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Field Efficacy of a Combination of Seed Treatment and Foliar Spray against Pest Complex in Green Gram

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ABSTRACT

Background: Pulses constitute the major source of dietary protein; therefore, it has ability to fulfil required protein recommended dietary allowance for vegetarian population of India. Pulse crop attack more than 200 insect pests and inflicting heavy damages at different growth stages that lead to significant economic losses to the farmers. The studies were conducted on green gram to find out the effective control measure of different crop stages against insect pests complex in green gram.

Methods: The field experiment was laid out in a randomized block design and the consist 12 treatments with seed treatment and foliar sprays of insecticides at 50 per cent flowering stages then these treatments were replicated thrice at both years 2017 and 2018.

Result: The experiments concluded that the reduction of sucking pests population like thrips, jassid and whitefly and larval population of *Maruca vitrata* and *Helicoverpa armigera* was found in seed treated with imidacloprid 48 FS and spray of flubendiamide at 50 per cent flowering stage in green gram with Rs. 10,678 net profit and 1:1.42 cost-benefit ratio.

Key words: Foliar spray, Gram pod borer, Green gram, Seed treatment, Spotted pod borer.

INTRODUCTION

India has 29 per cent vegetarians, which was more than everywhere in the world. India has sufficient food grain to meet the recommended dietary allowance (RDA). However, per capita pulse availability and consumption have declined since 1975 consequently, nutrient intake RDA was insufficient, especially protein (Ramachandran, 2006). Pulses constitute the major source of dietary protein; therefore, it can fulfill required protein RDA for a vegetarian population of India.

India is the largest producer and consumer of pulses in the world account for 33 per cent of world's area and 24 per cent of world's production. Green gram is one of the thirteen food legumes grown in India among them third important legume after chickpea and pigeon pea.

There are more than 200 insect pests belong to 48 families attack on green gram and inflicting heavy damages at different growth stages in different agro-climatic conditions (Lal and Sachan, 1987). Among them sucking pests like aphid, jassid, whitefly, bugs thrips and caterpillar like spotted pod borer, hairy caterpillar, tobacco caterpillar and blue butter flies are key pests in Gujarat. The sucking insect pests not only reduce the vigor of the plant by sucking the sap but transmit diseases and affect photosynthesis consequently reduce yield. Yellow mosaic virus disease cause 67 per cent yield losses in green gram and black gram that transmitted by whitefly (Jain *et al.*, 1995). Caterpillar damage reproductive parts like pods and cause significantly economical damage to the farmers. Several reports (Biswas and Bhunia, 2009; Khutwad *et al.*, 2002; Salam, 2005) shown the combination of the seed treatment and foliar spray against pest was more effective than alone spray and give complete protection against pest complex. Hence, the present studies were conducted on green gram to find out the effective and economical insecticides as a seed treatment and a foliar spray combination against insect pests complex in green gram.

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MATERIALS AND METHODS

The present study was conducted during *kharif* season year of 2017 and 2018 at Regional Research Station, Anand Agricultural University, Anand. The field experiment was laid out in a randomized block design (RBD) and the consist 12 treatments (Table 1) including control and these treatments were replicated thrice. Green gram variety GAM-5 which is commonly cultivated in this area was grown in plots had 5 rows, plot size 5.0 × 3.6 meter in each plot. The space between rows and plants were maintained 45 cm and 10 cm, respectively. Crop was raised by following all local recommended agronomical practice except insecticidal spray.

For seed treatment, 200 g of green gram seeds was taken in a plastic bag. Then 10 ml of water and required quantity of insecticide was added to this and stirred carefully. More water was added drop by drop and stirred well to get slurry. Plastic bag was tightened properly and vigorously shaken for 30 seconds to get uniform coated of the slurry on the seeds. Dressed seed was then air dried in shade

Table 1: Detail of treatments applied as a seed treatment and foliar spray in green gram.

Tr. no.	Name of the insecticides	Doses
T_1	Imidacloprid 48 FS - Spinosad 45 SC	Seed treatment @ 5 ml/kg (2.4 g a.i./kg seed) - Foliar spray@ 4 ml/10 lit (90 g a.i./ha) of water at 50% flowering.
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC	Seed treatment @ 5 ml/kg (2.4 g a.i./kg seed) -Foliar spray@ 2 ml/10 lit (48g a.i./ha) of water at 50% flowering.
T_3	Imidacloprid 48 FS - Chlorantraniliprole 18.5 SC	Seed treatment @ 5 ml/kg (2.4 g a.i./kg seed) -Foliar spray@ 2 ml/l lit (18.5g. a.i./ha) of water at 50% flowering.
T_4	Thiamethoxam 30 FS - Spinosad 45 SC	Seed treatment @ 5 ml/kg (1.5 g a.i./kg seed) - Foliar spray@ 4 ml/10 lit (90 g a.i./ha) of water at 50% flowering.
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC	Seed treatment @ 5 ml/kg (1.5 g a.i./ kg seed) - Foliar spray@ 2 ml/10 lit (48g a.i./ha) of water at 50% flowering.
T_6	Thiamethoxam 30 FS - Chlorantraniliprole 18.5 SC	Seed treatment @ 5 ml/kg (1.5 g a.i./ kg seed) - Foliar spray@ 2 ml/l lit (18.5g. a.i./ha) of water at 50% flowering.
T_7	Imidacloprid 48 FS	Seed treatment @ 5 ml/kg (2.4 g a.i./kg seed).
T_8	Thiamethoxam 30 FS	Seed treatment @ 5 ml/kg (1.5 g a.i./ kg seed).
T_9	Spinosad 45 SC	Foliar spray@ 4 ml/10 lit (90 g a.i./ha) of water at 50% flowering.
T_{10}	Flubendiamide 48 SC	Foliar spray@ 5 ml/10 lit (48 g a.i./ha) of water at 50% flowering.
T_{11}	Chlorantraniliprole 18.5 SC	Foliar spray@ 5 ml/10 lit (18.5 g. a.i./ha) of water at 50% flowering.
T_{12}	Control	No seed treatment and spray.

overnight and sown on the next day. For foliar application, the treatment's wise application of insecticides were done at 50 per cent flowering of the green gram. Spray fluid was taken 500 liters per hectare. All sprays were done by using knapsack sprayer in the morning hours. To avoid cross contamination of insecticides, utmost care taken as spray pump was washed thrice with fresh water while switching over from one insecticide to another.

For the count of aphid, jassid and whitefly, 5 plants randomly selected in net plot area of each treatment. The population jassid and whitefly will be recorded from three leaves (upper, middle and lower) of the selected plants. The data from each plot were recorded early in the morning at every week after 10 days of sowing up to 60 days after sowing for sucking pest. The observations of the number of larvae per plant were recorded on one day before and 1st, 3rd and 7th day after spray from randomly selected 5 plants per plot. At the time of harvest, pod damage was recorded from randomly selected 50 pods from each plot.

The data was analyzed of variance to determine the significance of treatments (Steel and Torrie, 1980). Means were separated by Duncan's new multiple range test (DMRT) (Duncan, 1955).

RESULTS AND DISCUSSION

Effect of seed treatment

Sucking pest population *viz.* thrips, jassid and whitefly on green gram at 10 to 60 day after sowing (DAS) was homogeneous in treatments indicated uniformly distribution in the experimental plot during *kharif* 2017 and 2018. The data of 10 to 60 DAS were analyzed and presented in Table 2.

Green gram seeds treated with imidacloprid 48 FS and thiamethoxam 30 FS which were T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 found significantly reduce a population of thrips compare to T_9, T_{10}, T_{11} and control in 2017. In 2018, significantly lowest thrips population was observed in seed treated with imidaclopriod 48 FS, which were T_1, T_2, T_3, T_7 followed by seed treated with thiomethoxam 30 FS which was T_4, T_5, T_6 and T_8. The data on pooled over year revealed that, significantly lowest thrips population was observed in seed treated with imidacloprid 48 FS, which were T_1, T_2, T_3 and T_7 followed by seed treated with thiomethoxam 30 FS, it was T_5 and T_6 (Table 2).

The pooled over periods data in 2017, indicate jassid population found significantly lowest in seed treated with imidacloprid 48 FS, which were T_1, T_2, T_3 and T_7 followed by seed treated with thiomethoxam 30 FS, that was T_4, T_5 and T_6. In 2018, significantly lowest jassid population was observed in seed treated with imidaclopriod 48 FS (T_1, T_2, T_3 and T_7) and thiamethoxam 30 FS (T_4, T_5, T_6 and $T_{8)}$ compared to T_9, T_{10}, T_{11} and control. The data of pooled over year revealed that the significantly lowest jassid population was found in seed treated with imidacloprid 48 FS which were T_1, T_2, T_3 and T_7 followed by seed treated with thiomethoxam 30 FS, it was T_4, T_5, T_6 and T_8 (Table 2).

Whitefly population was found significantly lowest in seed treated with thiamethoxam 30 FS, which were T_4, T_5,

Table 2: Efficacy of seed treatment against sucking pests of green gram.

Tr. no.	Treatments		Number of sucking insects per leaf								
			Thrips			Jassids			Whitefly		
			2017	2018	Pooled over years	2017	2018	Pooled over years	2017	2018	Pooled over years
T_1	Imidacloprid 48 FS - Spinosad 45 SC		1.04a	0.87a	0.96a	0.87ab	0.81ab	0.84a	0.95c	0.86c	0.91bcd
			(0.63)	(0.28)	(0.42)	(0.25)	(0.16)	(0.20)	(0.42)	(0.24)	(0.33)
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC		1.04a	0.88a	0.96a	0.85a	0.80ab	0.83a	0.99cd	0.78a	0.85ab
			(0.63)	(0.29)	(0.42)	(0.23)	(0.14)	(0.19)	(0.48)	(0.11)	(0.23)
T_3	Imidacloprid 48 FS- Chlorantraniliprole 18.5		1.05a	0.91a	0.98a	0.87ab	0.80a	0.83a	0.99cd	0.79ab	0.85ab
			(0.64)	(0.34)	(0.45)	(0.25)	(0.14)	(0.19)	(0.48)	(0.12)	(0.21)
T_4	Thiamethoxam 30 FS - Spinosad 45 SC		1.11a	1.08c	1.10c	0.94bc	0.86abc	0.90bc	0.88a	0.83bc	0.86abc
			(0.78)	(0.68)	(0.71)	(0.38)	(0.24)	(0.30)	(0.28)	(0.19)	(0.24)
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC		1.10a	1.05c	1.08bc	0.95bc	0.86abc	0.91c	0.89ab	0.78ab	0.83a
			(0.76)	(0.63)	(0.66)	(0.41)	(0.26)	(0.33)	(0.30)	(0.11)	(0.18)
T_6	Thiamethoxam 30 FS - Chlorantraniliprole 18.5		1.12a	1.05bc	1.08bc	0.95bc	0.87bc	0.91c	0.87a	0.80ab	0.83a
			(0.79)	(0.62)	(0.67)	(0.41)	(0.26)	(0.32)	(0.26)	(0.14)	(0.19)
T_7	Imidacloprid 48 FS		1.09a	0.96ab	1.02a	0.90ab	0.80a	0.85ab	0.90ab	0.81ab	0.84a
			(0.72)	(0.44)	(0.54)	(0.31)	(0.14)	(0.22)	(0.32)	(0.15)	(0.20)
T_8	Thiamethoxam 30 FS		1.14a	1.06c	1.99c	0.93ab	0.89cd	0.91c	0.89a	0.83bc	0.87abc
			(0.84)	(0.65)	(3.44)	(0.36)	(0.30)	(0.32)	(0.30)	(0.19)	(0.25)
T_9	Spinosad 45 SC		1.33b	1.25d	1.29d	1.05d	0.94de	0.99d	1.04cd	0.87c	0.94e
			(1.35)	(1.11)	(1.16)	(0.61)	(0.40)	(0.49)	(0.60)	(0.25)	(0.38)
T_{10}	Flubendiamide 48 SC		1.30b	1.28d	1.29d	1.01cd	0.95de	0.98d	1.02cd	0.88cd	0.92cde
			(1.27)	(1.18)	(1.17)	(0.52)	(0.42)	(0.46)	(0.56)	(0.27)	(0.35)
T_{11}	Chlorantraniliprole 18.5 SC		1.31b	1.31d	1.31d	1.04d	0.96de	1.00d	1.05d	0.92de	0.91bcde
			(1.31)	(1.26)	(1.22)	(0.59)	(0.43)	(0.50)	(0.61)	(0.34)	(0.33)
T_{12}	Control		1.36b	1.31d	1.33d	1.06d	0.97e	1.02d	1.08d	0.94e	0.94de
			(1.44)	(1.24)	(1.28)	(0.62)	(0.46)	(0.53)	(0.67)	(0.37)	(0.38)
S.Em. ±		(Treatment) T	0.05	0.03	0.02	0.03	0.03	0.018	0.04	0.012	0.02
		(Period) P	0.02	0.02	0.08	0.02	0.02	0.032	0.02	0.02	0.04
		(Year) Y	-	-	0.01	-	-	0.008	-	-	0.06
		T × P	0.08	0.07	0.05	0.06	0.06	0.041	0.06	0.04	0.033
		T × Y	-	-	0.03	-	-	0.026	-	-	0.021
		P × Y	-	-	0.02	-	-	0.017	-	-	0.014
		T × P × Y	-	-	0.07	-	-	0.058	-	-	0.047
C.D at 5%		T	0.13	0.09	0.07	0.09	0.07	0.052	0.10	0.05	0.07
		P	0.06	0.05	0.30	0.05	0.05	NS	0.05	0.03	0.14
		Y	-	-	0.027	-	-	0.021	-	-	0.02
		T × P	NS	0.69	NS	NS	NS	NS	NS	0.12	0.09
		T × Y	-	-	NS	-	-	NS	-	-	0.06
		P × Y	-	-	0.06	-	-	0.047	-	-	0.06
		T × P × Y	-	-	NS	-	-	NS	-	-	NS
C.V. %			11.66	10.95	11.34	10.70	11.44	11.06	13.48	8.73	9.29

Note: Figures in parentheses are retransformed values and those outside are √x+0.5 transform values.

Treatment mean(s) with a letter(s) in common are non-significant by DNMRT at 5% level of significant.

T_6 and T_8 in 2017. At 2018, significantly lowest whitefly population was observed in thiomethoxam (T_5, T_6 and T_7) and imidacloprid (T_1 and T_3). The pooled over year data indicated that significantly lowest whitefly population was observed in seed treated with imidacloprid 48 FS (T_2, T_3 and T_7) and thiamethoxam 30 (T_4, T_5, T_6 and T_8).

The results obtained from the present study revealed that the seed treatment with imidacloprid 48 FS @ 5.0 ml/kg was found more effective against thrips, jassid and whiteflies in green gram. The present findings are in accordance with many of the earlier reports. The seed treated with imidacloprid 48 FS @ 5.0 ml/kg followed by foliar spray with either of the neonicotiniods such as thiamethoxam 25 WG or acetameprid 20 SP were found effective against both the thrips and whiteflies in greengram (Mahalakshmi *et al*., 2018). Seed treated with thiomethoxam 25 WG @ 0.0035% and imidacloprid 70 WS @ 0.0035% which was protecting the greengram from whiteflies up to 25 days after sowing (Panduranga *et al*., 2011). Seed treated with imidacloprid 600 FS @ 10 ml/kg found significantly lowest population of whitefly, leafhopper and thrips with highest gross and net returns (Anusha *et al.,* 2016).

Effect of spray at 50 per cent flowering

The larval population of pod borar *viz.* spotted pod borer (*Maruca vitrata*), gram pod borer (*Helicoverpa armigera*) found non-significant difference before the spray of insecticides on treatments.

During 2017, the data of pooled over periods indicated that the significantly lowest larval population was found in spray with spinosad 45 SC (T_1), it was at par with all spray treatments *viz.* flubendiamide 48 SC (T_2, T_5 and T_{10}) and chlorantraniliprole 18.5 SC (T_3, T_6 and T_{11}). In 2018, the data of pooled over periods indicated that significantly lowest larval population was found in spray with flubendiamide 48 SC (T_5) and chlorantraniliprole 18.5 SC (T_6). During 2017, the data of pooled over periods indicated significantly lowest larval population was found in spray with spinosad 45 SC (T_1), it was at par with all spray treatment *viz.* flubendiamide 48 SC (T_2, T_5 and T_{10}) and chlorantraniliprole 18.5 SC (T_3, T_6 and T_{11}). In 2018, the data of pooled over periods indicated that significantly lowest larval population was found in spray with flubendiamide 48 SC (T_5) and chlorantraniliprole 18.5 SC (T_6). The pooled over years, data revealed that the significantly lowest larval population was observed in spray with flubendiamide 48 SC (T_2, T_5 and T_{10}) and chlorantraniliprole 18.5 SC (T_3, T_6 and T_{11}) (Table 3).

The data clearly stated that flubendiamide 48 SC and chlorantraniliprole 18.5 SC were highly effective against *Maruca vitrata*. These find also confirm by Mallikarjuna (2009) the highest larval reduction of pod borers with flubendiamide 480 SC and thiacloprid 48 SC followed by emamectin benzoate 55G and indoxacarb 14.5SC in dolichos bean. Mahalakshmi *et al.* (2013) reported that coragen 20% SC (chlorantranilip- role) at 20 g a.i./ha proved highly effective against the larval population of *Maruca vitrata* in blackgram.

During 2017, significantly lowest gram pod borer (*Helicoverpa armigera*) larval population was observed in spray with spinosad 45 SC (T_1, T_4 and T_9), flubendiamide 48 SC (T_2, T_5 and T_{10}) and chlorantraniliprole 18.5 SC (T_3, T_6 and T_{11}) compared to control (T_{12}) and only seed treatment (T_7 and T_8). In 2018, pooled over periods data indicated that significantly lowest larval population was observed in spray with spinosad 45 SC and chlorantraniliprole 18.5 SC which was T_2, T_8 and T_3, T_{11}, respectively. The pooled over year data indicated that significantly lowest larval population was observed in spray with spinosad 45 SC (T_1, T_4 and T_9), flubendiamide 48 SC (T_2, T_5 and T_{10}) and chlorantraniliprole 18.5 SC (T_3, T_6 and T_{11}) compared to control (T_{12}) and only seed treatment (T_7 and T_8) (Table 4). The current findings are also supported previously a finding by Kumar and Shivaraju (2009) that reported thiodicarb 75 WP @ 562.5g a.i/ha and flubendiamide 480 SC @ 48 g a.i/ha were highly effective for control the pod borers in blackgram.

Pod damage

At harvest stage, significantly lowest pod damage was recorded in spray at 50 per cent flowering with flubendiamide 48 SC (T_2, T_5 and T_{10}) which was at par with chlorantraniliprole 18.5 SC (T_3 and T_6). In 2018, the significantly lowest pod damage was recorded in spray at 50 per cent flowering with flubendiamide 48 SC (T_2, T_5 and T_{10}) which, was at par with chlorantraniliprole 18.5 SC (T_3 and T_6). The pooled over year data revealed that significantly lowest pod damage was recorded in spray at 50 per cent flowering with flubendiamide 48 SC (T_2, T_5 and T_{10}), it was at par with chlorantraniliprole 18.5 SC (T_3 and T_6) (Table 5). These finding also supported previously reported by Mahalakshmi *et al.* (2013) that coragen 20% SC (chlorantraniliprole) at 20 g a.i./ha proved highly effective against pod borer and less pod damage was observed in black gram.

Yield

The yield of green gram grain was found the significant highest in all combination of seed treated (imidacloprid 48 FS and thiomethoxam 30 FS) and spray at 50 per cent flowering (spinosd 45 SC, flubendiamide 48 SC and chlorantraniliprole 18.5 SC) which was T_1, T_2, T_3, T_4 and T_5 in 2017. The lowest green gram grain yield was 652 kg per hector was obtained in control. During 2018, the significantly highest green gram grain yield was observed in seed treated with imidacloprid 48 FS and spray at 50 per cent flowering with chlorantraniliprole 18.5 SC (T_3) which was at par with seed treated with imidacloprid 48 FS and spray with flubendiamide 48 SC (T_2) and seed treated with thiamethoxam 30 FS and spray with chlorantraniliprole 18.5 SC (T_5). The pooled over year data indicated that significantly highest yield was observed in seed treated with imidacloprid and thiomethoxam and spray at 50 per cent flowering with spinosd 45 SC, flubendiamide 48 SC and chlorantraniliprole 18.5 SC, which was T_1, T_2, T_3, T_4 and T_5. The lowest green gram grain yield was 770 kg per hector observed in control treatment. All combination treatment which was seed treated

Table 3: Efficacy of insecticide against *Maruca vitrata* in green gram.

Tr. no.	Treatments	Number of larvae per plant										Pooled over years
		2017-18					2018-19					
		Before	1 DAS	3 DAS	7 DAS	Pooled	Before	1 DAS	3 DAS	7 DAS	Pooled	
T_1	Imidacloprid 48 FS - Spinosad 45 SC	1.65	0.71a	0.71a	0.87a	0.76a	1.53	1.45de	1.44c	0.94b	1.28c	1.11b
		(2.23)	(0.00)	(0.00)	(0.26)	(0.08)	(1.83)	(1.60)	(1.59)	(0.39)	(1.14)	(0.73)
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC	1.42	0.71a	0.75a	1.02bcd	0.82a	1.50	1.07b	0.87b	0.71a	0.89b	0.89ab
		(1.51)	(0.00)	(0.06)	(0.53)	(0.18)	(1.74)	(0.65)	(0.26)	(0.00)	(0.28)	(0.29)
T_3	Imidacloprid 48 FS -Chlorantraniliprole 18.5 SC	1.66	0.75a	0.84ab	1.05cd	0.88a	1.55	1.24c	0.84b	0.71a	0.93b	0.94ab
		(2.26)	(0.06)	(0.20)	(0.60)	(0.27)	(1.91)	(1.05)	(0.20)	(0.00)	(0.36)	(0.38)
T_4	Thiamethoxam 30 FS - Spinosad 45 SC	1.65	0.71a	0.71a	0.91abc	0.78a	1.53	1.47def	1.45c	0.87b	1.26c	1.11bc
		(2.23)	(0.00)	(0.00)	(0.33)	(0.10)	(1.83)	(1.67)	(1.60)	(0.26)	(1.10)	(0.72)
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC	1.44	0.71a	0.79a	1.05cd	0.85a	1.47	0.87a	0.71a	0.71a	0.76a	0.83a
		(1.57)	(0.00)	(0.130	(0.60)	(0.22)	(1.66)	(0.26)	(0.00)	(0.00)	(0.08)	(0.20)
T_6	Thiamethoxam 30 FS-Chlorantraniliprole 18.5 SC	1.50	0.71a	0.84ab	1.08d	0.87a	1.53	0.87a	0.71a	0.71a	0.76a	0.85ab
		(1.74)	(0.00)	(0.20)	(0.66)	(0.26)	(1.83)	(0.26)	(0.00)	(0.00)	(0.08)	(0.22)
T_7	Imidacloprid 48 FS	1.53	1.25b	1.13c	1.35e	1.25b	1.55	1.37cd	1.40c	1.20d	1.32c	1.34cd
		(1.84)	(1.07)	(0.78)	(1.33)	(1.05)	(1.92)	(1.37)	(1.47)	(0.94)	(1.25)	(1.28)
T_8	Thiamethoxam 30 FS	1.72	1.56c	1.46d	1.38e	1.47c	1.57	1.55ef	1.58de	1.49c	1.54d	1.53d
		(2.46)	(1.93)	(1.64)	(1.40)	(1.65)	(1.97)	(1.89)	(1.99)	(1.73)	(1.87)	(1.85)
T_9	Spinosad 45 SC	1.47	0.71a	0.75a	0.87a	0.78a	1.34	1.47def	1.47d	0.87b	1.27c	1.11bc
		(1.66)	(0.00)	(0.06)	(0.26)	(0.10)	(1.30)	(1.67)	(1.67)	(0.26)	(1.12)	(0.73)
T_{10}	Flubendiamide 48 SC	1.62	0.71ab	0.84ab	0.93ab	0.83a	1.52	1.24c	0.91b	0.71a	0.95b	0.93ab
		(2.12)	(0.00)	(0.20)	(0.37)	(0.18)	(1.80)	(1.05)	(0.32)	(0.00)	(0.41)	(0.36)
T_{11}	Chlorantraniliprole 18.5 SC	1.56	0.79ab	0.94b	0.90ab	0.88a	1.40	1.27c	0.86b	0.71a	0.95b	0.94ab
		(1.94)	(0.13)	(0.39)	(0.31)	(0.27)	(1.45)	(1.11)	(0.25)	(0.00)	(0.40)	(0.38)
T_{12}	Control	1.84	1.58c	1.54d	1.49e	1.54c	1.57	1.59f	1.64e	1.51d	1.58d	1.57d
		(2.89)	(1.99)	(1.87)	(1.73)	(1.86)	(1.98)	(2.04)	(2.18)	(1.78)	(2.00)	(1.98)
S. Em. ±	(Treatment) T	0.09	0.07	0.04	0.05	0.03	0.09	0.06	0.04	0.04	0.04	0.09
	(Period) P	-	-	-	-	0.02	-	-	-	-	0.02	0.09
	(Year) Y	-	-	-	-	-	-	-	-	-	-	0.01
	P × T	-	-	-	-	0.05	-	-	-	-	0.07	0.10
	Y × T	-	-	-	-	-	-	-	-	-	-	0.04
	Y × P	-	-	-	-	-	-	-	-	-	-	0.02
	Y × P × T	-	-	-	-	-	-	-	-	-	-	0.01
C.D. at 5%	T	NS	0.21	0.13	0.14	0.09	NS	0.16	0.12	0.11	0.12	0.27
	P	-	-	-	-	0.05	-	-	-	-	0.06	NS
	Y	-	-	-	-	-	-	-	-	-	-	0.03
	T × P	-	-	-	-	0.16	-	-	-	-	0.21	NS
	Y × T	-	-	-	-	-	-	-	-	-	-	0.01
	Y × P	-	-	-	-	-	-	-	-	-	-	0.05
	Y × P × T	-	-	-	-	-	-	-	-	-	-	0.01
C.V. %		10.24	13.58	8.27	7.65	9.80	10.51	8.26	6.94	6.85	11.35	9.99

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x+0.5}$ transform values.

Treatment mean(s) with letter(s) in common are non-significant by DNMRT at 5 % level of significant. DAS: Day after spray.

Table 4: Efficacy of insecticide against *Helicoverpa armigera* in green gram.

Tr. no.	Treatments	Number of larvae per plant										Pooled over years
		2017-18					2018-19					
		Before	1 DAS	3 DAS	7 DAS	Pooled	Before	1 DAS	3 DAS	7 DAS	Pooled	
T_1	Imidacloprid 48 FS - Spinosad 45 SC	1.06	0.79a	0.79a	0.87a	0.82a	0.87	0.84abc	0.84abc	0.75a	0.81bc	0.81 a
		(0.63)	(0.13)	(0.13)	(0.26)	(0.17)	(0.26)	(0.20)	(0.20)	(0.06)	(0.15)	(0.16)
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC	1.02	0.79a	0.79a	0.94a	0.84a	0.83	0.71a	0.71a	0.71a	0.71a	0.78a
		(0.54)	(0.13)	(0.13)	(0.39)	(0.21)	(0.19)	(0.00)	(0.00)	(0.00)	(0.00)	(0.10)
T_3	Imidacloprid 48 FS - Chlorantraniliprole 18.5 SC	1.17	0.83a	0.83a	1.02a	0.89a	0.93	0.71a	0.71a	0.71a	0.71a	0.80a
		(0.87)	(0.19)	(0.19)	(0.53)	(0.30)	(0.37)	(0.00)	(0.00)	(0.00)	(0.00)	(0.14)
T_4	Thiamethoxam 30 FS - Spinosad 45 SC	1.18	0.98a	0.84a	0.87a	0.90a	1.01	1.01cd	0.95cd	0.79a	0.92d	0.92a
		(0.89)	(0.46)	(0.20)	(0.26)	(0.31)	(0.53)	(0.53)	(0.40)	0.12)	(0.34)	(0.35)
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC	1.30	0.91a	0.79a	0.98a	0.89a	1.22	1.00cd	0.71a	0.71a	0.81bc	0.86a
		(1.19)	(0.330	(0.12)	(0.46)	(0.30)	(1.00)	(0.51)	(0.00)	(0.00)	(0.15)	(0.25)
T_6	Thiamethoxam 30 FS - Chlorantraniliprole 18.5 SC	1.18	1.02a	0.89a	0.94a	0.95a	1.01	0.87abc	0.75ab	0.75a	0.79bc	0.89a
		(0.89)	(0.53)	(0.30)	(0.39)	(0.41)	(0.53)	(0.26)	(0.06)	(0.06)	(0.13)	(0.30)
T_7	Imidacloprid 48 FS	1.24	1.22bc	1.17c	1.30b	1.23b	1.08	1.27e	1.22e	1.08bc	1.19f	1.21b
		(1.05)	(1.00)	(0.87)	(1.20)	(1.02)	(0.66)	(1.12)	(0.99)	(0.66)	(0.92)	(0.97)
T_8	Thiamethoxam 30 FS	1.10	1.30c	1.25c	1.28b	1.28b	1.00	1.10de	1.05d	0.98b	1.04e	1.16b
		(0.72)	(1.18)	(1.07)	(1.13)	(1.13)	(0.51)	(0.71)	(0.59)	(0.46)	(0.59)	(0.84)
T_9	Spinosad 45 SC	1.24	0.83a	0.75a	0.87a	0.82a	1.13	0.91bcd	0.87bc	0.79a	0.86cd	0.84a
		(1.03)	(0.19)	(0.06)	(0.26)	(0.17)	(0.78)	(0.33)	(0.26)	(0.12)	(0.24)	(0.20)
T_{10}	Flubendiamide 48 SC	1.21	0.91a	0.84a	0.87a	0.87a	1.06	0.79ab	0.71a	0.71a	0.74ab	0.82a
		(0.97)	(0.33)	(0.20)	(0.25)	(0.26)	(0.63)	(0.13)	(0.00)	(0.00)	(0.04)	(0.17)
T_{11}	Chlorantraniliprole 18.5 SC	1.21	1.05b	0.98b	1.05b	1.02a	1.05	0.84abc	0.71a	0.71a	0.75ab	0.89a
		(0.97)	(0.59)	(0.46)	(0.59)	(0.55)	(0.59)	(0.20)	(0.00)	(0.00)	(0.06)	(0.29)
T_{12}	Control	1.34	1.40c	1.33c	1.32b	1.35b	1.27	1.27e	1.24e	1.11c	1.21f	1.28b
		(1.31)	(1.47)	(1.26)	(1.25)	(1.32)	(1.12)	(1.12)	(1.05)	(0.73)	(0.96)	(1.14)
S. Em. ±	(Treatment) T	0.10	0.05	0.05	0.05	0.03	0.07	0.06	0.04	0.04	0.03	0.049
	(Period) P					0.01					0.02	0.04
	(Year) Y											0.008
	T × P					0.05					0.05	0.035
	Y × T											0.028
	Y × P											0.014
	Y × P × T											0.049
C. D. at 5%	T	NS	0.15	0.16	0.16	0.08	NS	0.19	0.13	0.11	0.08	0.153
	P					0.04					0.04	NS
	Y											0.023
	T × P					NS					NS	NS
	Y × T											0.079
	Y × P											0.04
	Y × P × T											NS
C. V. %		14.89	8.58	9.96	9.13	8.15	10.92	11.80	8.79	8.14	10.07	9.06

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x+0.5}$ transform values.

Treatment mean(s) with letter(s) in common are non-significant by DNMRT at 5% level of significant., DAS: Day after spray.

Table 5: Pod damage and grain yield of green gram.

Tr. no.	Treatments	Pod damage (%)			Yield kg/ha		
		2017	2018	Pooled over year	2017	2018	Pooled over year
T_1	Imidacloprid 48 FS - Spinosad 45 SC	1.90bc (3.33)	3.24bc (10.00)	2.57b (6.12)	1158 ab	1115b	1137abcd
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC	1.86abc (3.00)	2.04a (3.65)	1.95a (3.29)	1208ab	1341a	1274a
T_3	Imidacloprid 48 FS - Chlorantraniliprole 18.5 SC	1.86abc (3.00)	1.95a (3.32)	1.91a (3.13)	1120ab	1346a	1233ab
T_4	Thiamethoxam 30 FS - Spinosad 45 SC	1.94c (3.33)	3.24bc (10.00)	2.59b (6.21)	1270a	1119b	1195abc
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC	1.56ab (2.00)	1.77a (2.65)	1.67a (2.28)	1247a	1113b	1180abc
T_6	Thiamethoxam 30 FS - Chlorantraniliprole 18.5 SC	1.46ab (1.67)	1.66a (2.24)	1.56a (1.93)	1232a	1151ab	1191abc
T_7	Imidacloprid 48 FS	4.69e (21.67)	4.77de (22.22)	4.73de (21.86)	878c	996bc	937de
T_8	Thiamethoxam 30 FS	4.43e (19.33)	4.53de (19.99)	4.48de (19.55)	997c	953bc	975cde
T_9	Spinosad 45 SC	2.65d (6.67)	2.78bc (7.23)	2.72b (6.88)	946c	1033bc	989cde
T_{10}	Flubendiamide 48 SC	1.34a (1.33)	1.58a (2.00)	1.46a (1.64)	1000bc	1055bc	1027bcd
T_{11}	Chlorantraniliprole 18.5 SC	3.57d (14.33)	3.76c (13.61)	3.66c (12.90)	817cd	1031bc	924de
T_{12}	Control	5.30f (27.67)	5.31e (27.65)	5.30e (27.61)	652d	887c	770e
S. Em. ±	(Treatment) T	0.37	0.18	0.211	75.75	62.00	69.763
	(Year) Y	-	-	0.084	-	-	19.981
	Y × T	-	-	0.29	-	-	69.217
C. D. at 5%	T	1.08	0.54	0.60	222.19	181.84	217.15
	Y × T	-	-	NS	-	-	197.83
C. V. %		23.47	10.38	17.45	12.57	9.81	11.21

Note: Treatment mean(s) with letter(s) in common are non-significant by DNMRT at 5% level of significant.

Table 6: Economics of treatments of green gram.

Tr. no.	Treatment	Quantity of insecticide (ml/ha)			Cost of Insecticide (` /ha)			Labour cost of per ha	Cost of cultivation	Total Cost per ha	Yield (kg per ha.)	Net over control (kg/ha)	Realization per ha. (`)	Net profit (`)	ICBR
		Seed treatment	Spray	Total	Seed treatment	Spray	Total								
T_1	Imidacloprid 48 FS - Spinosad 45 SC	100	200	300	450	3840	4290	534	24460	26212	1137	367	26424	212	1:1.01
T_2	Imidacloprid 48 FS - Flubendiamide 48 SC	100	100	200	450	1662	2112	534	24460	25610	1274	504	36288	10678	1:1.42
T_3	Imidacloprid 48 FS - Chlorantraniliprole 18.5 SC	100	100	200	450	1924	2374	534	24460	25636	1233	463	33336	7700	1:1.30
T_4	Thiamethoxam 30 FS - Spinosad 45 SC	100	200	300	285	3840	4125	534	24460	25987	1195	425	30600	4613	1:1.18
T_5	Thiamethoxam 30 FS - Flubendiamide 48 SC	100	100	200	285	1662	1947	534	24460	25385	1180	410	29520	4135	1;1.16
T_6	Thiamethoxam 30 FS - Chlorantraniliprole 18.5 SC	100	100	200	285	1924	2209	534	24460	25411	1191	421	30312	4901	1:1.19
T_7	Imidacloprid 48 FS	100	-	100	450	-	450	178	24460	25088	937	167	12024	-13064	1:0.48
T_8	Thiamethoxam 30 FS	100	-	100	285	-	285	178	24460	24863	975	205	14760	-10103	1:0.59
T_9	Spinosad 45 SC	-	200	200	-	3840	3840	356	24460	25584	989	219	15768	-9816	1:0.62
T_{10}	Flubendiamide 48 SC	-	100	100	-	1662	1662	356	24460	24982	1027	257	18504	-6478	1:0.74
T_{11}	Chlorantraniliprole 18.5 SC	-	100	100	-	1924	1924	356	24460	25008	924	154	11088	-13920	1:0.44
T_{12}	UTC	-	-	-	-	-	-	-	24460		770	-	-	-	-

Note: Labour: 178 ` per days,
Green gram prize: 72 ` per kg.

with imidacloprid 48 FS, thiomethoxam 30 FS and spray with spinosd 45 SC, flubendiamide 48 SC and chlorantraniliprole 18.5 SC at 50 per cent flowering were found highly effective against insect pests and which was reflected on greengram yield (Table 5).

Economics

The perusal of the data (Table 6) indicated that the highest net profit of Rs. 10,678/ ha was obtained from T_2 (seed treated with imidacloprid 48 FS and spray with flubendiamide 48 SC) followed by T_3 (seed treated with imidacloprid 48 FS and spray with chlorantraniliprole 18.5 SC), T_6 (seed treated with thiamethoxam 30 FS and spray with chlorantraniliprole 18.5 SC), T_4 (seed treated with thiamethoxam 30 FS and spray with spinosad 45 SC), T_5 (seed treated with thiamethoxam 30 FS and spray with flubendiamide 48 SC), T_1 (seed treated with imidacloprid 48 FS and spray with spinosad 45 SC) with net profits of Rs. 7,700, Rs. 4,901, Rs. 4,613, Rs. 4,135 Rs. 212, per hectare, respectively.

However, when viewed from the angle of cost-benefit ratio, a maximum profit of Rs. 1.42 per rupee invested was obtained in T_2 (seed treated with imidacloprid 48 FS and spray with flubendiamide 48 SC), T_3 (seed treated with imidacloprid 48 FS and spray with chlorantraniliprole 18.5 SC), T_6 (seed treated with thiamethoxam 30 FS and spray with chlorantraniliprole 18.5 SC), T_4 (seed treated with thiamethoxam 30 FS and spray with spinosad), T_5 (seed treated with thiamethoxam 30 FS and spray with flubendiamide 48 SC), T_1 (seed treated with imidacloprid 48 FS and spray with spinosad 45 SC), T_{10} (flubendiamide 48 SC), T_9 (spray with spinosad 45 SC), T_8 (seed treated with thiamethoxam 30 FS), T_7 (seed treated with imidacloprid 48 FS) and T_{11} (spray with chlorantraniliprole 18.5 SC) with cost-befit ratio of Rs. 1.30, Rs. 1.19, Rs. 1.18, Rs. 1.16, Rs. 1.01, Rs. 0.74, Rs. 0.62, Rs. 0.59 and Rs. 0.48 and Rs. 0.44 per rupee invested, respectively. The relative performance of the treatment terms of net profit generated per hectare in descending order was as follows:

$$T_2 > T_3 > T_6 > T_4 > T_5 > T_1 > T_{10} > T_9 > T_8 > T_7 > T_{11}$$

Seed treated with imidacloprid 48 FS and spray flubendiamide 48 SC at 50 per cent flowering stage (T_2) which give highest net profit Rs. 10,678 and highest cost-benefit ratio (1:1.42) among of all treatments.

CONCLUSION

In a nutshell, seed treated with imidacloprid 48 FS was found highly effective against sucking insect pests *via.* jassid, thrips and whitefly in greengam. At 50 per cent flowering stage, spray of flubendiamide 48 SP and chlorantraniliprole 18.5 SC insecticides both was significantly reduced population of spotted pod borer (*Maruca vitrata*) and gram pod borer (*Helicoverpa armigera)* in greengram. The seed treated with imidacloprid 48 FS and thiomethoxam 30 FS followed by spray with spinosd 45 SC, flubendiamide 48 SC and chlorantraniliprole 18.5 SC at 50 per cent flowering stages provides the higher seed yield. However, highest net profit and cost-benefit ratio was found in seed treated with imidacloprid 48 FS and spray of flubendiamide at 50 per cent flowering stage in green gram.

Conflict of interest

On behalf of all the authors, I declare that there are no conflicts of interest regarding the publication of this manuscript.

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