

Response of beneficial arthropods to sequential insecticide applications in cotton agro-ecosystem

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Abstract

An experiment was conducted in *Kharif* crop season with transgenic hybrid cotton (RCH 650 in spacing of 1.00 × 0.45 meters with a plot size of 7.0 × 5.85 meters) replicated thrice at Research Farm, Cotton Research Station, Sirsa to record the relative toxicity and build-up of natural enemies after application of different insecticide in cotton habitat. Field evaluation of insecticides in cotton agroecosystem showed that monocrotophos 36 SL, profenophos 50 EC, imidacloprid 200 SL, and dimethoate 30 EC caused severe reductions in natural enemies populations. Monocrotophos 36 SL recorded the lowest mean populations of ladybird beetle (0.24 adults/plant) and spiders (0.47–1.08 spiders/plant), while profenophos 50 EC resulted in minimum green lacewing abundance (0.46–0.69 larvae/plant) and yellow wasp activity (0.07–0.12 wasps/plant). Nymphal parasitization of whitefly was also lowest under monocrotophos 36 SL (4.22–4.36%) and imidacloprid 200 SL (≈5.37%). In contrast, water and nimbecidine 300 ppm supported higher populations of natural enemies and parasitization levels (up to 5.95%), indicating their relative safety in the cotton ecosystem. Thus, while selecting an insecticide for the management of a target pest, negative effects on natural enemies, its survival and growth, reproduction and changes in behaviour must be kept in mind.

Keywords: Cotton, Green lacewing, Ladybird beetle, Nymphal parasitization, Spider, Yellow paper Wasp, Whitefly

Introduction

Cotton, scientifically known as *Gossypium spp.*, is an important genetically modified crop now a day, extensively cultivated in tropical and sub-tropical regions of more than 80 countries worldwide and industrially developed as a yearly product in both tropical and temperate areas of the world. Cotton (*Gossypium hirsutum*) is one of the principal fiber crops known by various names such as “King of Fiber” and or “The White Gold” and major source of raw material for domestic textile industry that provides sustenance to millions of farmers and the workers involved in the cotton industries, right from processing to trading of cotton (Dahiya *et al.* 2013; Amit *et al.*, 2024) [10, 21]. In India, cotton occupies an area of 114.84 lakh hectares, yielding 297.24 lakh bales with a productivity rate of 440.0 kg/ha (Anonymous, 2024) [5]. However, cotton production in India faces challenges due to the presence of 162 species of insect pests, resulting in losses ranging from 10-30 per cent (Anonymous, 2014; Ram *et al.*, 2025) [3, 32]. Major insect pests such as leafhopper (*Amarasca biguttula biguttula*), whitefly (*Bemisia tabaci*), thrips (*Thrips tabaci* Lindemann), aphid (*Aphis gossypii* Glover) and mealybug (*Phenacoccus solenopsis* Tinsley) cause significant damage to the crop by sucking sap (Shera *et al.*, 2013) [38]. Weather conditions play a crucial role in deciding the population dynamics of these sap-

sucking pests a various crop growth stages (Jeyakumar *et al.*, 2008) [19].

Biological control emerges as a reliable and environment-friendly approach to manage insect pests and maintain their population below economic threshold levels (Bale *et al.*, 2008; Kumar *et al.*, 2016) [7, 22]. Natural enemies, such as ladybird beetle, *Coccinella septempunctata*, *Cheilomenes sexmaculata*; green lacewing, *Chrysoperla zastrowi sillemi*; parasitoid, *Encarsia lutea*; yellow paper wasp, *Polistes spp.*, and spiders, act as agents of biological control by preying and feeding up on insect pests, thus safeguarding the crop from damage (Kedar *et al.*, 2014; Patel and Radadia, 2018) [20, 29].

Chemical insecticides emerge as most reliable, economical and preferred pest management tools but that often is not without associated direct and indirect adverse impacts on environment. The application of these insecticides affects the abundance as well as the efficacy of bio-control agents present in field, thereby influencing their effectiveness in controlling pest populations (Dhaka and Pareek, 2007; Rawal *et al.*, 2017) [11, 33]. To advocate and adopt safer and judicious use of insecticide, supporting information regarding their impact on non-target organism as well as natural enemies of targeted pest became inevitable. Furthermore, experimental conditions at research farm and farmer field vary in many aspects and

experimental conclusion derived at farmer field is more meaningful in this scenario. In light of this, the present study aims to record and analyse the population build-up of natural enemies after insecticidal application in cotton at farmer's field.

Materials and Methods

Study was conducted at Research Farm, Cotton Research Station (CRS), Sirsa (Haryana) during *Kharif* season on transgenic hybrid cotton (RCH 650) in Randomized Block Design (RBD) with three replications. Cotton crop was sown in spacing of 1.00 × 0.45 meters with a plot size of 7.0 × 5.85 meters. All the cultural practices including insecticides for the raising the cotton crop were followed as per the recommendation of "Package of practices of *Kharif* crops" of CCS Haryana Agricultural University, Hisar (Anonymous, 2019) [4]. Insecticides were applied as and when sucking pests reached the economic threshold level (Table 1).

Observations: The observations on population build-up of natural enemies (Kumar *et al.*, 2016) [22] were recorded at one day before and one, three, five and seven days after application of insecticide on randomly selected five plants using beat basket method (basket with diameter 30 cm and height 37.5 cm). The population of yellow wasp, *Vespa* spp. was recorded by observing the number of wasps visiting the randomly selected five plants per two minutes. The per cent parasitization of *Bemisia tabaci* (nymphs) and *Phenacoccus solenopsis* was recorded by using the following formula-

$$\text{Per cent parasitization (\%)} = \frac{\text{Total number of parasitized individuals observed}}{\text{Total number of individuals observed}} \times 100$$

Data of different treatments were analyzed by using OPSTAT software (Sheoran *et al.*, 1998) [37].

Table 1: Insecticides evaluated at research farm

Sr. No.	Insecticides applied	Dose/ha
1.	Dimethoate 30 EC	750 ml
2.	Oxydemeton methyl 25 EC	1.0 L
3.	Imidacloprid 200 SL	100 ml
4.	Thiamethoxam 25 WP	100 g
5.	Profenophos 50 EC	1.5 L
6.	Quinalphos 25 EC	2.0 L
7.	Ethion 50 EC	2.0 L
8.	Monocrotophos 36 SL	1.5 L
9.	Spinosad 45 SC	200 ml
10.	Nimbecidine 300 ppm	2.5 L
11.	Water	500 L
12.	Control	

Results and Discussion

Although, a number of insecticides have been validated by different government institutions like; the Central Insecticide Board and Registration Committee, Department of Agriculture and Farmers' Welfare and State and Central Agricultural Universities for the management of insect-pests in a variety of field crops. Application of these insecticides may affect the abundance as well as the efficacy of bio-control agents present in the field against targeted insect-pests. Number of various natural enemies against whitefly was recorded after treatment of different insecticides at Research Farm, CRS, Sirsa. Numbers of different natural enemies prior to the application of different chemicals observed at par in each plot. First application of insecticides was made during the *Kharif* crop season in 30th SMW (25th July) and second in 32nd SMW (7th of August in month). Population build up of natural enemies was recorded after one, three, five and seven days of spray of insecticides.

Table 2: Population of ladybird beetle, *C. septempunctata*, *C. sexmaculata* after treatment of insecticides

DAT Treatments	Population of ladybird beetle (adults/plant)											
	Pre-Treatment		1DAA		3DAA		5DAA		7DAA		Mean	
	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A
Dimethoate 30 EC	0.60 (1.26)	0.67 (1.28)	0.20 (1.09)	0.20 (1.09)	0.40 (1.18)	0.27 (1.12)	0.47 (1.21)	0.47 (1.21)	0.67 (1.29)	0.54 (1.24)	0.44 (1.20)	0.37 (1.17)
Oxydemeton methyl 25 EC	0.67 (1.29)	0.60 (1.26)	0.27 (1.12)	0.14 (1.06)	0.34 (1.15)	0.34 (1.15)	0.40 (1.18)	0.54 (1.24)	0.47 (1.21)	0.60 (1.26)	0.37 (1.17)	0.41 (1.18)
Imidacloprid 200 SL	0.47 (1.21)	0.80 (1.34)	0.14 (1.06)	0.14 (1.06)	0.27 (1.12)	0.20 (1.09)	0.34 (1.15)	0.27 (1.12)	0.34 (1.15)	0.47 (1.21)	0.28 (1.13)	0.27 (1.13)
Thiamethoxam 25 WP	0.54 (1.23)	0.94 (1.39)	0.20 (1.09)	0.34 (1.15)	0.34 (1.15)	0.54 (1.21)	0.60 (1.26)	0.60 (1.26)	0.67 (1.29)	0.74 (1.32)	0.46 (1.20)	0.56 (1.25)
Profenophos 50 EC	0.74 (1.32)	0.74 (1.31)	0.14 (1.06)	0.20 (1.09)	0.20 (1.09)	0.27 (1.12)	0.34 (1.15)	0.34 (1.15)	0.47 (1.21)	0.47 (1.21)	0.29 (1.13)	0.32 (1.15)
Quinalphos 25 EC	0.80 (1.34)	0.80 (1.34)	0.34 (1.12)	0.27 (1.12)	0.40 (1.18)	0.34 (1.15)	0.47 (1.24)	0.47 (1.21)	0.74 (1.29)	0.67 (1.29)	0.49 (1.22)	0.44 (1.20)
Ethion 50 EC	0.87 (1.36)	1.07 (1.44)	0.14 (1.06)	0.27 (1.12)	0.40 (1.18)	0.34 (1.15)	0.54 (1.24)	0.40 (1.18)	0.60 (1.26)	0.54 (1.24)	0.42 (1.19)	0.39 (1.18)
Monocrotophos 36 SL	0.40 (1.18)	0.54 (1.24)	0.07 (1.03)	0.07 (1.03)	0.20 (1.09)	0.14 (1.06)	0.27 (1.12)	0.34 (1.15)	0.40 (1.18)	0.40 (1.18)	0.24 (1.11)	0.24 (1.11)
Spinosad 45 SC	0.54 (1.23)	0.67 (1.28)	0.27 (1.12)	0.34 (1.15)	0.34 (1.15)	0.40 (1.18)	0.40 (1.18)	0.47 (1.21)	0.54 (1.24)	0.60 (1.26)	0.39 (1.18)	0.46 (1.20)
Nimbecidine 300 ppm	0.47	0.87	0.27	0.40	0.34	0.47	0.67	0.54	0.80	0.74	0.52	0.54

	(1.24)	(1.37)	(1.12)	(1.18)	(1.15)	(1.21)	(1.29)	(1.24)	(1.34)	(1.32)	(1.23)	(1.24)
Water	0.60 (1.26)	0.74 (1.32)	0.47 (1.15)	0.47 (1.21)	0.54 (1.23)	0.60 (1.26)	0.74 (1.32)	0.67 (1.29)	0.87 (1.37)	0.80 (1.34)	0.66 (1.28)	0.64 (1.28)
Control	0.94 (1.39)	1.14 (1.46)	0.87 (1.37)	1.07 (1.44)	0.80 (1.34)	0.87 (1.37)	0.94 (1.39)	0.87 (1.37)	1.07 (1.44)	0.94 (1.39)	0.92 (1.38)	0.94 (1.39)
CD (p = 0.05)	NS	NS	0.11	0.07	0.06	0.07	0.08	0.12	0.07	0.11	0.04	0.04

Figures in parentheses are square root transformed values ($\sqrt{n+1}$), DAA: days after application, 1A: at first application, 2A: at second application

Population of ladybird beetle, that has been established as an important predator of sucking pests in cotton ecosystem was found minimum in monocrotophos 36 SL (0.07 adults/plant) after one day of insecticidal treatments that was statistically similar with all treatments except treatment of water (0.47 adults/plant) alone (Table 2). After three days of treatment, population of ladybird beetle was found at rock bottom in monocrotophos 36 SL and profenophos 50 EC with only 0.2 adults per plant. This pattern was continue even after five days of spray, as the population build-up of ladybird beetle was found minimum in monocrotophos 36 SL (0.27 adults/plant) which was statistically equal with oxydemeton methyl 25 EC (0.40 adults/plant) and imidacloprid 200 SL (0.34 adults/plant). After seventh day, the population of ladybird beetle was minimum in imidacloprid 200 SL (0.34 adults/plant) which was statistically equal with oxydemeton methyl 25 EC (0.47 adults/plant), profenophos 50 EC (0.47 adults/plant) and monocrotophos 36 SL (0.40 adults/plant). In second treatment, minimum build-up in population of ladybird beetle was observed in monocrotophos 36 SL (0.07 adults/plant) after one day of treatment which was statistically at par with dimethoate

30 EC (0.20 adults/plant), oxydemeton methyl 25 EC (0.14 adults/plant) and profenophos 50 EC (0.20 adults/plant). After three days of treatment population of ladybird beetle was found again undershot in monocrotophos 36 SL (0.14 adults/plant) which was statistically similar with dimethoate 30 EC (0.27 adults/plant), imidacloprid 200 SL (0.20 adults/plant) and profenophos 50 EC (0.27 adults/plant). On fifth day, number of ladybird beetle was found at bottom in imidacloprid 200 SL (0.27 adults/plant) and again at seven day of treatment, its population was least in monocrotophos 36 SL (0.4 adults/plant) which was statistically at par with dimethoate 30 EC (0.54 adults/plant), oxydemeton methyl 25 EC (0.60 adults/plant), imidacloprid 200 SL (0.47 adults/plant), profenophos 50 EC (0.47 adults/plant), quinalphos 25 EC (0.67 adults/plant), ethion 50 EC (0.54 adults/plant) and spinosad 45 SC (0.60 adults/plant). Average number of ladybird beetle was minimum in monocrotophos 36 SL (0.24 adults/plant) which was statistically at par to treatment (Table 2) of imidacloprid 200 SL (0.27 adults/plant) and profenophos 50 EC (0.32 adults/plant).

Table 3: Population of green lacewing, *Chrysoperla* spp after treatment of insecticides

DAT Treatments	Green lacewing (larvae/plant)											
	Pre-Treatment		1DAA		3DAA		5DAA		7DAA		Mean	
	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A
Dimethoate 30 EC	1.67 (1.62)	1.34 (1.52)	0.60 (1.26)	0.34 (1.15)	0.67 (1.29)	0.47 (1.21)	1.27 (1.50)	0.54 (1.24)	1.34 (1.53)	0.67 (1.29)	0.97 (1.39)	0.51 (1.23)
Oxydemeton methyl 25 EC	1.67 (1.63)	1.54 (1.59)	0.40 (1.18)	0.60 (1.26)	0.80 (1.34)	0.74 (1.29)	1.34 (1.53)	0.87 (1.37)	1.47 (1.57)	1.07 (1.44)	1.01 (1.41)	0.82 (1.35)
Imidacloprid 200 SL	1.67 (1.62)	1.40 (1.55)	0.47 (1.21)	0.47 (1.21)	1.27 (1.50)	0.54 (1.24)	1.40 (1.55)	0.67 (1.29)	1.54 (1.59)	0.87 (1.37)	1.17 (1.47)	0.64 (1.28)
Thiamethoxam 25 WP	1.80 (1.67)	1.27 (1.49)	0.54 (1.24)	0.40 (1.15)	0.60 (1.26)	0.60 (1.26)	1.47 (1.57)	0.74 (1.32)	1.54 (1.59)	1.14 (1.46)	1.04 (1.42)	0.72 (1.31)
Profenophos 50 EC	1.40 (1.55)	1.27 (1.50)	0.20 (1.09)	0.27 (1.12)	0.54 (1.24)	0.34 (1.15)	0.87 (1.36)	0.47 (1.21)	1.14 (1.46)	0.74 (1.32)	0.69 (1.29)	0.46 (1.20)
Quinalphos 25 EC	1.47 (1.57)	1.54 (1.59)	0.60 (1.26)	0.54 (1.24)	0.74 (1.32)	0.67 (1.29)	1.20 (1.48)	0.80 (1.34)	1.40 (1.55)	0.94 (1.39)	0.99 (1.40)	0.74 (1.32)
Ethion 50 EC	1.54 (1.59)	1.60 (1.61)	0.34 (1.15)	0.47 (1.21)	0.47 (1.21)	0.40 (1.18)	1.34 (1.53)	0.60 (1.26)	1.47 (1.57)	1.34 (1.53)	0.91 (1.37)	0.71 (1.30)
Monocrotophos 36 SL	1.54 (1.59)	1.47 (1.57)	0.67 (1.29)	0.40 (1.18)	0.80 (1.34)	0.54 (1.21)	1.14 (1.46)	0.67 (1.29)	1.27 (1.50)	0.80 (1.34)	0.97 (1.40)	0.61 (1.26)
Spinosad 45 SC	1.74 (1.65)	1.40 (1.55)	0.47 (1.21)	0.67 (1.29)	0.74 (1.32)	0.80 (1.34)	1.40 (1.55)	1.07 (1.44)	1.67 (1.63)	1.20 (1.48)	1.07 (1.43)	0.94 (1.39)
Nimbecidine 300 ppm	1.80 (1.67)	1.47 (1.57)	0.74 (1.32)	0.74 (1.32)	0.87 (1.37)	1.00 (1.41)	1.60 (1.61)	1.14 (1.46)	1.74 (1.65)	1.27 (1.50)	1.24 (1.49)	1.04 (1.43)
Water	1.87 (1.69)	1.34 (1.53)	1.14 (1.46)	0.80 (1.34)	1.40 (1.55)	0.87 (1.37)	1.47 (1.57)	1.20 (1.48)	1.60 (1.61)	1.47 (1.57)	1.41 (1.55)	1.09 (1.44)
Control	1.94 (1.71)	1.60 (1.61)	1.60 (1.61)	1.40 (1.55)	1.74 (1.65)	1.54 (1.59)	1.94 (1.71)	1.54 (1.59)	2.07 (1.74)	1.67 (1.63)	1.84 (1.68)	1.54 (1.59)
CD (p = 0.05)	NS	NS	0.12	0.07	0.09	0.06	0.09	0.06	0.09	0.06	0.09	0.05

Figures in parentheses are square root transformed values ($\sqrt{n+1}$), DAA: days after application, 1A: at first application, 2A: at second application

Green lacewing was found undershot in profenophos 50 EC (0.2 larvae/plant) after one day of treatment, which was statistically at par with ethion 50 EC (0.34 larvae/plant), imidacloprid 200 SL (0.47 larvae/plant), oxydemeton methyl 25 EC (0.40 larvae/plant) and spinosad 45 SC (0.47 larvae/plant), at third day, green lacewing was recorded least in ethion 50 EC (0.47 larvae/plant). After five days of spray, the build-up in population abundance of green lacewing (Table 3) was observed minimum in profenophos 50 EC (0.87 larvae/plant) that was statistically at par with dimethoate 30 EC (1.27 larvae/plant), ethion 50 EC (1.47 larvae/plant), imidacloprid 200 SL (1.40 larvae/plant), monocrotophos 36 SL (1.14 larvae/plant), oxydemeton methyl 25 EC (1.34 larvae/plant), quinalphos 25 EC (1.40 larvae/plant) and spinosad 45 SC (1.40 larvae/plant). Treatment of profenophos 50 EC (1.14 larvae/plant) resulted in minimum population build-up of green lacewing after seven days of treatment. Average build-up of green lacewing after seven days of first treatment was recorded at minimal level due to the application of profenophos 50 EC (0.69 larvae/plant), build-up was comparatively higher in treatment of water (1.41 larvae/plant)

followed by nimbecidine 300 ppm (1.24 larvae/plant). Abundance of green lacewing was minimum due to the treatment of profenophos 50 EC (0.27 larvae/plant) after one day of treatment which was statistically at par with dimethoate 30 EC (0.34 larvae/plant), monocrotophos 36 SL (0.40 larvae/plant) and thiamethoxam 25 WP (0.40 larvae/plant). After three days of treatment, profenophos 50 EC (0.34 larvae/plant) resulted in highest negative impact on population build-up of green lacewing was statistically at par with dimethoate 30 EC (0.47 larvae/plant), ethion 50 EC (0.40 larvae/plant) and monocrotophos 36 SL (0.54 larvae/plant). Same pattern was continue also after five days of spray. Green lacewing was at bottom in dimethoate 30 EC (0.67 larvae/plant) after seven days of spray. Average build-up in its population after seven days of treatment was found minimum due to application of profenophos 50 EC (0.46 larvae/plant) which was found statistically equal with dimethoate 30 EC (0.51 larvae/plant), while on contrast, the treatment of water alone (1.09 larvae/plant) followed by nimbecidine 300 ppm (1.04 larvae/plant) resulted in fairer build-up of green lacewing (Table 3).

Table 4: Population of spiders after treatment of insecticides

DAT Treatments	Spiders/plant											
	Pre-Treatment		1DAA		3DAA		5DAA		7DAA		Mean	
	1A	2A										
Dimethoate 30 EC	1.47 (1.57)	2.07 (1.74)	0.27 (1.12)	1.07 (1.44)	0.40 (1.18)	1.27 (1.50)	0.74 (1.31)	1.67 (1.63)	0.87 (1.37)	1.74 (1.65)	0.57 (1.25)	1.44 (1.56)
Oxydemeton methyl 25 EC	1.27 (1.50)	2.20 (1.78)	0.40 (1.18)	0.94 (1.39)	0.54 (1.24)	1.20 (1.48)	0.60 (1.26)	1.60 (1.61)	1.14 (1.46)	1.80 (1.67)	0.67 (1.29)	1.39 (1.54)
Imidacloprid 200 SL	1.34 (1.52)	2.40 (1.83)	0.27 (1.12)	0.87 (1.37)	0.34 (1.15)	0.94 (1.39)	0.74 (1.32)	1.94 (1.71)	0.94 (1.39)	2.07 (1.75)	0.58 (1.25)	1.46 (1.56)
Thiamethoxam 25 WP	1.40 (1.55)	2.34 (1.82)	0.27 (1.12)	0.87 (1.37)	0.40 (1.18)	1.34 (1.53)	1.00 (1.41)	1.67 (1.63)	1.20 (1.48)	2.14 (1.77)	0.72 (1.30)	1.51 (1.58)
Profenophos 50 EC	1.34 (1.52)	2.14 (1.77)	0.34 (1.15)	0.80 (1.34)	0.60 (1.26)	1.07 (1.44)	0.80 (1.34)	1.54 (1.59)	1.27 (1.50)	1.87 (1.69)	0.76 (1.32)	1.32 (1.52)
Quinalphos 25 EC	1.14 (1.42)	2.07 (1.74)	0.34 (1.15)	0.94 (1.39)	0.54 (1.24)	1.47 (1.57)	0.60 (1.26)	1.60 (1.61)	0.87 (1.37)	1.94 (1.71)	0.59 (1.26)	1.49 (1.57)
Ethion 50 EC	1.14 (1.45)	2.27 (1.80)	0.40 (1.18)	0.60 (1.26)	0.54 (1.24)	0.87 (1.37)	0.74 (1.32)	1.54 (1.59)	0.94 (1.39)	1.67 (1.63)	0.66 (1.28)	1.17 (1.46)
Monocrotophos 36 SL	1.07 (1.43)	2.27 (1.80)	0.20 (1.09)	0.54 (1.24)	0.40 (1.18)	0.74 (1.32)	0.54 (1.24)	1.47 (1.57)	0.74 (1.32)	1.54 (1.59)	0.47 (1.21)	1.08 (1.43)
Spinosad 45 SC	1.27 (1.45)	2.07 (1.74)	0.34 (1.15)	0.74 (1.29)	0.47 (1.21)	1.14 (1.46)	0.60 (1.26)	1.40 (1.55)	0.80 (1.34)	1.60 (1.61)	0.56 (1.24)	1.22 (1.49)
Nimbecidine 300 ppm	1.54 (1.61)	2.14 (1.75)	0.47 (1.21)	1.20 (1.46)	0.80 (1.34)	1.40 (1.55)	1.14 (1.46)	1.74 (1.65)	1.20 (1.48)	2.07 (1.75)	0.91 (1.37)	1.61 (1.61)
Water	1.40 (1.46)	2.34 (1.82)	0.80 (1.34)	1.27 (1.50)	0.87 (1.37)	1.47 (1.57)	0.94 (1.39)	1.87 (1.69)	1.14 (1.46)	2.27 (1.81)	0.94 (1.39)	1.72 (1.64)
Control	1.60 (1.50)	2.47 (1.86)	1.14 (1.46)	1.67 (1.69)	1.40 (1.55)	2.27 (1.81)	1.54 (1.59)	2.47 (1.86)	1.60 (1.61)	2.60 (1.90)	1.42 (1.55)	2.26 (1.80)
CD (p = 0.05)	NS	NS	0.06	0.11	0.06	0.06	0.11	0.09	0.06	0.11	0.06	0.06

Figures in parentheses are square root transformed values ($\sqrt{n+1}$), DAA: days after application, 1A: at first application, 2A: at second application

Monocrotophos 36 SL (0.2 spiders/plant) was found most unfavorable insecticide for the activities of spiders (Table 4) after one day of treatment that was statistically similar with dimethoate 30 EC (0.27 spiders/plant), imidacloprid 200 SL (0.27 spiders/plant), profenophos 50 EC (0.34 spiders/plant),

quinalphos 25 EC (0.34 spiders/plant), spinosad 45 SC (0.34 spiders/plant) and thiamethoxam 25 WP (0.27 spiders/plant). After three days of application in comparison to control (1.40 spiders/plant), the number of spiders was least in imidacloprid 200 SL (0.34 spiders/plant) which was statistically equal with

the treatments of dimethoate 30 EC (0.40 spiders/plant), monocrotophos 36 SL (0.40 spiders/plant), spinosad 45 SC (0.47 spiders/plant) and thiamethoxam 25 WP (0.40 spiders/plant). Abundance of spiders was at bottom in the plot treated with monocrotophos 36 SL with 0.54 spiders per plant, after five days of treatment. Similarly, after seven days of treatment, the population of spiders was recorded undershot in monocrotophos 36 SL (0.74 spiders/plant), statistically at par with dimethoate 30 EC (0.87 spiders/plant), quinalphos 25 EC (0.87 spiders/plant) and spinosad 45 SC (0.80 spiders/plant), in comparison to control (1.60 spiders/plant). It can be revealed from the data presented (Table 4), after seven days of treatment mean build-up in population abundance of spiders was again minimum in treatment of monocrotophos 36 SL (0.47 spiders/plant). Population of spiders was at highest level in treatment of water (0.94 spiders/plant) followed by nimbecidine 300 ppm (0.91 spiders/plant). Spiders were found minimum in monocrotophos 36 SL (0.54 spiders/plant) after second application at one day after at par with ethion 50 EC (0.60 spiders/plant), profenophos 50 EC (0.80 spiders/plant) and spinosad 45 SC (0.74 spiders/plant) (Table 4). In the same

line, monocrotophos 36 SL severely affected the build-up in activities of spiders (0.74 spiders/plant) after three days of treatment statistically similar to ethion 50 EC (0.87 spiders/plant). After five days of spray, the population of spiders was least in treatment of spinosad 45 SC (1.4 spiders/plant) statistically at par with dimethoate 30 EC (1.67 spiders/plant), ethion 50 EC (1.54 spiders/plant), oxydemeton methyl 25 EC (1.60 spiders/plant), monocrotophos 36 SL (1.54 spiders/plant), profenophos 50 EC (1.54 spiders/plant), quinalphos 50 EC (1.60 spiders/plant) and thiamethoxam 25 WP (1.67 spiders/plant). At seventh day, the minimum population of spiders was observed in monocrotophos 36 SL (1.54 spiders/plant). It is quite clear from Table 4 that monocrotophos 36 SL (1.08 spiders/plant) exhibited knock down impact on spiders statistically at par with ethion 50 EC (1.17 spiders/plant) and spinosad 45 SC (1.22 spiders/plant). Application of water (1.72 spiders/plant) followed by nimbecidine 300 ppm (1.61 spiders/plant) was observed most favourable to the post insecticidal treatment build-up of spiders in cotton ecosystem.

Table 5: Population of yellow paper wasp, *Polistes* spp. after treatment of insecticides

DAT Treatments	Yellow paper wasps/plant											
	Pre-Treatment		1DAA		3DAA		5DAA		7DAA		Mean	
	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A
Dimethoate 30 EC	0.34 (1.15)	0.54 (1.23)	0.07 (1.03)	0.07 (1.03)	0.07 (1.03)	0.20 (1.09)	0.20 (1.09)	0.27 (1.12)	0.34 (1.15)	0.34 (1.15)	0.17 (1.08)	0.22 (1.10)
Oxydemeton methyl 25 EC	0.40 (1.18)	0.54 (1.23)	0.07 (1.03)	0.00 (1.00)	0.14 (1.06)	0.20 (1.09)	0.27 (1.12)	0.20 (1.09)	0.34 (1.15)	0.27 (1.12)	0.21 (1.10)	0.17 (1.08)
Imidacloprid 200 SL	0.34 (1.15)	0.40 (1.18)	0.00 (1.00)	0.07 (1.03)	0.14 (1.06)	0.14 (1.06)	0.14 (1.06)	0.20 (1.09)	0.14 (1.06)	0.20 (1.09)	0.11 (1.05)	0.16 (1.07)
Thiamethoxam 25 WP	0.40 (1.18)	0.47 (1.21)	0.07 (1.03)	0.20 (1.09)	0.14 (1.06)	0.27 (1.12)	0.20 (1.09)	0.27 (1.12)	0.34 (1.15)	0.40 (1.18)	0.19 (1.09)	0.29 (1.13)
Profenophos 50 EC	0.60 (1.26)	0.54 (1.24)	0.00 (1.00)	0.07 (1.03)	0.07 (1.03)	0.07 (1.03)	0.07 (1.03)	0.14 (1.06)	0.14 (1.06)	0.20 (1.09)	0.07 (1.03)	0.12 (1.06)
Quinalphos 25 EC	0.34 (1.15)	0.80 (1.34)	0.14 (1.06)	0.14 (1.06)	0.20 (1.09)	0.20 (1.09)	0.34 (1.15)	0.34 (1.15)	0.40 (1.18)	0.40 (1.18)	0.27 (1.13)	0.27 (1.13)
Ethion 50 EC	0.47 (1.21)	0.27 (1.12)	0.00 (1.00)	0.07 (1.03)	0.07 (1.03)	0.20 (1.09)	0.20 (1.18)	0.20 (1.09)	0.20 (1.09)	0.27 (1.12)	0.12 (1.07)	0.19 (1.09)
Monocrotophos 36 SL	0.54 (1.23)	0.34 (1.15)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.07 (1.03)	0.14 (1.06)	0.20 (1.09)	0.34 (1.15)	0.27 (1.12)	0.14 (1.06)	0.14 (1.06)
Spinosad 45 SC	0.67 (1.28)	0.67 (1.29)	0.07 (1.03)	0.14 (1.06)	0.20 (1.09)	0.14 (1.06)	0.27 (1.03)	0.27 (1.12)	0.34 (1.15)	0.40 (1.18)	0.22 (1.10)	0.24 (1.11)
Nimbecidine 300 ppm	0.67 (1.28)	0.67 (1.29)	0.14 (1.06)	0.07 (1.03)	0.14 (1.06)	0.34 (1.15)	0.27 (1.12)	0.34 (1.15)	0.60 (1.26)	0.54 (1.21)	0.29 (1.13)	0.31 (1.14)
Water	0.40 (1.18)	0.47 (1.21)	0.14 (1.06)	0.14 (1.06)	0.20 (1.09)	0.27 (1.12)	0.27 (1.12)	0.34 (1.15)	0.40 (1.18)	0.60 (1.26)	0.26 (1.12)	0.34 (1.15)
Control	0.60 (1.26)	0.80 (1.34)	0.27 (1.15)	0.47 (1.21)	0.40 (1.18)	0.40 (1.18)	0.54 (1.24)	0.47 (1.21)	0.60 (1.26)	0.67 (1.29)	0.46 (1.20)	0.51 (1.22)
CD (p = 0.05)	NS	NS	0.07	0.08	0.08	0.07	0.12	0.07	NS	0.06	0.03	0.04

Figures in parentheses are square root transformed values ($\sqrt{n+1}$), DAA: days after application, 1A: at first application, 2A: at second application

After one day of treatment, ethion 50 EC, imidacloprid 200 SL, monocrotophos 36 SL and profenophos 50 EC were proved most harmful to individuals of yellow wasp as no activities of wasps were observed there, while after three days of treatment comparatively less activity of wasps was observed in

dimethoate 30 EC, ethion 50 EC, monocrotophos 36 SL and profenophos 50 EC with 0.07 wasps per plant. Profenophos 50 EC (0.07 wasps/plant) was statistically at par with dimethoate 30 EC (0.20 wasps/plant), imidacloprid 200 SL (0.14 wasps/plant), monocrotophos 36 SL (0.14 wasps/plant),

oxydemeton methyl 25 EC (0.27 wasps/plant), quinalphos 25 EC (0.34 wasps/plant), spinosad 45 SC (0.34 wasps/plant) and thiamethoxam 25 WP (0.34 wasps/plant) that resulted in minimum activity of yellow wasps after five days of treatment. After seven days of spray, the yellow wasps were found undershot in imidacloprid 200 SL and profenophos 50 EC with only 0.14 wasps per plant (Table 5). Average population of yellow wasps was found minimum in profenophos 50 EC (0.07 wasps/plant) after seven days of treatment, was statistically comparable to imidacloprid 200 SL (0.11 wasps/plant) and monocrotophos 36 SL (0.14 wasps/plant), while the mean build-up of wasp was found maximum in nimbecidine 300 ppm (0.29 wasps/plant) followed by treatment of water alone (0.26 wasps/plant). Presence of yellow wasp was not noticed in treatment of oxydemeton methyl 25 EC and monocrotophos 36

SL after one day of second treatment (Table 5). After three days of spray, profenophos 50 EC and monocrotophos 36 were found most discomforting to yellow wasp with 0.07 wasps per plant in each treatment, respectively. Profenophos 50 EC (0.14 wasps/plant) was found to cause maximum loss to build-up of yellow wasp population after five days of treatment. After seven days of spray, imidacloprid 200 SL and profenophos 50 EC were noticed to have lowest number of yellow wasp individuals with a population of 0.2 wasps per plant. Yellow wasp, after seven days of treatment (Table 5) was found undershot in profenophos 50 EC (0.12 wasps/plant) which was statistically at par with dimethoate 30 EC (0.34 wasps/plant), ethion 50 EC (0.27 wasps/plant), imidacloprid 200 SL (0.20 wasps/plant), monocrotophos 36 SL (0.27 wasps/plant) and oxydemeton methyl 25 EC (0.27 wasps/plant).

Table 6: Nymphal parasitization of whitefly, *Bemisia tabaci* after treatment of insecticides

DAT Treatments	Nymphal parasitization of whitefly (%)											
	Pre-Treatment		1DAA		3DAA		5DAA		7DAA		Mean	
	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A	1A	2A
Dimethoate 30 EC	4.78 (12.61)	9.08 (17.16)	2.79 (9.59)	3.57 (10.88)	4.48 (12.21)	4.03 (11.57)	5.01 (12.93)	4.47 (11.79)	5.61 (13.69)	5.51 (13.57)	4.48 (12.11)	4.39 (12.06)
Oxydemeton methyl 25 EC	7.63 (15.97)	9.68 (17.94)	2.86 (9.72)	4.34 (12.01)	3.59 (10.90)	5.16 (13.09)	5.85 (13.98)	5.61 (13.67)	5.97 (14.14)	6.76 (15.06)	4.57 (12.19)	5.47 (13.48)
Imidacloprid 200 SL	9.14 (17.09)	6.72 (14.69)	3.26 (10.39)	3.68 (11.03)	3.52 (10.79)	4.35 (12.02)	4.83 (12.79)	5.38 (13.40)	5.37 (13.39)	5.85 (13.99)	4.25 (11.82)	4.82 (12.62)
Thiamethoxam 25 WP	8.38 (16.42)	9.07 (17.17)	2.51 (9.10)	4.18 (11.78)	3.66 (11.02)	4.88 (12.76)	5.48 (13.52)	5.33 (13.34)	5.64 (13.73)	7.06 (15.40)	4.33 (11.85)	5.37 (13.32)
Profenophos 50 EC	6.19 (14.34)	5.65 (12.94)	2.57 (9.22)	3.72 (11.10)	4.50 (12.24)	4.43 (12.13)	5.51 (12.57)	5.08 (13.00)	5.82 (13.94)	5.48 (13.52)	4.60 (12.25)	4.68 (12.45)
Quinalphos 25 EC	8.75 (17.12)	9.69 (18.61)	4.23 (11.80)	3.52 (10.80)	4.86 (12.72)	4.83 (12.69)	5.78 (13.89)	6.04 (14.22)	5.93 (14.08)	6.42 (14.66)	5.2 (13.15)	5.21 (13.10)
Ethion 50 EC	7.16 (15.10)	5.98 (13.47)	2.89 (9.74)	4.02 (11.55)	4.21 (11.82)	4.17 (11.77)	5.41 (13.44)	4.22 (12.65)	5.73 (13.84)	5.43 (13.46)	4.56 (12.23)	4.46 (12.16)
Monocrotophos 36 SL	8.54 (16.55)	7.15 (15.17)	2.75 (9.53)	3.51 (10.79)	3.73 (11.13)	3.66 (11.01)	4.89 (12.75)	5.05 (12.98)	5.49 (13.54)	5.21 (13.18)	4.22 (11.75)	4.36 (11.98)
Spinosad 45 SC	7.25 (15.56)	5.97 (14.07)	3.25 (10.37)	4.27 (11.90)	5.03 (12.95)	5.31 (13.32)	5.93 (14.07)	6.04 (14.22)	6.31 (14.54)	6.94 (15.26)	5.13 (12.99)	5.64 (13.68)
Nimbecidine 300 ppm	8.09 (15.95)	8.01 (16.41)	4.73 (12.54)	4.31 (11.97)	6.72 (15.01)	4.87 (12.74)	7.06 (15.39)	7.03 (15.36)	7.45 (15.83)	7.4 (15.78)	6.49 (14.70)	5.91 (13.97)
Water	6.12 (14.23)	10.14 (17.46)	5.71 (13.81)	4.83 (12.68)	5.91 (14.05)	5.41 (13.44)	6.18 (14.38)	6.64 (14.92)	6.62 (14.90)	6.92 (15.24)	6.11 (14.29)	5.95 (14.08)
Control	9.64 (17.94)	10.42 (18.02)	7.41 (15.78)	7.62 (16.01)	8.16 (16.59)	7.94 (16.35)	8.39 (16.83)	8.62 (17.05)	9.34 (17.79)	8.53 (16.97)	8.33 (16.75)	8.18 (16.60)
CD (p = 0.05)	NS	NS	1.11	0.90	0.71	0.98	0.92	0.94	0.46	0.55	0.96	0.73

Figures in parentheses are angular transformed values, DAA: days after application, 1A: at first application, 2A: at second application

Nymphal parasitization of whitefly was found minimum in thiamethoxam 25 WP (2.51% parasitization) after one day of application of insecticides (Table 6) was statistically similar with dimethoate 30 EC (2.79% parasitization), ethion 50 EC (2.89% parasitization), monocrotophos 36 SL (2.75% parasitization), oxydemeton methyl 25 EC (2.86% parasitization) and profenophos 50 EC (2.57% parasitization). After three days of treatment, imidacloprid 200 SL affected the most *i.e.*, 3.52% nymphal parasitization recorded to cause the least build-up in terms of nymphal parasitization of whitefly. Again at 5th days of treatment, imidacloprid 200 SL caused

4.83% parasitization) statistically at par with dimethoate 30 EC (5.01% parasitization), ethion 50 EC (5.41% parasitization), monocrotophos 36 SL (4.89% parasitization), profenophos 50 EC (5.51% parasitization) and thiamethoxam 25 WP (5.48% parasitization). Once again, Imidacloprid 200 SL resulted in minimum nymphal parasitization of whitefly with 5.37 per cent parasitization at seventh day of application statistically at par with dimethoate 30 EC (5.61% parasitization), ethion 50 EC (5.73% parasitization), monocrotophos 36 SL (5.49% parasitization) and thiamethoxam 25 WP (5.64% parasitization). However, 4.22% nymphal parasitization of

whitefly (Table 6) was found minimum in treatment of monocrotophos 36 SL at 7th day of application. After the second spray schedule, Monocrotophos 36 SL (3.51% parasitization) was found most discomforting to build-up in nymphal parasitization of whitefly after one day of spray (Table 6), which was statistically at par with dimethoate 30 EC (3.57% parasitization), ethion 50 EC (4.02% parasitization), imidacloprid 200 SL (3.68% parasitization), profenophos 50 EC (3.72% parasitization) and quinalphos 25 EC (3.52% parasitization). Again at 3rd day of treatment, monocrotophos 36 SL (3.66 % parasitization) was found most disastrous to build-up of nymphal parasitization of whitefly. Ethion 50 EC (4.22% parasitization) resulted in minimum of nymphal parasitization after five days of spray which was statistically at par with dimethoate 30 EC (4.47% parasitization), imidacloprid 200 SL (5.38% parasitization), monocrotophos 36 SL (5.05% parasitization), profenophos 50 EC (5.08% parasitization) and thiamethoxam 25 WP (5.33% parasitization). Again at seven day of treatment ethion 50 EC (4.64% parasitization) resulted in lowest build-up in nymphal parasitization of whitefly. Nymphal parasitization of whitefly after seven days of treatment was found minimum in monocrotophos 36 SL (4.36% parasitization) was statistically equal with dimethoate 30 EC (4.39% parasitization), ethion 50 EC (4.46% parasitization), imidacloprid 200 SL (4.82% parasitization) and profenophos 50 EC (4.68% parasitization) whereas the average nymphal parasitization of whitefly was observed maximum in application of water alone (5.95% parasitization) followed by nimbecidine 300 ppm (5.91% parasitization).

In present investigation, post treatment of different insecticides after first spray expansion in population of *Chrysoperla zastrowi sillemi* was recorded minimum in profenophos 50 EC that was statistically at par with ethion 50 EC. Plots treated with monocrotophos 36 SL caused lowest increase in population of *Coccinella septempunctata* statistically at par with imidacloprid 200 SL and profenophos 50 EC. Activity of spiders was found least in monocrotophos 36 SL which was statistically equal with application of dimethoate 30 EC, imidacloprid 200 SL, quinalphos 50 EC and spinosad 45 SC. Population of *Vespa* spp. was lowest in profenophos 50 EC after post treatment build-up and nymphal parasitization of *Bemisia tabaci* was least in monocrotophos 36 SL treatment. Build-up in population of *Chrysoperla zastrowi sillemi*, *Coccinella septempunctata* and spiders was highest in treatment of water alone followed by nimbecidine 300 ppm, whereas the population of *Vespa* spp. and nymphal parasitization of *Bemisia tabaci* was recorded maximum in nimbecidine 300 ppm. After second schedule of insecticidal treatment, the population of *Chrysoperla zastrowi sillemi* was recorded undershot in case of profenophos 50 EC, monocrotophos 36 SL caused maximum dent in *Coccinella septempunctata*, spiders were found at worst situation in monocrotophos 36 SL, on the other hand aggregation of *Vespa* spp. was minimum in profenophos 50 EC statistically at par with dimethoate 30 EC, ethion 50 EC, imidacloprid 200 SL, monocrotophos 36 SL and oxy demeton methyl 25 EC.

Nymphal parasitization of *Bemisia tabaci* was found at rock bottom in use of monocrotophos 36 SL that was statistically at par with diamethoate 30 EC, ethion 50 EC, imidacloprid 200 SL and profenophos 50 EC. It is quite comforting that *Chrysoperla zastrowi sillemi*, *Coccinella septempunctata*, spiders, *Vespa* spp. and nymphal parasitization of *Bemisia tabaci* were observed highest in application of Neem based plant origin insecticide namely nimbecidine 300 ppm as compared to other inorganic insecticides.

Results of present work are in parallel lines with inference of Balikai and Lingappa (2003) [8] who concluded in sorghum that the chemicals like monocrotophos, quinalphos and methyl parathion were most toxic insecticide against *C. septempunctata* in Karnataka conditions. A number of authors including Gour and Pareek (2005) [14], Halappa *et al.* (2013) [16], Hussain *et al.* (2017) [18], and Gupta *et al.* (2018) [15] observed imidacloprid as well as monocrotophos as moderately toxic chemicals against ladybird beetle. On the other hand, Pandi *et al.* (2013) [28] stated that Neem based insecticide azadirachtin 1500 ppm was safest to *C. Sexmaculata* while, Awasthi *et al.* (2013) [6] reported spinosad 45 SC as safest insecticide to different stages of Coccinellids predators in Akola (Maharashtra). Shinde and Radadia (2018) [41] also ascertained profenophos 50 EC as harmful insecticide against adults of ladybird beetle in Gujrat.

In present results of field work, minimum activities of green lacewing were demonstrated after first and second application of profenophos 50 EC and dimethoate 30 EC, while treatment of water alone succeeded by nimbecidine 300 ppm and spinosad 45 SC has bolstered more population of green lacewing. Results of investigations are in consonance with Reddy and Manjunatha (2000) [34] who stated a zero mortality of *C. carnea* due to application of nimbecidine in cotton. *C. carnea* larvae after 24 hours of treatment experienced Profenophos 50 EC as harmful in laboratory conditions (Nasreen *et al.* 2003) [27]. Similarly, a high mortality of *Chrysoperla* spp. established in plots sprayed with profenophos 40%+cypermethrin 4% (44 EC) (Shinde *et al.*, 2009) [40]. Low median lethal concentration (LC₅₀) value of profenophos for *C. carnea* was recorded by Shankarganesh *et al.* (2015) [36] in laboratory conditions in Gujrat. In addition, Kumar *et al.* (2013) [23] in Varanasi (U.P.) found least larval longevity and adult emergence after the application of dimethoate 30 EC, on one hand maximum fecundity, egg hatchability, larval duration, pupal duration and adult emergence of *C. carnea* were observed in case of plant origin pest control product like nimbecidine and NSKE treatments in laboratory conditions. Clothianidin had the detrimental effect on per cent egg hatchability and reduced fecundity rate of 212.67 eggs/female in *C. carnea* (Rahangdale *et al.*, 2017) [31] compared to diafenthiuron was found most safe with increased per cent eggs hatchability and higher fecundity rate of 355.33 eggs/female. El-Wakeil *et al.* (2006) [13] found no serious side effects on parasitism and emergence rates of *Trichogramma* spp. and on efficiency of *Chrysoperla*. No harmful effect of Neem products reported by Saxena *et al.* (1984) [35] and Mansour *et al.* (1986) [26] against predatory spiders. Patel (1987) [30] found

monocrotophos 36 EC more toxic against predatory spiders in cotton in Bhavnagar (Gujrat). Furthermore, Sherif *et al.* (2001)^[39] also found monocrotophos 36 SL more toxic to spiders in rice eliminating their 56.4 per cent population, while Kennedy and Ganesh (2012)^[21] determined high toxicity of monocrotophos 36 SL against spiders in mango orchard. Simultaneously, Benamú *et al.* (2007)^[9] observed spinosad as toxic compound against predatory spider, *Araneus pratensis* in soybean, while Hazarika (2008)^[17] reported ethion 50 EC as most toxic insecticide to predatory spiders in a tea garden of Assam. Dose of ethiprole 40% + imidacloprid 40% - 80 WG (125g/ha) recorded 41.20 and 58.13 per cent reduction of spiders and 35.74 and 56.21 per cent reduction of mirid bugs over control during trials at Coimbatore district of Tamil Nadu, respectively were found to be safer to the predators found in the rice ecosystem (Vinothkumar *et al.*, 2010)^[44] compared to acephate 75 SP + endosulfan 35 EC (Tank mixture) @ 750 + 1000 g/ml per ha that recorded higher reduction of 59.79 and 61.00 % of spiders.

Abundance of yellow wasp was found least in profenophos 50 EC treated field that is parallel to findings of Suh *et al.* (2000)^[43] as authors' classified profenophos 50 EC as harmful insecticide to parasitic wasp, *Trichogramma exiguum*. Nymphal parasitization of whitefly was minimum in monocrotophos 36 SL (4.28% parasitization) and was statistically homogenous with dimethoate 30 EC, ethion 50 EC, and profenophos 50 EC. Low nymphal parasitization per cent in present field work are in line with Sivasubramaniam (2006)^[42] and Amit (2019)^[1] who reported damage done to parasitoid of whitefly nymphs due to application of dimethoate 30 EC in field of cotton crops in Sirsa. Kumar *et al.* (2009)^[25] observed ethion 50 EC, monocrotophos 36 SL and profenophos 50 EC as most deleterious insecticide against parasitization of mealybug in Sirsa (Haryana). Application of insecticide resulted in resurgence of cotton aphid and whitefly, possibly because of elimination of natural (Dillion *et al.*, 2012)^[12] enemies or better growth of plants under protected conditions. In foliar application of the systemic neonicotinoids like imidacloprid, clothianidin, admire, thiamethoxam and acetamiprid, Kumar *et al.* (2012)^[24] were able to remunerate these chemicals being highly toxic to natural enemies in comparison with spirotetramat, buprofezin and fipronil.

Thus, the resultant of the investigations is as profenophos 50 EC and ethion 50 EC minimized *Chrysoperla zastrowi sillemi* population expansion. Monocrotophos 36 SL, imidacloprid 200 SL and profenophos 50 EC reduced *Coccinella septempunctata* and spider populations. Monocrotophos 36 SL had the least spider activity and nymphal parasitization of *Bemisia tabaci*. Nimbecidine 300 ppm (neem-based) showed highest populations of beneficial insects, making it a more environmentally friendly option as compared to other insecticides. Nimbecidine 300 ppm and water treatments favored nymphal parasitization of whitefly (6.19% and 6.03% parasitization), respectively.

Conclusion

Present study investigated the impact of various insecticides on beneficial insects in cotton ecosystems. In case of *Chrysoperla*

zastrowi sillemi, profenophos 50 EC and ethion 50 EC minimized population expansion. Nimbecidine 300 ppm (neem-based) showed highest population build-up after water treatment. Application of monocrotophos 36 SL, imidacloprid 200 SL, and profenophos 50 EC reduced the populations of predatory beetles of *Coccinella septempunctata*. Spiders are more sensitive than many pests to some pesticides; Monocrotophos 36 SL is one of them which restricted the activities of spiders in cotton agro-ecosystems that counted statistically similar to Dimethoate 30 EC, imidacloprid 200 SL, quinalphos 50 EC, and spinosad 45 SC in cotton ecosystem. Profenophos 50 EC caused to have the lowest population of *Vespa* spp. while, nimbecidine 300 ppm showed highest population. Nimbecidine 300 ppm showed highest nymphal parasitization by *Encarsia* spp. (6.19%) of *Bemisia tabaci* making it a more environmentally friendly option and water (6.03% parasitization) treatments favored parasitization. Thus, findings highlights the potential risks of selecting broad-spectrum insecticides for the control of different insect-pests in field crops on beneficial organisms, which can disrupt the balance of the ecosystem and lead to unintended consequences, such as reduced biological control of pests, increased pesticide resistance and negative impacts on pollinators and other non-target organisms, or can result in an outbreak of pest populations of insects considered as minor. Strategies needed for Integrated Pest Management (IPM) should be emphasized considering the effects of insecticides on natural enemies and minimizing harm to beneficial organisms and environment.

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Authors' contribution

Conceptualization and designing of the research work (DK); Execution of experiments and data collection (KR); Analysis of data and interpretation (KR, DK, RK); Preparation of manuscript (BS, PK, VK).

Declaration of Interests

The authors have not conflict of interest to declare.

Data Sharing

All the relevant data are within the manuscript.

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