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INSECTICIDE SPRAY REGIMES TO MANAGE *HELICOVERPA ARMIGERA* (HUBNER) AND THEIR IMPACT ON NATURAL ENEMIES IN COTTON UNDER HIGH DENSITY PLANTING SYSTEM

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ABSTRACT

This study evaluated some new class insecticides viz., chlorantraniliprole 18.5SC, flubendiamide 480SC, spinosad 45%SC, indoxacarb 14.5SC and emamectin benzoate 5%SG in cotton under high density planting system (HDPS). These were evaluated against *Helicoverpa armigera* (Hubner) and their impact on natural enemies were also observed. Experiments were conducted at the ICAR-Central Institute for Cotton Research, Nagpur during 2013-14. Each of the new molecules were sprayed in eight different windows 60 days after sowing (DAS), 60 and 80 DAS, 60, 80 and 100 DAS, 60, 80 100 and120 DAS, 100 and 120 DAS, 80,100 and 120 DAS, 120 DAS and unsprayed control along with three replicates each were analysed in randomized complete block design. The damage by *H. armigera* was observed by counting healthy and damaged squares and bolls, and % worked out. The whole plant incidence was recorded in case of major predators sampled including spiders and coccinellids. The spray regime 2 (60 and 80 DAS), regime 3 (60, 80 and 100 DAS), regime 4 (60, 80, 100 and 120 DAS) and regime 6 (80, 100 and 120 DAS) were found superior in managing bollworms with by recording least square damage. The results on natural enemies' populations (spiders and coccinellids) clearly revealed that, all spray regimes were more or less safe to the natural enemies. However, spray regime 1 (spray at 60 DAS), regime 2 (spray at 60 and 80 DAS) and regime 3 (spray at 60, 80 and 100 DAS) recorded maximum natural enemies. Maximum natural enemies was reported at 80 DAS in all the insecticidal spray regimes. Chlorantraniliprole, flubendiamide, spinosad, indoxacarb and emamectin benzoate through the spray regime 2 (spray at 60 and 80 DAS) was observed to be the best option against *H. armigera* by controlling it in early stage itself and to sustain natural enemies in the cotton ecosystem.

Key words: Bollworms, *Helicoverpa armigera,* cotton, high density planting system, insecticides, natural enemies, spray regimes, Chlorantraniliprole, flubendiamide, spinosad, indoxacarb and emamectin benzoate

Diligent production and economic strategies are important for cotton growing farmers due to of expanding cost of cultivation and stagnating productivity. Adoption of high-density planting system (HDPS) and newly released desi cotton varieties offer an alternative way to the sustainable production and decreased production cost (Kumar et al., 2017). In India, cotton is grown in 12.23 million ha with productivity of 524 kg lint/ ha (Anonymous, 2017), and productivity has not shown any remarkable improvement in the last 10 years. Bollworms (BW) especially, American bollworm *Helicoverpa armigera* (Hubner) and pink bollworm, *Pectinophora gossypiella* (Saunders) cause considerable damage (Deore et al., 2010). Theoretically, higher planting density ensures earlier crop canopy cover, higher sunlight interception leading to higher and earlier yields at reduced cost. The obvious advantage of this system is earliness (Rossi et al., 2004) since high density planting needs less bolls/plant to achieve the same yield as compared to conventional cotton and the crop does not have to maintain the late formed bolls to mature. In general, it was observed that lower plant densities produce high values of growth and yield attributes/ plant, but yield/ unit area was higher with higher plant densities (Namdeo et al., 1991; Dhoble et al., 1992; Sharma et al., 2001). Changes in plant density modify the microclimate and this may alter the incidence of pests and diseases (Venugopalan et al., 2013). Early cotton genotypes early in duration (<150 days), tolerant to sucking pests having compact plant architecture ideally suited for HDPS and mechanised harvesting. These genotypes can provide higher cotton yields under HDPS and they require very less of inputs, management and time thus, providing better economic returns to the cotton growers (Parihar et al., 2018).

Chemical control is still the most important method for managing pests (Korkor et al., 1995) and the synthetic insecticides are often a part of management programs to control lepidopterous pests (Aydin and Gurken, 2006). The success of bollworms complex control program relies on use of insecticides belonging to different chemical groups in certain sequences, application time and spray intervals (Watson et al., 1986; El-Feel et al., 1991; Abd El-Mageed et al., 2007). Conventional insecticides have not provided a long-term solution to the bollworms problem, moreover as a result of continued massive use of certain synthetic insecticides against the cotton pests has resulted in development of tolerant and resistant strains (Schmutterer, 1985). In addition to this, the toxicity of conventional insecticides to the natural enemies present in various agroecosystems has been demonstrated in laboratory tests and most of them were found harmful to the different parasites and predators (Balakrishnan et al., 2009; Sahito et al., 2011; Sabry and El-Sayed, 2011). Novel substances with different biochemical targets are effective at low doses and have less exposure in the environment. This study focuses on some new insecticides viz*.,* chlorantraniliprole, flubendiamide, emamectin benzoate indoxacarb and spinosad (with new mode of actions, low dose and environmentally safe) by evaluating different spray regimes against cotton bollworms and its impact on natural enemies.

MATERIALS AND METHODS

A field experiment were conducted to study the effect of different insecticide spray regimes on cotton (*Gossypium hirsutum*) for the management of bollworms and its impact on under HDPS. Sowing was done with Suraj (non Bt) variety with spacing of 45x 10 cm during 2013-2014 under rainfed condition in a deep black soil and followed all recommended agronomic practices to raise crop (Venugopalan et al., 2013). The five insecticides viz*.,* chlorantraniliprole 18.5 SC, flubendiamide 480 SC, spinosad 45 SC, indoxacarb 14.5 SC and emamectin benzoate 5 SG at 27.75, 600, 56.25, 36.25 and 10 g.ai/ha, respectively were used at 60 DAS, 80 DAS, 100 DAS and 120 DAS in 8 treatments (spray regimes) including control in 3 replicates each were arranged in randomized complete block design. Details of different spray regimes are given in Table 1.

Treatment-wise application of insecticides was given as per the regimes by using high volume knapsack sprayer with required concentration. Control plots were kept without spray throughout the season for comparison. The incidence of *H. armigera* on squares and bolls damage were observed in six randomly selected plants/ plot. Number of spiders and coccinellids/ plant was also observed. In each plot, data was recorded from six pre-tagged plants. The observation was recorded at 60, 80, 100, 120 days after sowing by counting the number of insects prior to and after each spray applications i.e., 3 and 7 DAT. The data obtained for square damage and the data on natural enemies were subjected to arcsine and square root transformation respectively, and were subjected to ANOVA in randomized complete block design (RBD, p=0.05) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The data on square damage as influenced with chlorantraniliprole in different spray regimes during 2013-14 and comparison of different spray regime are given in Table 2. The results showed that square damage at 80 DAS was nil in the regime 4 and which was at par with regime 2, 3, 6 and 7, recording 0.78 to 4.20% damage; maximum damage was noticed in the regime 1 (6.20%); similarly, at 100 DAS, results were non-significant among all treatments, but at 120 DAS regime 4 was the best (1.04%) followed by regime 5 and 6 (1.65 and 2.40%). Similarly, for emamectin benzoate, data at 80 DAS showed there was no damage was observed in regime 4 followed by regime 3 (0.37%) and all remaining regimes found at par with this and at 100 DAS lowest damage was noticed in the regime 3 (0.57%) and regime 4 (1.12%). Likewise, at 120 DAS

Table 1. Regime wise insecticidal treatment sprays at different days after sowing (2013-14)

Spray regime	Spraying (DAS)			
Regime 1	60 DAS	–	–	–
Regime 2	60 DAS	80 DAS	–	–
Regime 3	60 DAS	80 DAS	100 DAS	–
Regime 4	60 DAS	80 DAS	100 DAS	120 DAS
Regime 5	–	–	100 DAS	120 DAS
Regime 6	–	80 DAS	100 DAS	120 DAS
Regime 7	–	–	–	120 DAS
Regime 8 (control)	–	–	–	–

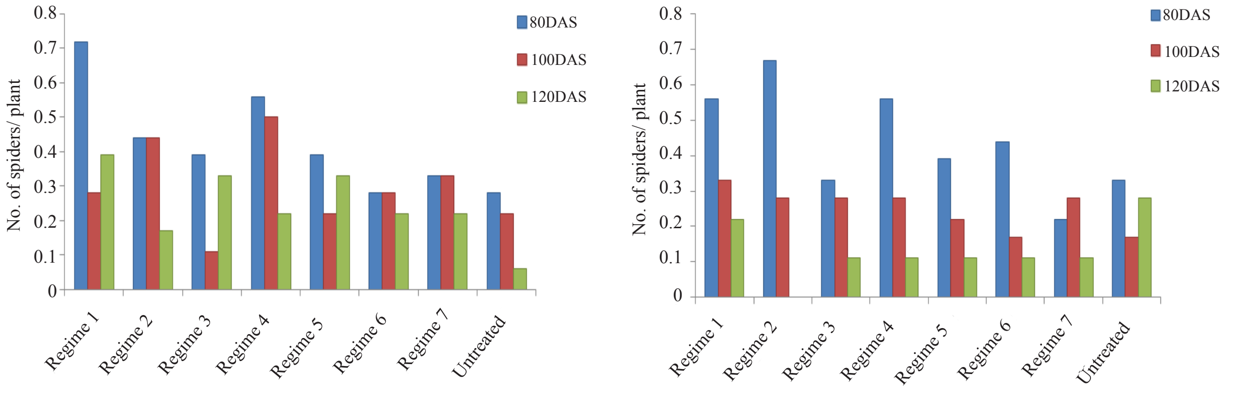
Table 2. Effect of insecticides spray regimes on bollworms and yield of cotton under HDPS (2013-14)

Treatment	Square damage (%)														
	Clorantraniliprole			Emamectin benzoate			Flubendiamide			Indoxacarb			Spinosad		
	80DAS	100DAS	120DAS	80DAS	100DAS	120DAS	80DAS	100DAS	120DAS	80DAS	100DAS	120DAS	80DAS	100DAS	120DAS
Regime 1	6.20 (14.25)	31.18 (30.17)	6.30 (14.46)	3.78 (11.06)	7.43 (12.77)	3.42 (8.57)	3.84 (11.15)	2.22 (4.99)	2.19 (6.89)	7.03 (15.07)	14.38 (21.77)	1.71 (6.14)	5.56 (10.85)	5.53 (13.47)	2.78 (5.59)
Regime 2	0.78 (2.94)	6.68 (14.91)	5.29 (12.86)	1.15 (4.99)	3.69 (9.02)	5.08 (10.57)	1.42 (5.51)	3.29 (8.45)	3.19 (10.13)	0.99 (4.65)	8.68 (17.03)	0.00 (0.00)	2.17 (4.93)	0.00 (0.00)	3.13 (8.32)
Regime 3	0.84 (4.30)	2.56 (7.38)	5.21 (13.10)	0.37 (2.01)	0.57 (2.52)	5.56 (8.03)	0.28 (1.76)	0.71 (2.80)	4.85 (12.44)	0.82 (4.24)	2.33 (5.11)	0.00 (0.00)	2.96 (9.67)	4.13 (11.16)	2.21 (6.88)
Regime 4	0.00 (0.00)	5.18 (10.79)	1.04 (3.39)	0.00 (0.00)	1.12 (4.97)	0.00 (0.00)	0.29 (1.79)	2.45 (5.24)	0.00 (0.00)	2.52 (8.71)	10.61 (18.32)	0.00 (0.00)	1.74 (6.19)	1.60 (5.87)	1.47 (5.68)
Regime 5	4.42 (11.91)	4.63 (12.04)	1.65 (6.00)	6.41 (13.72)	3.69 (8.66)	4.55 (9.96)	2.98 (9.77)	0.93 (3.20)	2.15 (6.89)	10.39 (18.69)	2.73 (9.49)	0.00 (0.00)	12.65 (20.68)	3.24 (10.19)	3.29 (10.39)
Regime 6	1.75 (6.07)	3.53 (10.80)	2.40 (7.26)	1.87 (7.67)	1.82 (6.28)	1.26 (3.73)	0.45 (2.23)	3.44 (8.34)	3.00 (9.95)	1.11 (3.51)	4.24 (11.50)	2.35 (7.12)	4.12 (9.59)	2.01 (6.51)	0.69 (2.77)
Regime 7	4.20 (11.82)	15.61 (22.81)	1.74 (6.15)	5.71 (13.08)	10.35 (18.49)	0.78 (2.92)	3.70 (10.97)	6.64 (14.73)	1.87 (6.41)	6.54 (14.72)	16.26 (23.72)	0.79 (2.96)	13.51 (21.37)	7.38 (15.72)	2.22 (6.83)
Untreated	4.72 (12.46)	14.42 (21.98)	7.06 (15.14)	16.13 (23.17)	18.26 (25.03)	5.88 (13.99)	3.63 (10.91)	12.21 (20.34)	4.92 (12.72)	15.23 (22.48)	14.27 (21.90)	4.72 (12.41)	11.02 (18.93)	10.87 (19.12)	7.14 (15.41)
SEm	1.87	7.29	2.73	2.33	3.42	4.86	1.70	3.82	2.30	2.00	2.93	2.04	3.12	2.17	3.16
CD (p = 0.05)	5.68	NS	8.27	7.07	10.37	NS	5.15	NS	6.98	6.08	8.89	6.19	9.47	6.58	NS

Treatment	Seed cotton yield (kg/ ha)				
	Chlorantraniliprole	Emamectin benzoate	Flubendiamide	Indoxacarb	Spinosad
Regime 1	1324	1590	1859	1513	1708
Regime 2	1715	1977	1974	2021	2036
Regime 3	1828	2054	2018	2235	1952
Regime 4	1973	2220	2159	1832	2120
Regime 5	1754	1824	2061	1877	1627
Regime 6	1893	2132	1870	2156	1766
Regime 7	1403	1374	1626	1457	1982
Regime 8 (Control)	1348	1262	1517	1332	1418
SEm	1.87	1.82	2.32	2.34	2.52
CD (p = 0.05)	NS	5.53	NS	NS	NS

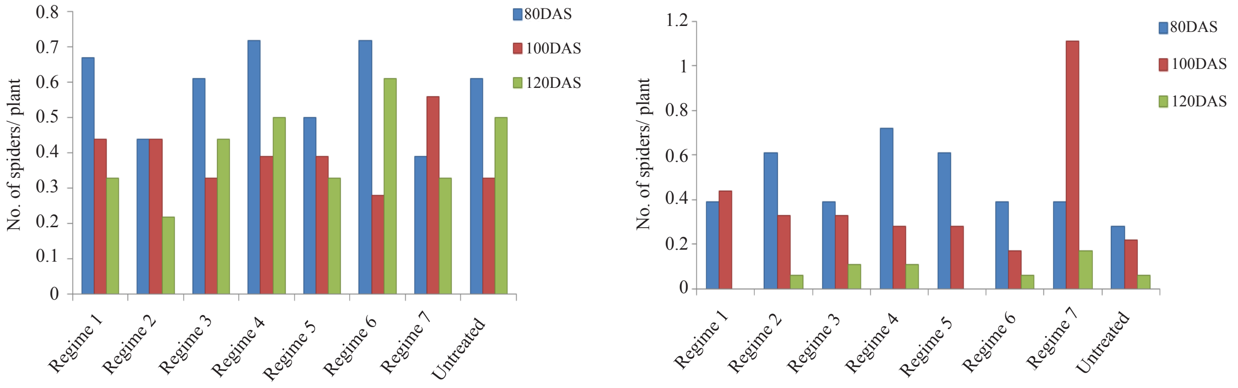
Figures in parentheses are arcsine transformed values; NS = Non-significant non-significant results were observed among all regimes. However, no damage was observed in regime 4. The plots sprayed with flubendiamide showed that regime 3 (0.28%) was found superior at 80 DAS, followed by regime 4. Similarly, at 100 DAS non-significant results were observed, while at 120 DAS the damage was nil in regime 4. About indoxacarb, the results revealed less damage in spray regimes 2 and 3 (0.99 and 0.82%); at 100 DAS, the significantly superior ones were regime 3 and 5 (2.33 and 2.73%, respectively); maximum damage was in regime 7 (16.26%); and the damage was nil in regimes 2, 3, 4 and 5 at 120 DAS. Spinosad treated plots exhibited a minimum damage in regime 4 and 2 (1.74 and 2.17%) and these were at par with regime 1, 3 and 6; there was no damage was noticed in the regime 2 and it was followed by regime 4 (1.60%) at 100 DAS; at 120 DAS the results were found non-significant; spray regime 6 and 4 were found superior (0.69 and 1.47%, respectively (Table 2).

The boll damage was found negligible and below economic threshold level in all treatments except in



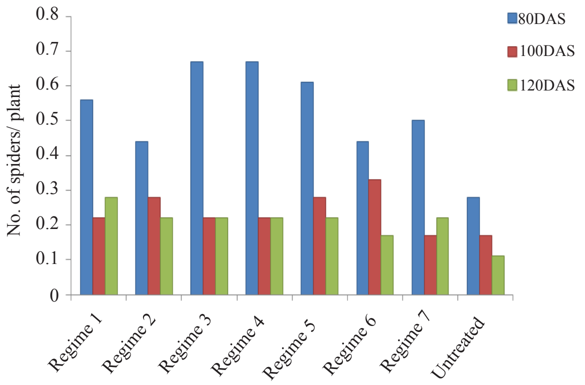
a. Clorantraniliprole

b. Emamectin benzoate



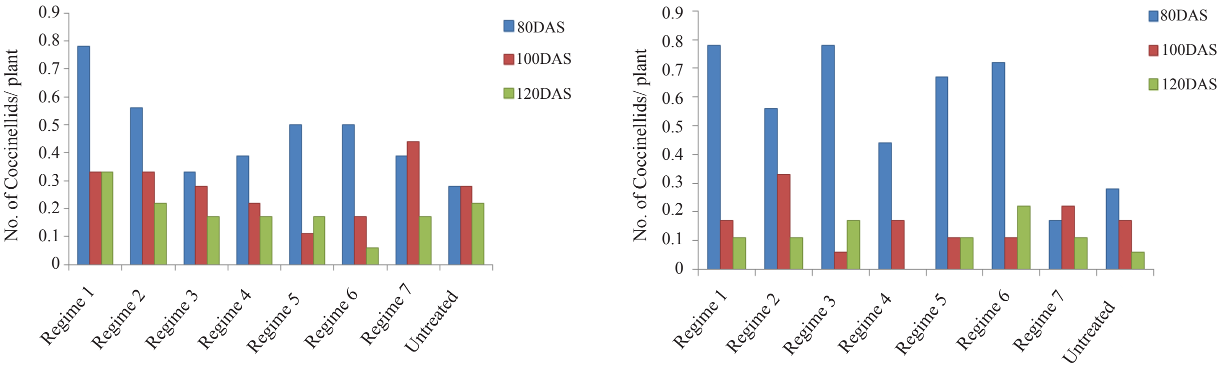
c. Flubendiamide

d. Indoxacarb



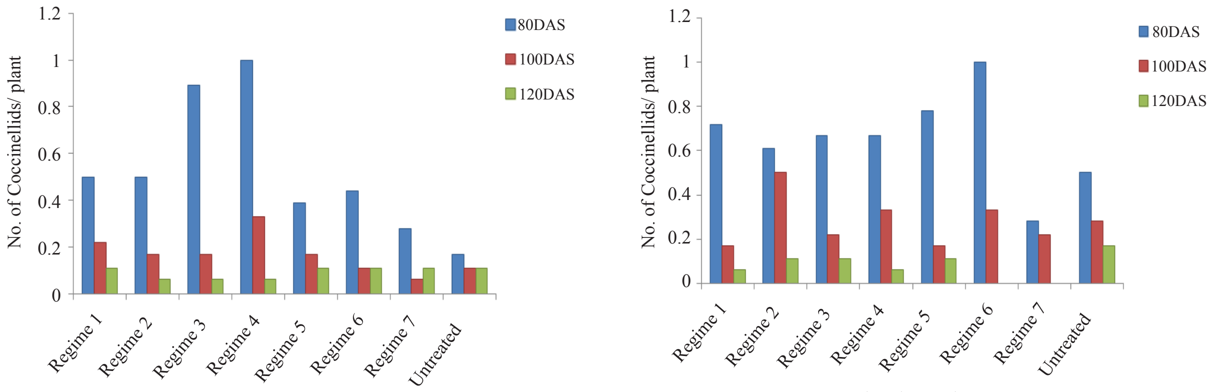
e. Spinosad

Fig. 1. Impact of different insecticides spray regimes on spider population on cotton under HDPS (2013-14)



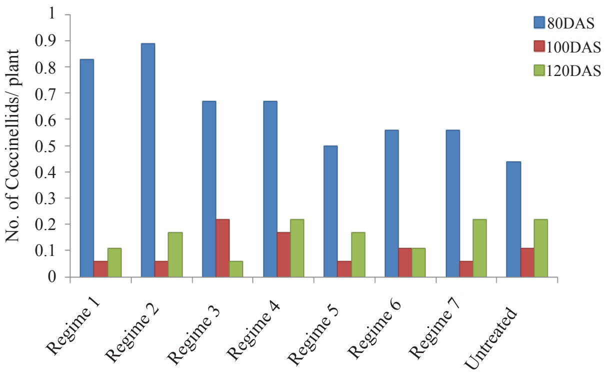
a. Clorantraniliprole

b. Emamectin benzoate



c. Flubendiamide

d. Indoxacarb



e. Spinosad

Fig. 2. Impact of different insecticides spray regimes on coccinellid population on cotton under HDPS (2013-14)

untreated plots; this might be attributed to effective control of pest in square and flowering stage itself; and control plot was showing damage above ETL, indicating that insecticides were effective against bollworm on cotton under HDPS. The counts on spiders and coccinellids during 2013-14 in different spray regimes presented in (Fig. 1, 2) reveal the variations in their occurrence was non-significant among spray regimes including control; all the insecticidal treatments were observed equally safe; however, spray regime 1 (spray at 60 days after sowing) and 2 (spray at 60 and 80 days after sowing) recorded maximum counts. The data on seed cotton yield from insecticide spray regimes during 2013-14 given in Table 3 reveal that differences are statistically non-significant; however, regime 4 led to maximum (1973 kg/ ha); in case of emamectin benzoate it was 2220 kg/ ha.

The present study was carried out to evaluate spray regime windows to find the most effective spray window against bollworms and to find spray interval that pose minimal impact on natural enemies.

Insecticide resistance rendered insecticides ineffective, thus increasing the need for repeated applications, wastage of resources and consequent environmental pollution (Kranthi, 2007). Resistance of key insect pests to insecticides continues to be a significant problem (Cook et al., 2005; Dhingra et al., 1988; McCaffery et al., 1989; Armes et al., 1992 & 1994; Kranthi et al., 2001). In India, the first case of control failure after spraying synthetic pyrethroids from suspected insecticide resistance in *H. armigera* (Hubner) was from Guntur in Andhra Pradesh (Reddy, 1990). The success of bollworm control programs relies mainly on the spraying those insecticides belonging to novel modes of action in a particular time interval. Chemicals such as spinosad, indoxacarb, emamectin benzoate, novaluron and lufenuron ensured effective control and less toxic to beneficial insects (Kranthi, 2007). The most probable reason for increased use of new chemistry insecticides is resistance (Razaq, 2006). There is a need to develop alternative insecticides/ techniques, allowing rational use of pesticides (Barrania et al., 2016). Sharah and Ali (2008) concluded that it is very important to determine which of the available insecticides are most effective and economical at particular stage of crop phenology, doses and intervals should the spray be done to achieve the best result. Spray regimes 2 and 3 was effective in taking care of bollworms in the initial stage itself by minimising square damage in early growth stages. Earlier reports of (Donnelly and Adeyemi, 1966; Akinlosotu, 1969; Fadare, 1984) clearly revealed that early chemical intervention reduced the damage levels of flowers.

In the present study, flubendiamide, emamectin benzoate and spinosad were found relatively superior. Flubendiamide 60 g a.i. ha^{-1} showed marked reduction in the larvae and damage (Thilagam et al., 2010); Tomar et al., 2005) also obtained similar results with square damage caused by bollworms. Saleh et al. (2013) observed that emamectin benzoate achieved high efficacy against pink and spotted bollworms; Gupta et al. (2005) and Sontakke et al. (2007) found this as the most potent. Johnson et al. (1997) and Dandale et al. (2000) observed that spinosad was quite effective. Ghure et al. (2008) observed that indoxacarb and spinosad were effective. The present results agree with those of Johnson et al. (2000), Haidar et al. (2002); Omar et al. (2005), Ghure et al. (2008) and Gosalwad et al. (2009). Chlorantraniliprole also proved equally effective under high density planting system in the present study and this is in accordance with Dhengre et al. (2017); Ma et al. (2000) reported that chlorantraniliprole was found to be the most effective against *H. armigera* in cotton. These pesticides were effective against targeted arthropod pests but relatively non-harmful to natural enemies (De Clercq, 1995; Charleston, 2005).

Insecticides evaluated in present investigation not only effective for controlling bollworms but were relatively safe on spiders and coccinellids. Ruberson et al. (1998) and Lacey et al. (1997) assumed the compatibility of natural enemies with pesticides depends on a range of factors; Tohnishi et al. (2005) and Kubendran et al. (2006) found flubendiamide to be least toxic against beneficial arthropods. Chlorantraniliprole at doses ranging from 20- 50 g a.i./ ha was safe to natural enemies (Misra, 2011; Yang et al., 2012). These diamides are relatively safe to natural enemies (Brugger et al., 2010); spinosad was found to be harmless to *Coccinella septempunctata* grubs (Olszak and Sekrecka, 2008). Spray regime 1 (spray at 60 days after sowing) and 2 (spray at 60 and 80 days after sowing) recorded maximum counts of spiders and coccinellids. Interestingly, in all insecticidal spray regimes maximum natural enemy population was noticed 80 DAS. The insecticides, flubendiamide, emamectin benzoate, spinosad and chlorantraniliprole are thus superior as spray regimes against bollworms; in particular, spray regime 2 (spray at 60 and 80 DAS) was the best and can be recommended under HDPS system in cotton.

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REFERENCES

Akinlosotu T A. 1969. A note on the spiny bollworm, *Earias biplaga* Wlk. of Kenaf, Nigeria. Journal of Entomology 2: 1-3.

Anonymous, 2017. Annual Report 2017-18. All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu, India.

Armes N J, Banerjee S K, DeSouza K R, Jadhav D R, King A B S, Kranthi K R, Regupathy A, Suruluvelu T, Rao N V. 1994. Insecticide resistance in *Helicoverpa armigera* (Hubner) in India: Recent developments. Proceedings. Brighton crop protection conference -pests and diseases. pp. 437-442.

Armes N J, Jadhav D R, Bond G S, King A B. 1992. Insecticide resistance in *Helicoverpa armigera* (Hubner) in South India. Pesticide Science 34(4): 355-364.

Aydin H, Gürkan M O. 2006. The efficacy of spinosad on different strains of *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae). Turkish Journal of Biology 30(1): 5-9.

Balakrishnan N, Kumar B V, Sivasubramanian P. 2009. Bioefficacy of bifenthrin 10 EC against sucking insects, bollworms and natural enemies in cotton. Madras Agricultural Journal 96(1/6): 225-229.

Brickle D S, Turnipseed S G, Sullivan M J, Dugger P, Richer D. 1999. The efficacy of insecticides and rats against cotton bollworm (Lepidoptera: Noctuidae) in Bt cotton. Proceedings. Conventional cotton conference, Florida, USA. pp. 934-936.

Briggs R E, Patterson L L, Massey G D. 1967. Within and between-row spacing of cotton. Arizona Annual Report. University of Arizona Agricultural Extension Service, Arizona. pp. 6-7.

Brugger K E, Cole P G, Newman I C, Parker N, Scholz B, Suvagia P, Walker G, Hammond T G. 2010. Selectivity of chlorantraniliprole to parasitoid wasps. Pest Management Science 66(10): 1075-1081.

Charleston D S, Kfir R, Dicke M, Vet L E. 2005. Impact of botanical pesticides derived from *Melia azedarach* and *Azadirachta indica* on the biology of two parasitoid species of the diamondback moth. Biological Control 33(2): 131-142.

Dandale H G, Rao N G V, Tikar S N, Nimbalkar S A. 2000. Efficacy of spinosad against cotton bollworms in comparison with some synthetic pyrethroids. Pestology 24(11): 6-10.

De Clercq P, De Cock A, Tirry L, Viñuela E, Degheele D. 1995. Toxicity of diflubenzuron and pyriproxyfen to the predatory bug *Podisus maculiventris*. Entomologia Experimentalis et Applicata 74: 17-22.

Deore J S, Borikar P S, Yadav G A, Dhumal M S. 2010. Efficacy of newer insecticides against bollworm complex in cotton. Pestology 34: 12-17.

Dhengre N N, Kankale M D, Patil B V, Sontakke B K. 2017. Bio-efficacy of certain newer insecticides against cotton bollworm under high density planting system. Journal of Applied Zoological Ressearch 28(2): 190-196.

Dhingra S, Phokela A, Mehrotra K N. 1988. Cypermethrin resistance in the populations of *Heliothis armigera* (Hubner). National Academy Science Letters, India 11(4): 123-125.

Donnelly J, Adeyemi S A O. 1966. Entomology sectional report, Research Div, MANR, Western Nigeria, 63-64 seasons. pp. 35-44.

El-Feel E A, Khidr A A, Kahla M A, Abbass M G. 1991. Effect of sequence, time intervals and early spray of different insecticides on pink bollworm, *Pectinophora gossypiella* (Sounders.) infestation and cotton yield. Egyptian Journal of Agricultural Research 69: 73-81.

El-Mageed A A, Anwar E M, Elgohary L R A, Dahi H F. 2007. Evaluation of several programs of sequences pesticides application on cotton bollworms and some other sucking pests in cotton field. Journal of Entomology 4(2): 93-103.

Fadare T A. 1984. Effect of timing of insecticide application to control kenaf insects. Nigeria Journal of Entomology 4: 43-49.

Ghure S T, Kharbade S B, Patil S D. 2008. Bioefficacy of new pesticides against bollworm complex of cotton (*Gossypium* spp.). International Journal of Plant Protection 1(2): 106-109.

Gosalwad S S, Kamble S K, Wadnerkar D W, Awaz K B. 2009. Efficacy of some newer insecticides for control of cotton bollworms. Journal of Cotton Research and Development 23(2): 282-285.

Gupta G P, Raghuraman M, Birah A, Singh B. 2005. Field efficacy of newer insecticides against bollworms in cotton. Indian Journal of Entomology 67(1): 16.

Haidar K, Iqtidar A, Nazir A, Aher G M, Amjad A. 2002. Comparative efficacy of new vs. old chemistry insecticides for the control of *Helicoverpa armigera* (Hubner) on cotton crop. Pakistan Entomology 24: 121-124.

Johnson D R, Lorenz G M, Hopkins J D, Page L M. 2000. Comparison of new insecticides for control of *Heliothine* species in cotton. Special reports-University of Arkansas Agricultural Experiment Station 198: 266-270.

Johnson D R, Meyers H, Page B L M, Singer T L. 1997. Comparison of new insecticides for the control of the bollworm and tobacco budworm in Arkansas. Special reports-University of Arkansas Agricultural Experiment Station 183: 191-193.

Korkor A A, Awad M Z F, Hamid A M, Abo-Salem M B. 1995. Screening of some insecticides against bollworms and whitefly attacking cotton plants. Computer Science- Research and Development 50: 141-157.

Kranthi K R. 2007. Insecticide resistance management in cotton to enhance productivity. Model training course on cultivation of long staple cotton (ELS). Central Institute for Cotton Research Regional Station, Coimbatore, Tamil Nadu, India. pp. 15-22.

Kranthi K R, Jadhav D, Wanjari R, Kranthi S, Russell D. 2001. Pyrethroid resistance and mechanisms of resistance in field strains of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). Journal of Economic Entomology 94(1): 253-263.

Kubendran D, Chandrasekaran S, Kumar B V, Kuttalam S. 2006. Assessment of safety of flubendimide 480 SC to natural enemies. Pestology 32(12): 19-22.

Kumar P, Karle A S, Singh D, Verma L. 2017. Effect of high density planting system (HDPS) and varieties on yield, economics and quality of desi cotton. International Journal of Current Microbiology and Applied Sciences 6(3): 233-238.

Lacey L A, Mesquita A L, Mercadier G, Debire R, Kazmer D J, Leclant F. 1997. Acute and sublethal activity of the entomopathogenic fungus *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes) on adult *Aphelinus asychis* (Hymenoptera: Aphelinidae). Environmental Entomology 26(6): 1452-1460.

Ma D L, Gordh G, Zalucki M P. 2000. Toxicity of biorational insecticides to *Helicoverpa* spp. (Lepidoptera: Noctuidae) and predators in cotton field. International Journal of Pest Management 46(3): 237-240.

McCaffery A R, King A B S, Walker A J, El-Nayir H. 1989. Resistance to synthetic pyrethroids in the bollworm, *Heliothis armigera* (Hubner) from Andhra Pradesh, India. Pesticide Science 27(1): 65-76.

Mehetre S S. 1992. Natural crossing in cotton (*Gossypium* Sp.): Its significance in maintaining varietal purity and production of hyrbid seed using male sterile lines. Journal of Cotton Research and Development 6: 2.

Misra H P. 2011. Bio-efficacy of chlorantraniliprole against shoot and fruit borer of brinjal, *Leucinodes orbonalis* (Guenee). Journal of Insect Science 24(1): 60-64.

Namdeo K N, Sharma J K, Choudhary S K, Mandloi C. 1991. Effect of planting dates and geometry on growth and yield of *Hirsutum* cotton under rainfed condition. Journal of Cotton Research and Development 5: 59-62.

Olszak R W, Sekrecka M. 2008. Influence of some insecticides and acaricides on beneficial mites and on *Coccinella septempunctata* (Coleoptera: Coccinellidae) larvae. IOBC/ WPRS Bulletin 35: 101-108.

Omar R E M, Desuky W M H, Darwish A A, Amer A E A. 2005. Evaluation of chinmix, spintor and biorepel against the cotton bollworms in the field. Annals of Agricultural Science, Moshtohor 43(4): 1981-1989.

Parihar L B, Rathod T H, Paslawar A N and Kahate N S. 2018. Effect of high-density planting system (HDPS) and genotypes on growth parameters and yield contributing traits in upland cotton. International Journal of Current Microbiology and Applied Sciences 7(12): 2291-2297.

Raghuraman M, Birah A, Singh B, Gupta G P. 2008. Bioefficacy of a newer insecticide emamectin benzoate 5% EC against cotton bollworms. Indian Journal of Entomology 70(3): 264-268.

Razaq M. 2006. Toxicological responses of *Helicovrpa armigera* (Hubner), *Bemisia tabaci* (Gennadius), and *Amrasaca devastans* from Pakistan to PBO and selected insecticides. Ph.D. Thesis, University of Agriculture, Faisalabad, Pakistan.

Reddy A S. 1990. *Heliothis armigera* (Hubner) a serious threat to cotton cultivation in Andhra Pradesh. Proceedings of national workshop on *Heliothis* management, Tamil Nadu Agricultural University, Coimbatore. pp. 249-263.

Rossi J, Novick G, Murray J, Landivar J, Zhang S, Baxevanos D, Mateos A, Kerby T, Hake K, Krieg D. 2004. Ultra narrow row cotton: global perspective. Proceedings of the technical seminar of the 63rd plenary meeting of the ICAC: How to improve yields and reduce pesticide use, Mumbai, India. pp. 7-11.

Ruberson J, Nemoto H, Hirose Y. 1998. Pesticides and conservation of natural enemies in pest management. In conservation biological control, Academic Press. pp. 207-220.

Sabry K H, El-Sayed A A. 2011. Biosafety of a biopesticide and some pesticides used on cotton crop against green lacewing, *Chrysoperla carnea* (Stehens) (Neuroptera: Chrysopidae). Journal of Biopesticides 4(2): 214-218.

Sahito H A, Abro G H, Syed T S, Memon S A, Mal B, Kaleri S. 2011. Screening of pesticides against cotton mealybug, *Phenacoccus solenopsis* (Tinsley) and its natural enemies on cotton crop. International Research Journal of Biochemistry and Bioinformatics 19: 232-236.

Saleh A A, Elgohary L R, Watson W M, Elabasy A S. 2013. Efficiency of some new insecticides on cotton bollworms, *Pectinophora gossypiella* (Saunders.) and *Earias insulana* (BoisdJournal of Plant Protection and Pathology 4: 617-624.

Schmutterer H. 1985. Which insect pests can be controlled by application of neem seed kernel extracts under field conditions. Zeitschrift für Angewandte Entomologie 100(1-5): 468-475.

Sharah H A, Ali E A. 2008. Impact of insecticide spray regimes on insect abundance in cowpea (*Vigna unguiculata*) in North Eastern Nigeria. International Journal of Agriculture and Biology 10(3): 255-260.

Sharma J K, Upadhayay M, Andloi K C M. 2001. Effect of spacing and fertility levels on growth and yield of *Hirsutum* genotypes. Journal of Cotton Research and Development 15(2): 151-153.

Sontakke B K, Das N, Swain L K. 2007. Bio-efficacy of emamectin benzoate against bollworm complex in cotton. Annals of Plant Protection Sciences 15(1): 1-3.

The Hitavada: The people's paper. 2017. CICR develops cotton genotypes that mature in 120 days. Dated 22 March 2017.

Thilagam P, Sivasubramanian P, Kuttalam S. 2010. Bioefficacy of flubendiamide 480 SC against American bollworm in cotton and biochemical changes. Annals of Plant Protection Sciences 18(2): 384-387.

Tohnishi M, Nakao H, Furuya T, Seo A, Kodama H, Tsubata K, Fujioka S, Kodama H, Hirooka T, Nishimatsu T. 2005. Flubendiamide, a novel insecticide highly active against lepidopterous insect pests. Journal of Pesticide Sciences 30(4): 354-360.

Tomar S P S, Choudhary R K, Shrivastava V K. 2005. Evaluation of bioefficacy of flubendiamide 20 WDG (Ril 038) against bollworms on cotton. Journal of Cotton Research and Development 19(2): 231-233.

Venugopalan M V, Kranthi K R, Blaise D, Lakde S, Sankaranarayana K. 2013. High density planting system in cotton-The Brazil Experience and Indian Initiatives. Cotton Research Journal 5(2): 172-185.

Watson W M, Rashed A M, Hussein N M, Guirguis M W. 1986. Potencies of certain insecticides against the pink bollworm, *Pectinophora gossypiella* (Saund.) as influenced by chemical control program in Egypt. Bulletin of the Entomological Society of Egypt, Economic Series 15: 9-86.

Yang H, Wang Z, Jin D C. 2011. Effects of chlorantraniliprole on experimental populations of *Cyrtorhinus lividipennis* (Reuter) (Hemiptera: Miridae). Acta Ecologica Sinica 32: 5184-5190.

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