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Efficacy of thiamethoxam against whitefly, *Bemisia tabaci* (Gennadius) under open field conditions in okra

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ABSTRACT: A field experiment was conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India during the summer season, 2021-22 to evaluate a neonicotinoid, thiamethoxam against whitefly, *Bemisia tabaci* (Gennadius) along with other new molecules. Among the various doses of foliar application thiamethoxam, sprayed twice at an interval of 10 days on okra, resulted in 87-90 per cent reduction over untreated control. Seed treatment with thiamethoxam 30% FS formulation was also effective against *B. tabaci* upto 45 days from seed treatment. Foliar application of thiamethoxam (50 g a.i. per ha) gave highest yield and ICBR ratio and it was in line with the appliaction of thiamethoxam 37.5 and 25 g a.i. per ha. All the tested insecticide formulations were found to be safe for coccinellid beetles, except dimethoate 30 EC @ 600 g a.i. / ha, which have negative effect on coccinellid beetles as recorded in the okra ecosystem in comparison to the higher dose of thiamethoxam 25 WG (double dose @ 50 g a.i. ha^{-1}). Results also showed that none of the insecticide formulations had phytotoxicity effect in okra ecosystem.

Keywords: Okra, thiamethoxam, field bioefficacy, *B. tabaci*, phytotoxicity coccinellids beetle, phytotoxicity

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench, belongs to the Malvaceae family and is commonly known as lady's finger. In various tropical countries, okra is one of the most widely grown vegetables. India is the world's largest okra producer, and its contribution to okra production is 72.9 per cent globally. In India, it is cultivated on 531 thousand hectares and has an annual production of 6466 thousand metric tonnes and a productivity of nearly 12.2 metric tonnes ha^{-1}. In Bihar, it is cultivated on 59.20 thousand hectares, with annual production of 794.10 thousand metric tonnes and a productivity of nearly 13.72 metric tonnes ha^{-1} (Anonymous, 2022). Different kinds of biotic and abiotic factors reduce okra yield. Biotic factors is considered to be major constraints on okra yield. Okra crop is infested by more than 37 species of insect pests, from seedlings to fruiting stage like sucking insect pests *viz.,* leaf hopper, *Amrasca biguttula biguttula* Ishida, whitefly, *Bemisia tabaci* (Gennadius), spider mites, *Tetranychus cinnabarinus* Boisduval, aphids, *Aphis gossypii* (Glover), yellow thrips, *Scirtothrips dorsalis* Hood and the borers, *i.e.,* fruit borer, *Helicoverpa armigera* (Hubner), and shoot and fruit borer, *Earias vittela* and *E. insulana* (Fabricius). In okra crops, sucking insect pests like whiteflies, leafhoppers, aphids, and thrips are the most prevalent. During the early stages of the crop, whitefly desap the plants, make them weak, and reduces yield by 54.04 per cent (Chaudhary and Dadeech, 1989).

Insecticidal sprays are frequently used to manage these destructive sucking pest, but this has resulted in toxic residues, the eradication of natural enemies, environmental disruption, and the emergence of resistance. In order to meet these problems, insecticides from a more recent generation have lower toxicity toward non-target species, stronger efficacy against the pests they are intended to control, and are not as tenacious as earlier insecticides. The study on new formulation of neonicotinoid insectcides lacks bioefficacy, phytotoxicity, and safety towards coccinellid beetles. Chemical management is the most effective strategy since the okra whitefly multiplies and spreads quickly in a short amount of time under favourable climatic circumstances. In light of this, the current interpretation was employed to analyze thiamethoxam's field evaluation against whitefly, *B. tabaci* in okra ecocsytem under North Bihar conditions.

Table 1. Efficacy of selected insecticide formulations used in okra for the management of whitefly, *Bemisia tabaci* (Gennadius) during summer season in 2021-2022

Treatments	Mean number of whiteflies/three leaves/plants – I spray: 34 DAS	38 DAS	42 DAS	45 DAS	Reduction over untreated control (%)	Mean number of whiteflies/three leaves/plants – II spray: 45 DAS	48 DAS	52 DAS	55 DAS	Reduction over untreated control (%)	Overall reduction over untreated control (%)
Seed treatment											
Thiamethoxam 30.00 % FS @ 1.7 g a.i. /kg of seed	7.67 (2.86)^{bc}	8.33 (2.97)^{b}	9.33 (3.13)^{b}	12.67 (3.63)^{b}	44.84	12.67 (3.63)^{b}	14.33 (3.85)^{b}	17.00 (4.18)^{b}	18.33 (4.34)^{b}	26.95	34.97
Thiamethoxam 30.00 %FS @ 2.55 g a.i./kg of seed	6.40 (2.63)^{c}	7.74 (2.86)^{bc}	8.74 (3.04)^{b}	12.07 (3.55)^{b}	48.11	12.07 (3.55)^{b}	14.07 (3.81)^{b}	15.40 (3.99)^{b}	16.40 (4.11)^{b}	32.55	39.51
Thiamethoxam 30.00 % FS @ 3.4 g a.i. /kg of seed	6.00 (2.55)^{c}	7.33 (2.80)^{bc}	8.67 (3.03)^{b}	10.33 (3.29)^{b}	52.10	10.33 (3.29)^{b}	13.33 (3.71)^{b}	14.67 (3.89)^{b}	16.00 (4.05)^{b}	35.28	42.82
Foliar spray											
-	1DBT	3 DAT	7 DAT	10 DAT	-	1 DBT	3 DAT	7 DAT	10 DAT	-	-
Thiamethoxam 25 WG @ 25 g a.i. / ha.	14.47 (3.85)^{a}	5.80 (2.50)^{bc}	2.13 (1.62)^{c}	3.13 (1.89)^{cd}	79.86	3.13 (1.89)^{cd}	2.10 (1.61)^{cd}	1.13 (1.27)^{c}	0.80 (1.12)^{c}	94.04	87.70
Thiamethoxam 25 WG @ 37.5 g a.i. / ha.	13.66 (3.74)^{ab}	5.66 (2.48)^{bc}	1.99 (1.57)^{c}	2.66 (1.78)^{cd}	81.28	2.66 (1.78)^{cd}	1.96 (1.56)^{cd}	0.99 (1.20)^{c}	0.66 (1.07)^{c}	94.66	88.68
Thiamethoxam 25 WG @ 50 g a.i. / ha.	13.15 (3.65)^{ab}	4.82 (2.30)^{c}	1.82 (1.42)^{c}	2.49 (1.73)^{d}	83.41	2.49 (1.73)^{c}	1.79 (1.50)^{d}	0.82 (1.14)^{c}	0.49 (0.99)^{c}	95.41	90.04
Pyriproxyfen 10 EC @ 50 g a.i. / ha.	13.65 (3.76)^{ab}	7.32 (2.79)^{bc}	3.32 (1.95)^{c}	4.98 (2.33)^{c}	71.57	4.98 (2.33)^{c}	3.98 (2.11)^{c}	1.98 (1.57)^{c}	1.65 (1.47)^{c}	88.79	81.12
Imidacloprid 17.80 SL @ 20 g a.i. / ha.	15.01 (3.94)^{a}	6.34 (2.61)^{bc}	2.34 (1.62)^{c}	3.34 (1.96)^{cd}	78.12	3.34 (1.96)^{cd}	2.31 (1.66)^{cd}	1.21 (1.30)^{c}	0.87 (1.16)^{c}	93.51	86.63
Dimethoate 30 EC @ 600 g a.i. / ha.	15.86 (4.04)^{a}	6.86 (2.70)^{bc}	2.86 (1.83)^{c}	3.86 (2.06)^{cd}	75.28	3.86 (2.06)^{cd}	3.20 (1.92)^{cd}	1.86 (1.52)^{c}	1.53 (1.42)^{c}	90.29	83.60
Untreated control (Water spray)	14.89 (3.92)^{a}	16.22 (4.09)^{a}	18.89 (4.40)^{a}	19.89 (4.52)^{a}	-	19.89 (4.52)^{a}	20.55 (4.59)^{a}	23.22 (4.87)^{a}	24.22 (4.97)^{a}	-	-
F value	*	*	*	*	-	*	*	*	*	-	-
SEM±	0.19	0.12	0.19	0.11	-	0.11	0.11	0.10	0.11	-	-
CD (P=0.05)	0.58	0.37	0.55	0.33	-	0.33	0.34	0.30	0.30	-	-
CV%	9.64	7.65	13.61	7.30	-	7.30	7.44	7.07	7.74	-	-

*Significant at (P≤0.05); Figures within the parentheses indicates $\sqrt{x+0.5}$ transformed values; Mean followed by the same letter do not differ significantly by TUKEY test (P=0.05)

DAS= Day after sowing DBT= Day before treatment DAT= Day after treatment

MATERIALS AND METHODS

Field experiment

An open field experiment was conducted at RPCAU, Pusa, Samastipur (25.98 °E longitude; 85.68 °N latitude), Bihar, India in a Randomized Block Design (RBD) to evaluate thiamethoxam's field effectiveness against whitefly, *B. tabaci* in okra crop under North Bihar conditions during *summer* season of 2021-22 with ten treatments *viz.,* T_1) thiamethoxam 30% FS @ 1.7 g a.i. /kg of seed; T_2) thiamethoxam 30%FS @ 2.55 g a.i./kg of seed; T_3) thiamethoxam 30 % FS @ 3.4 g a.i. /kg of seed; T_4) thiamethoxam 25 WG @ 25 g a.i. / ha; T_5) thiamethoxam 25% WG @ 37.50 g a.i. per ha; T_6) thiamethoxam 25% WG @ 50 g a.i. per ha; T_7) pyriproxyfen 10 EC @ 50 g a.i. / ha; T_8) imidacloprid 17.80 SL @ 20 g a.i. / ha; T_9) dimethoate 30 % EC @ 600 g a.i per ha (standard check); T_{10}) untreated control (water spray). Each treatment is having an area of 6 x 5 m^2 with three replications. Sowing of the okra crop (var. Kashi kranti) was sown in March, 2022 according to the standard recommended agronomic practices. Spray solution was calculated with 500 litre of water for one spray for one hectare and in total, two sprays were given with a gap of 10 days. The first application was given when the pest population reached at Economic Threshold Level (ETL). Spraying was done using a knapsack sprayer.

Bioefficacy against *B. tabaci*

For identification of the okra whitefly, five plants were chosen randomly and tagged. The population of nymphs and adults of whitefly were counted from three leaves per plant, one from the top, middle, and bottom of those plants that were pre-selected. The sightings were identified as pretreatment count (1 day prior to treatment) and post treatment observations on the whitefly population at 3, 7, and 10 days after each spray. In case of seed treatments the whitefly population was recorded at 34 days after sowing in each seed treated plot. For each treatment, after every spray, the percentage reduction (PR) of whiteflies over the untreated control was computed using the given formula PR = [(control count-treatment count/ control count)] × 100. Marketable okra fruit yields per treatment were tallied at each harvest, combined, and expressed in kg ha^{-1}. Using the following formula, the yield was converted to a ha^{-1} basis *i.e.,* yield (kg ha^{-1}) = [(yield per plot (kg)/plot size (m^2)] × 10000 then it was analyzed statistically. To combat okra whitefly, the ICBR (Incremental Cost Benefit Ratio) of several treatments was computed.

Safety evaluation of coccinellid beetles

The safety evaluation of several insecticide formulations on coccinellid beetles in okra was also investigated. In each plot, ten plants were randomly chosen one day before treatment, then 3, 7, and, 10 days following after each application. Later the observed result was analyzed statistically.

Phytotoxicity in the okra ecosystem

The phytotoxic effects of different formulations of insecticides on okra leaves, flowers, and fruits were also studied. Five plants were randomly selected in each plot. The plants were examined for phytotoxic symptoms *viz.,* necrosis, epinasty, hyponasty, chlorosis, and wilting one day before spraying, 3, 7, and 10 days after each application. The per cent leaf injury was calculated by using the following equation *i.e.,* % leaf injury = [(total grade point/maximum grade × no. of leaves observed)] ×100. The phytotoxicity symptoms were graded based on the per cent injured leaves as per the Central Insecticides Board and Registration Committee's (CIB & RC, India) grade scale *viz.,* no. phytotoxicity grade 0; 1-10% - grade 1; 11-20% - grade 2; 21-30% - grade 3; 31-40% - grade 4; 41-50% - grade 5; 51-60% - grade 6; 61-70% - grade 7; 71-80% - grade 8; 81-90% - grade 9; 91-100% - grade 10.

Statistical analysis

The data on the okra whitefly population and coccinellid beetles in different treatments were subjected to Analysis of Variance (ANOVA) following Randomized Block Design (RBD) using the statistical software SPSS. TUKEY test was used to compare the mean differences between the treatments at 5% level of significance.

RESULTS AND DISCUSSION

Bioefficacy of selected insecticide formulations against *B. tabaci*

The incidence of okra whitefly, before and after two spray of insecticidal treatments in 2021-22 are illustrated in Table 1. The nymphs and adults mean population of whitefly prior to spraying was ranged in 7.67 to 14.98 per three leaves/plants. After the first insecticidal application, whitefly population was significantly reduced in all the treated plots, but augmented in control plots. Three days after 1st application of insecticides spray, results showed that the thiamethoxam (50 g a.i. per ha) treated plot had the least mean whitefly population (4.82) followed by thiamethoxam at 37.5 g a.i. per ha (5.66), thiamethoxam at 25 g a.i. per ha (5.80), imidacloprid 17.80 SL @ 20 g a.i. / ha (6.34), and dimethoate 30 EC

Table 2. Economics of selected insecticide formulations used in okra for the management of whitefly, *Bemisia tabaci* (Gennadius) during summer season in 2021-22

Treatments	Yield (kg ha^{-1})	ICBR
Thiamethoxam 30.00 % FS @ 1.7 g a.i. /kg of seed	8168	1:2.69
Thiamethoxam 30.00 %FS @ 2.55 g a.i./kg of seed	8184	1:2.83
Thiamethoxam 30.00 % FS @ 3.4 g a.i. /kg of seed	8197	1:2.93
Thiamethoxam 25 WG @ 25 g a.i. / ha.	8261	1:3.89
Thiamethoxam 25 WG @ 37.5 g a.i. / ha.	8282	1:3.97
Thiamethoxam 25 WG @ 50 g a.i. / ha.	8310	1:4.14
Pyriproxyfen 10 EC @ 50 g a.i. / ha.	8234	1:2.35
Imidacloprid 17.80 SL @ 20 g a.i. / ha.	8253	1:3.73
Dimethoate 30 EC @ 600 g a.i. / ha.	8242	1:1.24
Untreated control (Water spray)	7919	

@ 600 g a.i. / ha (6.86). Comparatively less effective treatments were pyriproxyfen 10 EC @ 50 g a.i. / ha (7.32). Seven days after 1st spray application, again least mean whitefly population was recorded per treatement at three diffrerent dose of thiamethoxam 50, 37.5 and 25 g a.i. per ha were1.82, 1.99, and 2.13, respectively. Furthermore, followed by imidacloprid 17.80 SL @ 20 g a.i. / ha (2.34), dimethoate 30 EC @ 600 g a.i. / ha (2.86) and pyriproxyfen 10 EC @ 50 g a.i. / ha (3.32). After ten days of 1st spray, the population of whitefly started increasing in comparison to 7 days in all the treatments.

Three days after 2nd application of insecticides spray, it was noticed that the whitefly population was least in thiamethoxam at 50 and 37.5 g a.i per ha *i.e.,* 1.79 and 1.96 and followed by thiamethoxam at 25g a.i per ha (2.10), imidacloprid at 20 g a.i. / ha (2.31), and dimethoate at 600 g a.i. / ha (3.20) which was statistically at par. Comparatively less effective treatments were pyriproxyfen at 50 g a.i. / ha (3.98). Seven days after 2nd spray application, it was reflected in line with the one-day post-application in terms of efficacy, again thiamethoxam at 50 g a.i per ha (0.82) showed a significant reduction in whitefly population followed by thiamethoxam at 37.5 g a.i per ha (0.99), thiamethoxam at 25g a.i per ha (1.13), imidacloprid at 20 g a.i. / ha (1.21), and dimethoate at 600 g a.i. / ha (1.86). Again the comparatively less effective treatments were pyriproxyfen at 50 g a.i. / ha (1.98). Ten days after the 2nd spray post-appliance, the same trend was followed. In case of seed treatements, thiamethoxam 30% FS @ 1.7 g a.i. /kg of seed, thiamethoxam 30 %FS @ 2.55 g a.i./ kg of seed, and Thiamethoxam 30% FS @ 3.4 g a.i. /kg of seed were effective upto 45 days after sowing, then the population of whitefly gradually increased in all the treatemets over untreated control. Hence, the order of efficacy of these treatments were T_{6-} thiamethoxam 25 WG @ 50 g a.i. per ha > T_5 -thiamethoxam 25 WG @ 37.5 g a.i. per ha > T_6 - thiamethoxam 25 WG @ 25 g a.i. per ha > T_8 - imidacloprid 17.80 SL @ 20 g a.i. / ha > T_9 - Dimethoate 30 EC @ 600 g a.i. per ha > T_9 - pyriproxyfen 10 EC @ 50 g a.i. / ha > T_3 - thiamethoxam 30 % FS @ 1.7 g a.i. /kg of seed > T_2 - thiamethoxam 30%FS @ 2.55 g a.i./kg of seed > T_1 - thiamethoxam 30% FS @ 3.4 g a.i. /kg of seed.

The current findings correspond closely to those of (Ghosal and Chatterjee, 2013), who found that imidacloprid (17.8 SL), thiamethoxam (25 WG), and oxydemeton methyl (25 EC) were applied to brinjal in decreasing order. According to Ghosal *et al.,* 2013), imidacloprid 17.8 SL was the most efficient neonicotinoids pesticide against aphids, with a population reduction of 84.54% compared to control. In addition to being found at par with imidacloprid, the other two neonicotinoids, thiamethoxam 25 WG (84.36%) and acetamiprid 20 SP (84.25%), also performed better than acephate 75 WP (76.38%) and dimethoate 30 EC (73.53%). (Berwa *et al.,* 2017) reported that imidacloprid 17.8% SL (35.6 g a.i./ha) treatments were significantly effective against the jassids, *Amrasca biguttula biguttula* (Ishida), aphid, *Aphis gossypii* Glover, and whitefly, *Bemisia tabaci* (Gennadius) as it recorded the lowest population. The cumulative effect of foliar spraying with thiamethoxam 25 WG @ 0.006% was shown to be the most efficient against aphids among the treatments evaluated according to Patil *et al.* (2014). Lambda cyhalothrin 5 EC @ 0.004% was ranked second. Karthik *et al.* (2020) evaluated thiamethoxam 25% WG 25 g a.i. ha^{-1} (84.71-91.73, 94.12 - 98.11% reduction over control was highly effective against aphid, whitefly, and leaf hoppers which was on par with 50 g a.i. ha^{-1} (64.28 - 76.90, 83.70 – 87.92 % reduction over control) and 75 g a.i. ha^{-1} (73.48 - 81.26 and 85.26 - 92.42% reduction over control) after first and second spray, respectively. Imidacloprid was the next best effective control against arecanut whitefly and scale insects (Dubey *et al.,* 2020).

able 3. Safety evaluation of selected insecticide formulations against coccinellids in okra (summer 2021-22)

Treatments	Mean number of coccinellids/ten plants – I spray 34 DAS	38 DAS	42 DAS	45 DAS	Mean	Mean number of coccinellids/ten plants – II spray 45 DAS	48 DAS	52 DAS	55 DAS	Mean	Overall mean
Seed treatment											
Thiamethoxam 30.00 % FS @ 1.7 g a.i. /kg of seed	4.20 (2.13)^{ab}	4.87 (2.31)^{b}	5.20 (2.39)^{bc}	6.53 (2.64)^{a}	5.53 (2.45)^{cd}	6.53 (2.64)^{a}	7.20 (2.77)^{ab}	7.87 (2.89)^{b}	8.20 (2.95)^{ab}	7.76 (2.74)^{b}	6.64 (2.62)^{bc}
Thiamethoxam 30.00 %FS @ 2.55 g a.i./kg of seed	4.13 (2.15)^{ab}	4.80 (2.30)^{b}	5.13 (2.37)^{bcd}	6.13 (2.57)^{b}	5.36 (2.42)^{cd}	6.13 (2.57)^{b}	6.80 (2.70)^{ab}	7.47 (2.82)^{b}	8.13 (2.93)^{ab}	7.47 (2.82)^{bcd}	6.41 (2.62)^{bc}
Thiamethoxam 30.00 % FS @ 3.4 g a.i. /kg of seed	3.40 (1.97)^{b}	3.73 (2.06)^{b}	4.40 (2.21)^{cd}	5.40 (2.43)^{b}	4.51 (2.23)^{de}	5.40 (2.43)^{b}	6.07 (2.56)^{ab}	6.73 (2.69)^{b}	7.73 (2.86)^{ab}	6.84 (2.71)^{cd}	5.68 (2.47)^{c}
Foliar spray											
-	**1 DBT**	**3 DAT**	**7 DAT**	**10 DAT**	**Mean**	**1 DBT**	**3 DAT**	**7 DAT**	**10 DAT**	**Mean**	-
Thiamethoxam 25 WG @ 25 g a.i. / ha.	5.77 (2.49)^{ab}	5.43 (2.43)^{ab}	7.77 (2.87)^{ab}	8.43 (2.99)^{b}	7.21 (2.77)^{ab}	8.43 (2.99)^{b}	6.77 (2.68)^{ab}	7.77 (2.87)^{b}	8.44 (2.98)^{ab}	7.66 (2.85)^{bc}	7.43 (2.82)^{b}
Thiamethoxam 25 WG @ 37.5 g a.i. / ha.	6.70 (2.67)^{ab}	5.04 (2.35)^{b}	6.70 (2.68)^{abc}	7.37 (2.80)^{b}	6.37 (2.61)^{bc}	7.37 (2.80)^{b}	6.04 (2.54)^{ab}	6.70 (2.68)^{b}	7.70 (2.85)^{ab}	6.81 (2.70)^{cd}	6.59 (2.66)^{bc}
Thiamethoxam 25 WG @ 50 g a.i. / ha.	7.57 (2.83)^{a}	4.90 (2.32)^{b}	6.57 (2.64)^{abc}	7.23 (2.74)^{b}	6.23 (2.59)^{bc}	7.23 (2.74)^{b}	5.90 (2.53)^{ab}	6.57 (2.66)^{b}	7.57 (2.83)^{bc}	6.68 (2.68)^{d}	6.46 (2.64)^{bc}
Pyriproxyfen 10 EC @ 50 g a.i. / ha.	5.32 (2.40)^{ab}	4.98 (2.33)^{b}	6.32 (2.61)^{abc}	7.32 (2.79)^{b}	6.21 (2.58)^{bc}	7.32 (2.79)^{b}	6.98 (2.73)^{ab}	7.65 (2.85)^{b}	7.65 (2.85)^{ab}	7.43 (2.82)^{bcd}	6.82 (2.70)^{bc}
Imidacloprid 17.80 SL @ 20 g a.i. / ha.	5.01 (2.34)^{ab}	4.67 (2.27)^{b}	5.34 (2.42)^{bc}	6.67 (2.67)^{b}	5.56 (2.46)^{cd}	6.67 (2.67)^{b}	6.01 (2.52)^{ab}	7.01 (2.73)^{b}	8.01 (2.91)^{ab}	7.01 (2.74)^{bcd}	6.29 (2.60)^{bc}

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Dimethoate 30 EC @ 600 g a.i. / ha.	5.53	3.53	2.86	4.53	3.64	4.53	3.86	3.53	4.53	3.97	3.81
	(2.45)[ab]	(1.99)[b]	(1.83)[d]	(2.22)[b]	(2.03)[e]	(2.22)[b]	(2.08)[b]	(2.00)[c]	(2.21)[c]	(2.11)[e]	(2.07)[d]
Untreated control	6.55	7.89	8.55	8.89	8.44	8.89	9.89	10.55	11.55	10.67	9.55
(Water spray)	(2.65)[ab]	(2.90)[a]	(3.00)[a]	(3.06)[b]	(2.99)[a]	(3.06)[b]	(3.22)[a]	(3.32)[a]	(3.46)[a]	(3.34)[a]	(3.17)[a]
F value	*	*	*	*	*	*	*	*	*	*	*
SEM±	0.15	0.10	0.11	0.24	0.21	0.16	0.15	0.08	0.12	0.21	0.22
CD(P=0.05)	0.44	0.30	0.32	0.50	0.61	0.49	0.46	0.24	0.37	0.63	0.71
CV%	10.56	7.41	7.39	10.80	14.24	10.80	10.09	5.02	7.41	13.42	11.97

*Significant at ($P \leq 0.05$); Figures within the parentheses indicates $\sqrt{x+0.5}$ transformed values; Mean followed by the same letter do not differ significantly by TUKEY test (P=0.05)

DAS= Day after sowing

DBT= Day before treatment

DAT= Day after treatment

Economics of selected insecticide formulations in okra

Maximum marketable fruit yield of 8310 kg ha^{-1} was recorded in thiamethoxam 25 WG @ 50 g a.i. / ha, which was on par with thiamethoxam 25 WG @ 37.5 g a.i. / ha of yield 8282 kg ha^{-1}, followed by thiamethoxam 25 WG @ 25 g a.i. / ha giving 8261 kg ha^{-1} and imidacloprid 17.80 SL @ 20 g a.i. / ha giving 8253 kg ha^{-1}**.** The maximum incremental cost benefit ratio (4.14) was achieved in thiamethoxam 25 WG @ 50 g a.i. / ha treatment. This was followed by thiamethoxam 25 WG @ 37.5 g a.i. / ha (3.97), thiamethoxam 25 WG @ 25 g a.i. / ha (3.89) and imidacloprid 17.80 SL @ 20 g a.i. / ha (3.73) (Table 2). Raghuraman and Gupta (2006) showed that neonicotinoids were a cost-effective way to control the population of cotton-sucking bugs while increasing production. Neonicotinoids have been recommended by Saha et al. (2011); Kencharaddi and Balikai (2012) as a superior alternative for controlling a variety of sucking pests with a high C: B ratio. Here, imidacloprid 17.8 SL, thiamethoxam 25 WG, and Acetamiprid 20 SP at 40 g a.i. ha^{-1} were effective in reducing aphid and recorded increased yields with the highest cost-benefit ratio.

Phytotoxicity of selected insecticide formulation on okra

No phytotoxic symptoms were seen to have appeared on the okra leaves, flowers or fruits which were used during the insecticidal treatments for the management of whitefly, comprising of three dosages of thiamethoxam 30% FS (1.7, 2.55, and 3.4 g a.i. kg^{-1} of seed) and thiamethoxam 25 WG (25, 37.5, and 50 g a.i. ha^{-1}) and three other insecticides with field recommended dosages namely pyriproxyfen 10 EC @ 50 g a.i. ha^{-1} imidacloprid 17.80 SL @ 20 g a.i. ha^{-1}, and dimethoate 30 EC @ 600 g a.i. ha^{-1}**.**

Safety of selected insecticide formulations on okra

Coccinellids were the main predators of the sucking pests in the okra ecosystem during the study period. Results revealed that among all the treatments, the highest mean population of coccinellids was observed in thiamethoxam 25 WG @ 25 g a.i. / ha (7.43) followed by pyriproxyfen 10 EC @ 50 g a.i. / ha (6.82), thiamethoxam 30% FS @ 1.7 g a.i. /kg of seed (6.64), thiamethoxam 25 WG @ 37.5 g a.i. / ha (6.59), thiamethoxam 25 WG @ 50 g a.i. / ha (6.46), thiamethoxam 30% FS @ 2.55 g a.i. / kg of seed (6.41), imidacloprid 17.80 SL @ 20 g a.i. / ha (6.29), and recorded the lowest population in dimethoate 30 EC @ 600 g a.i. / ha (3.81) over untreated control (Table 3). The results also showed that dimethoate @ 600 g a.i. / ha gave negative effect on coccinellid beetle population. Ghosal et al. (2013) reported that dimethoate showed toxicity towards a population of coccinellids.

CONCLUSION

Farmers are unaware of the damage caused by whitefly which causes both direct and indirect damage to okra crops. On brief account of the field evaluation carried out, to cope with the rapidly multiplying whitefly population, the insecticidal application would reduce the populations drastically over the control plots. Although the highest yield, economics, and lowest whitefly population were encountered in plots treated by thiamethoxam 25 WG @ 50 g a.i. per ha followed by 37.5 g a.i. per ha and 25 g a.i. per ha. But, keeping in view of the economic and judicious usage of the insecticides, thiamethoxam 25 WG @ 25 g a.i. per ha could be employed in obtaining good fruit yields as well as reducing whitefly populations. All the tested insecticide formulations were found to be safer for coccinellids except for dimethoate 30 EC @ 600 g a.i. / ha, which have negative effect on coccinellid beetles, as observed in the okra ecosystem, when it was compared with the higher doses of thiamethoxam 25 WG at double dose of 50 g a.i. ha^{-1}. None of the insecticide formulations have phytotoxic effect in okra ecosystem.

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