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Research Article

Effect of selected neonicotinoids on predatory coccinellids in Bt cotton ecosystem

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ABSTRACT: Field studies were conducted in two villages *viz*., Mambattu and Salai in Tamil Nadu to assess the toxicity of five neonicotinoids *viz*., imidacloprid 17.8 SL, acetamiprid 20 SP, thiacloprid 21.7 SC, thiamethoxam 25 WDG and clothianidin 50 WDG to coccinellid predators in Bt cotton. At 1, 3, 7 and 14 days after treatment, standard check monocrotophos recorded maximum reduction of 78.8, 83.5, 70.4 and 62.6% respectively. Among neonicotinoids, clothianidin was found to be comparatively more toxic to coccinellids, followed by thiamethoxam and thiacloprid. Acetamiprid was found to be safest among chemical treatments with population reduction of 45.6, 53.9, 36.5 and 24.7% respectively at 1, 3, 7 and 14 days after treatment followed by imidacloprid and thiacloprid. Two rounds of spray of neonicotinoids on Bt cotton had significant impact on the coccinellids, when compared with untreated control plots. However, monocrotophos recorded relatively lowest population of coccinellids compared to untreated control and neonicotinoids. With significant population built-up after 7 days after acetamiprid and imidacloprid sprays, the 2 neonicotinoids may be suitable candidates for inclusion in integrated pest management of sucking insect pests in major Bt cotton growing areas as these insecticides are comparatively less toxic to predators as compared to other neonicotinoids like thiacloprid, thiamethoxam and clothianidin and non-selective insecticide like monocrotophos.

KEY WORDS: Bt cotton, coccinellids, natural enemies, neonicotinoids

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INTRODUCTION

India is one of the largest producers of cotton in the world accounting for about 25% of the world cotton production. The yield per hectare is presently 462 kg/ha which is lower than the world average productivity of 759 kg/ha (CCI, 2021). Hybrid cotton was introduced in India for the first time in 1970. However, it was soon realized that hybrids were highly susceptible to pest attack and damage. This became a severe problem especially from 1993-94 onwards, leading to frequent crop failures as well as fluctuating and declining yields. Over 150 different insect pest species are reported to attack cotton at various stages of its growth causing severe reduction in yields. It was at this juncture that the transgenic varieties with Bt arrived on the world stage and then in the country. Government of India allowed the cultivation of three genetically modified Bt cotton hybrids in April 2002 (Vasant and Namboodiri, 2009). Introduction of Bt cotton has successfully controlled the bollworms and other lepidopteran pests damaging cotton crop. (Kranthi, 2012). The Bt toxin can effectively control specific lepidopteran species but lack resistance against sucking pests (Hofs *et al*., 2006). These sucking pests occur at all the stages of crop growth and responsible for indirect yield losses. A reduction of 22.85% in seed cotton yield due to sucking pests has been reported by Satpute *et al.,* 1988 and Dhawan *et al*., 1988. Sucking insect pests *viz*., jassids (*Amrasca biguttula biguttula* Ishida), aphids (*Aphis gossypii* Glover), whiteflies (*Bemisia tabaci* Gennadius) and thrips, (*Thrips tabaci* Lindeman) are deleterious to the process of cotton growth and development with their ability to build up to serious proportions as a result of rapid and prolific breeding in cotton plant. The wide ranges of alternate hosts, especially continuous production of vegetables besides wild hosts facilitate their sustenance in the absence of cotton.

Since the introduction of synthetic insecticides, their application has made a major contribution to improve the yield production, but it was also soon discovered to be problematic in many ways. Today insect pest species of economic importance as pests those are resistant to more than thirty different chemical insecticides are no longer a rarity. These show direct toxicity to predators, pollinators, fishes and humans (Pimentel, 1981), pesticide resistance (Schmutterer, 1981) and increased environmental and social risks.

Nicotinoids represent a class of compounds with a unique mode of action due to their interactions with acetylcholine (Ach) receptors (Vastrad, 2003). Studies have revealed nicotinic acetylcholine receptors (nAchR) to be the molecular targets of neonicotinoids. As a result, there is no cross resistance to conventional insecticides such pyrethroids, organophosphates and carbamates (Yamamoto, 1996).

The neonicotinoids *viz.,* imidacloprid, acetamiprid, thiacloprid, thiamethoxam and clothianidin are insecticides used by the farmers to mitigate dominance of sucking pests such as aphids, thrips, whiteflies and leafhoppers on cotton (Bass *et.al*, 2015). The need for more selective insecticides was one of the key themes during the evolution of poison free management of insect-pests (Sparks, 2013). A significant advantage of these products is their effectiveness with minimal side-effects on natural enemies of the pests (Bueno and Freitas, 2004; Bacci, 2009) and therefore these beneficial insects can be conserved using selective insecticides.

Sucking insect pests in cotton ecosystem attract their natural enemies like coccinellid beetles, spiders, syrphids and chrysopids. Some of the common coccinellid beetles found in the cotton ecosystem are *Coccinella* spp., *Harmonia* spp. and *Cheilomenes sexmaculata* (Fab.). These predatory insects play an important role in keeping the sucking insect pest population under check. But, indiscriminate use of chemical insecticides adversely affects the beneficial insects and spiders' population too. It is therefore necessary to assess the neonicotinoid insecticides for their relative bio-efficacy on sucking insect pests and safety to ecosystem and natural enemies.

MATERIALS AND METHODS

Five neonicotinoids were evaluated in farmers' fields in two villages *viz.,* Salai in Villupuram district, and Mambattu Village in, Chengalpattu district of Tamil Nadu during 2015 and 2016.

A total of seven treatments including a standard check and control were imposed in the trials at farmers' fields (Table 1). Following insecticide doses were selected for controlling Bt cotton sucking insect pests *viz*., aphids and jassids.

Experiments were laid in Randomized Block Design (RBD), with each treatment replicated thrice and the pre- and post-treatment counts were taken as per the standard methodologies adopted by earlier workers. Each plot size was 25 m^2 (5 m x 5 m). Treatments were initiated when the pest population exceeded ETL. Pre-treatment count was taken a day before the spray and post-treatment counts were taken on 1, 3, 7 and 14 days after spray. Second spray was given on 15th day after first spray and counts were taken 1, 3, 7 and 14 days after second spray.

Natural enemies' population, predatory coccinellid grubs and adults were recorded from all the treated and control plots in Bt cotton ecosystem. Coccinellid beetles observed in the cotton ecosystem were *Coccinella* spp., *Harmonia* sp., *Illeis cincta*, *Anegleis cardoni* and *Cheilomenes sexmaculata.* To determine the impact of habitat manipulation on natural enemies, their presence on ten tagged plants from each plot were recorded. In case of coccinellids, grubs and adults present on tagged plants were counted. After spraying the post treatment count was made on 1st, 3rd, 7th and 14th day after each spray were recorded to assess the safety to coccinellids. Pre-treatment count was taken, 24 hours before spraying.

The coccinellid counts in the field experiments were transformed in to square root value as per the standard requisites (Gomez and Gomez, 1984). The analysis of variance in different experiments was carried out in AGRES ver. 7.01.

Table 1. Details of treatments used in the study

Treatments	Dose (gm ai/ha)	Formulation (gm or ml/ha)	Dilution in water (L/ha)
T1 – Imidacloprid 17.8% SL	25	140	500
T2 – Acetamiprid 20% SP	10	50	500
T3 – Thiacloprid 21.7% SC	30	140	500
T4 – Thiamethoxam 25% WG	25	100	500
T5 – Clothianidin 50% WDG	20	40	500
T6 – Monocrotophos 36% SL	175	500	500
T7 – Untreated Check	-	-	

Reduction over Control (ROC)

The per cent reduction in population of insect pests and natural enemies' vis-à-vis control was computed using the method described by Henderson and Tilton, 1955.

$$\text{Per cent reduction in population} = 100 \times \left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Where, Ta = Number of insects after treatment
Tb = Number of insects before treatment
Ca = Number of insects in untreated check after treatment
Cb = Number of insects in untreated check before treatment

RESULTS AND DISCUSSION

Pre-treatment count of coccinellid population did not vary significantly among the treatments. There was a significant reduction in coccinellid population count in both neonicotinoids and monocrotophos treated plots compared to the control plots, 1, 3, 7 and 14 days after spraying. The result showed that pre-treatment population of coccinellids, among different treatments, varied from 5.67 to 6.57 per 10 plants and 7.60 to 9.17 per 10 plants during 2015 and 2016 (Table 1 and 2) in Mambattu village. The observations revealed that after 2 sprays, the highest population was recorded from control plot. The neonicotinoid group of insecticides *viz*., imidacloprid, acetamiprid, thiacloprid, thiamethoxam and clothianidin, decreased the coccinellid population on the first day and third day after spraying. But, the coccinellid population has slowly built-up after 7 days after spraying. At 14 days after spraying, the lowest coccinellid population per 10 plants was recorded from monocrotophos treated plots during both the years (2.67 and 3.30). Among neonicotinoids, clothianidin treated plot, recorded the lowest coccinellid population per plants (3.57 and 4.24) followed by thiamethoxam (4.33 and 5.00). Acetamiprid treated plots recorded the highest coccinellid population (5.7 and 6.6) followed by imidacloprid (5.3 and 6.27) (Table 1 and 2).

Data from Fig. 1 indicated the mean reduction percentages of coccinellids (grubs and adults) caused by imidacloprid, acetamiprid, thiacloprid, thiamethoxam, clothianidin and monocrotophos, during 2015 and 2016 in Mambattu village. The data clearly shows that the coccinellid population reduced during 1 and 3 days after spraying and the population bounced back during 7 and 14 days after spraying. The population reduction percentages of coccinellids were 30.8, 24.7, 39.7, 47.1, 54.7 and 62.7 respectively, at 14 days after spraying. At 1, 3, 7 and 14 days after treatment, monocrotophos recorded maximum population reduction of coccinellids. At 1, 3, 7 and 14 days after treatment, monocrotophos recorded maximum population reduction of 78.8, 83.5, 70.4 and 62.6% respectively. Among neonicotinoids, clothionidin was found

Table 2. Effect of neonicotinoids on coccinellids - Mambattu village - First Season

Treatments	PTC	No. of coccinellids/ 10 plants							
		First spray				Second spray			
		1DAS	3DAS	7DAS	14DAS	1DAS	3DAS	7DAS	14DAS
T1	6.00 (2.45)	3.37 (1.84)	3.00 (1.73)	4.07 (2.02)	4.67 (2.16)	3.47 (1.86)	3.23 (1.80)	4.67 (2.16)	5.30 (2.30)
T2	6.57 (2.56)	3.63 (1.91)	3.43 (1.85)	4.43 (2.10)	5.23 (2.29)	4.00 (2.00)	3.57 (1.89)	5.13 (2.26)	5.70 (2.39)
T3	6.33 (2.52)	3.00 (1.73)	2.67 (1.63)	3.83 (1.96)	4.43 (2.10)	2.93 (1.71)	2.80 (1.67)	4.10 (2.02)	4.87 (2.21)
T4	6.23 (2.50)	2.37 (1.54)	2.40 (1.55)	3.23 (1.80)	4.00 (2.00)	2.33 (1.53)	2.23 (1.49)	3.67 (1.92)	4.33 (2.08)
T5	5.97 (2.44)	2.00 (1.41)	2.13 (1.46)	2.57 (1.60)	3.27 (1.81)	2.07 (1.44)	1.77 (1.33)	2.83 (1.68)	3.57 (1.89)
T6	5.67 (2.38)	1.23 (1.11)	1.10 (1.05)	1.57 (1.25)	2.33 (1.53)	1.47 (1.21)	1.33 (1.15)	2.07 (1.44)	2.67 (1.63)
T7	6.53 (2.56)	6.47 (2.54)	6.70 (2.59)	6.23 (2.50)	7.10 (2.66)	7.00 (2.65)	7.27 (2.70)	7.70 (2.77)	7.43 (2.73)
SEd	**NS**	**0.015**	**0.016**	**0.011**	**0.019**	**0.013**	**0.011**	**0.016**	**0.017**
CD(.05)		**0.031**	**0.035**	**0.023**	**0.041**	**0.028**	**0.022**	**0.033**	**0.036**

Figures in parentheses are square root transformed values.
PTC – Pre Treatment Count DAS – Days after spray

Table 3. Effect of neonicotinoids on coccinellids - Mambattu village - Second Season

reatments	PTC	No. of coccinellids per 10 plants							
		First spray				Second spray			
		1DAS	3DAS	7DAS	14DAS	1DAS	3DAS	7DAS	14DAS
T1	8.33 (2.89)	4.00 (2.00)	3.40 (1.84)	4.13 (2.03)	5.57 (2.36)	3.57 (1.89)	3.13 (1.77)	5.00 (2.24)	6.27 (2.50)
T2	7.60 (2.76)	4.57 (2.14)	3.73 (1.93)	4.80 (2.19)	6.23 (2.50)	4.33 (2.08))	4.00 (2.00)	5.43 (2.33)	6.60 (2.57)
T3	8.70 (2.95)	3.43 (1.85)	2.67 (1.63)	4.20 (2.05)	5.00 (2.24)	3.10 (1.76)	2.83 (1.68)	4.33 (2.08)	5.57 (2.36)
T4	9.17 (3.03)	3.10 (1.76)	2.33 (1.53)	3.70 (1.92)	4.33 (2.08)	1.70 (1.30)	2.27 (1.51)	3.73 (1.93)	5.00 (2.24)
T5	9.10 (3.02)	2.33 (1.53)	1.90 (1.38)	3.47 (1.86)	3.70 (1.92)	2.40 (1.55)	1.67 (1.29)	3.40 (1.84)	4.24 (2.06)
T6	8.00 (2.83)	1.47 (1.21)	1.30 (1.14)	2.33 (1.53)	2.93 (1.71)	1.97 (1.40)	1.20 (1.10)	3.00 (1.73)	3.30 (1.82)
T7	8.60 (2.93)	9.13 (3.02)	10.30 (3.21)	9.40 (3.07)	9.47 (3.08)	10.00 (3.16)	10.27 (3.20)	10.30 (3.21)	9.67 (3.11)
SEd	**NS**	**0.016**	**0.011**	**0.042**	**0.015**	**0.013**	**0.013**	**0.017**	**0.018**
CD(.05)		**0.034**	**0.022**	**0.088**	**0.032**	**0.027**	**0.026**	**0.035**	**0.038**

Figures in parentheses are square root transformed values.
PTC – Pre Treatment Count DAS – Days after spray

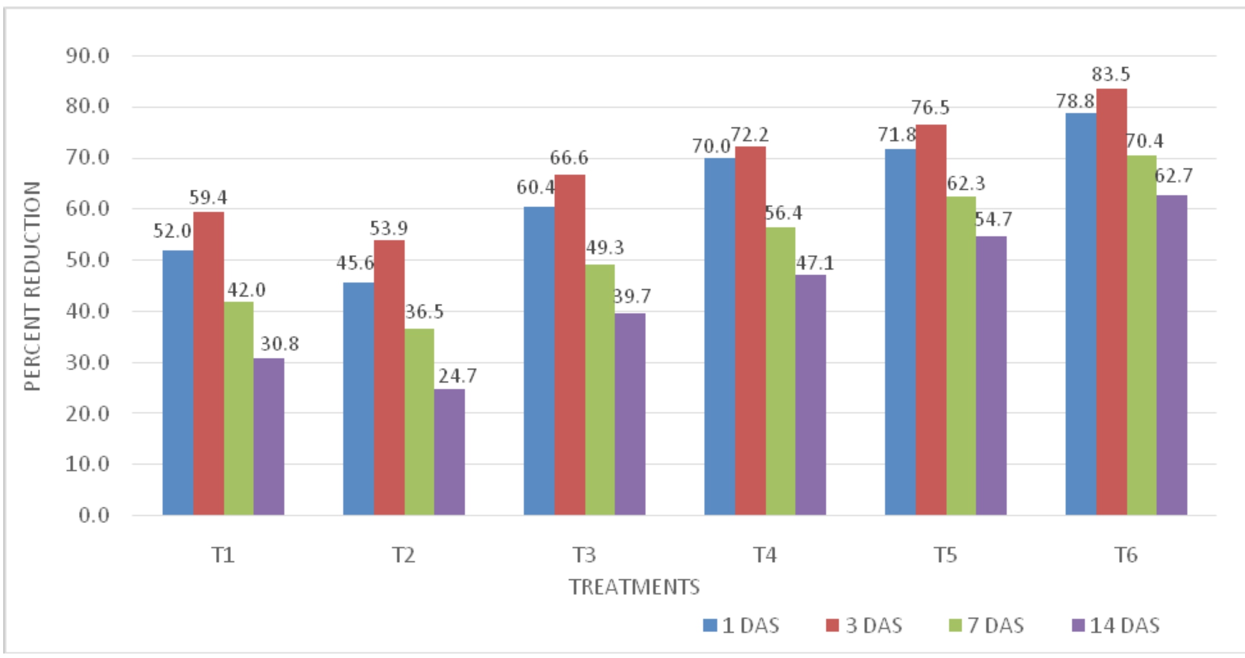

Fig. 1. Percent reduction of coccinellids - average of two seasons - Mambattu village.

Table 4. Effect of neonicotinoids on coccinellids - Salai village - First season

Treat-ments	PTC	No. of coccinellids per 10 plants							
		First spray				Second spray			
		1DAS	3DAS	7DAS	14DAS	1DAS	3DAS	7DAS	14DAS
T1	7.00 (2.65)	4.33 (2.08)	3.67 (1.92)	4.57 (2.14)	5.27 (2.30)	4.00 (2.00)	3.50 (1.87)	4.67 (2.16)	5.90 (2.43)
T2	7.33 (2.71)	4.40 (2.10)	4.10 (2.02)	5.00 (2.24)	5.90 (2.43)	4.10 (2.02)	3.87 (1.97)	5.33 (2.31)	6.17 (2.48)
T3	7.70 (2.77)	4.10 (2.02)	3.33 (1.82)	4.40 (2.10)	5.03 (2.24)	3.67 (1.92)	3.27 (1.81)	4.20 (2.05)	5.20 (2.28)
T4	7.83 (2.80)	3.67 (1.92)	3.07 (1.75)	4.00 (2.00)	4.77 (2.18)	3.43 (1.85)	2.97 (1.72)	4.23 (2.06)	4.80 (2.19)
T5	6.67 (2.58)	3.00 (1.73)	2.40 (1.55)	3.33 (1.82)	3.63 (1.91)	2.47 (1.57)	2.33 (1.53)	3.40 (1.84)	4.33 (2.08)
T6	7.13 (2.67)	2.40 (1.55)	2.00 (1.41)	2.67 (1.63)	3.40 (1.84)	2.10 (1.45)	1.93 (1.39)	2.77 (1.66)	3.73 (1.93)
T7	7.43 (2.73)	8.33 (2.89)	9.60 (3.10)	9.00 (3.00)	9.33 (3.05)	9.67 (3.11)	10.10 (3.18)	10.53 (3.24)	10.00 (3.16)
SEd	**NS**	**0.006**	**0.012**	**0.018**	**0.010**	**0,015**	**0.009**	**0.014**	**0.018**
CD(.05)		**0.012**	**0.025**	**0.039**	**0.022**	**0.031**	**0.018**	**0.030**	**0.038**

Figures in parentheses are square root transformed values.
PTC – Pre Treatment Count DAS – Days after spray

Table 5. Effect of neonicotinoids on coccinellids - Salai village – Second season

Treatments	PTC	No. of coccinellids/10 plants							
		First spray				Second spray			
		1DAS	3DAS	7DAS	14DAS	1DAS	3DAS	7DAS	14DAS
T1	7.37 (2.71)	4.13 (2.03)	3.47 (1.86)	4.50 (2.12)	5.13 (2.26)	3.70 (1.92)	3.33 (1.82)	4.80 (2.19)	5.63 (2.37)
T2	6.10 (2.47)	4.67 (2.16)	3.93 (1.98)	5.20 (2.28)	5.73 (2.39)	4.33 (2.08)	3.67 (1.92)	5.30 (2.30)	6.20 (2.49)
T3	5.43 (2.33)	3.70 (1.92)	3.20 (1.79)	4.33 (2.08)	4.67 (2.16)	3.43 (1.85)	3.00 (1.73)	3.80 (1.95)	4.77 (2.18)
T4	7.00 (2.65)	3.40 (1.84)	3.00 (1.73)	3.67 (1.92)	4.33 (2.08)	3.10 (1.76)	2.67 (1.63)	4.00 (2.00)	4.57 (2.14)
T5	5.67 (2.38)	2.67 (1.63)	2.30 (1.52)	3.00 (1.73)	3.50 (1.87)	2.43 (1.56)	2.10 (1.45)	3.27 (1.81)	4.00 (2.00)
T6	6.53 (2.56)	2.10 (1.45)	1.57 (1.25)	2.33 (1.53)	3.07 (1.75)	1.77 (1.33)	1.73 (1.32)	2.50 (1.58)	3.43 (1.85)
T7	6.20 (2.49)	6.47 (2.54)	7.00 (2.65)	7.23 (2.69)	7.70 (2.77)	7.93 (2.82)	8.03 (2.83)	7.67 (2.77)	7.50 (2.74)
SEd	**NS**	**0.016**	**0.015**	**0.017**	**0.013**	**0.008**	**0.008**	**0.018**	**0.015**
CD(.05)		**0.033**	**0.031**	**0.036**	**0.027**	**0.017**	**0.017**	**0.037**	**0.032**

Figures in parentheses are square root transformed values.
PTC – Pre Treatment Count DAS – Days after spray

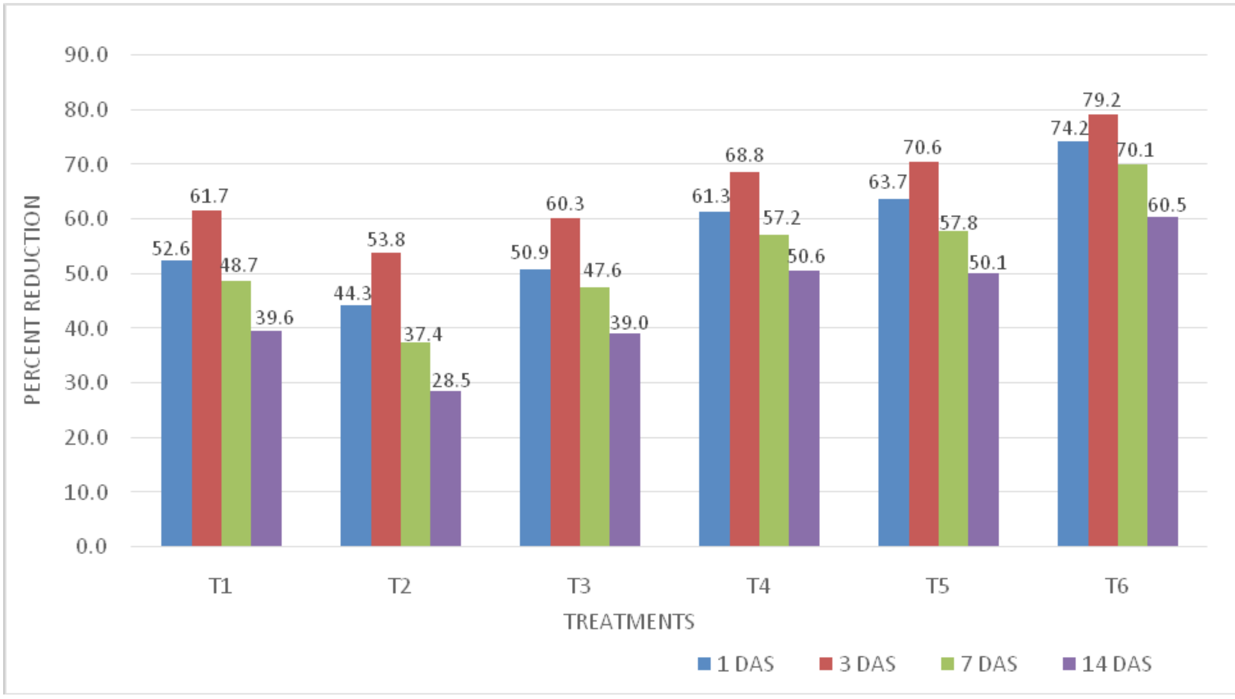

Fig. 2. Percent reduction of coccinellids - average of two seasons - Salai village.

to be comparatively more toxic to coccinellids, followed by thiamethoxam and thiacloprid. Acetamiprid was found to be safest among chemical treatments with population reduction percentages of 45.6, 53.9, 36.5 and 24.7% respectively, at 1, 3, 7 and 14 days after treatment followed by imidacloprid.

The results of the field studies at Salai village showed that pre-treatment population of coccinellids, among different treatments, varied from 6.67 to 7.83 per 10 plants and 5.43 to 7.37 per 10 plants during 2015 and 2016 (Table 3 and 4). The observations revealed that after 2 sprays, the highest population was recorded from control plot. The neonicotinoid group of insecticides *viz*., imidacloprid, acetamiprid, thiacloprid, thiamethoxam and clothianidin, decreased the coccinellid population on the first day and third day after spraying. But, the coccinellid population has slowly built-up after 7 days after spraying. The lowest coccinellid population per 10 plants was recorded from monocrotophos treated plots during both the years (3.73 and 3.43) at 14 days after spraying. Among neonicotinoids, clothianidin treated plot, recorded the lowest coccinellid population per plants (4.33 and 4.00) followed by thiamethoxam (4.80 and 4.57). Acetamiprid treated plots recorded the highest coccinellid population (6.17 and 6.2) followed by imidacloprid (5.9 and 5.63) (Table 3 and 4). Reduction in the population of coccinellids was observed immediately after the application of insecticides. Though there was an initial setback in the population, it started increasing gradually after 7 days after spraying. However, the population was found to be less than untreated check in all the insecticide treated plots.

Data from Fig. 2 indicated the mean reduction percentages of coccinellids (grubs and adults) caused by imidacloprid, acetamiprid, thiacloprid, thiamethoxam, clothianidin and monocrotophos, during 2015 and 2016 in Salai village. The data clearly shows that the coccinellid population reduced during 1 and 3 days after spraying and the population bounced back during 7 and 14 days after spraying. The population reduction percentages of coccinellids were 30.8, 24.7, 39.7, 47.1, 54.7 and 62.7 respectively, at 14 days after spraying. At 1, 3, 7 and 14 days after treatment, monocrotophos recorded maximum population reduction of 74.2, 79.2, 70.1 and 60.5 respectively. Among neonicotinoids, clothianidin was found to be comparatively more toxic to coccinellids, followed by thiamethoxam and thiacloprid. Acetamiprid was found to be safest among chemical treatments with population reduction percentages of 44.3, 53.8, 37.4 and 28.5% respectively at 1, 3, 7 and 14 days after treatment followed by imidacloprid.

Two rounds of spray of neonicotinoids on Bt cotton had significant impact on the *Coccinellid*s (grubs and adults), when compared with untreated control plots. However, monocrotophos recorded relatively lowest population of coccinellids compared to untreated control and neonicotinoids. The result showed that monocrotophos was toxic to coccinellids. The side effects of neonicotinoids against non-target insects especially predators has been demonstrated in the tests under laboratory conditions (Mizell and Sconyers, 1992; Awasthi *et al*., 2013). The results of a field study have also reported less toxicity of these insecticides for a variety of predators (Mensah, 2002).

The non-selective organophosphate insecticides can bring serious problems of reduction in the population of beneficial insects on the crops all over the world. Hence, in order to preserve natural enemies, selective insecticides, relatively compatible with biocontrol agents should be available to include in the programs of Integrated Pest Management (IPM) (Fernandes *et al*., 2010). With significant population built-up after 7 days after acetamiprid and imidacloprid sprays, the present studies have shown that these two neonicotinoids may be suitable candidates for inclusion in Integrated Pest Management of sucking insect pests in major Bt cotton growing areas because these have proved comparatively less toxic to predators as compared to broad spectrum neonicotinoids like thiacloprid, thiamethoxam and clothianidin and non-selective, broad spectrum organophosphate insecticide like monocrotophos.

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