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Conservation of natural enemies in cotton ecosystem with pre-dosing of lufenuron prior to the use of traditional insecticides

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ABSTRACT: Studies were carried out on conservation of natural enemies in cotton ecosystem by studying deleterious effect of chemical pesticide, pre-dosing with insect growth regulator. Insect growth regulator, lufenuron @ 24, 50, 255 and 290ppm was used before the application of chlorpyriphos against cotton bollworms particularly, *Helicoverpa armigera* (Hübner). In all the experiments, lufenuron (Match 5EC) proved safe to eggs and adults of *Chrysoperla carnea* (Stephens) at all the dosages, which helped in the conservation of natural fauna. The use of insect growth regulator is thus suggested prior to the use of chlorpyriphos in cotton against cotton pests as conservation practice.

KEY WORDS: American bollworm, cotton, chlorpyriphos, *Chrysoperla carnea*, lufenuron

INTRODUCTION

Cotton is one of the most important cash crops of India that suffers heavily from the attack of different pests. Insect pests known to thrive on cotton include sucking pests and bollworms. Among the different species of bollworms, *Helicoverpa armigera* (Hübner) is the most dreaded pest. In Punjab, more than 50 per cent damage to cotton has been estimated in terms of cotton yield (Dhawan, 2000). Inspite of the extensive use of conventional insecticides for its control, the menace of this dreaded pest could not be tackled to a desired level. The widespread and indiscriminate use of these insecticides has led to the development of resistance to most of the insecticides (Kapoor *et al*., 2000). Besides, other problems like insect pest resurgence, toxicity to natural enemies, pollution of environment, pesticide residue in food and health hazards, etc. have been significant as a result of the use of potent pesticides. In order to mitigate the ill effects of pesticides and to conserve natural enemies of insect pests, a chitin synthesis inhibitor, lufenuron, has been included in the chemical control strategy for cotton bollworms, as it is selective in action and eco–friendly in nature. Lufenuron has been identified as potent against *H. armigera* under Punjab conditions (Butter *et al*., 2003). Studies were undertaken to evaluate it as a pre–dosing chemical with a view to reduce the usage of conventional insecticides and conserve natural enemies.

MATERIALS AND METHODS

The trials were conducted at Punjab Agricultural University, Ludhiana, during 2004–05 and 2005–06 on LH 1556 variety using a randomized block design (RBD) with six treatments and four replications. The crop was sown during last week of April with a spacing of 67.5 x 60.0cm in a 4 x 7m plot. To test the impact of pre–dosing with insect growth regulator (IGR), LC values were worked out. The LC_{50} and LC_{90} values worked out in the laboratory for 2nd and 3rd instar larvae of *H. armigera* were 24, 290ppm and 50, 255ppm, respectively. The quantity of spray fluid was 250 litres per hectare with knapsack sprayer. Chlorpyriphos spray was given at an interval of 7 days after the pre–dosing with lufenuron (spray interval between lufenuron and chlorpyriphos was determined by taking into account the residual toxicity under laboratory experiments). Subsequent sprays of lufenuron were given at an interval of 10 days after the spray of conventional insecticide (chlorpyriphos) during the entire effective boll formation period (28th July to 24th September during 2004–05 and 4th August to 28th September during 2005–06). In all, 8 sprays (4 each of lufenuron and chlorpyriphos) were given. The observations were recorded on ten randomly selected plants in each plot excluding border rows. All the records were made before the application of IGR/chlorpyriphos and 24 hours and 96 hours after the application. The population of natural enemies was recorded on 10 randomly selected plants in each plot on whole plant basis. The data were analyzed statistically after necessary transformation.

RESULTS AND DISCUSSION

Lufenuron as pre–treatment before the use of chlorpyriphos or lufenuron alone (290 ppm) was found to be significantly safer compared to chlorpyriphos to *C. carnea*

as indicated by eggs load in treated plots, whereas, lufenuron @ 255ppm (alone) or as pre-dose prior to chlorpyriphos caused significant reduction in eggs (5.01 and 3.14 eggs / 10 plants) as compared to control (18.56 and 18.68 eggs / 10 plants), 24 and 96h after spray, respectively (Table 1). Lufenuron (alone) was at par where pre-dosing with lufenuron was done after the application of chlorpyriphos @ 1 g a.i./l with respect to the egg number on cotton, 24 and 96 h after the spray. Lufenuron (24 ppm) treatment had no deleterious effect on the predator while chlorpyriphos alone significantly reduced the number of eggs (4.18 and 2.51 eggs / 10 plants) as compared to untreated check (19.18 and 18.87 eggs / 10 plants), 24 and 96h after the spray respectively. Lufenuron @ 50ppm proved safe to predator whereas, chlorpyriphos (4 g a.i. l^{-1}) showed deleterious effect on egg load. All the treatments of chlorpyriphos with pre-dose of lufenuron proved safe to the predator, *C. carnea* as these treatments recorded significantly higher number of eggs as compared to chlorpyriphos treated plots.

After 96h, significantly higher reduction in lacewing adults in chlorpyriphos was obtained when pre-dosing with lufenuron (290ppm) was done. These treatments (lufenuron as pre-treatment before chlorpyriphos) as well as lufenuron alone found statistically safe to predator as compared to chlorpyriphos. The reduction in population was recorded in all the treatments, after 24 and 96h of the spray and it was significantly high (0.12 adults / 10 plants) in chlorpyriphos followed by chlorpyriphos treatments with pre-dosing of lufenuron (255ppm). Lufenuron (24ppm) was statistically on par with untreated control with respect to influence on predatory adults (Table 2). The population of adults was significantly reduced (0.06 adults / 10 plants) in chlorpyriphos followed by chlorpyriphos treatments with pre-dosing of lufenuron.

The present study indicated that all the treatments (lufenuron as pre-treatment prior to the use of chlorpyriphos or alone) found comparatively safe to the eggs and adults of predator, *C. carnea*. These results corroborate with the findings of Arora *et al*. (1993), Liu and Chen (2000), Vadodaria *et al*. (2000), Dhawan (2000), Medina *et al*. (2003) and Vadodaria *et al*. (2004) who demonstrated safety of the insect growth regulators to *C. carnea.*

Chlorpyriphos alone or chlorpyriphos with pre–treatment of lufenuron found extremely toxic to all the species of coccinellids found in cotton ecosystem. Like the earlier findings, lufenuron (255ppm) alone again proved safe to the predators as 0.51 adults per 10 plants were recorded and the level was significantly higher than population recorded in lufenuron as pre–treatment before chlorpyriphos (Table 3). Similarly, after 96h of spray, lufenuron (24ppm) alone proved safe (1.64 adults / 10 plants) to the predator. The decrease in the population was recorded among all the treatments except lufenuron (50ppm) after the spray. The lufenuron alone was safe, whereas chlorpyriphos showed toxic effect on the predatory beetles.

The data demonstrated significantly less population of predators (0.09 bugs / 10 plants) in chlorpyriphos, 96h after the spray (Table 4). Based on pooled data of two years, lufenuron (290ppm) proved safe to the predators as 0.90 bugs per 10 plants were recorded which was significantly higher than the population of the predators recorded in the treatments (where lufenuron was used as pre–treatment before the application of chlorpyriphos). Chlorpyriphos (4g a.i./l) had significantly low predatory bug population (0.65 to 0.09 bugs / 10 plants). Lufenuron (255ppm) alone recorded higher population (0.84 bugs / 10 plants), 96 h after the spray. A slight decrease in population of predators was recorded among all the treatments except treatments lufenuron (24ppm) alone and untreated control. Chlorpyriphos (4g a.i. l^{-1}) alone again showed deleterious effect on predatory bugs and it had significantly the low population (0.07 number of the predators), after 96h of spray. Lufenuron (50 ppm) alone proved harmless to the predators. Minimum population (0.07 number / 10 plants) was recorded in chlorpyriphos, after 96h of spray. The treatments (where pre-dosing with lufenuron before chlorpyriphos was done) were statistically at par with respects to the population of predatory bugs.

The present studies revealed that chlorpyriphos was harmful to the natural enemies, whereas, lufenuron alone was safe to the coccinellids and predatory bugs. The lufenuron as pre-dose before the application of chlorpyriphos in cotton recorded the higher population of natural enemies as compared to chlorpyriphos alone. Similar reports on the safety of the insect growth regulators to coccinellids and predatory bugs were presented earlier too (Hattingh and Tate, 1995; Angeli *et al*., 2000; Vadodaria *et al*., 2000 and Ramanjaneyulu *et al*., 2004).

After 24 and 96h of spray, the reduction in the population of spiders was recorded among all the treatments except lufenuron alone and control. The chlorpyriphos proved highly toxic to spiders followed by chlorpyriphos with pre-dosing of lufenuron @ 290ppm (T_1, T_2 and T_3). Chlorpyriphos also proved highly toxic to spiders followed by chlorpyriphos with pre-dosing of lufenuron (255, 24 and 50ppm). Like earlier findings, lufenuron conserved the spiders and did not differ significantly from control in cotton ecosystem (Table 5). The present findings indicated that lufenuron alone or as pre-treatment before the use of chlorpyriphos recorded higher population of spiders as compared to the chlorpyriphos alone with respect to the population of spiders. The findings of Dhawan (2000), Patil *et al*. (2001) and Vadodaria *et al*. (2004) are in agreement with the present findings in which safety of the lufenuron to the spiders has also been demonstrated.

Table 1. Effect of various treatments involving the use of chlorpyriphos and lufenuron on the fecundity of *Chrysoperla carnea* (Stephens) in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean number of eggs / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. 1^{-1}) (T_1)	10.15 (3.16)	9.31 (3.04)	8.28 (2.89)	9.65 (3.09)	8.78 (2.96)	7.12 (2.69)	10.21 (3.15)	10.31 (3.15)	9.43 (3.01)	9.71 (3.08)	9.84 (3.07)	8.98 (2.93)
Lufenuron followed by chlorpyriphos (2g a.i. 1^{-1}) (T_2)	11.71 (3.35)	10.82 (3.24)	9.25 (3.02)	11.21 (3.29)	10.29 (3.16)	8.78 (2.93)	12.09 (3.37)	12.40 (3.43)	11.81 (3.34)	11.82 (3.36)	11.93 (3.36)	11.40 (3.28)
Lufenuron followed by chlorpyriphos (1g a.i. 1^{-1}) (T_3)	12.37 (3.44)	11.78 (3.37)	10.59 (3.23)	11.90 (3.38)	11.25 (3.29)	10.12 (3.16)	13.93 (3.60)	14.25 (3.64)	13.68 (3.58)	13.56 (3.55)	13.81 (3.58)	13.21 (3.52)
Lufenuron followed by l ufenuron (T_4)	12.65 (3.48)	12.34 (3.47)	10.96 (3.31)	12.18 (3.43)	11.81 (3.39)	10.50 (3.24)	18.34 (4.07)	18.25 (4.08)	18.21 (4.13)	17.82 (4.02)	18.09 (4.07)	17.84 (4.09)
Chlorpyriphos (4 g a.i. 1^{-1}) followed by chlorpyriphos (4g a.i. 1^{-1}) (T_5)	6.59 (2.59)	5.46 (2.37)	3.75 (2.04)	6.68 (2.57)	5.01 (2.29)	3.14 (1.91)	5.04 (2.30)	4.18 (2.12)	2.51 (1.76)	4.76 (2.26)	3.85 (2.06)	2.21 (1.69)
Control (T_6)	18.70 (4.12)	19.06 (4.20)	19.50 (4.29)	18.18 (4.07)	18.56 (4.15)	18.68 (4.20)	18.75 (4.13)	19.18 (4.19)	18.87 (4.21)	18.29 (4.08)	18.68 (4.13)	18.43 (4.16)
CD (P = 0.05)	(0.13)	(0.13)	(0.17)	(0.14)	(0.13)	(0.15)	(0.16)	(0.16)	(0.17)	(0.16)	(0.16)	(0.18)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Table 2. Effect of various treatments involving the use of chlorpyriphos and lufenuron on the adult population of *Chrysoperla carnea* (Stephens) in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean number of *C. carnea* adults / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. l^{-1}) (T_1)	2.59 (1.84)	1.71 (1.60)	0.96 (1.34)	2.40 (1.79)	1.53 (1.54)	0.93 (1.33)	2.90 (1.91)	1.87 (1.63)	1.71 (1.54)	2.76 (1.88)	1.68 (1.58)	1.60 (1.52)
Lufenuron followed by chlorpyriphos (2g a.i. l^{-1}) (T_2)	2.81 (1.88)	1.81 (1.61)	1.17 (1.41)	2.67 (1.84)	1.67 (1.57)	1.09 (1.39)	3.09 (1.96)	2.03 (1.67)	1.85 (1.58)	2.89 (1.90)	1.84 (1.62)	1.73 (1.55)
Lufenuron followed by chlorpyriphos (1g a.i. l^{-1}) (T_3)	3.00 (1.93)	2.06 (1.69)	1.29 (1.46)	2.81 (1.89)	1.89 (1.64)	1.23 (1.43)	3.31 (2.00)	2.28 (1.75)	2.12 (1.68)	3.23 (1.98)	2.12 (1.71)	2.03 (1.66)
Lufenuron followed by lufenuron (T_4)	3.12 (1.96)	2.87 (1.91)	1.93 (1.65)	2.93 (1.92)	2.68 (1.87)	1.81 (1.62)	4.56 (2.25)	4.81 (2.31)	5.06 (2.36)	4.32 (2.19)	4.65 (2.26)	4.90 (2.32)
Chlorpyriphos (4 g a.i. l^{-1}) followed by chlorpyriphos (4g a.i. l^{-1}) (T_5)	1.48 (1.51)	0.59 (1.23)	0.08 (1.03)	1.32 (1.46)	0.50 (1.20)	0.12 (1.05)	1.23 (1.44)	0.48 (1.19)	0.09 (1.03)	1.18 (1.42)	0.39 (1.15)	0.06 (1.02)
Control (T_6)	5.12 (2.36)	5.00 (2.35)	4.87 (2.33)	5.00 (2.34)	4.84 (2.31)	4.81 (2.31)	4.62 (2.26)	5.03 (2.34)	5.15 (2.37)	4.73 (2.30)	4.90 (2.32)	5.12 (2.37)
CD (P = 0.05)	(0.10)	(0.11)	(0.11)	(0.10)	(0.11)	(0.11)	(0.12)	(0.13)	(0.14)	(0.11)	(0.13)	(0.14)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Table 3. Effect of various treatments involving the use of chlorpyriphos and lufenuron the population of coccinellids in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean population of coccinellids (adults) / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. 1^{-1}) (T_1)	0.82 (1.30)	0.43 (1.16)	0.21 (1.08)	0.70 (1.26)	0.39 (1.14)	0.17 (1.06)	0.98 (1.35)	0.50 (1.18)	0.51 (1.18)	0.89 (1.32)	0.42 (1.15)	0.45 (1.16)
Lufenuron followed by chlorpyriphos (2g a.i. 1^{-1}) (T_2)	0.98 (1.34)	0.57 (1.21)	0.31 (1.12)	0.89 (1.31)	0.51 (1.19)	0.26 (1.10)	1.06 (1.37)	0.56 (1.20)	0.56 (1.20)	0.93 (1.32)	0.45 (1.16)	0.46 (1.16)
Lufenuron followed by chlorpyriphos (1g a.i. 1^{-1}) (T_3)	1.01 (1.36)	0.71 (1.25)	0.40 (1.15)	0.90 (1.32)	0.62 (1.22)	0.34 (1.13)	1.26 (1.42)	0.70 (1.25)	0.65 (1.23)	1.15 (1.39)	0.57 (1.21)	0.54 (1.19)
Lufenuron followed by lufenuron (T_4)	1.09 (1.38)	1.06 (1.37)	0.59 (1.22)	0.96 (1.35)	0.93 (1.33)	0.51 (1.19)	1.50 (1.48)	1.51 (1.49)	1.64 (1.52)	1.37 (1.44)	1.39 (1.45)	1.51 (1.49)
Chlorpyriphos (4 g a.i. 1^{-1}) followed by chlorpyriphos (4g a.i. 1^{-1}) (T_5)	0.40 (1.16)	0.06 (1.02)	0.03 (1.01)	0.31 (1.12)	0.05 (1.01)	0.03 (1.01)	0.36 (1.14)	0.11 (1.04)	0.01 (1.00)	0.28 (1.11)	0.08 (1.03)	0.01 (1.00)
Control (T_6)	1.71 (1.54)	1.68 (1.54)	1.70 (1.54)	1.59 (1.51)	1.56 (1.51)	1.59 (1.51)	1.71 (1.55)	1.64 (1.52)	1.75 (1.55)	1.59 (1.51)	1.51 (1.49)	1.62 (1.52)
CD (P = 0.05)	(0.09)	(0.09)	(0.08)	(0.08)	(0.09)	(0.08)	(0.09)	(0.09)	(0.10)	(0.09)	(0.09)	(0.10)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Table 4. Effect of various treatments involving the use of chlorpyriphos and lufenuron on the population of predatory bugs in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean number of *C. carnea* adults / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. 1^{-1}) (T_1)	1.17 (1042)	0.50 (1.19	0.28 (1.11)	1.04 (1.38)	0.45 (1.17)	0.23 (1.09)	1.32 (1.46)	0.56 (1.20)	0.57 (1.20)	1.23 (1.44)	.48 (1.18)	0.51 (1.18)
Lufenuron followed by chlorpyriphos (2g a.i. 1^{-1}) (T_2)	1.32 (1.45)	0.65 (1.24)	0.39 (1.15)	1.23 (1.42)	0.57 (1.21)	0.32 (1.13)	1.39 (1.48)	0.62 (1.23)	0.62 (1.22)	1.26 (1.44)	0.51 (1.19)	0.52 (1.18)
Lufenuron followed by chlorpyriphos (1g a.i. 1^{-1}) (T_3)	1.35 (1.46)	0.78 (1.28)	0.46 (1.18)	1.23 (1.43)	0.68 (1.25)	0.40 (1.16)	1.57 (1.52)	0.78 (1.28)	0.71 (1.25)	1.46 (1.49)	0.64 (1.23)	0.61 (1.21)
Lufenuron followed by lufenuron (T_4)	1.42 (1.49)	1.40 (1.47)	0.90 (1.33)	1.31 (1.46)	1.25 (1.43)	0.84 (1.31)	1.78 (1.57)	1.81 (1.58)	1.92 (1.61)	1.67 (1.54)	171 (1.56)	1.81 (1.58)
Chlorpyriphos (4 g a.i. 1^{-1}) followed by chlorpyriphos (4g a.i. 1^{-1}) (T_5)	0.75 (1.28)	0.12 (1.05)	0.09 (1.03)	0.65 (1.25)	0.10 (1.04)	0.09 (1.04)	0.70 (1.26)	0.17 (1.07)	0.07 (1.03)	0.62 (1.24)	0.14 (1.05)	.07 (1.03)
Control (T_6)	2.03 (1.64)	1.96 (1.62)	1.95 (1.62)	1.87 (1.60)	1.85 (1.60)	1.89 (1.61)	2.00 (1.61)	1.96 (1.62)	2.03 (1.64)	1.89 (1.61)	1.84 (1.59)	1.90 (1.61)
CD (P = 0.05)	(0.08)	(0.09)	(0.08)	(0.08)	(0.09)	(0.08)	(0.08)	(0.10)	(0.06)	(0.08)	(0.09)	(0.10)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Table 5. Effect of various treatments involving the use of chlorpyriphos and lufenuron on the population of spiders in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean number of spiders / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. 1^{-1}) (T^1)	5.00 (2.40)	2.10 (1.67)	2.57 (1.81)	4.71 (2.34)	1.98 (1.64)	2.65 (1.82)	4.93 (2.39)	2.07 (1.66)	2.60 (1.81)	5.18 (2.44)	2.20 (1.69)	2.64 (1.80)
Lufenuron followed by chlorpyriphos (2g a.i. 1^{-1}) (T^2)	5.59 (2.51)	2.48 (1.77)	3.18 (1.95)	5.28 (2.44)	2.37 (1.74)	3.00 (1.90)	5.50 (2.50)	2.45 (1.75)	3.01 (1.90)	5.75 (2.54)	2.59 (1.78)	3.15 (1.93)
Lufenuron followed by chlorpyriphos (1g a.i. 1^{-1}) (T^3)	6.90 (2.74)	3.40 (1.99)	4.34 (2.21)	6.62 (2.69)	3.28 (1.97)	4.12 (2.17)	6.84 (2.73)	3.34 (1.98)	4.12 (2.16)	7.12 (2.79)	3.50 (2.01)	4.28 (2.19)
Lufenuron followed by lufenuron (T^4)	10.06 (3.18)	10.12 (3.19)	10.96 (3.32)	9.78 (3.13)	9.56 (3.08)	10.71 (3.29)	10.06 (3.18)	10.03 (3.18)	10.62 (3.28)	10.25 (3.21)	10.00 (3.18)	10.28 (3.29)
Chlorpyriphos (4 g a.i. 1^{-1}) followed by chlorpyriphos (4g a.i. 1^{-1}) (T^5)	2.90 (1.94)	0.29 (1.11)	0.48 (1.19)	2.62 (1.86)	0.59 (1.19)	0.45 (1.18)	2.71 (1.89)	0.31 (1.12)	0.46 (1.18)	2.87 (1.92)	0.31 (1.12)	0.46 (1.18)
Control (T^6)	10.37 (3.23)	10.65 (3.27)	11.40 (3.39)	10.09 (3.18)	10.59 (3.26)	11.18 (3.35)	10.40 (3.23)	10.93 (3.31)	11.28 (3.37)	10.68 (3.68)	10.90 (3.32)	11.46 (3.40)
CD (P = 0.05)	(0.14)	(0.21)	(0.19)	(0.15)	(0.22)	(0.19)	(0.15)	(0.21)	(0.19)	(0.15)	(0.20)	(0.20)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Table 6. Effect of various treatments involving the use of chlorpyriphos and lufenuron on the adult population of yellow wasp in cotton crop (pooled data 2004 and 2005)

Treatment	* Mean number of yellow wasps / 10 plants											
	Lufenuron @ 290ppm			Lufenuron @ 255 ppm			Lufenuron @ 24ppm			Lufenuron @ 50ppm		
	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray	24h before spray	24h after spray	96h after spray
Lufenuron followed by chlorpyriphos (4g a.i. 1^{-1}) (T^1)	7.48 (2.71)	4.70 (2.18)	6.40 (2.55)	7.15 (2.66)	4.59 (2.17)	6.45 (2.56)	7.46 (2.73)	4.50 (2.13)	6.17 (2.50)	6.96 (2.62)	4.42 (2.13)	6.21 (2.51)
Lufenuron followed by chlorpyriphos (2g a.i. 1^{-1}) (T^2)	7.75 (2.77)	5.17 (2.28)	6.90 (2.64)	7.40 (2.71)	4.95 (2.25)	6.67 (2.62)	7.71 (2.77)	4.98 (2.24)	6.65 (2.58)	7.21 (2.67)	4.71 (2.19)	6.42 (2.56)
Lufenuron followed by chlorpyriphos (1g a.i. 1^{-1}) (T^3)	8.10 (2.82)	5.90 (2.44)	7.59 (2.76)	7.75 (2.75)	5.67 (2.41)	7.35 (2.74)	8.09 (2.84)	5.64 (2.37)	7.35 (2.71)	7.57 (2.72)	5.45 (2.36)	7.10 (2.69)
Lufenuron followed by lufenuron (T^4)	8.32 (2.85)	7.76 (2.74)	8.40 (2.88)	7.96 (2.80)	7.56 (2.72)	8.15 (2.86)	8.31 (2.87)	7.51 (2.68)	8.18 (2.84)	7.78 (2.72)	7.31 (2.66)	7.90 (2.80)
Chlorpyriphos (4 g a.i. 1^{-1}) followed by chlorpyriphos (4g a.i. 1^{-1}) (T^5)	6.85 (2.63)	1.87 (1.58)	5.45 (2.40)	6.53 (2.57)	1.62 (1.51)	5.18 (2.36)	6.90 (2.65)	1.78 (1.56)	5.23 (2.35)	6.35 (2.76)	1.51 (1.48)	4.93 (2.30)
Control (T^6)	8.89 (2.94)	8.60 (2.90)	9.09 (3.01)	8.53 (2.88)	8.50 (2.90)	8.84 (2.98)	8.87 (2.95)	8.21 (2.83)	8.87 (2.97)	8.39 (2.54)	8.28 (2.85)	8.59 (2.93)
CD (P = 0.05)	(0.08)	(0.13)	(0.08)	(0.08)	(0.14)	(0.09)	(0.08)	(0.14)	(0.09)	(0.08)	(0.14)	(0.09)

* Mean based on 8 observations (8 sprays and 4 replications); figures in parentheses are $\sqrt{n+1}$ transformations, while figures outside parentheses are original mean values.

Lufenuron (290ppm) alone had no deleterious effect on the yellow wasp population after the spray. Similarly, after 24 and 96h of spray, lufenuron @ 255, 24 and 50ppm also proved safe to wasps (Table 6). After 96h of spray, the highest population (8.15 wasps / 10 plants) of yellow wasp was recorded in plots treated with lufenuron (255ppm). Similarly, after 24 and 96h of spray, lufenuron @ 24 and 50ppm also proved safe to wasps (Table 6), whereas chlorpyriphos (4g a.i. l^{-1}) alone proved harmful and it had significantly the lowest population of yellow wasp.

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