in Kanpur for the four years of study except 2016; wherein the infestation started from 40th SMW to 41st SMW (Fig 2) according to prevailing weather condition of the year. The peak larval population was recorded on 46th SMW (8.00/plant) and 44th SMW (13.33/plant) during 2014 and 2017 whereas during *Kharif* 2015 and 2016, peak population was recorded in 41st SMW (5.13/plant and 9.67/plant). A similar finding of peak *Maruca* larval webbing (24.00; 24.88 and 25/plant) in 40th SMW during *Kharif* 2015-2017 was reported from Ludhiana (30.9010° N, 75.8071° E) by Taggar *et al*. (2019). Except for the *Kharif* 2017 (4 week difference) there was a difference of 1 week in peak *Maruca* larval webbing between Ludhiana (40th SMW) and Kanpur (41st SMW). The present finding is not in agreement with Chaitanya *et al*. (2012) and Sampathkumar and Durairaj (2015); wherein they had reported peak *M. vitrata* population (17.3/plant and 9.38/plant) during December (49th SMWand 50th SMW). The probable reason may be due to differences in weather parameters like prevalence of longer day length and higher minimum temperature in December in their study location *i.e.* Tirupathi (13.6288° N, 79.4192° E); Coimbatore (11.0123° N, 76.9355° E) than our study location *i.e.* Kanpur (26.4932° N, 80.2742° E).It can be inferred from the present report

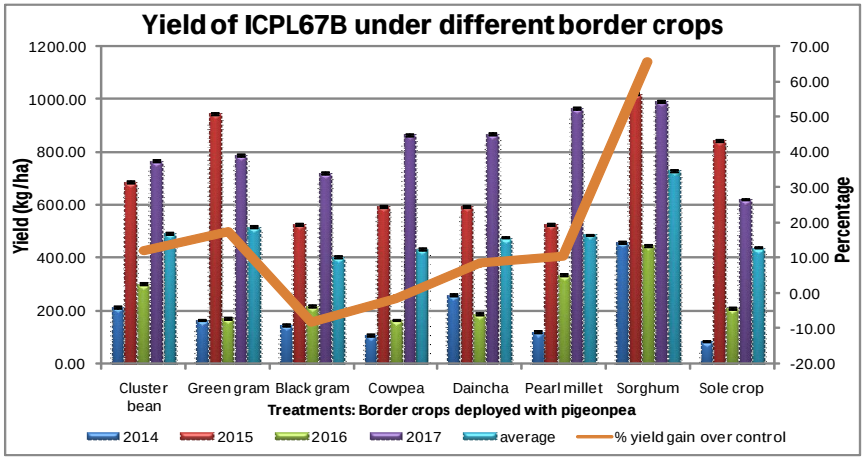


Fig 1: Effect of different border crops on pigeonpea yield.

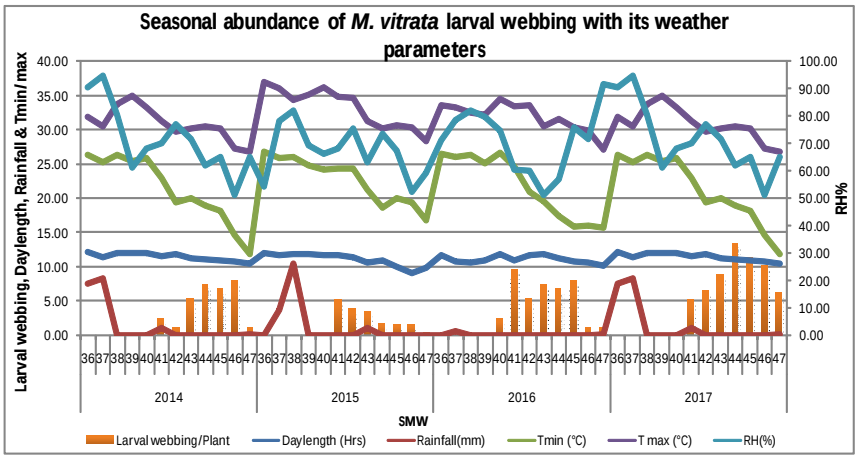


Fig 2: Seasonal abundance of *M. vitrata* on pigeonpea.

Table 5: Multiple Regression coefficients of abiotic factors on *M. vitrata* larval population.

Variables	Regression coefficients	Standard error	t value	P-value
Intercept	33.14	42.09	0.79	0.44
Daylength (h)	1.53	0.89	1.73	0.09
Rainfall (mm)	-0.02	0.22	-0.08	0.93
T min	-0.35	0.26	-1.33	0.19
T max =Ln(x+1)	-9.05	13.43	-0.67	0.50
RH (%)	-0.12	0.06	-2.02	0.05

**significant @ 5% level ; *significant @ 10% level.

R^2 value=0.408; adjusted R^2=0.337673; F value=5.79238; Significance F= 0.000374 (significance @ 1% level).

along with Taggar *et al*. (2019) and Chaitanya *et al*. (2012) that the peak larval population of *Maruca* is gradually shifting from North India to South India, during its course of time from September towards December. It appears that *M. vitrata* is migrating from North to South India during winter progression in India. A similar kind of *M. vitrata* migration was already reported in Western Africa by Ba *et al*. (2009). In spite of the South-North migration occurrence in Western Africa there was a reduced gene flow in *M. vitrata* populations (Agunbiade *et al*., 2012).

The regression coefficients observed for day length, rainfall, minimum temperature, maximum temperature and RH was 1.53,-0.02,-0.35,-9.05 and -0.12 respectively. The results on regression analysis (Table 5) yielded the following equation and showed that the 6 weather parameters together explained the variation in *Maruca* larval population (ML) by 41% (R^2=0.41).

ML= 33.14 + 1.53 (Day length) -0.02 (Rainfall) -0.35 (T min) -9.05 (T max) -0.12 (RH)

Out of 6 weather parameters studied, RH was found to influence the ML significantly. If the other weather parameters were at their mean level a unit rise in RH will decrease the larval population by 0.12 times. The second most influencing weather parameter was day length. A unit increase in day length will result in increased ML by 1.53 times. The present result corroborates with that of Sreekanth *et al*. (2015) wherein they observed significant correlation between *M. vitrata* population and sunshine hours (0.656) and evening relative humidity (RH-II) (-0.609). Research has shown that lack of rain, relative humidity and temperature may influence seasonal abundance of *M. vitrata* (Agunbiade *et al*., 2012). The present finding supports Sampathkumar and Durairaj (2015); who also had reported that five weather parameters including sunshine hours (1.495 times) had significantly influenced *M. vitrata* population in pigeonpea at Coimbatore.

CONCLUSION

The present study concludes that the sorghum and pearl millet as a border crop (2 rows) with pigeonpea (ICPL67B) has resulted in the lowest incidence of spotted pod borer, *M. vitrata* larval webbing and at the same time higher activity of its natural enemies *viz*., *C. sexmaculata*, *C. septempunctata* and spiders. Further sorghum as border crop with pigeonpea has recorded highest yield among the 8 treatments (Cluster bean, Green gram, Black gram, Cowpea, Daincha, Sorghum, Pearl millet and sole crop) tested. Hence this farmscaping system can be well fitted in integrated pest management package designed for spotted pod borer management in short duration pigeonpea. Further, relative humidity and day length exerted significant influence on the *Maruca* larval webbing in Kanpur. The *Maruca* incidence started during 41st SMW every year. Hence, by planning a prophylactic insecticidal spray before the onset of favourable weather or *Maruca* incidence will be helpful for successful management of the insect pest.

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Authors contribution

Dr. Sujayanand, G.K. conceived, planned and executed the experiment. Dr. Anup Chandra edited the manuscript. Sonika Pandey assisted in data collection. Dr. Sriphad Bhatt and Dr. Anup Chandra assisted in data analysis and preparation of graphs.

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