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Research Note

Efficacy of botanicals and bio-pesticides on population dynamics of bollworm complex and their safety to the predators in non-*Bt* cotton

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ABSTRACT: A field investigation was carried out to assess the population fluctuation of bollworm complex and their natural enemies on non-*Bt* cotton. Twenty treatments including four botanicals were evaluated initially against sucking pests and continued further for check against bollworm complex with scheduling HaNPV, Bt and spinosad. The minimium egg and larval population of *Helicoverpa armigera* was reported in the application of NSE 5% and Azadirachtin 1500 ppm followed by spinosad 45 and HaNPV 250 LE/ha. However, the application of NSE 5% and Azadirachtin 1500 ppm followed by spinosad 45 SC was better in reducing larval population of *Easias vitella*. The treatment schedules comprising four botanicals followed by spinosad 45 SC as well as Bt 1000 g/ha have been found effective in reducing the larval population of pink bollworm in green bolls. The sole treatments of botanicals and the applications of botanicals followed by HaNPV 250 LE/ha have been observed to be safer to adults of coccinellids beetles, *Chrysoperla zastrowi sillemi* eggs and larvae as well as spiders.

KEY WORDS: Cotton, Bollworm complex, Natural Enemies

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In India, cotton is cultivated in three zones on an area of about 94.06 lakh ha with the average productivity of 502 kg lint/ha. Maharashtra is leading state in acreage of cotton cultivation (35.03 lakh ha), but far away from average productivity of India i.e. 296 kg lint/ha (Anonymous, 2010). After the introduction of *Bt* cotton in 2002 the productivity steadily increased, but, it falls short of world's average productivity of 620 kg lint/ha (Basu and Tanweer, 2008). Despite substantial improvement during 2004-05 in *Bt* cotton to reduce the cost of protection for bollworm complex, sucking pest complex and other minor pests emerged as new threat in *Bt* cotton. Besides, many farmers believe on non- *Bt* cotton in an era of *Bt* cotton.

Amongst the bollworms complex, American bollworm (*Helicoverpa armigera* Hub.), spotted bollworm (*Earias vitella* Fab.) and pink bollworm (*Pectinophora gossypiella* Saunders) are of regular occurrence on non-Bt cotton. Chemical insecticides were considered the only alternative for the management of bollworms on non-*Bt* cotton. However, it has been observed that adequate control of bollworms could not be achieved due to resistance to several insecticides. Biorational and microbial pesticides have been advocated as suitable alternatives, because of biosafety and environmental safety. Present investigation was carried out to evaluate the performance of different botanicals and biopesticides for the management of complex network of bollworms in cotton.

A research trial on management of bollworm complex of cotton with plant products was carried out in the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2004-05 and 2005-06 with a view to evaluate the performance of herbal extracts with HaNPV, *Bacillus thurungiensis* and spinosad on cotton bollworm complex and their natural enemies. Twenty different treatments consisting of NSE 5%, neem oil 1%, synthetic neem formulation (Azadirachtin 1500 ppm) @ 2ml/lit, CASE 5% and untreated control were evaluated initially for sucking pests and continued for bollworm complex management with biopesticides. The treatments undertaken for sucking pests continued for bollworms followed by HaNPV 250 LE/ha, Bt 1000 g/ha and spinosad 45 SC @ 0.01% (0.2 ml/lit) along with untreated control. The treatment sprays for bollworm management were

undertaken from the initiation of the damage and were repeated at an interval of 10 days. Four sprays were for sucking pests and three sprays for bollworm complex were given on a plot size of 6.0 m x 4.8 m (28.80 sq m). Following observations were undertaken to study population dynamics.

Observations on the number of eggs, larvae of *H. armigera* per plant were recorded from randomly selected five plants from each net plot at 3, 5 and 10 days after spraying and the average egg population per plant was worked out. Incidence of *P. gossypiella* was recorded by plucking 15 green bolls from the border line plants at 105, 120 and 135 days old crop. These bolls were dissected out and observed for the presence of *P. gossypiella* and per cent infestation worked out.

Observations were made on the population of eggs and larvae of *Chrysoperla zastrowi sillemi*, larval and adults of *Cheilomenes sexmaculata* and spiders on randomly selected five plants from each whole plant at 3, 5 and 10 days after each spray during both the years. These observations were analyzed for each year and also the two years data were pooled for analysis using ANOVA.

The pooled data on egg population revealed that marginal effects in reducing the *H. armigera* egg population over control plots was found in all treatments. It was also been noticed that the egg population was kept at minimum up to 3 DAS (days after spray), which increased slightly at 5 and 10 DAS (Table 1). The application of NSE 5% and azadirachtin 1500 ppm followed by HaNPV proved slightly better by recording 0.39 and 0.41 egg per plant at 3 DAS, respectively and found equal with NSE 5% followed by spinosad (0.40 egg/plant). The egg population observed in HaNPV treatment was comparable with the findings of Ameta *et al*. (2004).

The botanicals, NSE 5% and azadirachtin 1500 ppm had the identical effects in recording the egg population between 0.44 and 0.46/plant, 3 DAS and is comparable with findings of Panickar *et al*. (2003) who reported ovicidal effect on *H. armigera* eggs with commercial azadirachtin.

The data on larval population of *H. armigera* depicted that most of the treatments have shown similar effect as in case of egg count (Table 1). The lowest larval population was observed in NSE 5% and Azadirachtin 1500 ppm followed by spinosad (0.41 and 0.42 larva/plant) on 5th DAS and was statistically similar with NSE 5% and Azadirachtin 1500 ppm followed by HaNPV (each 0.47 larvae/plant). The sole application of spinosad as well as sole application of NSE 5% have shown similar performance in containing the larval population on 5th DAS observation on 10th DAS revealed that the application of botanicals followed by biopesticides have proved better over the sole application of botanicals. Similar results have been reported by Sreenivas and Patil (2001) with the use of Azadirachtin and HaNPV. Minimum larval population with Azadirachtin and spinosad was reported by Dandale *et al*. (2004) and Patil *et al*. (2004). Likewise, the lowest population of *H. armigera* by the application of spinosad was reported on cotton crop with NSE 5% by Sarode *et al*. (1995) and Anonymous (2007).

The treatments showed maximum effectiveness on 5th day as compared to 3rd and the population of larval of *E. Vitella* increased on 10th day of observation (Table 2). The lowest larval population was observed with NSE 5% and Azadirachtin 1500 ppm followed by spinosad recording 0.32 and 0.34 larva/plant on 5th DAS, which were on par with NSE 5% and Azadirachtin 1500 ppm followed by *Bt* (0.37 larva/plant for each treatment). The sole application of NSE 5% as well as spinosad on untreated control have shown reduction in the larval population of *E. vitella* up to 0.40 and 0.54 larva/plant on 5th DAS. The applications of botanicals followed by biopesticides have proved better over the sole applications of botanicals. Dandale *et al*. (2004) reported effective results with Azadirachtin and spinosad as well as Azadirachtin and *Bt* and Jeyakumar and Gupta (2002) found superior results with the application of Azadirachtin and *Bt*.

The application of NSE 5% and azadirachtin 1500 ppm followed by spinosad emerged as the best treatments by recording the lowest larval population of *P. gossypiella* of 0.15 larvae for each. Treatments with neem oil 1% and CASE 5% followed by spinosad recorded 0.18 larvae per green boll for each treatment and these treatments were found statistically similar. The sole applications of spinosad and Bt also recorded less population of pink bollworm larvae (0.21 larva /green boll) and were found on par. The effectiveness of spinosad against pink bollworm have been reported by Gopalaswamy *et al*. (2000) and Ulaganathan and Gupta (2004) who observed the minimum population in module consisting of neem products and spinosad as well as Bt. Whereas, Jeyakumar and Gupta (2002) found the minimum larval population in Azadirachtin and *Bt*.

Table 1. Effect of treatments on eggs and larval population of *Helicoverpa armigera*

Sl. No.	Treatments	Population of *H. armigera* eggs/leaf			Population of *H. armigera* larva/plant		
		3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS
1.	NSE 5%	0.44 (0.66)	0.67 (0.81)	0.66 (0.81)	0.69 (0.83)	0.51 (0.71)	0.83 (0.90)
2.	NSE 5% fb HaNPV	0.39 (0.63)	0.46 (0.67)	0.53 (0.72)	0.65 (0.81)	0.47 (0.68)	0.78 (0.88)
3.	NSE 5% fb Bt	0.71 (0.84)	0.82 (0.90)	0.8 (0.92)	0.84 (0.91)	0.66 (0.81)	0.98 (0.99)
4.	NSE 5% fb Spinsad	0.40 (0.63)	0.57 (0.76)	0.60 (0.77)	0.57 (0.75)	0.41 (0.64)	0.71 (0.84)
5.	Neem oil 1%	0.99 (0.99)	1.15 (1.07)	1.17 (1.08)	1.14 (1.06)	0.99 (0.99)	1.29 (1.13)
6.	Neem oil 1% fb HaNPV	0.85 (0.92)	1.01 (1.00)	0.93 (0.97)	1.01 (1.00)	0.84 (0.92)	1.17 (1.08)
7.	Neem oil 1% fb Bt	0.91 (0.95)	1.05 (1.02)	1.00 (1.00)	1.01 (1.00)	0.85 (0.92)	1.17 (1.08)
8.	Neem oil 1% fb Spinosad	0.93 (0.96)	1.02 (1.01)	1.06 (1.03)	0.98 (0.99)	0.81 (0.90)	1.14 (1.07)
9.	Azadi. 1500 ppm	0.46 (0.67)	0.69 (0.83)	0.72 (0.85)	1.13 (1.06)	1.02 (1.01)	1.24 (1.11)
10.	Azadi. 1500 ppm fb HaNPV	0.41 (0.63)	0.49 (0.70)	0.57 (0.75)	0.65 (0.81)	0.47 (0.68)	0.79 (0.89)
11.	Azadi. 1500 ppm fb Bt	0.77 (0.87)	0.91 (0.95)	0.85 (0.92)	0.85 (0.92)	0.67 (0.82)	0.99 (0.99)
12.	Azadi. 1500 ppm fb Spinosad	0.46 (0.67)	0.65 (0.81)	0.60 (0.77)	0.61 (0.78)	0.42 (0.64)	0.76 (0.87)
13.	CASE 5%	0.96 (0.98)	1.16 (1.08)	1.21 (1.10)	1.15 (1.07)	1.00 (1.00)	1.31 (1.14)
14.	CASE 5% fb HaNPV	0.69 (0.83)	0.80 (0.90)	0.77 (0.88)	0.83 (0.91)	0.65 (0.80)	0.97 (0.98)
15.	CASE 5% fb Bt	0.81 (0.90)	0.91 (0.95)	0.93 (0.97)	0.97 (0.98)	0.69 (0.83)	1.12 (1.05)
16.	CASE 5% fb Spinsad	0.66 (0.81)	0.81 (0.90)	0.81 (0.90)	0.79 (0.89)	0.63 (0.79)	0.98 (0.99)
17.	UC fb HaNPV	1.01 (1.00)	1.19 (1.09)	1.08 (1.04)	0.82 (0.90)	0.61 (0.77)	0.94 (0.96)
18.	UC fb Bt	0.99 (0.99)	1.21 (1.10)	1.13 (1.06)	1.04 (1.01)	0.95 (0.97)	1.30 (1.14)
19.	UC fb Spinosad	1.01 (1.01)	1.18 (1.09)	1.08 (1.04)	0.80 (0.89)	0.50 (0.70)	0.81 (0.90)
20.	Untreated control	1.20 (1.10)	1.54 (1.22)	1.50 (1.22)	1.74 (1.29)	1.47 (1.19)	1.90 (1.36)
	'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.04	0.04	0.03	0.05	0.03	0.02
	CD ($P = 0.05$)	0.11	0.11	0.09	0.14	0.08	0.07
	CV%	10.51	9.64	7.77	12.90	8.15	5.55

Figures in parentheses are corresponding square root transformed values
fb = followed by, UC = Untreated control

Table 2. Effect of treatments on population of *Earias vitella* larvae and *Pectinophora gossypiella* larvae in green bolls

Sl. No.	Treatments	Population of *E. vitella* larvae/plant			Population of *P. gossypiella* larva/green boll		
		3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS
1.	NSE 5%	0.53 (0.73)	0.40 (0.63)	0.68 (0.82)	0.27 (0.52)	0.26 (0.51)	0.31 (0.55)
2.	NSE 5% fb HaNPV	0.97 (0.98)	0.79 (0.89)	1.07 (1.03)	0.24 (0.49)	0.25 (0.50)	0.28 (0.53)
3.	NSE 5% fb Bt	0.50 (0.70)	0.37 (0.60)	0.65 (0.80)	0.20 (0.45)	0.20 (0.44)	0.24 (0.49)
4.	NSE 5% fb Spinsad	0.44 (0.66)	0.32 (0.56)	0.59 (0.77)	0.18 (0.42)	0.15 (0.39)	0.20 (0.45)
5.	Neem oil 1%	1.15 (1.07)	1.16 (1.07)	1.20 (1.09)	0.31 (0.55)	0.29 (0.53)	0.31 (0.55)
6.	Neem oil 1% fb HaNPV	1.05 (1.03)	0.83 (0.91)	1.07 (1.03)	0.26 (0.51)	0.23 (0.48)	0.26 (0.51)
7.	Neem oil 1% fb Bt	0.74 (0.86)	0.62 (0.78)	0.90 (0.95)	0.22 (0.46)	0.20 (0.45)	0.29 (0.53)
8.	Neem oil 1% fb Spinosad	0.76 (0.87)	0.65 (0.80)	0.88 (0.94)	0.21 (0.45)	0.18 (0.42)	0.22 (0.47)
9.	Azadi. 1500 ppm	1.24 (1.11)	1.23 (1.11)	1.28 (1.13)	0.31 (0.55)	0.29 (0.53)	0.31 (0.55)
10.	Azadi. 1500 ppm fb HaNPV	1.05 (1.03)	0.83 (0.91)	1.07 (1.03)	0.24 (0.49)	0.25 (0.50)	0.28 (0.53)
11.	Azadi. 1500 ppm fb Bt	0.51 (0.71)	0.37 (0.60)	0.66 (0.81)	0.20 (0.45)	0.20 (0.44)	0.24 (0.49)
12.	Azadi. 1500 ppm fb Spinosad	0.48 (0.69)	0.34 (0.58)	0.61 (0.78)	0.18 (0.42)	0.15 (0.38)	0.20 (0.45)
13.	CASE 5%	1.18 (1.08)	1.20 (1.10)	1.24 (1.11)	0.33 (0.57)	0.31 (0.55)	0.33 (0.57)
14.	CASE 5% fb HaNPV	1.11 (1.05)	0.92 (0.96)	1.13 (1.06)	0.26 (0.51)	0.23 (0.48)	0.26 (0.51)
15.	CASE 5% fb Bt	0.71 (0.84)	0.60 (0.77)	1.03 (1.00)	0.22 (0.46)	0.20 (0.45)	0.29 (0.53)
16.	CASE 5% fb Spinsad	0.69 (0.83)	0.57 (0.76)	0.83 (0.91)	0.21 (0.45)	0.18 (0.42)	0.22 (0.47)
17.	UC fb HaNPV	1.11 (1.05)	1.09 (1.04)	1.17 (1.08)	0.27 (0.52)	0.26 (0.51)	0.31 (0.55)
18.	UC fb Bt	0.71 (0.84)	0.60 (0.77)	1.03 (1.00)	0.29 (0.53)	0.21 (0.45)	0.26 (0.51)
19.	UC fb Spinosad	0.64 (0.80)	0.54 (0.73)	0.78 (0.88)	0.29 (0.53)	0.21 (0.45)	0.26 (0.51)
20.	Untreated control	1.58 (1.22)	1.54 (1.21)	1.77 (1.31)	0.49 (0.70)	0.57 (0.75)	0.51 (0.71)
	'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.04	0.02	0.03	0.01	0.02	0.02
	CD ($P = 0.05$)	0.12	0.07	0.09	0.04	0.06	0.05
	CV%	11.90	7.41	8.14	6.99	11.27	8.66

Figures in parentheses are corresponding square root transformed values
fb = followed by, UC = Untreated control

Table 3. Effect of treatments on population of *Cheilomenes sexmaculata* eggs and larvae

Sl. No.	Treatments	Population of *C. carnea* eggs/leaf			Population of *C. carnea* larva/plant		
		3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS
1.	NSE 5%	0.26 (0.51)	0.32 (0.55)	0.41 (0.62)	0.15 (0.38)	0.19 (0.44)	0.28 (0.52)
2.	NSE 5% fb HaNPV	0.19 (0.43)	0.23 (0.47)	0.33 (0.56)	0.08 (0.28)	0.08 (0.28)	0.17 (0.40)
3.	NSE 5% fb Bt	0.14 (0.37)	0.18 (0.41)	0.27 (0.50)	0.07 (0.25)	0.05 (0.21)	0.10 (0.31)
4.	NSE 5% fb Spinsad	0.10 (0.31)	0.18 (0.40)	0.26 (0.47)	0.05 (0.23)	0.06 (0.24)	0.16 (0.37)
5.	Neem oil 1%	0.21 (0.45)	0.27 (0.51)	0.36 (0.58)	0.11 (0.33)	0.13 (0.36)	0.21 (0.45)
6.	Neem oil 1% fb HaNPV	0.15 (0.39)	0.17 (0.41)	0.26 (0.50)	0.06 (0.24)	0.07 (0.25)	0.14 (0.37)
7.	Neem oil 1% fb Bt	0.12 (0.34)	0.15 (0.37)	0.23 (0.45)	0.06 (0.24)	0.05 (0.23)	0.10 (0.31)
8.	Neem oil 1% fb Spinosad	0.10 (0.31)	0.17 (0.39)	0.26 (0.47)	0.06 (0.24)	0.07 (0.27)	0.15 (0.36)
9.	Azadi. 1500 ppm	0.24 (0.49)	0.30 (0.53)	0.38 (0.60)	0.15 (0.38)	0.19 (0.43)	0.27 (0.51)
10.	Azadi. 1500 ppm fb HaNPV	0.22 (0.47)	0.25 (0.48)	0.33 (0.55)	0.09 (0.29)	0.11 (0.33)	0.19 (0.42)
11.	Azadi. 1500 ppm fb Bt	0.13 (0.36)	0.14 (0.37)	0.22 (0.45)	0.07 (0.25)	0.07 (0.26)	0.13 (0.35)
12.	Azadi. 1500 ppm fb Spinosad	0.09 (0.30)	0.19 (0.42)	0.27 (0.48)	0.05 (0.22)	0.05 (0.23)	0.11 (0.31)
13.	CASE 5%	0.23 (0.47)	0.24 (0.48)	0.32 (0.55)	0.13 (0.36)	0.17 (0.42)	0.26 (0.50)
14.	CASE 5% fb HaNPV	0.19 (0.44)	0.19 (0.44)	0.28 (0.51)	0.06 (0.24)	0.07 (0.25)	0.12 (0.33)
15.	CASE 5% fb Bt	0.11 (0.33)	0.17 (0.39)	0.25 (0.47)	0.07 (0.25)	0.05 (0.23)	0.10 (0.31)
16.	CASE 5% fb Spinsad	0.09 (0.30)	0.17 (0.39)	0.23 (0.44)	0.07 (0.27)	0.05 (0.21)	0.06 (0.24)
17.	UC fb HaNPV	0.15 (0.39)	0.19 (0.43)	0.27 (0.51)	0.08 (0.27)	0.06 (0.24)	0.15 (0.38)
18.	UC fb Bt	0.11 (0.33)	0.13 (0.36)	0.21 (0.43)	0.07 (0.26)	0.07 (0.25)	0.16 (0.38)
19.	UC fb Spinosad	0.09 (0.29)	0.17 (0.39)	0.24 (0.46)	0.05 (0.22)	0.05 (0.21)	0.12 (0.33)
20.	Untreated control	0.40 (0.63)	0.62 (0.75)	0.81 (0.85)	0.31 (0.54)	0.35 (0.59)	0.52 (0.71)
	'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.02	0.02	0.02	0.02	0.02	0.02
	CD (P = 0.05)	0.05	0.06	0.05	0.07	0.06	0.06
	CV%	11.32	10.61	8.93	19.45	16.91	12.47

Figures in parentheses are corresponding square root transformed values
fb = followed by, UC = Untreated control

Table 4: Effect of treatments on population of Lady bird bectle adult and spiders

Sl. No.	Treatments	Population of LBB adult/plant			Population of Spider adult/plant		
		3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS
1.	NSE 5%	1.51 (1.22)	1.70 (1.29)	1.77 (1.33)	0.17 (0.41)	0.23 (0.47)	0.33 (0.58)
2.	NSE 5% fb HaNPV	1.07 (1.03)	1.26 (1.12)	1.36 (1.17)	0.14 (0.37)	0.13 (0.35)	0.22 (0.46)
3.	NSE 5% fb Bt	1.00 (0.99)	1.07 (1.03)	1.14 (1.06)	0.11 (0.34)	0.12 (0.34)	0.20 (0.44)
4.	NSE 5% fb Spinsad	0.68 (0.82)	0.83 (0.91)	0.94 (0.97)	0.07 (0.25)	0.11 (0.32)	0.19 (0.42)
5.	Neem oil 1%	0.83 (0.91)	0.94 (0.97)	1.03 (1.01)	0.17 (0.41)	0.19 (0.44)	0.29 (0.53)
6.	Neem oil 1% fb HaNPV	0.61 (0.77)	0.69 (0.82)	0.79 (0.89)	0.14 (0.37)	0.13 (0.35)	0.22 (0.45)
7.	Neem oil 1% fb Bt	0.49 (0.70)	0.57 (0.75)	0.67 (0.82)	0.11 (0.34)	0.12 (0.34)	0.20 (0.44)
8.	Neem oil 1% fb Spinosad	0.47 (0.68)	0.55 (0.74)	0.64 (0.80)	0.07 (0.27)	0.10 (0.31)	0.18 (0.41)
9.	Azadi. 1500 ppm	1.29 (1.13)	1.49 (1.22)	1.56 (1.25)	0.18 (0.42)	0.21 (0.45)	0.30 (0.55)
10.	Azadi. 1500 ppm fb HaNPV	0.99 (0.99)	1.15 (1.07)	1.25 (1.12)	0.14 (0.37)	0.13 (0.35)	0.22 (0.45)
11.	Azadi. 1500 ppm fb Bt	0.81 (0.89)	0.95 (0.97)	1.03 (1.01)	0.11 (0.33)	0.12 (0.34)	0.20 (0.44)
12.	Azadi. 1500 ppm fb Spinosad	0.64 (0.80)	0.76 (0.87)	0.87 (0.93)	0.09 (0.29)	0.10 (0.31)	0.18 (0.41)
13.	CASE 5%	1.16 (1.07)	1.18 (1.09)	1.26 (1.12)	0.18 (0.42)	0.19 (0.44)	0.29 (0.54)
14.	CASE 5% fb HaNPV	0.71 (0.84)	0.86 (0.92)	0.95 (0.97)	0.13 (0.36)	0.12 (0.35)	0.21 (0.45)
15.	CASE 5% fb Bt	0.64 (0.79)	0.77 (0.87)	0.87 (0.93)	0.11 (0.33)	0.11 (0.33)	0.20 (0.43)
16.	CASE 5% fb Spinsad	0.52 (0.71)	0.63 (0.79)	0.74 (0.86)	0.08 (0.28)	0.10 (0.30)	0.18 (0.41)
17.	UC fb HaNPV	0.54 (0.72)	0.55 (0.74)	0.67 (0.82)	0.13 (0.35)	0.12 (0.34)	0.21 (0.44)
18.	UC fb Bt	0.52 (0.71)	0.54 (0.73)	0.66 (0.81)	0.11 (0.33)	0.11 (0.32)	0.19 (0.42)
19.	UC fb Spinosad	0.47 (0.67)	0.53 (0.72)	0.64 (0.80)	0.08 (0.28)	0.09 (0.29)	0.20 (0.43)
20.	Untreated control	1.94 (1.36)	2.06 (1.43)	2.83 (1.66)	0.37 (0.59)	0.50 (0.69)	0.81 (0.87)
	'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.04	0.03	0.03	0.02	0.02	0.02
	CD ($P = 0.05$)	0.11	0.09	0.08	0.05	0.06	0.07
	CV%	10.25	7.91	6.52	13.20	14.18	12.75

Figures in parentheses are corresponding square root transformed values
fb = followed by, UC = Untreated control

Effect of treatments on natural enemies of bollworm complex

The data on population of natural enemies of bollworm complex have shown their maximum population on 10th day after application and the population gradually increased thereafter.

All the treatments have shown safety to *C. zastrowi sillemi* eggs (Table 3). However, the sole application of NSE 5% was considered the most safe by recording 0.41 egg/plant next to untreated control (0.81 egg/plant). The other treatments viz., NSE 5%, Azadirachtin 1500 ppm, Neem oil 1%, CASE 5% and untreated control followed by HaNPV recorded higher numbers of *C. z. sillemi* eggs in the range of 0.26 to 0.33 per plant. Tanwar *et al*. (2004) also observed the maximum *C. carnea* eggs in IPM block consisting of NSE 5% application. Tayade (2007) reported the non-toxic effect to *C. z. sillemi* eggs to NSE and Azadirachtin. The similar relative safety of these biopesticides against *C. z. sillemi* eggs has been reported by Ameta *et al*. (2004) and Dandale *et al*. (2004).

The data (Table 3) revealed that the treatments showed varying degree of bio-safety to *C. z. sillemi* larvae. The treatments having sole applications of Azadirachtin 1500 ppm, CASE 5% and Neem oil 1% registered better number of population ranging from 0.21 to 0.27 larva/plant. The performance of these botanicals in their safety to larvae was documented by Tayade (2007), Ameta *et al*. (2004) and Tanwar *et al*. (2004).

In general, maximum *C. sexmaculata* adults were noticed in an untreated control plots (2.83 LBB adults/plant) at 10 DAS, but all the botanicals and their schedule with biopesticides were safer to adults of *C. sexmaculata* but with varying degrees. The treatments of NSE 5% and Azadirachtin 1500 ppm were found to be equal and proved to be most safe over others. Shinde *et al*. (2007) and Tayade (2007) also reported the safety of NSE 5% and Azadirachtin 1500 ppm by recording higher LBB adult population on cotton. NSE 5% and Azadirachtin 1500 ppm followed by the application biopesticides *viz.,* HaNPV and *Bt*. Patil and Pawar (1994) who observed the highest was the next safest population in untreated plots followed by HaNPV. They noted lowest LBB after 3 days of spray which increased after 7 and 14 days. The safety of NSE and HaNPV to the LBB adults has also been reported by Biradar *et al*. (2002). Likewise, safety of Bt to the LBB adult was reported by Shinde *et al*. (2007).

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