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Field Efficacy of Jatropha Oil, NPV and NSKE against *Helicoverpa armigera* and *Thysanoplusia orichalcea* in Chickpea

JAGDISH JABA[1,3]*, A. KUZHANDHAIVEL PILLAI[2,3] AND MEENA AGNIHOTRI[3]

[1]Department of ICM-Entomology, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru - 502 319, Telangana, India

[2]Department of Entomology, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India

[3]Department of Entomology, College of Agriculture, G. B. Pant University of Agriculture & Technology Pantnagar - 263 145, Uttarakhand, India

KEY WORDS

Chickpea

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Jatropha oil

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ABSTRACT The investigation was carried out to evaluate bioefficacy of biopesticides such as Jatropha oil, NSKE and NPV in various combinations along with control under chickpea-coriander intercropping ecosystem for three seasons against *Helicoverpa armigera*. The results revealed that the most effective treatment was T_4 (chickpea; Jatropha treated) + coriander (NPV treated) followed by T_9 (chickpea; Jatropha treated alone). The pooled mean of lowest damage for 3 years (2011, 2012, and 2013) was in chickpea (Jatropha treated) + coriander (NPV treated) treatments followed by chickpea (Jatropha treated) treatment alone. The mean grain yield of 1292 kg/ha was recorded for T_4 treatment in chickpea (Jatropha at 5 mL/L) + coriander (NPV at 0.5 mL/L). The maximum coriander yield of 1008 kg/ha was obtained in T_2 treatment, i.e., chickpea (NSKE treated) + coriander (untreated). The present results suggest that *Jatropha curcas* seed oil either alone or in combination with other biopesticides could be used as botanical insecticide against chickpea pests under any integrated pest management strategy for insect pest control.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important pulse crop in semi-arid tropical and subtropical areas of the world. In terms of global grain legume production, it ranks third after *Phaseolus* beans, peas (Khanapara and Kapadia, 2011). India is the largest producer and consumer of pulses in the world accounting for 33% of the global area and 22% of production (Anonymous, 2011). However, yield of chickpea varies considerably among locations, cultivars, seasons, and cropping systems due to both biotic and abiotic factors. In most areas, insect infestation causes heavy yield losses. More than 150 species of insects were reportedly feeding on chickpea, although only a few species of insects cause significant and consistent damage to the crop (Sharma, 2016). Among these, the borer *Helicoverpa armigera* (Ha) (Hubner) Hardwick is of regular occurrence,

*Corresponding author: E-Mail: jaba.jagdish@gmail.com

causing economic damage in chickpea ranging from 40% to 67.3% (Srivastava, 2003) and in the recent past the appearance of minor pest semilooper, *Thysanoplusia orichalcea* in chickpea does cause the defoliation of leaves.

Management of chickpea pod borer involves field application of suitable intefrated pest management strategies of which insecticides are the integral components. Under farmstead, a large array of insecticides are used for pest control, but over the period, indiscriminate and overuse of insecticides proved counterproductive in crop ecosystem on many aspects. Development of insecticide resistance, pesticide residues on produce, resurgence of some of the unexpected pests such as mites, mealybugs, and whiteflies, destruction of natural enemies of key pests and above all endangering human ecosystem, all became serious constraints (Armes *et al.,* 1996). In view of these facts, an alternative strategy is required and the use of biopesticides is more promising. Under this background, the present study was conducted where botanical and microbial biopesticides were evaluated under field conditions to control chickpea pod borer.

MATERIALS AND METHODS

The field experiments were conducted at Norman E. Borlaug Crop Research Centre (NEB-CRC), G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India (29°N latitude, 79.29°E longitude and 243.8 m above the mean sea level) during *Rabi* season of 2011, 2012 and 2013. The field efficacy of the different combinations of biopesticides, *viz.,* T_1 chickpea (NSKE) + coriander (NPV); T_2 chickpea (NSKE) + coriander (untreated); T_3 chickpea (untreated) + coriander (NPV); T_4 chickpea (Jatropha) + coriander (NPV); T_5 chickpea (Jatropha) + coriander (untreated); T_6 chickpea (Jatropha +NSKE mixed) + coriander (NPV); T_7 chickpea (Jatropha +NSKE each 5 rows) + coriander (NPV); T_8 chickpea (NSKE); T_9 chickpea (Jatropha); T_{10} chickpea (NPV) were evaluated along with control T_{11} chickpea (untreated) + coriander (untreated). The chickpea variety PG-186 and coriander variety - Haritha were planted in a plot (15 m^2), wity a spacing of 30 cm × 10 cm and 5 m length of rows. The crop was raised during the past week of October in randomized block design with three replications. Spraying was initiated after sufficient population built up of pod borer was observed in the field.

The larval population of Ha was recorded from one square meter area of each plot. Observations were made at one day before and mean of 3rd and 7th day and 10th day after each spray. Two biopesticidal sprays were carried out with knapsack sprayer, first at 50% flowering stage and subsequent sprays were done after 15 days of the first spray on chickpea. This study was framed to devise a cost-effective and an environment-friendly strategy for the management of major pest Ha in chickpea and minor pest green semilooper, *T. orichalcea* (To).

Pod damage at maturity of the crop was recorded from pods of 16 plants per plot at random in each plot. Sample pods were examined for the pod damage, based on healthy clear pods without any external damage symptom and pods attacked by Ha having big circular holes without larval exuviae on the pods. Besides, above total number of pods and number of damaged pods by various pod borers were recorded separately for each sample and converted into percent pod damage as:

$$\text{Pod damage}(\%) = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

The yields were assessed by harvesting the central rows after leaving the border rows on each side at maturity. After harvesting and threshing, chickpeas were dried in open sunlight to stabilize the moisture content and then weighed. The total yield per plot was calculated as:

$$\text{Equivalent yield} = \frac{\begin{array}{c}\text{Yield of intercrop per hactare} \times \\ \text{Price of intercrop (Rs per quintal)}\end{array}}{\text{Price of sole crop (Rs per quintal)}}$$

The percent increase in yield over the control was calculated using the following equation given by Rijal *et al.* (2008).

$$Y = \frac{T - C}{C} \times 100$$

Where, Y = Yield increase (%), T = Yield from treatment plot and C = Yield from control plot

Statistical Analysis

The data for the years were pooled as there were significant differences among years. The statistical procedures used included, analysis of variance that was used to compare variables using Statistical Package for Social Sciences software for identifying promising genotypes. Where significant differences were observed, critical difference at 5% level of probability was used to separate the test and means for difference.

RESULTS AND DISCUSSION

Effect on the Larval Population during *Rabi* 2011

The data recorded on larval population at pre- and post-treatments are presented in Table 1**.** There was no

Table 1. Effect of combination of biopesticides against Ha and To in chickpea during *Rabi* 2011

Treatments	Observations on larval population/m^2 area*							
	DBFS		10 DAFS		DBSS		10 DASS	
	Ha	To	Ha	To	Ha	To	Ha	To
T_1	2.16^a (1.60)	2.5^a (1.13)	24.66^{cd} (5.01)	2.67^{ab} (1.74)	44.50^a (6.68)	2.83^{ab} (1.81)	30.83^{abc} (5.58)	0.00^a (0.70)
T_2	1.33^a (1.35)	3.5^a (1.22)	21.33^{abc} (4.67)	3.83^{abc} (2.07)	40.83^a (6.40)	4.33^{ab} (2.19)	32.66^{a-e} (5.70)	0.00^a (0.70)
T_3	2.66^a (1.66)	2.5^a (1.14)	21.66^{abc} (4.69)	1.83^{ab} (1.51)	43.66^a (6.54)	7.83^c (2.88)	31.16^{a-d} (5.58)	0.17^a (0.804)
T_4	1.16^a (1.28)	2.5^a (1.13)	5.66^a (2.41)	2.33^{ab} (1.66)	38.83^a (6.18)	3.33^{ab} (1.94)	25.50^{ab} (5.05)	0.17^a (0.804)
T_5	2.00^a (1.55)	1.5^a (0.97)	4.16^a (2.02)	1.17^a (1.27)	59.50^a (7.73)	2.33^a (1.68)	25.16^{ab} (5.03)	0.00^a (0.70)
T_6	1.16^a (1.22)	3.5^a (1.24)	18.33^{ab} (4.33)	2.67^{ab} (1.77)	40.83^a (6.17)	3.00^{ab} (1.86)	44.83^{ef} (6.73)	0.00^a (0.70)
T_7	1.66^a (1.46)	1.00^a (0.90)	9.66^a (3.18)	2.33^{ab} (1.67)	53.50^a (7.29)	2.33^a (1.68)	52.83^f (7.29)	0.00^a (0.70)
T_8	2.50^a (1.70)	3.5^a (1.28)	16.50^b (4.08)	3.50^{ab} (1.98)	44.50^a (6.64)	4.00^{ab} (2.06)	37.83^{b-e} (6.18)	0.00^a (0.70)
T_9	1.66^a (1.42)	2.5^a (1.14)	19.66^{ab} (4.48)	2.17^{ab} (1.62)	55.16^a (7.43)	3.00^{ab} (1.85)	33.33^{a-e} (5.81)	0.00^a (0.70)
T_{10}	2.16^a (1.63)	4.5^a (1.14)	23.33^{cd} (4.88)	5.17^{bc} (2.36)	41.50^a (6.45)	7.00^c (2.72)	44.16^{def} (6.67)	0.00^a (0.70)
T_{11}	2.50^a (1.73)	1.50^a (13.8)	31.16^d (5.62)	5.83^c (2.49)	56.66^a (7.55)	9.17^a (3.10)	54.83^a (7.43)	0.17^a (0.80)
SEM±	-	-	0.287**	0.230*	-	0.166**	0.292**	-
CD at 5%	-	-	0.839	0.673	-	0.486	0.857	-

*Data presented in parentheses are square root transformed value$\sqrt{N + 0.5}$, **Data presented in parentheses are angular transformed value. In a column, means followed by the common letter (s) are not significant in DMRT at 5% level of significance (Treatment 1: Chickpea [NSKE treated] + coriander [NPV treated]; Treatment 2: Chickpea [NSKE treated] + coriander [untreated]; Treatment 3: Chickpea [untreated] + coriander [NPV treated]; Treatment 4: Chickpea [Jatropha treated] + coriander [NPV treated]; Treatment 5: Chickpea [Jatropha treated] + coriander [untreated]; Treatment 6: Chickpea [Jatropha+NSKE mixed] + coriander [NPV treated]; Treatment 7: Chickpea [Jatropha+NSKE each 5 rows]+coriander [NPV treated]; Treatment 8: Chickpea [NSKE treated]; Treatment 9: Chickpea [Jatropha treated]; Treatment 10: Chickpea [NPV treated] and Treatment 11: Chickpea [untreated] + coriander [untreated]). DBFS: Day before first spray, DBSS: Day before second spray, DAFS: Day after first spray, SEM: Standard error of the mean, CD: Critical difference, Ha: *Helicoverpa armigera*, To: *Thysanoplusia orichalcea*, DMRT: Duncan's multiple range test.

significant difference between mean larval population of Ha, but significant difference was seen in case of To on 3rd and 7th day before the first spray. Mean larval population varied from 2.5 to 9.92/m^2. The highly significant deviation was noticed on 10th days after first spray. The lowest larval population of Ha was 4.16/m^2 in T_5 treatment, i.e. chickpea (Jatropha treated) + coriander (untreated). The maximum population (24.66) was recorded in T_1 treatment, i.e., chickpea (NSKE treated) + coriander (NPV treated) in comparison to control T_{11} (31.16). Larval population of To was lowest at 10 DAFS in T_5 treatment (1.17) and maximum (3.83) in T_2 treatment in comparison to control where 5.83 larvae were recorded. The days before second spray, the larval population of To gradually started declining in all the treatments and was highly significant that varied from minimum (2.33) in T_5 to maximum (7.83) in T_3 in comparison to control (9.17). However, after 3 and 7 days after second spray (DASS) larval population of Ha was not significantly different in T_2 (29.99) compared to controls (47.41), However, in case of To no insect population was seen on the crop during the similar period of treatment. At 10 DASS, the T_5 treatment was very effective with minimum larval population of Ha (25.16); however, maximum population was recorded in T_7 treatment (52.83) and controls (54.83).

Impact on the Larval Population during *Rabi* 2012

On 3rd and 7th DAFS larval population of Ha varied significantly from 7.24/m^2 (T_5) to 15.66/m^2 (T_{10}) in comparison with control 17.33/m^2 (T_{11}) and for To the population ranged from 3.5/m^2 (T_4) to 7.08/m^2 (T_1) as compared to controls (9.41). At 10 DAFS, the trend was similar (Table 2). It was ascertained that the lowest Ha larval population was 5.16/m^2 in (T_5) and the highest of 26.0/m^2 in (T1). The population of both pests was once again recorded before second spray was initiated. The efficacy of treatments after the first spray was highly significant; minimal larval population of Ha and To was in T_7 (22.0 and 2.33, respectively) and the maximum population of Ha larvae was in in T_{10} (50.33). In controls, however, the larval population was comparativel very high (45.67 and 9.83, respectively).

After 3rd and 7th, DASS larval population of Ha ranged between 21.16 and 26.99/m^2 in comparison with controls (38.42). The significant difference was noticed by 10th DASS, the lowest population of Ha larvae recorded was in T_9 (14.83) followed by T_7 (19.83) and

Table 2. Effect of combination of biopesticides against Ha and To in chickpea during *Rabi* 2012

Treatments	Observations on larval population/m^2 area*							
	DBFS		10 DAFS		DBSS		10 DASS	
	Ha	To	Ha	To	Ha	To	Ha	To
T_1	1.16[ab]	0.50[a]	26.00[cd]	2.67[abc]	42.16[de]	3.83[ab]	30.66[a]	0.00[a]
	(1.19)	(1.0)	(5.14)	(1.74)	(6.52)	(2.07)	(5.50)	(0.7)
T_2	1.50[a]	0.83[a]	22.66[bcd]	3.50[abc]	37.00[cde]	4.33[ab]	23.66[a]	0.00[a]
	(1.40)	(1.11)	(4.81)	(1.98)	(6.12)	(2.19)	(4.77)	(0.7)
T_3	0.16[ab]	0.83[a]	23.00[bcd]	1.83[ab]	49.50[e]	7.50[c]	23.33[a]	0.00[a]
	(0.80)	(1.14)	(4.83)	(1.51)	(7.07)	(2.82)	(4.72)	(0.7)
T_4	1.33[ab]	1.33[a]	7.00[a]	2.33[abc]	27.66[a]	3.67[ab]	21.66[a]	0.00[a]
	(1.31)	(1.29)	(2.69)	(1.66)	(5.27)	(2.01)	(4.68)	(0.7)
T_5	0.33[ab]	0.67[a]	5.16[a]	1.50[a]	27.66[ab]	2.33[a]	27.66[a]	0.00[a]
	(0.90)	(1.05)	(2.28)	(1.38)	(5.28)	(1.68)	(5.24)	(0.7)
T_6	0.50[ab]	1.50[a]	19.66[bc]	2.67[abc]	34.83[cd]	3.67[ab]	25.00[a]	0.00[a]
	(1.00)	(1.33)	(4.48)	(1.77)	(5.94)	(2.04)	(5.03)	(0.7)
T_7	0.33[ab]	0.33[a]	10.66[a]	2.33[abc]	22.00[a]	2.33[a]	19.83[a]	0.00[a]
	(0.87)	(0.90)	(3.33)	(1.67)	(4.73)	(1.68)	(4.50)	(0.7)
T_8	2.83[ab]	1.17[a]	17.50[b]	2.83[abc]	32.33[bc]	4.00[ab]	28.33[a]	0.00[a]
	(1.72)	(1.28)	(4.20)	(1.79)	(5.68)	(2.06)	(5.32)	(0.7)
T_9	0.66[ab]	0.67[a]	20.66[bc]	2.17[abc]	37.66[cde]	3.00[ab]	14.83[a]	0.00[a]
	(1.05)	(1.07)	(4.59)	(1.62)	(6.17)	(1.85)	(3.91)	(0.7)
T_{10}	1.00[ab]	1.33[a]	24.33[cd]	5.50[cd]	50.33[f]	7.33[c]	20.16[a]	0.00[a]
	(1.21)	(1.35)	(4.98)	(2.44)	(7.12)	(2.79)	(4.53)	(0.7)
T_{11}	2.66[ab]	2.67[a]	28.00[d]	9.17[abc]	45.67[de]	9.83[ab]	38.5[a]	0.17[b]
	(1.22)	(1.76)	(5.32)	(3.09)	(6.42)	(3.21)	(4.70)	(0.8)
SEM±	-	-	0.273**	0.231**	0.190**	0.161**	0.37*	-
CD at 5%	-	-	0.79	0.67	0.55	0.472	1.08	-

*Data presented in parentheses are square root transformed value$\sqrt{N + 0.5}$, **Data presented in parentheses are angular transformed value. In a column, means followed by the common letter (s) are not significant in DMRT at 5% level of significance (Treatment 1: Chickpea [NSKE treated] + coriander [NPV treated]; Treatment 2: Chickpea [NSKE treated] + coriander [untreated]; Treatment 3: Chickpea [untreated] + coriander [NPV treated]; Treatment 4: Chickpea [Jatropha treated] + coriander [NPV treated]; Treatment 5: Chickpea [Jatropha treated] + coriander [untreated]; Treatment 6: Chickpea [Jatropha+NSKE mixed] + coriander [NPV treated]; Treatment 7: Chickpea [Jatropha+NSKE each 5 rows] + coriander [NPV treated]; Treatment 8: Chickpea [NSKE treated]; Treatment 9: Chickpea [Jatropha treated]; Treatment 10: Chickpea [NPV treated] and Treatment 11: Chickpea [untreated] + coriander [untreated]). DBFS: Day before first spray, DASS: Day after second spray, DAFS: Day after first spray, SEM: Standard error of the mean, CD: Critical difference, Ha: *Helicoverpa armigera*, To: *Thysanoplusia orichalcea*, DMRT: Duncan's multiple range test.

the maximum population of 30.66/m^2 was recorded in T_1 in comparison to controls = 38.5/m^2 (Table 2).

Effect on the Larval Population during *Rabi* 2013

Before spraying of all the 11 treatments, there was uniform statistically significant difference of larval populations of Ha and To. This definitely impacted the populations after 3rd and 7th DAFS (Table 3). At 10 DAFS, this trend continued and minimum of Ha larvae was 11.5/m^2 (T_1) and maximum of 25.33/m^2 (T_{10}). The minimum of To population observed was 3.66/m^2 (T_3) and maximum of 11.0/m^2 (T_{10}), which was approximately half to one-fourth of the population recorded under control conditions (35.17 and 12.17/m^2, respectively. Before second spray minimum larval population of Ha was in T_1 (35.22) and that of To in T_5 (4.66). In untreated plots, the population was too high (Table 4). The mean larval population of Ha on 3rd and 7th DASS varied significantly with a lowest record of 15.97/m^2 in (T_6) and highest of 58.67/m^2 in (T_3). To also showed similar trend and it declined compared to previous two years. The extremely significant deviation was observed among treatment at 10th DASS (Table 3).

Table 3. Effect of combination of biopesticides against Ha and To in chickpea during *Rabi* 2013

Treatments	Observations on larval population/m^2 area*							
	DBFS		10 DAFS		DBSS		10 DASS	
	Ha	To	Ha	To	Ha	To	Ha	To
T_1	1.00^{a}	1.00^{a}	11.50^{a}	5.33^{a}	35.52^{a}	7.66^{abc}	17.54^{c}	0.00^{a}
	(1.19)	(1.21)	(3.44)	(2.3)	(5.99)	(2.8)	(4.25)	(0.7)
T_2	1.17^{a}	1.67^{ab}	23.00^{bc}	7.00^{a}	50.47^{e}	8.66^{c}	23.01^{e}	0.00^{a}
	(1.28)	(1.41)	(4.82)	(2.7)	(7.14)	(3.0)	(4.85)	(0.7)
T_3	1.00^{a}	3.00^{abc}	20.83^{ab}	3.66^{a}	79.59^{h}	15.0^{abc}	33.36^{i}	0.00^{a}
	(1.15)	(1.81)	(4.59)	(2.0)	(8.95)	(3.9)	(5.82)	(0.7)
T_4	1.67^{a}	4.50^{c}	19.50^{ab}	5.00^{a}	38.56^{bc}	7.33ab	10.54^{a}	0.00^{a}
	(1.46)	(2.24)	(4.46)	(2.3)	(6.25)	(2.7)	(3.32)	(0.7)
T_5	0.67^{a}	$3.33b^{c}$	24.67^{bc}	4.00^{a}	40.49^{c}	4.66^{ab}	20.54^{d}	0.00^{a}
	(1.07)	(1.95)	(5.01)	(2.1)	(6.40)	(2.2)	(4.59)	(0.7)
T_6	0.67^{a}	2.50^{ab}	15.83^{ab}	5.33^{a}	41.15^{c}	7.33^{ab}	12.32^{b}	0.00^{a}
	(1.07)	(1.73)	(4.02)	(2.4)	(6.45)	(2.7)	(3.58)	(0.7)
T_7	0.67^{a}	1.83^{ab}	16.17^{ab}	4.66^{a}	37.09^{ab}	4.66^{ab}	20.02^{d}	0.00^{a}
	(1.07)	(1.49)	(4.08)	(2.2)	(6.13)	(2.2)	(4.53)	(0.7)
T_8	0.50^{a}	2.33^{ab}	15.83^{ab}	5.66^{a}	60.27^{f}	8.00^{ab}	28.46^{g}	0.00^{a}
	(0.98)	(1.65)	(4.00)	(2.4)	(7.79)	(2.8)	(5.38)	(0.7)
T_9	1.17^{a}	1.67^{ab}	19.83^{ab}	4.33^{a}	44.99^{d}	6.33^{a}	10.03^{a}	0.00^{a}
	(1.24)	(1.46)	(4.50)	(2.1)	(6.74)	(2.)	(3.24)	(0.7)
T_{10}	0.50^{a}	1.67^{ab}	25.33^{bc}	11.0^{a}	67.92^{g}	14.6^{ab}	25.37^{f}	0.00^{a}
	(0.98)	(1.47)	(5.04)	(3.3)	(8.27)	(3.8)	(5.09)	(0.7)
T_{11}	2.83^{a}	5.50^{bc}	35.17^{c}	12.17^{b}	102.00^{h}	9.33^{abc}	$38.5j^{h}$	0.00^{a}
	(1.82)	(2.41)	(5.97)	(3.55)	(10.11)	(3.13)	(6.24)	(0.7)
SEM±	0.128*	0.185**	0.298**	0.291**	0.752**	0.174**	0.381**	-
CD at 5%	0.375	0.541	0.846	0.851	0.219	0.508	0.114	-

*Data presented in parentheses are square root transformed value $\sqrt{N + 0.5}$, **Data presented in parentheses are angular transformed value. In a column, means followed by the common letter (s) are not significant in DMRT at 5% level of significance (Treatment 1: Chickpea [NSKE treated] + coriander (NPV treated); Treatment 2: Chickpea [NSKE treated] + coriander [untreated]; Treatment 3: Chickpea [untreated] + coriander [NPV treated]; Treatment 4: Chickpea [Jatropha treated] + coriander [NPV treated]; Treatment 5: Chickpea [Jatropha treated] + coriander [untreated]; Treatment 6: Chickpea [Jatropha + NSKE mixed] + coriander [NPV treated]; Treatment 7: Chickpea [Jatropha + NSKE each 5 rows] + coriander [NPV treated]; Treatment 8: Chickpea [NSKE treated]; Treatment 9: Chickpea [Jatropha treated]; Treatment 10: Chickpea [NPV treated] and Treatment 11: Chickpea [untreated] + coriander [untreated]). DBFS: Day before first spray, DASS: Day after second spray, DAFS: Day after first spray, SEM: Standard error of the mean, CD: Critical difference, Ha: *Helicoverpa armigera*, To: *Thysanoplusia orichalcea,* DMRT: Duncan's multiple range test.

Table 4. Pooled mean effect of combination of biopesticides against Ha and To in chickpea during *Rabi* 2011-2013

Treatments	Pooled observations on larval population/m^2 area*							
	DBFS		10 DAFS		DBSS		10 DASS	
	Ha	To	Ha	To	Ha	To	Ha	To
T_1	2.16^{a}	0.78^{a}	24.66^{cd}	4.78^{abc}	44.50^{a}	4.00^{abc}	30.83^{abc}	0.00^{a}
	(1.60)	(1.12)	(5.01)	(2.28)	(6.68)	(2.11)	(5.58)	(0.7)
T_2	1.33^{a}	1.22^{ab}	21.33^{abc}	6.22^{c}	40.83^{a}	5.67^{def}	32.66^{a-e}	0.00^{a}
	(1.35)	(1.26)	(4.67)	(2.54)	(6.40)	(2.46)	(5.70)	(0.7)
T_3	2.66^{a}	1.56^{ab}	21.66^{abc}	3.44^{ab}	43.66^{a}	7.11^{f}	31.16^{a-d}	0.06^{a}
	(1.66)	(1.42)	(4.69)	(1.97)	(6.54)	(2.75)	(5.58)	(0.74)

(Contd...)

Table 4. (*Continued*)

Treatments	Pooled observations on larval population/m^2 area*							
	DBFS		10 DAFS		DBSS		10 DASS	
	Ha	To	Ha	To	Ha	To	Ha	To
T_4	1.16^a	2.22^b	5.66^a	3.00^a	38.83^a	3.78^{abc}	25.50^{ab}	0.06^a
	(1.28)	(1.64)	(2.41)	(1.87)	(6.18)	(2.05)	(5.05)	(0.74)
T_5	2.00^a	1.50^{ab}	4.16^a	3.00^a	59.5	3.11^a	25.16^{ab}	0.00^a
	(1.55)	(1.40)	(2.02)	(1.83)	(7.73)	(1.89)	(5.03)	(0.7)
T_6	1.16^a	1.72^{ab}	18.33^{ab}	3.50^{ab}	40.83^a	3.50^{ab}	44.83^{ef}	0.00^a
	(1.22)	(1.46)	(4.33)	(1.99)	(6.17)	(1.99)	(6.73)	(0.7)
T_7	1.66^a	0.83^a	9.66^a	3.61^{ab}	53.50^a	3.06^a	52.83^f	0.00^a
	(1.46)	(1.14)	(3.18)	(2. 02)	(7.29)	(1.88)	(7.29)	(0.7)
T_8	2.50^a	1.56^{ab}	16.50^b	4.39^{abc}	44.50^a	4.28^{abcd}	37.83^{b-e}	0.00^a
	(1.70)	(1.42)	(4.08)	(2.20)	(6.64)	(2.16)	(6.18)	(0.7)
T_9	1.66^a	1.06^a	19.66^{ab}	2.78^a	55.16^a	3.00^a	33.33^{a-e}	0.00^a
	(1.42)	(1.24)	(4.48)	(1.79)	(7.43)	(1.86)	(5.81)	(0.7)
T_{10}	2.16^a	1.50^{ab}	23.33^{cd}	5.61^{abc}	41.50^a	6.22^{ef}	44.16^{def}	0.00^a
	(1.63)	(1.41)	(4.88)	(2.47)	(6.45)	(2.59)	(6.67)	(0.7)
T_{11}	2.78^a	3.22^{ab}	39.61^d	9.05^c	67.22^a	9.44^a	43.94^a	0.11^a
	(1.80)	(1.91)	(6.25)	(3.08)	(8.22)	(3.15)	(6.66)	(0.77)
SEM±	0.102*	0.118*	0.289**	0.196**	0.213**	0.107**	0.174**	-
CD at 5%	0.302	0.342	0.86	0.572	0.623	0.312	0.507	-

*Data presented in parentheses are square root transformed value$\sqrt{N + 0.5}$, **Data presented in parentheses are angular transformed value. In a column, means followed by the common letter (s) are not significant in DMRT at 5% level of significance (Treatment 1: Chickpea [NSKE treated] + coriander [NPV treated]; Treatment 2: Chickpea [NSKE treated] + coriander [untreated]; Treatment 3: Chickpea [untreated] + coriander [NPV treated]; Treatment 4: Chickpea [Jatropha treated] + coriander [NPV treated]; Treatment 5: Chickpea [Jatropha treated] + coriander [untreated]; Treatment 6: Chickpea [Jatropha+NSKE mixed] + coriander [NPV treated]; Treatment 7: Chickpea [Jatropha+NSKE each 5 rows] + coriander [NPV treated]; Treatment 8: Chickpea [NSKE treated]; Treatment 9: Chickpea [Jatropha treated]; Treatment 10: Chickpea [NPV treated] and Treatment 11: Chickpea [untreated] + coriander [untreated] [control]). DBFS: Day before first spray, DAFS: Day after first spray, DBSS: Day before second spray, DASS: Day after second spray, SEM: Standard error of the mean, CD: Critical difference, Ha: *Helicoverpa armigera*, To: *Thysanoplusia orichalcea*, DMRT: Duncan's multiple range test.

Table 5. Pooled mean effect of combination of biopesticides on per cent pod damage and grain yield in chickpea *Rabi* 2011-13

Treatments	Pooled pod damage (%)*	Pooled mean chickpea (kg/ha)	Pooled mean coriander (kg/ha)	Equivalent yield kg/ha	Yield increase over control (%)	Avoidable loss in (%)
T_1	78.30^b	684.52	2222	3894	32.31	24.42
	(62.27)					
T_2	79.93^b	836.43	1833	3484	65.37	39.53
	(63.49)					
T_3	77.99^b	743.42	2315	4087	46.98	31.96
	(62.11)					
T_4	54.91^a	1292.14	2363	4705	156.15	60.96
	(47.82)					
T_5	78.86^b	881.98	1926	3664	83.40	45.47
	(62.70)					
T_6	77.87^b	713.91	2256	3973	32.12	24.31
	(61.95)					

(Contd...)

Table 5. (*Continued*)

Treatments	Pooled pod damage (%)*	Pooled mean chickpea (kg/ha)	Pooled mean coriander (kg/ha)	Equivalent yield kg/ha	Yield increase over control (%)	Avoidable loss in (%)
T_7	80.73[b] (64.70)	831.13	1667	3239	72.56	42.05
T_8	78.60[b] (62.52)	843.57	0	844	66.78	40.04
T_9	61.71[a] (51.77)	1148.04	0	1148	126.98	55.94
T_{10}	79.74[b] (63.59)	863.46	0	863	70.03	41.19
T_{11}	81.52[b] (64.57)	715.86	1337	2647	0.00	0.00
SEM±	2.70** (1.99)	-	-	-	-	-
CD at 5%	7.90 (5.82)	-	-	-	-	-

*Data presented in parentheses are square root transformed value$\sqrt{N + 0.5}$, **Data presented in parentheses are angular transformed value. In a column, means followed by the common letter (s) are not significant in DMRT at 5% level of significance. SEM: Standard error of the mean, CD: Critical difference, DMRT: Duncan's multiple range test.

Cumulative Effect on the Larval Population during 3 Years of Observations

The pooled mean data of 2011-12, 2012-13 and 2013-14 on larval population before and post-treatments are presented in Table 4**.** Before spraying, there was uniform statistical significant distribution of Ha and To larvae on plants (Table 4).

A minimum of 5.08/m^2 (T_6) and maximum of 8.16/m^2 (T_2) larvae were recorded on 3rd and 7th day after the first spray in comparison to controls where 14.55 larvae/m^2 were recorded. It also showed a significant difference between the treatments in *To* population and population varied from 5.19 (T_7) to 8.02/m^2 (T_3) in comparison to 11.55/m^2 (T_{11}) in control plots. At 10 DAFS, the pooled mean of all season suggests significant deviation in population of both larvae with respect to treatments. The lowest Ha larvae of 4.16/m^2 were onserved in (T_5) and highest of 24.66/m^2 in (T_1). The lowest To population was 2.78/m^2 in (T_9) and highest of 6.22/m^2 in (T_2) compared to 39.61 and 9.05/m^2, respectively, in control plots for both pests. The pooled mean population of both pests was recorded before second spray initiation in field condition. Before this spray, minimum larval population of Ha was in T_4 (38.83) and maximum in T_9 (55.16/m^2) and the To population was lowest in T_9 (3.0) and highest in T_3 (7.11) in comparison to controls, which was 67.22 and 9.44/m^2, respectively, for both pests. The pooled for 3 years also reflected a similar trend of gradual decline in the population of To larvae in field condition after second spray. The highly significant difference among treatments was noticed by 10th DASS; the pooled mean of the lowest population of Ha larvae recorded in T_5 was 25.16 larvae/m^2 followed by T_4 (25.5 larvae/m^2) while the highest population of 52.83 was recorded in T_7 in comparison to control (43.94).

The pooled data of three years of biopesticides, *viz.,* Jatropha oil, NSKE and NPV in various combination of treatments with control, under chickpea-coriander intercropping agroecosystem showed that most effective treatment was T_4 (chickpea; Jatropha treated + coriander; NPV treated) followed by T_9 (chickpea; Jatropha treated) as compared to other treatments and control. Jatropha oil was also most effective in lone sprays as well against major pest of chickpea. As of today, the major studies of efficacy of Jatropha oil are only under *in vivo* condition against major pests and the present study is the first one to demonstrate the efficacy under field conditions. It is well known that Jatropha seed oil is effective against many storage insect pests under laboratory condition when compared to other plant products (Adabie-Gomez *et al.*, 2006; Henning, 2007). Apart from, the insecticidal activities of Jatropha oil containing phorbol esters have been reported as an effective protectant for *Manduca sexta*, Ha, *Aphis gossypii*, *Pectinophora gossypiella*, *Empoasca biguttula*, *Callosobruchus chinensis*, *Sitophilus zeamais*, *Phthorimaea operculella*, *Culex* sp., *Sesamia calamistis*, *Busseola fusca*, *Periplaneta Americana*, *Blattella germanica*, and *Oncopeltus fasciatus* under laboratory conditions (Wink *et al.*, 1997).

Ha and adult white fly *Bemisia tabaci* was studied by Aravinda *et al.* (2009) under controlled conditions. Some preliminary studies of Jatropha oil under field condition against pests complex of red gram in Pantnagar did suggest earlier that 1% treatment significantly reduced pod damage by *M. vitrata* followed by NSKE 5% and *B. bassiana* at the rate of 1.5 kg/ha (Pillai, 2012). It was suggested that this oil could act as both repellant and killing agent for insect pests the present study, therefore, provide ample evidence for the efficacy of Jatropha oil as a botanical insecticide that can be used in combination with other biopesticides in any integrated pest management strategy.

Effect on Pod Damage during *Rabi* 2011, 2012, and 2013

The pooled mean of 3 years study shows that percent damage of chickpea by pod borer could be significantly prevented. The lowest pod borer damage recorded was 54.91% in chickpea (Jatropha treated) + coriander (NPV treated) followed by 61.71% in chickpea (Jatropha treated alone). The highest pod damage recorded was 80.73% in chickpea (Jatropha + NSKE each five rows) + coriander (NPV treated) in comparison to control with 81.52% pod damage (Table 5).

Assessment of Yield in Chickpea and Intercrop Coriander

The pooled mean data of all *Rabi* seasons it was observed that the mean grain yield (kg/ha) had varying significance. Minimum yield was recorded in T_{1} (684.52 kg/ha) and maximum in T_4 (1292 kg/ha). In T_9 treatment yield obtained was 1148 kg/ha in comparison to control (715 kg/ha). The maximal coriander yield was obtained in T_{2} (1008 kg/ha) compared to controls (192 kg/ha) (Table 5).

The highest equitable yield was obtained T_3 (3761.5 kg/ha) and lowest in T_7 (2708.5 kg/ha) comparison to control, which was 2172 kg/ha. The percent increase yield over control was highest in T_4, i.e. 156.15% followed by T_9 (126.98%) and lowest in T_1 (32.31%). The maximum percent avoidable loss recorded was in T_{4} (60.96%) and minimum in T_6 (24.31%). The present investigation on percent pod damage and grain yield is in agreement with earlier observations of Pillai (2012) who reported that the mean grain yield after Jatropha oil 1% treatment was 870.20 kg/ha in comparison to control (665.88 kg/ha) in pigeonpea against pod borer complex.

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