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Evaluation of Different Insecticides against Spotted Pod Borer, *M. vitrata* Infesting Vegetable Cowpea

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ABSTRACT

A field experiment was conducted at Anand Agricultural University, Anand during *kharif* 2021 to assess the bio-efficacy various insecticides against spotted pod borer, *Maruca vitrata* infesting vegetable cowpea of the nine evaluated insecticides chlorantraniliprole 18.5% SC, emamectin benzoate 5% SG were found the most effective in reducing the incidence of *M. vitrata*. However, spinetoram 11.7% SC and spinosad 45% SC were found mediocre in their effectiveness. Maximum (76.33 q/ha) green cowpea pod yield was recorded from the plot treated with chlorantraniliprole which was at par with emamectin benzoate (75.50 q/ha). The highest ICBR returns were obtained in the treatment of emamectin benzoate (1: 11.48) followed by chlorantraniliprole (1: 8.67), spinetoram (1: 5.20) and spinosad (1: 4.92).

Keywords Cowpea, Insecticide, *Maruca vitrata,* Spotted pod borer, Treatment.

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INTRODUCTION

Pulses are the important sources of proteins, vitamins and minerals for the predominantly vegetarian population and are popularly known as "Poor man's meat" and "Rich man's vegetable" (Singh and Singh 1992). The important grain legumes grown in India are Bengal gram, lentil, green gram, black gram, cowpea, red gram, peas. Among grain legumes cowpea (*Vigna unguiculata* (L.) Walp.) is one of the important pulses crop also known as black eyes bean or southern pea in English, while chola or choli, chavli, lobia in various vernacular languages in India. Cowpea is grown on about 0.07 million ha with an average productivity of 0.63 t/ha in India (CMIE 2020). As many as 21 insect pests of different groups have been recorded damaging the cowpea crop from germination to maturity. The avoidable losses in yield due to insect-pests have been recorded in the range of 66 to 100% in cowpea (Pandey *et al.* 1993). The reasonable grain yield can't be obtained without their management (Jackai and Daoust 1986 and Suh *et al.* 1986). Several control measures are available (Jackai 1985) but chemicals are the most effective, giving several folds' increase in grain yield (Jackai 1993). Chemical insecticides are used as the frontline defence sources against insect pest. However, their indiscriminate and continuous use creates a number of problems such as development of resistance against many insecticides, pest resurgence and environmental hazards including residue in soil, water and foods and to overcome the resistance problem some newer molecules need to be evaluated. Hence, the present investigation was conducted to study the efficacy different insecticides against spotted pod borer, *Maruca vitrata* under field conditions.

MATERIALS AND METHODS

A field experiment was carried out at Entomology farm of BA College of Agriculture, Anand Agricultural University, Anand, Gujarat during *kharif,* 2021. Cowpea variety AVCP-1 (Anand Vegetable Cowpea-1) sowing in the gross plot size of 4.2 × 4.5 m (Net plot: 3.0 × 3.6 m) at a spacing of 60 × 45 cm. The cowpea crop was grown by following all standard agronomical practices. The experiment was laid out in Randomized Block Design (RBD) with nine treatments and control viz., chlorantraniliprole 18.50 SC @ 0.006%, emamectin benzoate 5 SG @ 0.002%, flubendiamide 20 WG @ 0.012%, thiodicarb 75 WP @ 0.112%, lufenuron 5.4 EC @ 0.006%, lambda-cyhalothrin 5 EC @ 0.004%, spinosad 45 SC @ 0.013%, indoxacarb 14.5 SC @ 0.010%, spinotoram 11.7 SC @ 0.008% and control (no spray) along with three replications with a view to evaluate bio-efficacy of various insecticides against *M. vitrata*. Treatment wise application of insecticides was given at appearance of pest in the treated plot by using knapsack sprayer with required concentration. Subsequent spray was given after 15 days of first spray. The observations of *M. vitrata* larval population and pod damage were recorded prior to spraying as well as 3, 7, 10 and 14 days after each spray from ten randomly selected plants in each net plot. The data obtained were analyzed by following standard statistical technique (Steel and Torrie 1980) after using suitable transformation. Cowpea pods were harvested at different intervals and healthy and damaged pods weighted treatment wise from each net plot area. The healthy and damaged pods were weighted in kg and converted on hectare basis.

The per cent increased yield over control was also calculated by using following formula (Pradhan 1969).

$$\text{Yield increased over control} = 100 \times \frac{T - C}{C}$$

Where,

T = Yield of respective treatment (kg /ha)
C = Yield of control (kg/ha)

The avoidable losses due to *M. vitrata* incidence was calculated by applying formula which is given under.

$$\text{Avoidable loss \% in yield} = \frac{\text{Yield in treatment which gave the highest yield} - \text{Yield in any other treatment}}{\text{Yield in treatment which gave the highest yield}} \times 100$$

RESULTS AND DISCUSSION

Efficacy of insecticides on population of *M. vitrata*

The periodical and pooled over periods and sprays data of spotted pod borer, *M. vitrata* larval population on cowpea recorded during 2021 are presented in Table 1. The population of spotted pod borer was homogeneous before first spray in all the treatments as treatment difference was non-significant. All the treatments significantly reduced the larval population than control up to 15 days of first spray and second spray as well as in pooled.

First spray

The pest population recorded after three days of first spray (Table 1) on cowpea showed that the lowest (1.72/plant) larval population of *M. vitrata* were recorded from plots treated with chlorantraniliprole 18.5 SC and it was at par with emamectin benzoate 5 SG (1.78/plant), spinetoram 11.7 SC (2.02/plant) and spinosad 45 SC (2.12/plant). These four insecticides were found to be significantly superior to the remaining treatments. Flubendiamide 20 WG was the next best insecticide with recorded 3.81 larvae per plant and was at par with emamectin benzoate, spinetoram and spinosad. Among the evaluated insecticides, the highest (3.45/plant) larval population of *M. vitrata* was observed in plots treated with lambda-cyhalothrin 5 EC and it was at par with lufenuron 5.40 EC (3.39/ plant) and indoxacarb 14.5 SC (3.33/ plant) but superior than the control.

After seven days of first application (Table 1), the lowest number of larvae of *M. vitrata* (1.26/plant) was noticed from plots treated with chlorantraniliprole and it was at par with emamectin benzoate (1.32/ plant), spinetoram (1.59/plant) and spinosad (1.65/ plant) after seven days of spray. Flubendiamide 20

WG treated plots recorded 2.25 *M. vitrata* larvae per plant and it was at par with spinetoram and spinosad on one hand while, with thiodicarb on other hand of chronological order of effectiveness of the evaluated insecticides, the higher population of *M. vitrata* were found from plots treated with lambda-cyhalothrin (2.86 larvae/plant) and lufenuron (2.79 larvae/plant) after 7 days of first application.

On ten days after first spray, chlorantraniliprole (1.03), emamectin benzoate (1.09), spinetoram (1.33) and spinosad (1.39) were recorded lower *M. vitrata* larvae per plant and at par with each other. Flubendiamide (1.98 larvae/plant) and thiodicarb (2.05 larvae/plant) also exhibited significant efficacy. The treatments lambda-cyhalothrin (2.52 larvae/plant) lufenuron (2.45 larvae/plant) and indoxacarb (2.40 larvae/plant) were least effective in management of *M. vitrata* on cowpea (Table 1).

The data (Table 1) on larval population of *M. vitrata* collected after 14 days of first spray indicated that the insecticide chlorantraniliprole was the most effective (2.18 larvae/plant) in checking the incidence of pest and it was at par with emamectin benzoate (2.25 larvae/plant), spinetoram (2.39 larvae/plant) and Spinosad (2.49 larvae/plant). Latter three insecticides were at par with flubendiamide (3.37 larvae/plant) and thiodicarb (3.46 larvae/plant). The highest larval population of *M. vitrata* was in the plots treated with lambda-cyhalothrin (3.78/plant) and it was at par with lufenuron, indoxacarb, thiodicarb and flubendiamide.

Pooled over periods data of first spray (Table 1) exhibited the highest (1.53 larvae/plant) effectiveness of chlorantraniliprole and it was at par with emamectin benzoate (1.59 larvae/plant), spinetoram (1.82 larvae/plant) and spinosad (1.90 larvae/plants). The plots treated with lambda-cyhalothrin recorded the highest (3.14 larvae/ plant) population of *M.*

Table 1. Bio-efficacy of insecticides against spotted pod borer, *M. vitrata* infesting cowpea after first spray.

Sl. No.	Treatments	Conc (%)	Before spray	No. of larvae/ plant after indicated days of first spray 3	7	10	14	Pooled
T_1	Chlorantraniliprole 18.50 SC	0.006	2.14 (4.06)	1.49^{a} (1.72)	1.33^{a} (1.26)	1.24^{a} (1.03)	1.64^{a} (2.18)	1.42^{a} (1.53)
T_2	Emamectin benzoate 5 SG	0.002	2.11 (3.96)	1.51^{ab} (1.78)	1.35^{ab} (1.32)	1.26^{ab} (1.09)	1.66^{ab} (2.25)	1.44^{a} (1.59)
T_3	Flubendiamide 20 WG	0.012	2.08 (3.81)	1.83^{bcd} (2.83)	1.66^{bcd} (2.25)	1.57^{bcde} (1.98)	1.97^{bcd} (3.37)	1.76^{b} (2.58)
T_4	Thiodicarb 75 WP	0.112	2.02 (3.59)	1.85^{cd} (2.91)	1.68^{bcd} (2.31)	1.60^{cde} (2.05)	1.99^{bcd} (3.46)	1.78^{b} (2.66)
T_5	Lufenuron 5.40 EC	0.006	2.04 (3.65)	1.97^{d} (3.39)	1.81^{d} (2.79)	1.72^{e} (2.45)	2.05^{d} (3.69)	1.89^{b} (3.06)
T_6	Lambda-cyhalothrin 5 EC	0.004	1.96 (3.34)	1.99^{d} (3.45)	1.83^{d} (2.86)	1.74^{e} (2.52)	2.07^{d} (3.78)	1.91^{b} (3.14)
T_7	Spinosad 45 SC	0.013	2.02 (3.60)	1.62^{abc} (2.12)	1.47^{abc} (1.65)	1.38^{abcd} (1.39)	1.73^{abcd} (2.49)	1.55^{a} (1.90)
T_8	Indoxacarb 14.5 SC	0.010	1.96 (3.36)	1.96^{d} (3.33)	1.79^{cd} (2.70)	1.70^{de} (2.40)	2.04^{cd} (3.64)	1.87^{b} (3.00)
T_9	Spinetoram 11.7 SC	0.008	2.04 (3.66)	1.59^{abc} (2.02)	1.45^{ab} (1.59)	1.35^{abc} (1.33)	1.70^{abc} (2.39)	1.52^{a} (1.82)
T_{10}	Control	-	2.05 (3.70)	2.38^{e} (5.18)	2.41^{e} (5.30)	2.43^{f} (5.40)	2.46^{e} (5.55)	2.42^{c} (5.36)
	SEm ±	Treatments (T)	0.11	0.10	0.10	0.10	0.10	0.05
		Period (P)	-	-	-	-	-	0.03
		Spray (S)	-	-	-	-	-	-
		T × P	-	-	-	-	-	0.10
		T × S	-	-	-	-	-	-
		P × S	-	-	-	-	-	-
		T × P × S	-	-	-	-	-	-
CD at 5%			NS	Sig	Sig	Sig	Sig	Sig
CV (%)			9.18	9.54	9.91	10.56	9.11	9.47

Table 1. Continued.

Sl. No.	Treatments	Conc. (%)	Before spray	No. of larva(e)/ plant after indicated days of second spray 3	7	10	14	Pooled	Pooled over periods and sprays
T_1	Chlorantraniliprole 18.50 SC	0.006	2.14 (4.06)	1.40[a] (1.46)	1.26[a] (1.10)	1.18[a] (0.90)	0.99[a] (0.48)	1.21[a] (0.96)	1.32[a] (1.23)
T_2	Emamectin benzoate 5 SG	0.002	2.11 (3.96)	1.45[a] (1.60)	1.30[a] (1.19)	1.21[a] (0.96)	1.06[a] (0.62)	1.25[a] (1.07)	1.35[ab] (1.32)
T_3	Flubendiamide 20 WG	0.012	2.08 (3.81)	1.80[bc] (2.73)	1.72[b] (2.47)	1.66[b] (2.26)	1.47[b] (1.65)	1.66[b] (2.26)	1.71[c] (2.42)
T_4	Thiodicarb 75 WP	0.112	2.02 (3.59)	1.84[bc] (2.89)	1.76[b] (2.61)	1.68[b] (2.33)	1.50[b] (1.74)	1.70[bbc] (2.38)	1.74[c] (2.52)
T_5	Lufenuron 5.40 EC	0.006	2.04 (3.65)	1.96[c] (3.33)	1.91[b] (3.14)	1.87[b] (3.01)	1.73[b] (2.49)	1.87[d] (2.98)	1.88[d] (3.02)
T_6	Lambda-cyhalothrin 5 EC	0.004	1.96 (3.34)	1.97[c] (3.39)	1.94[b] (3.25)	1.90[b] (3.11)	1.78[b] (2.66)	1.90[d] (3.10)	1.90[d] (3.12)
T_7	Spinosad 45 SC	0.013	2.02 (3.60)	1.54[ab] (1.88)	1.40[a] (1.45)	1.32[a] (1.25)	1.14[a] (0.79)	1.35[a] (1.32)	1.45[b] (1.60)
T_8	Indoxacarb 14.5 SC	0.010	196 (3.36)	1.95[c] (3.31)	1.87[b] (3.00)	1.85[b] (2.94)	1.68[b] (2.33)	1.84[cd] (2.88)	1.86[d] (2.94)
T_9	Spinetoram 11.7 SC	0.008	2.04 (3.66)	1.52[ab] (1.82)	1.38[a] (1.39)	1.30[a] (1.19)	1.12[a] (0.76)	1.33[a] (1.27)	1.43[b] (1.53)
T_{10}	Control	-	2.05 (3.70)	2.52[d] (5.84)	2.49[c] (5.71)	2.44[c] (5.48)	2.38[c] (5.15)	2.46[e] (5.54)	2.44[e] (5.45)
SEm ±		Treatments (T)	0.11	0.10	0.10	0.10	0.10	0.05	0.03
		Period (P)	-	-	-	-	-	0.03	0.02
		Spray (S)	-	-	-	-	-	-	0.02
		T × P	-	-	-	-	-	0.10	0.07
		T × S	-	-	-	-	-	-	0.05
		P × S	-	-	-	-	-	-	0.03
		T × P × S	-	-	-	-	-	-	0.10
CD at 5%			NS	Sig	Sig	Sig	Sig	Sig	Sig.
CV (%)			9.18	9.82	10.42	10.65	11.85	10.25	9.81

Note: 1. Figures in parentheses are retransformed values and those outside are $\sqrt{X+0.5}$ transformed values
2. Treatment means with the letter(s) in common are not differing significantly by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance
3. Significant parameters and its interactions: S, P and P × S

vitrata and it was at par with lufenuron, indoxacarb, thiodicarb and flubendiamide with larval population of 3.06, 3.00, 2.66 and 2.58 per plant.

Second spray

More or less trends of effectiveness were observed after second spray as observed in first spray. The lower larval population of *M. vitrata* (1.46/plant) exhibited in the plots treated with chlorantraniliprole followed by emamectin benzoate (1.60/plant), spinetoram (1.82/plant) and spinosad (1.88/plant) after three days of spray (Table 1). They were statistically more or less equally effective with each other in reducing the population of *M. vitrata.* While, Flubendiamide and thiodicarb were stood next best group of insecticides in checking the larval population of *M. vitrata* in cowpea by recorded 2.73 and 2.89 larvae per plant, respectively. The higher (3.93 larvae/ plant) larval population was recorded from the plots treated with lambda-cyhalothrin followed by lufenuron (3.33 larvae/ plant) and indoxacarb (3.31 larvae/ plant) where, they were at par with each other.

Population of spotted pod borer, *M. vitrata* was noticed the lowest (1.10 larvae/plant) in plots treated with chlorantraniliprole which was at par with emamectin benzoate (1.92 larvae/ plant), spinetoram

(1.39 larvae/ plant) and spinosad (1.45 larvae/ plant) after seven days of spray (Table 1). Whereas, flubendiamide (2.47 larvae/ plant), thiodicarb (2.61 larvae/ plant), indoxacarb (3.00 larvae/ plant), lufenuron (3.14 larvae/ plant) and lambda-cyhalothrin (3.25 larvae/ plant) exhibited comparatively higher population of *M. vitrata* than effective insecticides but superior to the control. Similar trend of effectiveness of insecticides against *M. vitrata* on cowpea were also observed on ten and fourteen days after second spray.

Pooled over periods data of second spray (Table 1) indicated that the plots treated with the chlorantraniliprole observed lowest (0.96/plant) larval population of *M. vitrata* in cowpea and it was at par with emamectin benzoate (1.07/plant), spinetoram (1.27/plant) and spinosad (1.32/plant). Flubendiamide and thiodicarb were next group insecticides in checking the population of *M. vitrata* by recorded 2.26 and 2.38 larvae per plant, respectively and statically at par with each other of the tested insecticides against *M. vitrata,* lambda-cyhalothrin treated plots recorded the highest (3.10 larvae/ plant) population and it was at par with lufenuron (2.98 larvae/ plant) and indoxacarb (2.88 larvae/ plant).

Pooled over sprays

Pooled over sprays results (Table 1) on effectiveness of insecticides against *M. vitrata* infesting cowpea revealed that chlorantraniliprole @ 0.006% (1.23 larvae/ plant) was found significantly superior among all the evaluated insecticides except emamectin benzoate @ 0.002% (1.32 larvae/ plant) where it was at par with each other. Spinetoram @ 0.008% (1.53 larvae/ plant) and spinosad @ 0.013% (1.60 larvae/ plant) were next best insecticidal group in reducing the larval population of *M. vitrata* and at par with latter insecticide i.e., emamectin benzoate. While, flubendiamide @ 0.012% (2.42 larvae/ plant) and thiodicarb @ 0.112% (2.52 larvae/ plant) were the mediocre insecticidal group in their effectiveness against spotted pod borer. The plots treated with lambda-cyhalothrin @ 0.004% recorded higher (3.12 larvae/ plant) population of *M. vitrata* and it was at par with lufenuron @ 0.006 (3.02 larvae/ plant).

The above results are in accordance with the Muddu Krishna (2007) report that the emamectin benzoate 5 WG @ 0.002% was highly effective against *M. testulalis* infesting black gram. Patel *et al.* (2012) noticed that emamectin benzoate 5 SG significantly reduced the spotted pod borer damage in cowpea. Similarly, emamectin benzoate 5 WG @ 0.0025% lower down larval population as well as pod damage in black gram (Anonymous 2013). As per the report of Mahalakshmi *et al.* (2013), higher doses of chlorantraniliprole i.e., at 30, 25 and 20 g a.i./ha superior reduced the larval population of *M. vitrata* in black gram. Chlorantraniliprole 20 SC @ 0.006% and emamectin benzoate 5 WG @ 0.0015% were most effective insecticides in suppressing larval incidence of *M. vitrata* on green gram (Patel 2014). These reports are in agreement with the present conclusion.

Impact of insecticides on pod damage (%) due to *M. vitrata* in cowpea

In order to find out the impact of insecticides on pod damage caused by *M. vitrata,* observations were recorded before first spray as well as 3, 7, 10 and 14 days after sprays. The data on per cent pod damage of first spray and second spray as well as pooled over sprays are presented in Table 2. The pod damage before application was uniform in all the insecticidal treatments as treatment difference was non-significant. All the evaluated insecticidal significantly reduced the pod damage caused by *M. vitrata* in cowpea during both sprays as well as in pooled over sprays.

First spray

The lower (16.93%) cowpea pod damage caused by *M. vitrata* recorded in the treatment of chlorantraniliprole and it was at par with emamectin benzoate (17.18%), spinetoram (20.59%) and spinosad (20.81%) after 3 days of spray (Table 2). Flubendiamide (27.54%) was found significantly superior to remaining insecticides but equally effective to spinetoram and spinosad. Among the evaluated insecticides, significantly the highest (36.69%) pod damage was noticed in plots treated with lambda-cyhalothrin followed by lufenuron, indoxacarb and thiodicarb with 36.20, 36.04 and 35.87, respectively. These four inferior treatments were recorded statistically equal cowpea pod damage as control.

The results of seven days after spray (Table 2) indicated that the chlorantraniliprole protected plots had minimum (13.93%) damaged cowpea pods and it was at par with emamectin benzoate (14.21%), spinetoram (20.00%) and spinosad (20.87%). Plots treated with flubendiamide was exhibited 25.70% cowpea pod damage due to *M. vitrata.* It was at par with spinetoram and spinosad on one hand while, with thiodicarb and indoxacarb on other hand based on pod damage. Thiodicarb and indoxacarb were found pod damage 34.19 and 34.45% respectively. Among the evaluated insecticides, the highest (34.74%) damage noted in the treatment of lambda-cyhalothrin and it was at par with lufenuron (35.11%), indoxacarb (34.45%) and thiodicarb (34.19%). However, these treatments were significantly superior to control.

The spotted pod borer, *M. vitrata* caused lowest pod damage (9.04%) in the treatment of chlorantraniliprole after 10 days of spray (Table 2). Plots treated with emamectin benzoate and spinetoram were exhibited 9.73 and 12.76% pod damage, respectively. These insecticides (emamectin benzoate and spinetoram) were statistically equally effective as chlorantraniliprole. Spinosad (20.79%) and flubendiamide (19.53%) were found to be significantly more effective by recording lower cowpea pod damage than the remaining insecticides. Among the tested insecticides, the highest (29.97%) pod damage noted in the treatment lambda-cyhalothrin followed by lufenuron, indoxacarb and thiodicarb at 29.74, 28.81 and 28.27, respectively.

The data (Table 2) on per cent cowpea pod damage caused by *M. vitrata* collected after 14 days of first spray indicated that the chlorantraniliprole treated plots had minimum (14.82%) damaged and it was at par with emamectin benzoate (15.36%), spinetoram (18.93%) and spinosad (20.79%). Plots treated with flubendiamide was exhibited 23.00%

Table 2. Impact of insecticides on pod damage due to spotted pod borer, *M. vitrata* in cowpea after first spray.

Sl. No.	Treatments		Conc (%)	Before spray	Pod damage (%) after indicated days of first spray 3	7	10	14	Pooled
T_1	Chlorantraniliprole 18.50 SC		0.006	36.35 (35.13)	24.30[a] (16.93)	21.92[a] (13.93)	17.49[a] (9.04)	22.64[a] (14.82)	21.59[a] (13.54)
T_2	Emamectin benzoate 5 SG		0.002	33.28 (30.12)	24.49[a] (17.18)	22.14[a] (14.21)	18.18[ab] (9.73)	23.08[a] (15.36)	21.97[a] (14.00)
T_3	Flubendiamide 20 WG		0.012	32.88 (29.48)	31.59[b] (27.44)	30.46[bc] (25.70)	26.23[c] (19.53)	28.66[bc] (23.00)	29.23[c] (23.85)
T4	Thiodicarb 75 WP		0.112	34.43 (31.96)	36.79[c] (35.87)	35.78[cd] (34.19)	32.12[d] (28.27)	33.19[cd] (29.97)	34.47[d] (32.04)
T_5	Lufenuron 5.40 EC		0.006	37.50 (37.06)	36.99[c] (36.20)	36.34[d] (35.11)	33.05[d] (29.74)	33.99[d] (31.25)	35.09[d] (33.04)
T_6	Lambda-cyhalothrin 5 EC		0.004	37.26 (36.65)	37.28[c] (36.69)	36.71[d] (35.74)	33.19[d] (29.97)	34.44[d] (31.98)	35.41[d] (33.57)
T_7	Spinosad 45 SC		0.013	34.87 (32.68)	27.14[ab] (20.81)	27.18[ab] (20.87)	22.18[bc] (14.25)	27.13[ab] (20.79)	25.91[b] (19.09)
T_8	Indoxacarb 14.5 SC		0.010	33.65 (30.7)	36.89[c] (36.04)	35.94[cd] (34.45)	32.46[d] (28.81)	33.50[cd] (30.46)	34.70[d] (32.41)
T_9	Spinetoram 11.7 SC		0.008	35.05 (32.98)	26.99[ab] (20.59)	26.57[ab] (20.00)	20.93[ab] (12.76)	25.79[ab] (18.93)	25.07[b] (17.95)
T_{10}	Control		-	38.46 (38.69)	41.90[c] (44.59)	43.13[e] (46.73)	44.32[e] (48.81)	45.76[e] (51.33)	43.77[e] (47.86)
SEm ±		Treatments (T)		2.02	1.51	1.73	1.37	1.46	0.75
		Period (P)		-	-	-	-	-	0.48
		Spray (S)		-	-	-	-	-	-
		T × P		-	-	-	-	-	1.51
		T × S		-	-	-	-	-	-
		P × S		-	-	-	-	-	-
		T × P × S		-	-	-	-	-	-
CD at 5%				NS	Sig	Sig	Sig	Sig	Sig
CV (%)				9.90	8.06	9.48	8.47	8.18	8.50

Table 2. Continued.

Sl. No.	Treatments	Conc (%)	Before spray	Pod damage (%) after indicated days of second spray 3	7	10	14	Pooled	Pooled over periods and sprays
T_1	Chlorantraniliprole 18.50 SC	0.006	36.35 (35.13)	20.25[a] (11.98)	16.43[a] (8.00)	14.02[a] (5.87)	10.00[a] (3.02)	15.18[a] (6.85)	18.38[a] (9.94)
T_2	Emamectin benzoate 5 SG	0.002	33.28 (30.12)	20.61[ab] (12.39)	17.29[ab] (8.83)	14.36[a] (6.15)	10.27[a] (3.18)	15.63[a] (7.26)	18.80[a] (10.39)
T_3	Flubendiamide 20 WG	0.012	32.88 (29.48)	27.82[cd] (21.79)	23.02[c] (15.29)	21.83[bc] (13.82)	17.91[b] (9.45)	22.64[c] (14.82)	25.94[c] (19.13)
T_4	Thiodicarb 75 WP	0.112	34.43 (31.96)	33.56[de] (30.56)	28.53[d] (22.81)	26.62[cd] (20.07)	22.95[c] (15.2)	27.91[d] (21.92)	31.19[d] (26.82)
T_5	Lufenuron 5.40 EC	0.006	37.50 (37.06)	34.65[e] (32.33)	30.48[d] (25.72)	27.10[cd] (20.76)	23.33[c] (15.69)	28.89[d] (23.34)	31.99[d] (28.07)
T_6	Lambda-cyhalothrin 5 EC	0.004	37.26 (36.65)	34.89[e] (32.72)	31.72[d] (27.64)	27.89[d] (21.88)	23.69[c] (16.14)	29.55[d] (24.32)	32.48[d] (28.83)
T_7	Spinosad 45 SC	0.013	34.87 (32.68)	26.03[bc] (19.25)	21.16[bc] (13.03)	19.20[ab] (10.81)	15.12[b] (6.80)	20.38[bc] (12.12)	23.14[b] (15.44)
T_8	Indoxacarb 14.5 SC	0.010	33.65 (30.7)	34.01[e] (31.29)	28.89[d] (23.34)	26.81[cd] (20.35)	23.02[c] (15.29)	28.18[d] (22.30)	31.44[d] (27.21)
T_9	Spinetoram 11.7 SC	0.008	35.05 (32.98)	24.76[abc] (17.54)	19.75[abc] (11.41)	18.13[ab] (9.69)	14.48[ab] (6.25)	19.28[b] (10.90)	22.17[b] (14.24)
T_{10}	Control	-	38.46 (38.69)	47.95[f] (55.14)	46.03[e] (51.79)	43.39[e] (47.19)	41.27[d] (43.51)	44.66[e] (49.40)	44.22[e] (48.63)
SEm ±		Treatments (T)	2.02	1.76	1.41	1.66	1.50	0.77	0.54
		Period (P)	-	-	-	-	-	0.49	0.34
		Spray (S)	-	-	-	-	-	-	0.24
		T × P	-	-	-	-	-	1.54	1.08
		T × S	-	-	-	-	-	-	0.76
		P × S	-	-	-	-	-	-	0.48
		T × P × S	-	-	-	-	-	-	1.52
CD at 5%			NS	Sig	Sig	Sig	Sig	Sig	Sig.
CV (%)			9.90	10.00	9.30	12.02	12.89	10.58	9.41

Note : 1. Figures in parentheses are retransformed values and those outside are arcsine transformed values.
2. Treatment means with the letter(s) in common are not differing significantly by DNMRT at 5% level of significance.
3. Significant parameters and its interactions: P.

cowpea pod damage due to *M. vitrata.* It was at par with spinetoram and spinosad on one hand while, with thiodicarb and indoxacarb on other hand based on pod damage. Thiodicarb and indoxacarb were found pod damage 29.97 and 30.46% respectively. Among the evaluated insecticides, the highest (31.98%) damage found in the treatment of lambda-cyhalothrin but superior to control and it was at par with lufenuron (31.25%), indoxacarb (30.46%) and thiodicarb (29.97%).

The pooled over period of first spray data (Table 2) clearly exposed that the treatments of chlorantraniliprole (13.54%) and emamectin benzoate (14.00%) found significantly superior than all the evaluated insecticides against *M. vitrata* on cowpea. The pod damage was found 17.95 and 19.09 per cent in plots treated with spinetoram and spinosad, respectively and they were at par with each other but significantly superior to remaining insecticides followed by flubendiamide (23.85%). Among the evaluated insecticides, the highest (33.57%) pod damage was noticed in plots treated with lambda-cyhalothrin and it was more or less equally effective with lufenuron (33.57%), indoxacarb (33.04%) and thiodicarb (32.04%).

Second spray

After three days of second spray (Table 2), cowpea pod damage (11.98%) due to *M. vitrata* was recorded lower (11.98%) in chlorantraniliprole treated plot and it was at par with emamectin benzoate (12.39%) and spinetoram (17.54%). The treatment spinosad was noticed 19.25% pod damage and it was at par with emamectin benzoate, spinetoram and flubendiamide. The highest (32.72%) cowpea pod damage was found from the plots treated with lambda-cyhalothrin followed by lufenuron, indoxacarb and thiodicarb at 32.33, 31.29 and 30.56, respectively.

The spotted pod borer, *M. vitrata* caused the least cowpea pod damage (8.00%) in the treatment of chlorantraniliprole after seven days of spray (Table 2). Plots treated with emamectin benzoate and spinetoram were noted 8.83 and 11.41% pod damage, respectively. These insecticides (emamectin benzoate and spinetoram) were statistically equally effective as chlorantraniliprole. Spinosad (13.03%) and flubendiamide (15.29%) were found to be significantly more effective by recording lower cowpea pod damage than the remaining insecticides and it was at par with spinetoram. The treatment lambda-cyhalothrin recorded the highest (29.97%) pod damage caused by *M. vitrata* and statistically equally effective with lufenuron (25.72%), indoxacarb (23.34%) and thiodicarb (22.81%).

Cowpea pods significantly less damaged (5.87%) by *M. vitrata* in chlorantraniliprole treated plots and it was at par with emamectin benzoate (6.15%), spinetoram (9.69%) and spinosad (10.81%) after ten days of second spray (Table 2). Flubendiamide treated plots recorded 13.82% pod damage due to *M. vitrata* in cowpea. This treatment was at par with spinetoram and spinosad on one hand while, on other hand it was equally effective with thiodicarb (20.07%), indoxacarb (20.35%) and lufenuron (20.76%). Among the evaluated insecticides, the highest (21.88%) pod damage was noticed in the plots treated with lambda-cyhalothrin but superior than the control and statistically at par with lufenuron, indoxacarb and thiodicarb after ten days of spray.

The pod damage recorded 14 days after application (Table 2) showed the higher effectiveness (3.02%) of chlorantraniliprole and it was at par with emamectin benzoate (3.18%), spinetoram (6.25%). Spinosad (6.80%) and flubendiamide (9.45%) were emerged as next best effective insecticides in reducing cowpea pod damage due to *M. vitrata.* However, they were at par with spinetoram. Significantly the highest (16.14%) pod damage was noticed in plots treated with lambda-cyhalothrin than all the evaluated insecticides and it was at par lufenuron (15.29%), indoxacarb (15.29%) and thiodicarb (15.20%).

Pooled over periods data (Table 2) of second spray exhibited the higher effectiveness of chlorantraniliprole against *M. vitrata* on cowpea by recording 6.85% pod damage than rest of the insecticides except emamectin benzoate (7.26%). Spinetoram (10.90%) and spinosad (12.12%) were illustrated as next best effective insecticidal group. Flubendiamide protected plots recorded 14.82% pod damage and it was at par with spinosad. Pod damage due to *M. vitrata* after second spray noticed higher (24.32%) in the plots with lambda-cyhalothrin and it was at par with lufenuron (23.34%), indoxacarb (22.30%) and thiodicarb (21.92%).

Pooled over sprays

Pooled of two sprays (Table 2) indicated that the treatments chlorantraniliprole (9.94%) and emamectin benzoate 10.39% found significantly superior than rest of the insecticides. Spinetoram (14.24%) and spinosad (15.44%) were equally effective and appeared as next best group of insecticides. Flubendiamide treated plots recorded 19.13% cowpea pod damage and it was superior to the rest of insecticides. Among the valuated insecticides, the plot treated with lambda-cyhalothrin recorded the highest (28.83%) pod damage and it was at par with lufenuron (28.07%), indoxacarb (27.21%) and thiodicarb (26.82%). Considering the per cent cowpea pod damage due to *M. vitrata,* different insecticides arranged in descending order of efficacy as: Chlorantraniliprole (9.94%) < Emamectin benzoate (10.39%) < Spinetoram (14.24%) < Spinosad (15.44%) < Flubendiamide (19.13%) < Thiodicarb (26.82%) < Indoxacarb (27.21%) < Lufenuron (28.07%) < Lambda-cyhalothrin (28.83%).

The above findings are more or less similar with the report of Sreekanth *et al.* (2015), the lowest pigeon pea pod damage was recorded in chlorantraniliprole

Table 3. Impact of insecticides on yield and avoidable losses due to *M. vitrata* infesting cowpea.

Sl. No.	Treatments	Conc (%)	Green pod yield (q/ ha)	Increase in yield over control (%)	Avoidable loss (%)
T_1	Chlorantraniliprole 18.50 SC	0.006	76.33[a]	32.36	-
T_2	Emamectin benzoate 5 SG	0.002	75.50[a]	30.92	1.09
T_3	Flubendiamide 20 WG	0.012	64.83[bcd]	12.42	15.07
T_4	Thiodicarb 75 WP	0.112	63.70[cd]	10.46	16.55
T_5	Lufenuron 5.40 EC	0.006	62.00[d]	7.51	18.77
T_6	Lambda-cyhalothrin 5 EC	0.004	61.17[d]	6.07	19.86
T_7	Spinosad 45 SC	0.013	74.00[abc]	28.32	3.05
T_8	Indoxacarb 14.5 SC	0.010	62.93[d]	9.12	17.56
T_9	Spinetoram 11.7 SC	0.008	74.67[ab]	29.48	2.17
T_{10}	Control	-	57.67[d]	-	24.45
SEm ±			3.12	-	-
CD at 5%			Sig.	-	-
CV (%)			8.03	-	-

Note: Treatment mean with letter(s) in common are not differing significantly by DNMRT at 5% level of significance.

(4.30%) while, Pant *et al.* (2021) found that the chlorantraniliprole 18.5 SC was most effective insecticide by recording lowest (5.18 %) cowpea pod damage due to *M. vitrata.* Thus, the above results on significantly superior levels of chlorantraniliprole are in close association with the present outcome.

Impact on yield of green cowpea pod

The main aim of pest management is to suppress the target pests by using different components and to determine their ultimate effect on yield and economics. As a result, yield data were collected in order to determine the effect of various insecticidal molecules. On the basis of yield, increase in yield over control and avoidable losses were calculated, whereas by using cost of treatments, incremental cost benefit ratio (ICBR) was calculated.

Green cowpea pod yield

The data on green cowpea pod yield are presented in Table 3. The higher (76.33 q/ha) green cowpea pods were picked up from the plots treated with chlorantraniliprole and it was at par with emamectin benzoate (75.50 q/ha), spinetoram (74.67 q/ha) and spinosad (74.00 q/ha). The treatments flubendiamide (64.83 q/ha) and thiodicarb (63.70 q/ha) registered ordinary performance in cowpea pod yield. The lowest (61.17 q/ ha) cowpea pod yield was recorded from lambda-cyhalothrin treated plots and it was at par with lufenuron (62.00 q/ ha) and indoxacarb (62.93 q/ ha).

The outcomes of Patel *et al.* (2012), Anonymous (2013), Sreekanth *et al.* (2015) and Pant *et al.* (2021) support the present findings.

Increase in yield over control

Increase in yield over control in cowpea was worked out for different insecticidal treatment and presented in Table 3. The increase in yield over control ranged from 6.07 to 32.36 per cent due to application of insecticides. Maximum (32.36%) green cowpea pod yield was increased in the plots treated with chlorantraniliprole followed by emamectin benzoate (30.92%), spinetoram (29.48%) and spinosad (28.32%). Plots treated with flubendiamide (12.42%), thiodicarb (10.46%) and indoxacarb (9.12%) provided with average increase in the yield. Whereas, the lowest (6.07%) increase in yield was illustrated from the lambda-cyhalothrin protected plots followed by lufenuron (7.51%).

Avoidable losses

Avoidable losses in yield of cowpea was concerned, it varied from 1.09 to 19.86% in different treatments (Table 3). The avoidable loss was the lowest (1.09%) in the treatment of emamectin benzoate followed by spinetoram (2.17%) and spinosad (3.05%). The avoidable losses were calculated as 15.07 to 18.77% in the treatments of flubendiamide, thiodicarb, indoxacarb and lufenuron. Among the tested insecticides, the highest (19.86%) avoidable loss was calculated in the treatment of lambda-cyhalothrin.

Economics

The highest ICBR returns were obtained in the treatment of emamectin benzoate (1: 11.48) followed by chlorantraniliprole (1: 8.67), spinetoram (1: 5.20) and spinosad (1: 4.92). The ICBR was recorded 3.47 and 3.22 in the treatments of lambda-cyhalothrin and flubendiamide, respectively. The plots treated with indoxacarb, thiodicarb and lufenuron exhibited less (1: 2.56, 2.42 and 2.23) ICBR.

Overall, insecticides evaluated against *M. vitrata* based on larval population, pod damage, yield and economics reflected that the chlorantraniliprole 18.5 SC @ 0.006% and emamectin benzoate 5 SG @ 0.002% were found more effective whereas, spinetoram 11.7 SC @ 0.008%, spinosad 45 SC @ 0.013%, flubendiamide 20 WG @ 0.012%, thiodicarb 75 WP @ 0.112% and indoxacarb 14. SC @ 0.010 % considered as moderately effective insecticides in cowpea against *M. vitrata.* In contrast to this, insecticides lufenuron 5.4 EC @ 0.006% and lambda-cyhalothrin 5 EC @ 0.004% were failed to check the build-up of *M. vitrata* in cowpea.

CONCLUSION

From the foregoing results it can be concluded that among the nine insecticides evaluated, chlorantraniliporle and emamectin benzoate were found the most effective in reducing the incidence of *M. vitrata* infesting cowpea with the green cowpea pod yield of treatments 76.33 and 75.50 q/ha, respectively. Looking to the ICBR, the highest (1: 11.48) return obtained with the treatment of emamectin benzoate followed by chlorantraniliprole (1: 8.67), spinetoram (1: 5.20) and spinosad (1: 4.92).

REFERENCES

Anonymous (2013) Farming recommendation. Department of Entomology, BA. College of Agriculture, Anand Agricultural University, Anand. Retrieved from: http://www.aau.in/sites/default/files/4_reco_ento.pdf. Accessed 20 June 2022.

CMIE (2020) Retrieved from: https://commodities.cmie.com/. Accessed 16 May 2022.

Jackai LEN (1985) Cowpea entomology research at IITA and its impact on food production in the tropics. *Nigeria J. Entornal,* 6: 87-97.

Jackai LEN (1993) The use of neem in controlling cowpea pests. *IITA Res* 7: 5-11.

Jackai LE, Daoust RA (1986) Insect pests of cowpeas. *Annl Rev Entomol* 31(1): 95-119.

Mahalakshmi MS, Rao CR, Adinarayana M, Babu JS, Rao YK (2013) Evaluation of Coragen (DPX-E2Y45) against legume pod borer, *Maruca vitrata* (Geyer) (Lepidoptera: Pyralidae) on blackgram. *Int J PlAnimal Environm Sci* 3(4): 51-54.

Muddu Krishna P (2007) Population dynamics and management of lepidopteran insect pests of black gram (Master's thesis, Anand Agricultural University, Anand).

Pandey SN, Singh R, Sharma VK, Kanwat PM (1993) Losses due to insect pests in some *kharif* pulses. *Ind J Entomol* 53: 629-631.

Pant C, Regmi R, Bhusal S, Yadav S, Tiwari S, Wagle P, Bhandari M (2021) Efficacy of commercial insecticide for the management of cowpea pod borer (*Maruca vitrata*) on cowpea (*Vigna unguiculata* (L.) Walp) under field condition in Chitwan, Nepal. *Food Agribusiness Manage (FABM)* 2(2): 92-95. http://doi.org/10.26480/fabm.02.2021.92.95.

Patel HC (2014) Life table and management of spotted pod borer, *Maruca vitrata* (Geyer) in green gram, *Vigna radiata* (Linnaeus) Wilczek.

Patel PS, Patel IS, Panickar B, Ravindrababu Y (2012) Management of spotted podborer, *Maruca vitrata* in cowpea through newer insecticides. *Trends Biosci* 5(2): 149-151.

Pradhan S (1969) Insect Pests of Crops. National book trust, New Delhi, India, pp 80.

Singh U, Singh B (1992) Tropical grain legumes as important human foods. *Econ Bot* 46: 310-321. https://doi.org/10.1007/BF02866630.

Sreekanth M, Lakshmi MSM, Rao YK (2015) Efficacy and economics of certain new generation novel insecticides against legume pod borer, *Maruca vitrata* (Geyer) on pigeonpea (*Cajanus cajan* L.). *J Appl Biol Biotech* 3(3): 07-10. https://doi.org/ 10.7324/JABB.2015.3302.

Steel RGD, Torrie JH (1980) Principles and procedures of statistics, a biometrical approach (No. Ed. 2). McGraw-Hill Koga kusha, Ltd.

Suh JB, Jackai LN, Hammond WNO (1986) Observations on pod sucking bug populations on cowpea at Mokwa, Nigeria. *Trop Grain Leg Bull* 33: 17-19.