RESEARCH ARTICLE Legume Research- An International Journal, Volume 46 Issue 11: 1510-1517 (November 2023)

Synergism of Plant Oils with Different Insecticides against Pod Borer, *Helicoverpa armigera* (Hubner) Hardwick Infesting Chickpea

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10.18805/LR-5192

ABSTRACT

Background: Gram pod borer, *Helicoverpa armigera* (Hubner) Hardwick has developed high level of resistance against so many insecticides due to some operational and biotic factors. The resistance can be managed by many ways among which adding of plant materials in insecticidal solution, which is having a synergistic effect, is one of the better ways to overcome this problem.

Methods: In aim to break the resistance of insecticides towards this pest, an experiment was carried out to know the synergistic effect of different plant oils along with different insecticides against pod borer infesting chickpea at Junagadh Agricultural University, Junagadh (Gujarat) during two consecutive years *i.e.*, 2017-18 and 2018-19. The experiment was laid in randomize block design having nine treatments (two oils and three insecticides) along with control.

Result: The results revealed that the minimum (10.98%) pod damage was observed in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% which was found at par with flubendiamide 48 SC 0.015% + neem oil 0.5% (12.04%). As far as the yield and economic is concern, highest (2634 kg/ha) yield and net realization (57,008 Rs /ha) was recorded in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% followed by flubendiamide 48 SC 0.015% + neem oil 0.5% (2432 kg/ha and 45,934 Rs/ha). The highest (1:10.33) ICBR was obtained in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% followed by chlorantraniliprole 18.5 SC 0.006% (1:9.36) and flubendiamide 48 SC 0.015% + neem oil 0.5% (1:7.13).

Key words: Chickpea, *Helicoverpa armigera*, Insecticides, Plant oils, Pod borer.

INTRODUCTION

Pulses are important group among the food crops which occupies a unique position in the world of agriculture by virtue of their high protein content. Among all the pulses, chickpea (*Cicer arietinum* Linnaeus) is one of the important pulses grown in *rabi* season which is commonly known as “Bengal gram” or “Gram” and mainly grown in the Indian subcontinent. In India, the area under chickpea is 9.99 mha with a production of 11.91 mT with productivity of 1192 kg/ha during 2020-21 (Anonymous, 2023a). In Gujarat, the area under chickpea is 7.64 lakh hectares with a production of 13.91 lakh tonnes with productivity of 1820 kg/ha during 2022-23 (Anonymous, 2023b).

Insect pests are probably the main factor limiting the grain legume yields. More than 150 species of insects are known to attack pulse crops in India and out of these, about 25 causes serious damage to monsoon and winter pulse crops (Bindra, 1968). Among the different pests infesting chickpea crop, *Helicoverpa armigera* (Hubner) Hardwick (Lepidoptera: Noctuidae) is a cosmopolitan and polyphagous pest, which attacks numerous crops of agricultural importance, which feeds voraciously from seedling stage to maturity and causes about 70-80 per cent damage to the chickpea (Khare and Ujagir, 1977; Setiyawati *et al.*, 2000). Lal *et al*. (1986) estimated an annual loss of about 203 crore of rupees in chickpea in India. As per the report of ICRISAT, losses caused by *H. armigera* on chickpea and pigeon pea fields exceeded Rs.12,000 millio/year (Anonymous, 1996).

Looking to the economic importance of this pest, farmers are using several old /newer chemicals to combat the attack of pod borer. As per the feedback of farmers regarding management of *H. armigera*, it is difficult to manage with well known insecticides *viz.,* quinalphos 0.05%, indoxacarb 0.015%, spinosad 0.018%, chlorantraniliprole 18.5 SC @ 0.006 etc. Probable reason behind this is gram pod borer has developed high level of resistance against so many insecticides due to some operational and biotic factors in Gujarat. The resistance can be managed by many ways. Among various ways, adding of plant materials in insecticidal solution, which is having a synergistic effect, is one of the better ways to overcome this problem.

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How to cite this article: Shah, K.D., Jethva, D.M., Ghelani, M.K. and Acharya, M.F. (2023). Synergism of Plant Oils with Different Insecticides against Pod Borer, *Helicoverpa armigera* (Hubner) Hardwick Infesting Chickpea. Legume Research. 46(11): 1510-1517. doi: 10.18805/LR-5192.

Submitted: 15-06-2023 **Accepted:** 01-08-2023 **Online:** 24-08-2023

MATERIALS AND METHODS

The experiment was laid in randomize block design having nine treatments (Table 1) along with control to know its efficacy against *Helicoverpa armigera* in chickpea crop at Department of Entomology Farm, Junagadh Agricultural University, Junagadh during during two consecutive years *i.e.*, 2017-18 and 2018-19. Chickpea, cultivar GJG-5 was grown as per standard agronomical practices having 45 × 10 cm spacing and plot size of 4.0 × 2.7 m (gross) and 3.6 × 1.8 m (net) for each treatment. The first application of combination was applied when pest crossed its ETL (0.75 larvae/plant before flowering and 0.5 larvae/plant after flowering) and next sprays was given at 20 days interval. Sticker has been added @ 3 ml/10 lit. of water in each treatment during each spray. For recording the observations on numbers of eggs and larvae /plant, per cent pod damage, ten plants were selected randomly from each plot and observations were recorded prior as well as 3, 7 and 14 days after spraying of the combination. The yield and economics were also worked out. The pesticide residues were also carried out for effective treatment.

RESULTS AND DISCUSSION

Pooled data of both the years (Table 2 and 3) on synergistic effect of different insecticides and plant oils after 3 days of first spray revealed that the lowest (2.51) eggs/plant was observed in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5%. It was found statastically at par with flubendiamide 48 SC 0.015% + neem oil 0.5% (2.60 eggs/plant). The next better treatments were flubendiamide 48 SC 0.015%, chlorantraniliprole 18.5 SC 0.006% and spinosad 45 SC 0.018% + neem oil 0.5% which was also statistically at par with each other. More or less similar trend was observed after 7 and 14 days of first spray as well as 3, 7 and 14 days after second spray.

As far as the larval population is concern (Table 4), the synergistic effect of different insecticides and plant oils after 3 days of first spray revealed that the lowest population of 3.12 larvae/plant was observed in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5%. It was found statistically at par with flubendiamide 48 SC 0.015% + neem oil 0.5% (3.24 larvae/plant). The next better treatments were flubendiamide 48 SC 0.015%, spinosad 45 SC 0.018% + neem oil 0.5% and chlorantraniliprole 18.5 SC 0.006% which was also statistically at par with each other. More or less similar trend was observed after 7 and 14 days of first spray as well as 3, 7 and 14 days after second spray (Table 5).

The pooled data on chickpea pod damage (Table 6) revealed that the minimum (10.98%) pooled pod damage was observed in the treatment of chlorantraniliprole 18.5 SC 0.006 % + neem oil 0.5% which stood statistically at par with flubendiamide 48 SC 0.015% + neem oil 0.5% (12.04%). The pooled data on chickpea yield (Table 7) was found significantly differed in all the treatments over control.

The highest (2634 kg/ha) yield was recorded in the chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% and it was at par with the treatment of flubendiamide 48 SC 0.015% + neem oil 0.5% (2432 kg/ha). The highest (57,008 Rs/ha) net realization (Table 8) was obtained in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% followed by treatments of flubendiamide 48 SC 0.015% + neem oil 0.5% (45,934 Rs/ha). The highest (1:10.33) ICBR (Table 8) was obtained in the treatment of chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5%, which was followed by chlorantraniliprole 18.5 SC 0.006% (1:9.36) and flubendiamide 48 SC 0.015% + neem oil 0.5% (1:7.13).

Looking to the results, it is clearly exposed that due to heavy insecticidal spray of newer molecules leads to development of resistance in *H. armigera* and thus an approach of mixing of oils having synergistic effect *i.e.*, neem oil, sesame oil *etc.* can break the resistance and also useful in managing such notorious pest. However, some research on effect of insecticides on *H. armigera* were reviewed and results on bio-efficacy of each treatments were are in close conformity with the obtained results as the application of neem

Table 1: Details of treatments along with concentration and active ingredient/ha.

Treatments	Concentration	Qty. of formulated product in g. or ml/10 lit. water	gm a.i./ha	Qty. of formulation kg or lit./ha
T_1- Chlorantraniliprole 18.5 SC0.006%	0.006%	3.25	30	162.5 ml
T_2- Flubendiamide 48 SC 0.015%	0.015%	3.20	77	160 ml
T_3- Spinosad 45 SC 0.018%	0.018%	4.00	90	200 ml
T_4- Chlorantraniliprole 0.006 % + Neem oil 0.5%	0.006%+0.5%	3.25+50	30+2500	162.5 ml+2.5 lit
T_5- Chlorantraniliprole 0.006 % + Sesame oil 1%	0.006 %+1%	3.25+100	30+5000	162.5 ml+5.0 lit
T_6- Flubendiamide 0.015% + Neem oil 0.5%	0.015%+0.5%	3.20+50	77+2500	160 ml+2.5 lit
T_7- Flubendiamide 0.015% + Sesame oil 1%	0.015%+1%	3.20+100	77+5000	160 ml+5.0 lit
T_8- Spinosad 0.018% + Neem oil 0.5%	0.018%+0.5%	4.00+50	90+2500	200 ml+2.5 lit
T_9- Spinosad 0.018%+ Sesame oil 1%	0.018%+1%	4.00+100	90+5000	200 ml+5.0 lit
T_{10}- Control	-	-	-	-

Table 2: Synergism of different plant oils with different insecticides against eggs population of *H. armigera* in chickpea (First spray).

Treatments	No. of eggs/plant										
	Before		3 DAS			7 DAS			14 DAS		
	2017-18	2018-19	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC0.006%	2.26 (5.09)	2.35 (5.50)	1.99 (3.96)	1.98 (3.93)	1.86 (3.46)	1.70 (2.89)	1.31 (1.72)	1.51 (2.27)	1.37 (1.89)	0.85 (0.73)	1.11 (1.24)
T_2- Flubendiamide 48 SC 0.015%	2.05 (4.22)	2.19 (4.78)	1.96 (3.84)	1.94 (3.76)	1.85 (3.42)	1.66 (2.76)	1.40 (1.96)	1.53 (2.34)	1.41 (1.99)	0.98 (0.96)	1.20 (1.43)
T_3- Spinosad 45 SC 0.018%	2.24 (5.01)	2.34 (5.49)	2.10 (4.40)	2.20 (4.84)	2.11 (4.46)	1.93 (3.72)	1.76 (3.10)	1.85 (3.40)	1.62 (2.61)	1.62 (2.63)	1.62 (2.62)
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	2.08 (4.31)	2.32 (5.36)	1.65 (2.73)	1.70 (2.89)	1.58 (2.51)	1.36 (1.85)	1.20 (1.44)	1.28 (1.64)	1.07 (1.15)	0.69 (0.48)	0.88 (0.78)
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	2.24 (5.03)	2.26 (5.10)	2.08 (4.31)	2.17 (4.72)	2.12 (4.47)	1.88 (3.52)	1.78 (3.19)	1.83 (3.35)	1.72 (2.94)	1.62 (2.62)	1.67 (2.78)
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2.00 (4.01)	2.26 (5.10)	1.69 (2.87)	1.72 (2.94)	1.61 (2.60)	1.46 (2.13)	1.21 (1.47)	1.34 (1.78)	1.13 (1.29)	0.75 (0.56)	0.94 (0.89)
T_7- Flubendiamide 0.015% + Sesame oil 1%	2.07 (4.28)	2.22 (4.95)	2.17 (4.71)	2.05 (4.20)	2.04 (4.17)	2.02 (4.06)	1.82 (3.30)	1.92 (3.67)	1.74 (3.04)	1.76 (3.10)	1.75 (3.07)
T_8- Spinosad 0.018% + Neem oil 0.5%	2.26 (5.09)	2.36 (5.55)	2.00 (4.01)	2.02 (4.08)	1.92 (3.69)	1.65 (2.72)	1.45 (2.09)	1.55 (2.39)	1.44 (2.08)	1.07 (1.16)	1.26 (1.58)
T_9- Spinosad 0.018% + Sesame oil 1%	2.06 (4.24)	2.13 (4.55)	2.15 (4.60)	2.10 (4.42)	2.11 (4.46)	2.07 (4.30)	1.84(3.39)	1.96 (3.83)	1.82 (3.31)	1.79 (3.19)	1.80 (3.25)
T_{10}- Control	2.27 (5.14)	2.49 (6.21)	2.25 (5.06)	2.29 (5.25)	2.26 (5.10)	2.23 (4.99)	2.29 (5.23)	2.26 (5.11)	2.24 (5.01)	2.16 (4.66)	2.20 (4.83)
S.Em.±	0.11	0.14	0.11	0.10	0.08	0.12	0.12	0.09	0.11	0.10	0.07
C.D. at 5%	NS	NS	0.32	0.31	0.24	0.36	0.37	0.25	0.32	0.31	0.21
C.V. %	8.72	10.68	9.28	8.85	10.61	11.80	13.33	12.52	11.99	13.42	12.65
Y S.Em.±	-	-	-	-	0.04	-	-	0.04	-	-	0.03
C.D. at 5%	-	-	-	-	0.11	-	-	0.11	-	-	0.10
Y × T S.Em.±	-	-	-	-	0.12	-	-	0.12	-	-	0.11
C.D. at 5%	-	-	-	-	NS	-	-	NS	-	-	NS

Figures in parenthesis are original values, while outsides are square root transformed values. DAS- Day afters spraying.

Table 3: Synergism of different plant oils with different insecticides against eggs population of *H. armigera* in chickpea (Second spray).

Treatments	No. of eggs/plant										
	Before		3 DAS			7 DAS			14 DAS		
	2017-18	2018-19	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC0.006%	2.36 (5.58)	2.41 (5.83)	1.74 (3.02)	1.82 (3.32)	1.78 (3.17)	1.56 (2.42)	1.63(2.64)	1.59(2.53)	1.27(1.62)	1.39(1.92)	1.33 (1.77)
T_2- Flubendiamide 48 SC 0.015%	2.33 (5.44)	2.26 (5.11)	1.76 (3.10)	1.77 (3.14)	1.77 (3.12)	1.62 (2.64)	1.50 (2.24)	1.56 (2.43)	1.32 (1.74)	1.37 (1.87)	1.34 (1.80)
T_3- Spinosad 45 SC 0.018%	2.42 (5.84)	2.42 (5.84)	2.02 (4.09)	2.06 (4.26)	2.04 (4.18)	1.84 (3.38)	1.82 (3.30)	1.83 (3.34)	1.55 (2.39)	1.70 (2.89)	1.62 (2.64)
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	2.39 (5.73)	2.39 (5.70)	1.47 (2.15)	1.36 (1.86)	1.42 (2.00)	1.23 (1.51)	0.95 (0.89)	1.09 (1.18)	0.98 (0.95)	0.57 (0.32)	0.77 (0.60)
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	2.35 (5.51)	2.43 (5.88)	2.06 (4.24)	2.10 (4.42)	2.08 (4.33)	1.89 (3.58)	1.87 (3.48)	1.88 (3.53)	1.62 (2.61)	1.75 (3.05)	1.68 (2.82)
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2.34 (5.46)	2.36 (5.58)	1.51 (2.27)	1.39 (1.93)	1.45 (2.10)	1.37 (1.87)	0.89 (0.79)	1.13 (1.27)	1.05 (1.10)	0.74 (0.55)	0.89 (0.80)
T_7- Flubendiamide 0.015% + Sesame oil 1%	2.38 (5.65)	2.38 (5.65)	2.04 (4.14)	2.20 (4.85)	2.12 (4.49)	2.01 (4.04)	1.95 (3.78)	1.98 (3.91)	1.74 (3.04)	1.84 (3.38)	1.79 (3.21)
T_8- Spinosad 0.018% + Neem oil 0.5%	2.36 (5.55)	2.42 (5.85)	1.82 (3.33)	1.84 (3.39)	1.83 (3.36)	1.68 (2.83)	1.52 (2.31)	1.60 (2.56)	1.38 (1.89)	1.21 (1.47)	1.29 (1.68)
T_9- Spinosad 0.018% + Sesame oil 1%	2.21 (4.89)	2.21 (4.89)	2.12 (4.49)	2.25 (5.05)	2.18 (4.77)	2.00 (3.98)	1.98 (3.91)	1.99 (3.95)	1.85 (3.43)	1.85 (3.42)	1.85 (3.43)
T_{10}- Control	2.47 (6.08)	2.56 (6.55)	2.22 (4.94)	2.40 (5.76)	2.31 (5.34)	2.30 (5.27)	2.22 (4.92)	2.26 (5.10)	2.24 (5.04)	2.26 (5.10)	2.25 (5.07)
S.Em.±	0.10	0.10	0.13	0.10	0.08	0.16	0.12	0.10	0.13	0.15	0.10
C.D. at 5 %	NS	NS	0.40	0.29	0.24	0.48	0.37	0.29	0.38	0.44	0.28
C.V. %	7.03	6.96	12.33	8.85	10.69	16.06	13.10	14.76	14.84	17.33	16.10
Y S.Em.±	-	-	-	-	0.04	-	-	0.05	-	-	0.04
C.D. at 5%	-	-	-	-	NS	-	-	0.13	-	-	NS
Y × T S.Em.±	-	-	-	-	0.12	-	-	0.14	-	-	0.14
C.D. at 5%	-	-	-	-	NS	-	-	NS	-	-	NS

Figures in parenthesis are original values, while outsides are square root transformed values. DAS- Day after spraying.

Table 4: Synergism of different plant oils with different insecticides against population of *H. armigera* infesting chickpea (First spray).

Treatments	No. of larvae/plant										
	Before		3 DAS			7 DAS			14 DAS		
	2017-18	2018-19	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC0.006%	2.17 (4.71)	2.01 (4.05)	1.89 (3.57)	2.04 (4.16)	1.96 (3.86)	1.53 (2.33)	1.78 (3.16)	1.65 (2.73)	1.26 (1.59)	1.58 (2.48)	1.42 (2.01)
T_2- Flubendiamide 48 SC 0.015%	1.98 (3.92)	2.02 (4.07)	1.84 (3.37)	2.02 (4.09)	1.93 (3.72)	1.56 (2.42)	1.76 (3.09)	1.66 (2.75)	1.19 (1.41)	1.47 (2.17)	1.33 (1.77)
T_3- Spinosad 45 SC 0.018%	1.96 (3.84)	2.08 (4.33)	1.93 (3.73)	2.27 (5.16)	2.10 (4.42)	1.73 (3.01)	1.86 (3.47)	1.80 (3.23)	1.42 (2.02)	1.55 (2.39)	1.48 (2.20)
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	2.07 (4.29)	2.10 (4.42)	1.66 (2.76)	1.87 (3.51)	1.77 (3.12)	1.33 (1.78)	1.33 (1.76)	1.33 (1.77)	0.95 (0.90)	0.96 (0.93)	0.96 (0.92)
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	1.97 (3.88)	2.04 (4.17)	1.94 (3.76)	2.31 (5.32)	2.13 (4.53)	1.76 (3.11)	2.08 (4.31)	1.92 (3.68)	1.48 (2.20)	1.71 (2.93)	1.60 (2.55)
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2.07 (4.29)	2.01 (4.03)	1.67 (2.79)	1.93 (3.71)	1.80 (3.24)	1.37 (1.88)	1.58 (2.48)	1.47 (2.17)	1.02 (1.03)	1.15 (1.32)	1.08 (1.17)
T_7- Flubendiamide 0.015% + Sesame oil 1%	2.07 (4.27)	2.02 (4.10)	2.01 (4.02)	2.32 (5.39)	2.16 (4.68)	1.92 (3.68)	2.09 (4.39)	2.01 (4.02)	1.73 (2.99)	1.76 (3.09)	1.74 (3.04)
T_8- Spinosad 0.018% + Neem oil 0.5%	1.98 (3.91)	2.05 (4.20)	1.88 (3.52)	1.98 (3.92)	1.93 (3.72)	1.58 (2.50)	1.71 (2.92)	1.65 (2.71)	1.22 (1.50)	1.56 (2.42)	1.39 (1.93)
T_9- Spinosad 0.018% + Sesame oil 1%	2.05 (4.21)	2.20 (4.86)	2.02 (4.08)	2.35 (5.50)	2.18 (4.76)	1.94 (3.76)	2.12 (4.50)	2.03 (4.12)	1.70 (2.88)	1.80 (3.26)	1.75 (3.07)
T_{10}- Control	2.10 (4.41)	2.18 (4.76)	2.07 (4.28)	2.37 (5.63)	2.22 (4.93)	2.02 (4.09)	2.41 (5.83)	2.22 (4.92)	2.00 (3.99)	2.26 (5.13)	2.13 (4.54)
S.Em.±	0.11	0.08	0.08	0.08	0.06	0.08	0.09	0.06	0.09	0.07	0.06
C.D. at 5%	NS	NS	0.25	0.23	0.17	0.25	0.28	0.17	0.26	0.21	0.16
C.V. %	8.91	6.46	7.76	6.39	7.16	8.74	8.69	8.33	10.70	7.77	9.19
Y S.Em.±	-	-	-	-	0.03	-	-	0.03	-	-	0.02
C.D. at 5 %	-	-	-	-	0.08	-	-	0.08	-	-	0.07
Y × T S.Em.±	-	-	-	-	0.08	-	-	0.09	-	-	0.08
C.D. at 5%	-	-	-	-	NS	-	-	NS	-	-	NS

Figures in parenthesis are original values, while outsides are square root transformed values. DAS- Day after spraying.

Table 5: Synergism of different plant oils with different insecticides against population of *H. armigera* infesting chickpea (Second spray).

Treatments	No. of larvae/plant										
	Before		3 DAS			7 DAS			14 DAS		
	2017-18	2018-19	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC0.006%	2.26 (5.10)	2.08 (4.32)	1.53 (2.35)	1.54 (2.38)	1.54 (2.36)	1.38 (1.90)	1.44 (2.06)	1.41 (1.98)	1.25 (1.55)	1.28 (1.65)	26 (1.60)
T_2- Flubendiamide 48 SC 0.015%	2.12 (4.49)	2.05 (4.21)	1.56 (2.44)	1.49 (2.23)	1.53 (2.33)	1.41 (1.98)	1.40 (1.96)	1.40 (1.97)	1.17 (1.38)	1.22 (1.49)	1.20 (1.43)
T_3- Spinosad 45 SC 0.018%	1.94 (3.76)	1.94 (3.76)	1.62 (2.61)	1.84 (3.39)	1.73 (2.99)	1.57 (2.46)	1.65 (2.72)	1.61 (2.59)	1.44 (2.08)	1.53 (2.36)	1.49 (2.22)
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	1.96 (3.82)	2.00 (3.98)	1.27 (1.61)	1.28 (1.63)	1.27 (1.62)	1.01 (1.01)	1.03 (1.06)	1.02 (1.04)	0.79 (0.62)	0.95 (0.90)	0.87 (0.75)
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	1.97 (3.86)	2.00 (3.98)	1.65 (2.72)	1.88 (3.52)	1.76 (3.11)	1.61 (2.58)	1.90 (3.59)	1.75 (3.07)	1.41 (1.98)	1.81 (3.26)	1.61 (2.58)
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2.04 (4.17)	1.85 (3.44)	1.32 (1.74)	1.33 (1.77)	1.33 (1.76)	1.10 (1.20)	1.20 (1.44)	1.15 (1.32)	0.90 (0.82)	1.00 (0.99)	0.95 (0.90)
T_7- Flubendiamide 0.015% + Sesame oil 1%	2.11 (4.43)	2.06 (4.23)	1.76 (3.08)	1.95 (3.80)	1.85 (3.43)	1.73 (3.00)	2.05 (4.21)	1.89 (3.58)	1.69 (2.87)	1.99 (3.97)	1.84 (3.40)
T_8- Spinosad 0.018% + Neem oil 0.5%	1.96 (3.86)	2.07 (4.28)	1.55 (2.39)	1.59 (2.52)	1.57 (2.45)	1.36 (1.84)	1.41 (1.98)	1.38 (1.91)	1.21 (1.47)	1.32 (1.75)	1.27 (1.61)
T_9- Spinosad 0.018% + Sesame oil 1%	2.09 (4.37)	1.99 (3.98)	1.78 (3.17)	2.09 (4.35)	1.93 (3.74)	1.76 (3.11)	2.23 (4.99)	2.00 (4.00)	1.73 (3.01)	2.00 (4.00)	1.87 (3.49)
T_{10}- Control	2.26 (5.13)	2.15 (4.64)	2.02 (4.09)	2.41 (5.83)	2.22 (4.92)	2.07 (4.30)	2.41 (5.83)	2.24(5.03)	1.99 (3.94)	2.45 (6.02)	2.22 (4.93)
S.Em.±	0.13	0.11	0.08	0.10	0.07	0.09	0.08	0.06	0.08	0.08	0.05
C.D. at 5%	NS	NS	0.25	0.30	0.19	0.28	0.23	0.17	0.25	0.25	0.15
C.V. %	10.58	9.54	9.03	10.19	9.68	10.72	7.95	9.30	10.74	10.74	8.87
Y S.Em.±	-	-	-	-	0.03	-	-	0.03	-	-	0.02
C.D. at 5%	-	-	-	-	0.08	-	-	0.08	-	-	0.07
Y × T S.Em.±	-	-	-	-	0.09	-	-	0.09	-	-	0.07
C.D. at 5%	-	-	-	-	NS	-	-	NS	-	-	NS

Figures in parenthesis are original values, while outsides are square root transformed values. DAS- Day after spraying.

oil (300 ppm) was found efficient in suppressing the population of *H. armigera* in chickpea with respect to benefit cost analysis (Ramteke *et al.,* 2002). As per the report of Landge *et al.* (2013), rynaxypyr 20 SC @ 40 g a.i./ha was most effective in reducing larval population followed by flubendiamid 20 WDG @ 50 g a.i./ha. Chavan *et al*. (2014) recorded the minimum larval incidence of *H. armigera* (0.95 and 0.36 larva/ meter row length) in rynaxypyr 20 SC at 3 and 7 days after spraying, respectively, followed by flubendiamide 48 SC (1.47 and 0.78 larvae/MRL). According to Jayanth and Kumar (2022), chlorantraniliprole 18.5% SC + neem oil was found good treatment against gram pod borer with lower mean larval

Table 6: Synergism of different plant oils with different insecticides on pod damage by *Helicoverpa armigera* in chickpea.

Treatments	Percent pod damage		
	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC 0.006%	22.80 (15.02)	23.98 (16.51)	23.39 (15.76)
T_2- Flubendiamide 48 SC 0.015%	23.75 (16.22)	24.67 (17.42)	24.21 (16.82)
T_3- Spinosad 45 SC 0.018%	26.73 (20.23)	27.64 (21.52)	27.19 (20.88)
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	18.97 (10.57)	19.74 (11.41)	19.36 (10.98)
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	27.38 (21.16)	28.80 (23.21)	28.09 (22.17)
T_6- Flubendiamide 0.015% + Neem oil 0.5%	20.00 (11.69)	20.61 (12.39)	20.31 (12.04)
T_7- Flubendiamide 0.015% + Sesame oil 1%	30.49 (25.74)	31.54 (27.36)	31.01 (26.55)
T_8- Spinosad 0.018% + Neem oil 0.5%	23.32 (15.68)	23.55 (15.97)	23.44 (15.82)
T_9- Spinosad 0.018%+ Sesame oil 1%	31.33 (27.04)	33.27 (30.09)	32.30 (28.55)
T_{10}- Control	37.04 (36.29)	40.38 (41.97)	38.71 (39.11)
S.Em.±	1.01	1.12	0.76
C.D. at 5%	3.01	3.34	2.17
C.V. %	6.70	7.11	6.92
Y S.Em.±	-	-	0.34
C.D. at 5%	-	-	0.97
Y × T S.Em.±	-	-	1.07
C.D. at 5%	-	-	NS

Figures in parenthesis are original values, while outsides are arc sine transformed values. DAS- Day after spraying.

Table 7: Synergism of different plant oils with different insecticides on chickpea yield.

Treatments	Yield (kg/ha)		
	2017-18	2018-19	Pooled
T_1- Chlorantraniliprole 18.5 SC 0.006%	2287	2346	2316
T_2- Flubendiamide 48 SC 0.015%	2191	2160	2176
T_3- Spinosad 45 SC 0.018%	1846	1713	1779
T_4- Chlorantraniliprole 0.006 % + Neem oil 0.5%	2506	2762	2634
T_5- Chlorantraniliprole 0.006 % + Sesame oil 1%	1880	1790	1835
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2488	2377	2432
T_7- Flubendiamide 0.015% + Sesame oil 1%	1679	1611	1645
T_8- Spinosad 0.018% + Neem oil 0.5%	2228	2160	2194
T_9- Spinosad 0.018%+ Sesame oil 1%	1617	1420	1519
T_{10}- Control	1404	1235	1319
S.Em.±	159	152	103
C.D. at 5%	472	452	293
C.V. %	13.68	13.46	13.57
Y S.Em.±	-	-	49
C.D. at 5%	-	-	141
Y × T S.Em.±	-	-	156
C.D. at 5 %	-	-	NS

Table 8: Economics of synergism of different plant oils with different insecticides against *Helicoverpa armigera* infesting chickpea.

Treatments	Yield kg/ha	Yield increased over control Kg/ha	Additional income Rs.	Cost of treatment (Pesticides, labor charge, sticker *etc.*) (Rs/ha)	Net realization Rs/ha	ICBR
T_1- Chlorantraniliprole 18.5 SC 0.006 %	2316	997	47856	5113	42744	1:9.36
T_2- Flubendiamide 48 SC 0.015%	2176	857	41136	6490	34646	1:6.34
T_3- Spinosad 45 SC 0.018%	1779	460	22080	7450	14630	1:2.96
T_4- Chlorantraniliprole 0.006% + Neem oil 0.5%	2634	1315	63120	6113	57008	1:10.33
T_5- Chlorantraniliprole 0.006% + Sesame oil 1%	1835	516	24768	6613	18156	1:3.75
T_6- Flubendiamide 0.015% + Neem oil 0.5%	2432	1113	53424	7490	45934	1:7.13
T_7- Flubendiamide 0.015% + Sesame oil 1%	1645	326	15648	7990	7658	1:1.96
T_8- Spinosad 0.018% + Neem oil 0.5%	2194	875	42000	8450	33550	1:4.97
T_9- Spinosad 0.018%+ Sesame oil 1%	1519	200	9600	8950	650	1:1.07
T_{10}- Control	1319	-	-	-	-	

Note: 1. Quantity of water: 500 lit./ha/spray; 2. Cost of input: (a) Cost of respective treatment (Rs. /kg or lit.): 1. 4063 + 1000 + 50 = 5113, 2. 5440 + 1000 + 50 = 6490, 3. 6400 + 1000 + 50 = 7450, 4. 4063 +1000 + 1000+ 50 = 6113, 5. 4063 + 1500 + 1000 + 50 = 6613, 6. 5440 + 1000 + 1000+ 50 = 7490, 7. 5440 + 1500 + 1000 + 50 = 7990, 8. 6400 + 1000 + 1000+ 50 = 8450, 9. 6400 + 1500 + 1000 + 50 = 8950 (b): Labour charge (Rs/ha) = 1000 (c); Cost of sticker (Rs/ha) = 50; 3. Price of chickpea- Rs. 48 per kg.

population is 1.25 per treatment and it has recorded considerable yield (14.35 q/ha) with C:B ratio 1:2.46.

CONCLUSION

Looking to synergistic activity, yield and economics of the insecticides and oils, chlorantraniliprole 18.5 SC 0.006% + neem oil 0.5% and flubendiamide 48 SC 0.015% + neem oil 0.5% were found to be the most effective treatments for the management of *H. armigera* infesting chickpea.

Conflict of interest: None.

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