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Relative toxicity of noval insecticides against leaf eating caterpillar, *Spodoptera litura* Fabricius infesting soybean

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Abstract
A field experiment on evaluation of relative toxicity of eight different insecticides (Indoxacarb, flubendiamide, chlorantraniliprole, chlorfenapyr, novaluron, emamectin benzoate, beta-cyfluthrin, quinalphos) against leaf eating catterpillar of soybean was conducted at Agricultural Research Station, College of Agriculture, Anand Agricultural University, Jabugam. The results revealed that less numbers of *Spodoptera litura* (5.90 larvae/ 10 plants) were found in chlorantraniliprole whereas, minimum (9.86) larval population of *S. litura* also noticed in plots treated with emamectin benzoate (9.86) followed indoxacarb (13.91) and flubendiamide (14.52). The pest was suppressed significantly in plots sprayed with these insecticides over control.

Keywords: Relative toxicity, leaf eating catterpillar, *S. litura*, soybean, noval insecticides

Introduction
Soybean, *Glycine max* L. (Merrill) is one of the most important crops because of its seed protein and oil content, as well as its capacity to fix atmospheric nitrogen through symbiosis with soil-borne microorganisms. It is important as a predominant plant source of both animal feed protein and cooking oil (Schmutz *et al*., 2010) [7]. In India, the total area under soybean cultivation was 106.95 and 120.33 lac hectares with production 126.77 and 129.83 lac million tones and average productivity was 1185 and 1079 kg ha^{-1} in 2012 and 2013, respectively (Anonymous, 2013) [3]. The major soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Gujarat, Andhra Pradesh, Chhattisgarh and Karnataka. In Gujarat, the total area under cultivation is 68 thousand hectares (Anonymous, 2013) [3]. Vadodara, Chhotaudepur, Sabarkantha, Bharuch, Dahod and Amreli are major districts known for cultivation of this crop. Moreover, recently the area of cultivation is increasing in middle Gujarat region. The crop is mainly attacked by leaf eating caterpillar, *Spodoptera litura* Fabricius, green semilooper, *Chrysodeixis acuta* (Walker), grey semilooper, *Amyna octo* (Guenee) and gram pod borer, *Helicoverpa armigera* (Hubner) Hardwick, which are considered to be important lepidopteran pests (Singh *et al*., 1989; Sojitra, 1990 and Vyas, 1996) [8, 9, 11]. Of these, lepidopteran is the major pests of soybean in Gujarat state (Anonymous, 1989, Sojitra, 1990 and Vyas, 1996) [1, 9, 11]. Among the lepidopteran *S. litura* is one of the important pest cause yield loss in soybean cultivation. It also caused economic loss to many field, vegetables and fruits. Crop loss due to insect varies between 10 to 30 per cent for major crops (Sundar *et. al.*, 2018) [10]. In case of severe infestation, the entire crop is damaged badly, thus causing 40 per cent defoliation of leaf area. Therefore, it is necessary to evaluate these newer molecules against *S. litura* infesting soybean.

Materials and Methods
A field experiment on evaluation of relative toxicity of eight different insecticides (Table 1) against leaf eating catterpillar of soybean was conducted at Agricultural Research Station, College of Agriculture, Anand Agricultural University, Jabugam during the *Kharif* 2014 and 2016. The experiment was laid out in Randomized Block Design replicated thrice. The gross and net plot size was 3.0 x 2.7 m and 2.4 x 1.8 m, respectively. As and when required all the agronomical practices, except plant protection were followed. Considering the pest population in experimental area, two sprays were applied on need basis. The chemical spray was applied on appearance of *S. litura* by using high volume sprayer (knapsack) with required

concentration. Ten plants were selected randomly from each net plot area and tagged for recording the observations. The observations of leaf eating caterpillar, *S. litura* was recorded before spray, 3, 5, 10 and 15 days after each spray. At harvest, yield of seed was weighed from each net plot area. The data obtained were analyzed by using standard statistical techniques.

Treatment details

Sr. No.	Name of Insecticides	Conc. (%)	ml or g/ 10 litre of water	g.a.i. /ha
T_1	Indoxacarb 15.8 EC	0.0079	5 ml	39.5
T_2	Flubendiamide 480 SC	0.0145	3 ml	72
T_3	Chlorantraniliprole 18.5 SC	0.006	3 ml	30
T_4	Chlorfenapyr 10 EC	0.01	10 ml	50
T_5	Novaluron 10 EC	0.01	10 ml	50
T_6	Emamectin benzoate 5 WG	0.0025	5 g	12.5
T_7	Beta-cyfluthrin 25 EC	0.0125	5 ml	62.5
T_8	Quinalphos 25 EC	0.025	20 ml	250
T_9	Control (water spray)	-	-	-
(a.i. is calculated based on 500 litre of water/ha)				

Results and Discussion

It is revealed that, during 2014, the larval population (Table 1) of leaf eating catterpillar on soybean after first spray was found to minimum numbers (8.29 larvae/ 10 plants) in chlorantraniliprole followed by emamectin benzoate (11.63) and indoxacarb (13.62). These treatments proved significantly superior over rest of the insecticides. Excellent performance of chlorantraniliprole (3.53), emamectin benzoate (8.58) and indoxacarb (13.32) was also observed in second spray. Pooled over periods and sprays data indicated that the plots treated with chlorantraniliprole registered minimum (5.66) larval population followed by emamectin benzoate (10.05), indoxacarb (13.47) and novaluron (14.13).

During 2016, the minimum numbers of *S. litura* larvae (Table 2) after first spray was found (9.24 larvae/ 10 plants) in chlorantraniliprole followed by emamectin benzoate (12.04) and flubendiamide (15.68). Excellent performance of chlorantraniliprole (3.65), emamectin benzoate (7.40) and flubendiamide (12.74) was also observed in second spray. Pooled over periods and sprays data (Table 2) indicated that the plots treated with chlorantraniliprole registered minimum (6.15) larval population followed by emamectin benzoate (9.61), flubendiamide (14.21), indoxacarb (14.36) and novaluron (14.75).

The data on pooled over periods, sprays and years (Table 3) revealed that there was significant difference among the treatments and all the insecticidal treatments recorded significantly lower larval population than control. Among various treatments, the average larval population per ten plants ranged from 5.90 to 27.14. The chronological order of efficacy of various treatments against *S. litura* was chlorantraniliprole (5.90 larvae/ 10 plants)>emamectin benzoate (9.86) >indoxacarb (13.91) >flubendiamide (14.52) >novaluron (14.44) >chlorfenapyr (18.15) >beta-cyfluthrin (18.66) >quinalphos (21.62) >control (27.14). New chemical compound like chlorantraniliprole reported significantly superior over all other insecticides compounds and control. These are in conformity with the reports of Patil *et al.* (2014) [5] and Sakotsungba *et al.* (2018) [6] as they documented the effectiveness of this insecticide against *S. litura* infesting soybean, respectively.

The data on grain yield recorded in various insecticidal treatments as well as control during 2014 and 2016 are presented in Table 4. There was significant impact of insecticidal treatments on grain yield in both years. All the insecticidal treatment recorded significantly higher grain yield than control. Significantly highest (2164 kg/ha) grain yield was registered in plots treated with chlorantraniliprole than remaining insecticides (Table 2). Flubendiamide (2021 kg/ha), indoxacarb (1863 kg/ha) and emamectin benzoate (1755 kg/ha) ranked second, third and fourth after chlorantraniliprole, respectively. These results are in accordance with the findings of Natikar *et al.* (2016) [4] who showed effectiveness of flubendiamide, indoxacarb and chlorantraniliprole against leaf eating catterpillar infesting soybean, respectively. However, Patil *et al.* (2014) [5] recorded highest grain yield (19.88 q/ha) and cost benefit ratio (1: 4.02) of soybean in the treatment of chlorantraniliprole 18.5%SC @ 30 g.ai./ha at Aurangabad, Maharashtra which partially agreed with the present finding.

Conclusion

From the above results it may be concluded that based on relative toxicity of different insecticides, it is advised to apply two sprays (first at initiation of pest and second at 15 days after first spray) of chlorantraniliprole 0.006 per cent (3 ml/10 litre of water) or flubendamide 0.0145 per cent (3 ml/10 litre of water) or emamectin benzoate 0.0025 per cent (5 g/10 litre of water) or indoxacarb 0.0079 per cent (5 ml/ 10 litre of water) for effectively management of *S. litura* infesting soybean and obtained significantly higher grain yield.

Table 1: Effect of different insecticides on population of leaf eating caterpillar, *S. litura* infesting soybean (2014)

Sr. No.	Treatments	Average number of larva(e)/ 10 plants										
		First spray						Second spray				
		BS	3 DAS	5 DAS	10 DAS	15 DAS	Pooled	3 DAS	5 DAS	10 DAS	15 DAS	Pooled
1	Indoxacarb 15.8 EC	4.56	*3.57cde	3.23de	3.85cd	4.11bc	3.69ef	3.86cd	3.72cd	3.58cd	3.43c	3.65d
		(20.79)	(12.74)	(10.43)	(14.82)	(16.89)	(13.62)	(14.90)	(13.84)	(12.82)	(11.76)	(13.32)
2	Flubendiamide 480 SC	4.12	3.74bcd	3.68cd	4.07bcd	4.31bc	3.95de	3.45d	3.82bcd	3.68bcd	3.54c	3.75cd
		(16.97)	(13.99)	(13.54)	(16.56)	(18.58)	(15.60)	(11.90)	(14.59)	(13.54)	(12.53)	(14.06)
3	Chlorantraniliprole 18.5 SC	4.13	2.85e	2.50f	2.92e	3.25d	2.88g	1.81e	2.24e	1.88e	1.60e	1.88f
		(17.06)	(8.12)	(6.25)	(8.53)	(10.56)	(8.29)	(3.28)	(5.02)	(3.53)	(2.56)	(3.53)
4	Chlorfenapyr 10 EC	4.28	3.99abcd	3.89bc	4.26abc	4.49ab	4.16cd	4.26abc	4.14abc	4.02bc	3.89bc	4.08c
		(18.32)	(15.92)	(15.13)	(18.15)	(20.16)	(17.31)	(18.15)	(17.14)	(16.16)	(15.13)	(16.65)
5	Novaluron 10 EC	4.48	3.68bcd	3.58cd	3.98cd	4.23bc	3.87de	3.85cd	3.72cd	3.58cd	3.43c	3.65d
		(20.07)	(13.54)	(12.82)	(15.84)	(17.89)	(14.98)	(14.82)	(13.84)	(12.82)	(11.76)	(13.32)
6	Emamectin benzoate 5 WG	4.36	3.34de	3.04e	3.50d	3.77c	3.41f	3.20d	3.04d	2.86d	2.62d	2.93e
		(19.01)	(11.16)	(9.24)	(12.25)	(14.21)	(11.63)	(10.24)	(9.24)	(8.18)	(6.86)	(8.58)
7	Beta-cyfluthrin 25 EC	4.37	4.15abc	4.07abc	4.42abc	4.64ab	4.32bc	4.19bc	4.07bc	3.94bc	3.81bc	4.00cd
		(19.10)	(17.22)	(16.56)	(19.54)	(21.53)	(18.66)	(17.56)	(16.56)	(15.52)	(14.52)	(16.00)
8	Quinalphos 25 EC	4.47	4.39ab	4.31ab	4.64ab	4.96a	4.57ab	4.75ab	4.64ab	4.53ab	4.42ab	4.58b
		(19.98)	(19.27)	(18.58)	(21.53)	(24.60)	(20.88)	(22.56)	(21.53)	(20.52)	(19.54)	(20.98)
9	Control (water spray)	4.18	4.56a	4.46a	4.78a	4.89a	4.67a	4.96a	4.99a	5.02a	5.10a	5.02a
		(17.47)	(20.79)	(19.89)	(22.85)	(23.91)	(21.81)	(24.60)	(24.90)	(25.20	(26.01)	(25.20)
	S. Em.(+) Treatment (T)	0.22	0.24	0.15	0.18	0.17	0.10	0.21	0.25	0.26	0.24	0.11
	Period (P)	-	-	-	-	-	0.06	-	-	-	-	0.08
	T x P	-	-	-	-	-	0.20	-	-	-	-	0.23
	C.D. at 5 % Treatment (T)	NS	0.73	0.44	0.54	0.5	0.28	0.63	0.75	0.79	0.72	0.33
	Period (P)	-	-	-	-	-	0.18	-	-	-	-	0.22
	T x P	-	-	-	-	-	NS	-	-	-	-	NS
	C.V. (%)	8.84	11.1	7.09	7.65	6.76	8.64	9.43	11.4	12.46	11.83	10.83

*Figures in parentheses are retransformed values, those outside are $\sqrt{x}$ transformed values. NS : Not Significant DAS : Day after spray
Treatment means with letter(s)in common are not significant by DNMRT at 5 % level of significance BS : Before Spray

Table 2: Effect of different insecticides on population of leaf eating caterpillar, *S. litura* infesting soybean (2016)

Sr. No.	Treatments	Average number of larva(e)/ 10 plants										
		First spray						Second spray				
		BS	3 DAS	5 DAS	10 DAS	15 DAS	Pooled	3 DAS	5 DAS	10 DAS	15 DAS	Pooled
1	Indoxacarb 15.8 EC	4.67	*4.12bcd	3.86bc	3.82bcd	4.07bcd	3.97c	3.82bc	3.68bc	3.54bc	3.40bc	3.61c
		(21.81)	(16.97)	(14.90)	(14.59)	(16.56)	(15.76)	(14.59)	(13.54)	(12.53)	(11.56)	(13.03)
2	Flubendiamide 480 SC	4.46	4.21abcd	3.82bc	3.78bcd	4.04bcd	3.96c	3.78bc	3.64bc	3.50bc	3.35bc	3.57c
		(19.89)	(17.72)	(14.59)	(14.29)	(16.32)	(15.68)	(14.29)	(13.25)	(12.25)	(11.22)	(12.74)
3	Chlorantraniliprole 18.5 SC	4.46	3.39d	2.99c	2.71d	3.07d	3.04d	2.51d	2.10d	1.62d	1.41d	1.91e
		(19.89)	(11.49)	(8.94)	(7.34)	(9.42)	(9.24)	(6.30)	(4.41)	(2.62)	(1.99)	(3.65)
4	Chlorfenapyr 10 EC	5.01	4.57abc	4.50ab	4.42abc	4.65abc	4.53b	4.42b	4.31b	4.19b	4.07b	4.25b
		(25.10)	(20.88)	(20.25)	(19.54)	(21.62)	(20.52)	(19.54)	(18.58)	(17.56)	(16.56)	(18.06)
5	Novaluron 10 EC	4.56	4.17bcd	3.92bc	3.86bcd	4.11bcd	4.01c	3.86bc	3.72bc	3.59bc	3.44b	3.65c
		(20.79)	(17.39)	(15.37)	(14.90)	(16.89)	(16.08)	(14.90)	(13.84)	(12.89)	(11.83)	(13.32)
6	Emamectin benzoate 5 WG	4.52	3.76cd	3.33c	3.25cd	3.55cd	3.47d	3.09cd	2.93cd	2.75c	2.12cd	2.72d
		(20.43)	(14.14)	(11.09)	(10.56)	(12.60)	(12.04)	(9.55)	(8.58)	(7.56)	(4.49)	(7.40)
7	Beta-cyfluthrin 25 EC	4.63	4.71abc	4.60ab	4.56ab	4.78ab	4.66b	4.45b	4.33b	4.21b	4.08b	4.27b
		(21.44)	(22.18)	(21.16)	(20.79)	(22.85)	(21.72)	(19.80)	(18.75)	(17.72)	(16.65)	(18.23)
8	Quinalphos 25 EC	5.13	4.93ab	4.83ab	4.73ab	4.93ab	4.86b	4.73ab	4.62ab	4.51ab	4.39b	4.56b
		(26.32)	(24.30)	(23.33)	(5.43)	(24.30)	(23.62)	(22.37)	(21.34)	(20.34)	(19.27)	(20.79)
9	Control (water spray)	4.45	5.24a	5.27a	5.43a	5.62a	5.39a	5.69a	5.72a	5.76a	5.82a	5.75a
		(19.80)	(27.46)	(27.77)	(29.48)	(31.58)	(29.05)	(32.38)	(32.72)	(33.18)	(33.87)	(33.06)
	S. Em.(±) Treatment (T)	0.33	0.31	0.34	0.36	0.34	0.16	0.35	0.38	0.37	0.40	0.18
	Period (P)	-	-	-	-	-	0.11	-	-	-	-	0.12
	T x P	-	-	-	-	-	0.33	-	-	-	-	0.36
	C.D. at 5 % Treatment (T)	NS	0.92	1.01	1.08	1.02	0.47	1.06	1.14	1.10	1.20	0.51
	Period (P)	-	-	-	-	-	NS	-	-	-	-	0.34
	T x P	-	-	-	-	-	NS	-	-	-	-	NS
	C.V. (%)	12.25	12.16	14.12	15.38	13.64	13.63	15.16	16.84	16.99	19.36	16.30

*Figures in parentheses are retransformed values, those outside are $\sqrt{x}$ transformed values. NS : Not Significant DAS : Day after spray
Treatment means with letter(s)in common are not significant by DNMRT at 5 % level of significance BS : Before Spray

Table 3: Effect of different insecticides on population of leaf eating caterpillar, *S. litura* infesting soybean

Sr. No.	Treatments	Average number of larva(e)/ 10 plants					
		2014		2016		Pooled	
1	Indoxacarb 15.8 EC	*3.67c		3.79c		3.73d	
		(13.47)		(14.36)		(13.91)	
2	Flubendiamide 480 SC	3.85bc		3.77c		3.81d	
		(14.82)		(14.21)		(14.52)	
3	Chlorantraniliprole 18.5 SC	2.38e		2.48e		2.43f	
		(5.66)		(6.15)		(5.90)	
4	Chlorfenapyr 10 EC	4.12b		4.39b		4.26c	
		(16.97)		(19.27)		(18.15)	
5	Novaluron 10 EC	3.76c		3.84c		3.80d	
		(14.13)		(14.75)		(14.44)	
6	Emamectin benzoate 5 WG	3.17d		3.10d		3.14e	
		(10.05)		(9.61)		(9.86)	
7	Beta-cyfluthrin 25 EC	4.16b		4.47b		4.32bc	
		(17.31)		(19.98)		(18.66)	
8	Quinalphos 25 EC	4.58a		4.71b		4.65b	
		(20.98)		(22.18)		(21.62)	
9	Control (water spray)	4.85a		5.57a		5.21a	
		(23.52)		(31.02)		(27.14)	
		S. Em.(+)	C.D. at 5 %	S. Em.(+)	C.D. at 5 %	S. Em.(+)	C.D. at 5 %
	Treatment (T)	0.10	0.28	0.12	0.35	0.12	0.38
	Period (P)	0.06	NS	0.08	NS	0.08	NS
	Spray (S)	0.04	0.13	0.05	0.16	0.03	0.09
	Year (Y)	-	-	-	-	0.03	0.09
	T x P	0.20	NS	0.24	NS	0.14	NS
	T x S	0.14	0.39	0.17	0.49	0.10	0.28
	T x Y	-	-	-	-	0.10	0.28
	P x S	0.09	0.26	0.11	NS	0.06	0.19
	P x Y	-	-	-	-	0.07	0.19
	S x Y	-	-	-	-	0.05	NS
	T x P x S	0.28	NS	0.35	NS	0.20	0.20
	T x P x Y	-	-	-	-	0.20	0.20
	T x S x Y	-	-	-	-	0.14	0.14
	P x S x Y	-	-	-	-	0.09	0.09
	T x P x S x Y	-	-	-	-	0.29	NS
	C.V. (%)	12.77		15.11		12.74	

* Figures in parentheses are retransformed values, those outside are $\sqrt{x}$ transformed values. NS: Not Significant
Treatment means with letter(s) in common are not significant by DNMRT at 5 % level of significance.

Table 4: Impact of different insecticidal treatments on soybean grain yield

Sr. No.	Treatments	2014	2016	Pooled (kg/ha)
1	Indoxacarb 15.8 EC	1875ab	1852ab	1863ab
2	Flubendiamide 480 SC	2052a	1991ab	2021ab
3	Chlorantraniliprole 18.5 SC	2176a	2153a	2164a
4	Chlorfenapyr 10 EC	1705abc	1698ab	1701bc
5	Novaluron 10 EC	1412bcd	1389bc	1400cd
6	Emamectin benzoate 5 WG	1767abc	1744ab	1755b
7	Beta-cyfluthrin 25 EC	1366cd	1343bc	1354d
8	Quinalphos 25 EC	1026de	965c	995e
9	Control (water spray)	741e	772c	756f
	S. Em.(±)	146.63	194.50	190.10
	C.V. (%)	16.19	21.80	19.16

Treatment means with letter(s) in common are not significant by DNMRT at 5 % level of significance.

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