Int.J.Curr.Microbiol.App.Sci (2020) *9*(11): 3694-3704

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 11 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.911.443

Combined Effect of *Beauveria bassiana* (Balsamo) and Selected Chemical Insecticides against Sunflower Whitefly *Bemisia tabaci* Gennadius

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Keywords

Insecticides, Whitefly, Ecosystem, Mycelial growth

Article Info

Accepted:
24 October 2020
Available Online:
10 November 2020

A B S T R A C T

In-vitro compatibility studies of *B. bassiana* (Bb-5a) with ten insecticides were examined on PDA media by poisoned food technique to develop suitable combinations for the control of whitefly in sunflower ecosystem. Out of ten insecticides, nine insecticides *viz.*, imidacloprid, thiamethoxam, acetamiprid, clothianidin, acephate, fipronil, buprofezin, flonicamid and azadirachtin showed compatible with *B. bassiana* at recommended dose (RD), half of the recommended dose (0.5 × RD) and double the recommended dose (2 × RD) at 14th and 30th DAI. Whereas, diafenthiuron inhibited the mycelial growth and showed incompatible with *B. bassiana*. Among the compatible insecticides, thiamethoxam, flonicamid, acephate, buprofezin and azadirachtin could be used with *B. bassiana* against whiteflies in the field condition. Efficacy study revealed that combined application of RD and 0.5 × RD of thiamethoxam, flonicamid, acephate, buprofezin and azadirachtin with *B. bassiana* showed synergistic effect in controlling the pests than their individual application. Among the compatible combinations, *B. bassiana* with thiamethoxam and flonicamid showed ≥ 90 per cent whitefly control followed by acephate, buprofezin and azadirachtin.

Introduction

Among the oilseed crops, sunflower (*Helianthus annuus* L.) is one of the major oilseed crop and widely cultivated. It is popularly known as "Surajmukhi" as it follows the movement of the sun. It belongs to the genus '*Helianthus*', family 'Asteraceae' (Compositae). The name has its origin in Greek "Helios" means "Sun" and "Anthois" means "flower". It is native to Southern parts of USA and Mexico (Heiser, 1951). In India, the sunflower is being grown over an area of 0.52 m ha with a production of 0.34 million tonnes and the productivity of 643 kg per ha (Anon, 2016). In India Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu are the major sunflower growing states.

Sunflower crop was introduced to India during 1969 as an ornamental crop and as a supplement to oilseed crops to bridge the gap of recurring edible oil shortage in the country. The commercial cultivation of sunflower started in India during 1972-73 with a few imported varieties from USSR and Canada.

Now, the crop has been well accepted by the farming community because of its desirable attributes such as short duration, photoperiod insensitivity, adaptability to wide range of soil and climatic conditions, drought tolerance, lower seed rate, higher seed multiplication ratio and high quality of edible oil.

A diverse assemblage of both beneficial and harmful insect species is associated with the sunflower ecosystem. Though more than fifty insect species have been reported on sunflower, cutworms (*Agrotis* spp.), sucking pests, leaf and plant hoppers (*Amrasca biguttula biguttula* Ishida, *Empoasca* spp.), thrips (*Thrips palmi*), whitefly (*Bemisia tabaci* Gennadius), defoliators (*Spilosoma obliqua* Walker, *Spodoptera litura* Fabricius, and *Plusia orichalcea* Fab.), and capitulum borer (*Helicoverpa armigera* Hubner) are major pests of economic concern.

Sucking pests like whiteflies, leafhoppers and thrips contribute to considerable extent of loss to the crop. Sucking pests generally occurs at early stage of crop and its damage continues till grain filling stage. Whiteflies are of prime importances which under favourable conditions pose threat to the crop, which not only causes direct damage but also causes enormous loss indirectly as vector of sunflower leaf curl virus (Govindappa *et al*., 2011).

Recently, whitefly has emerged as the new potential sucking insect pest of sunflower and also acting as the vector of leaf curl begomovirus in Northern Karnataka, India (Katti, 2007).

Sunflower leaf curl disease transmitted by whitefly was noticed for the first time in the country and the disease was recorded on sunflower hybrid “Sun breed - 275” up to 40 per cent disease incidence in the fields of Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Northern Karnataka, during *Rabi* season of 2009 (Govindappa *et al.,* 2011).

The whitefly infestation has been noticed in an endemic form consecutively for the last three years in sunflower growing areas of Northern districts of Karnataka. The disease severity ranged from 10 - 58 per cent and correspondingly the increased population of *B. tabaci* (up to 200/leaf) was observed with an average of 14.70 *B. tabaci* per leaf both in open pollinated varieties and hybrids.

Farmers are unable to control the whiteflies even with the repeated insecticidal sprays resulted in pollution of natural resources and also development of resistance. Hence, there is need for evaluating the combined application of bio pesticides along with compatible insecticides against whitefly in sunflower.

Materials and Methods

The present investigation on the combined application of *B. bassiana* and compatible insecticides against sunflower whitefly was carried out during *rabi* season 2018 at Main Agricultural Research Station, University of Agricultural Sciences, Raichur. A field experiment was laid out in a randomized block design with 22 treatments and 3 replications.

Application of treatments in the experimental field

All the recommended agronomical practices were done in the experimental field. The treatments imposition at the mentioned doses was done two times (Table 1). First at 30 days after sowing and second treatment imposition at the 50 days after sowing. The water quantity used was 500 l/ha. The insecticides were applied by using knapsack sprayer during morning hours. Care was taken to rinse the sprayer thoroughly before and after each spray with water to avoid contamination from one treatment to another.

Method of observations

Two sprays were taken up, at 30 and 50 days after sowing. Observations on sucking pests *viz.*, whiteflies were made on six leaves comprising of two leaves each from the top, middle and bottom portion of five randomly selected plants from each plot. The population of sucking pests was recorded at one day before treatment and one, five and ten days after treatment. The mean population of each sucking pests was worked out and subjected to statistical analysis. The collected data converted to per cent mortality by using the following formula (Abbott, 1925).

$$\text{Per cent mortality} = \frac{C - T}{C} \times 100$$

Where, C - Pest population in the untreated check

T - Pest population in treatment

Results and Discussion

First spray

One day before spray

Differences in the whitefly population per six leaves among different treatments were not significant, indicating more or less uniform distribution of the pest in the experimental field with 11.44 to 16.64 whiteflies per six leaves.

One day after spray

The data on population of whitefly (Table 2 and Figure 1) recorded after first day of first spray, revealed that thiamethoxam + *B. bassiana* (T_3) gave significantly lowest whitefly population 2.07 per six leaves and on par with treatment of flonicamid + *B. bassiana* (T_7) 2.16 per six leaves. Next best lowest population was recorded in treatments of acephate + *B. bassiana* (T_{11}) and thiamethoxam + *B. bassiana* (T_4) followed by buprofezin + *B. bassiana* (T_{15}), flonicamid + *B. bassiana* (T_8) and azadirachtin + *B. bassiana* (T_{19}).

The remaining treatments showed relatively higher whitefly population (5.34 to 7.63/6 leaves). Treatments of azadirachtin alone (T_{18}), *B. bassiana* alone (T_2) and untreated control (T_{22}) exhibited significantly highest whitefly population (8.83 to 14.02/6 leaves) Similarly, efficacy of both control agents against whiteflies was observed at five and ten days after spray.

Overall mean of first spray

On the basis of overall mean, the differences in the mean number of whitefly population among different treatments were significant. Among the treatments, thiamethoxam + *B. bassiana* (T_3) was found to be most effective as it recorded significantly lowest whitefly population (1.32/6 leaves) and this treatment was on par with flonicamid + *B. bassiana* (T_7) (1.41/6 leaves) followed by acephate + *B. bassiana* (T_{11}) with 1.63 whiteflies per six leaves. Treatments of buprofezin + *B. bassiana* (T_{15}), azadirachtin + *B. bassiana* (T_{19}), thiamethoxam + *B. bassiana* (T_4) and flonicamid + *B. bassiana* (T_8) were on par with each other. Significantly highest whitefly population was recorded in azadirachtin + *B. bassiana* (T_{21}), *B. bassiana* alone (T_2) and untreated control (T_{22}) 6.50, 7.96 and 16.37 per six leaves respectively. The remaining treatments recorded relatively highest whitefly population (3.74 to 6.16/6 leaves).

Second spray

One day before spray

Differences in the whitefly population among different treatments were not significant and ranged from 10.77 to 15.42 per six leaves, indicating more or less uniform distribution of the whiteflies in the experimental field.

One day after spray

At first day of second treatment imposition, thiamethoxam + *B. bassiana* (T_3) showed significantly lowest whitefly population (1.33/6 leaves). Next lowest population was recorded in flonicamid + *B. bassiana* (T_7) (1.81/6 leaves). Acephate + *B. bassiana* (T_{11}) (3.07/6 leaves) was on par with buprofezin + *B. bassiana* (T_{15}) (3.27/6 leaves). Likewise, azadirachtin + *B. bassiana* (T_{19}) recorded pest population of 3.54 per six leaves.

Treatments of flonicamid + *B. bassiana* (T_8) (4.83/6 leaves) and thiamethoxam + *B. bassiana* (T_4) (4.72/6 leaves) were on par with each other. Similarly, remaining treatments recorded whitefly population that ranged from 5.16 to 10.12 per six leaves. Whereas, significantly highest whitefly population was recorded in treatments of *B. bassiana* alone (T_2) and untreated control (T_{22}) with 11.58 and 15.36 whitefly per six leaves respectively, similar trend was followed at five and ten days after spray (Table 3 and Figure 2).

Overall mean of second spray

Among the treatments, thiamethoxam + *B. bassiana* (T_3) was found to be most effective as it recorded significantly lowest whitefly population (1.06/6 leaves) followed by treatments of flonicamid + *B. bassiana* (T_7) (1.36/6 leaves), acephate + *B. bassiana* (T_{11}) (2.01/6 leaves) and buprofezin + *B. bassiana* (T_{15}) (2.14/6 leaves).

Likewise, significantly highest whitefly population was recorded in buprofezin + *B. bassiana* (T_{17}) (6.56/6 leaves) which was at par with treatments of azadirachtin + *B. bassiana* (T_{21}) (6.83/6 leaves), *B. bassiana* alone (T_2) (8.68/6 leaves) and untreated control (16.04/6 leaves). The remaining treatments exhibited relatively higher whitefly population (2.59 to 6.30/6 leaves).

Per cent reduction of whitefly population over untreated control in sunflower during *rabi* 2018

Among all the treatments, thiamethoxam + *B. bassiana* (T_3) recorded highest per cent reduction of whiteflies (91.87 %) followed by flonicamid + *B. bassiana* (T_7) (90.47 %), acephate + *B. bassiana* (T_{11}) (87.40 %), buprofezin + *B. bassiana* (T_{15}) (86.09 %) and azadirachtin + *B. bassiana* (T_{19}) (82.25 %).

The treatments of thiamethoxam + *B. bassiana* (T_4), flonicamid + *B. bassiana* (T_8), acephate + *B. bassiana* (T_{12}), buprofezin + *B. bassiana* (T_{16}) and thiamethoxam alone (T_1) showed 80.96, 79.96, 77.25, 73.59 and 72.40 per cent reduction of whiteflies respectively.

Remaining treatments recorded 70.74 to 58.58 per cent whitefly reduction. Comparatively lowest per cent reduction was observed in azadirachtin + *B. bassiana* (T_{21}) (56.46 %) and *B. bassiana* alone (T_2) (46.95 %) over untreated control (Table 4 and Figure 3).

Table.1 List of insecticide treatments applied for field experiment with *B. bassiana*

Treatment number	Treatments	Dose/l
T_1	Thiamethoxam alone @ FR dose	0.20 g
T_2	*B. bassiana* @ FR dose (2 x10^8 cfu/g)	2.00 g
T_3	Thiamethoxam @ FR dose + *B. bassiana* @ FR dose	0.20 g + 2.00 g
T_4	Thiamethoxam @ 0.5 X FR dose + *B.bassiana* @ FR dose	0.10 g + 2.00 g
T_5	Thiamethoxam @ 0.5 X FR dose + *B. bassiana* @ 0.5 X FR dose	0.10 g + 1.00 g
T_6	Flonicamid alone @ FR dose	0.40 g
T_7	Flonicamid @ FR dose + *B. bassiana* @ FR dose	0.40 g + 2.00 g
T_8	Flonicamid @ 0.5 X FR dose + *B.Bassiana* @ FR dose	0.20 g + 2.00 g
T_9	Flonicamid @ 0.5 X FR dose + *B.bassiana* @ 0.5 X FR dose	0.20 g + 1.00 g
T_{10}	Acephate alone @ FR dose	1.00 g
T_{11}	Acephate @ FR dose + *B. bassiana* @ FR dose	1.00 g + 2.00 g
T_{12}	Acephate @ 0.5 X FR dose + *B.bassiana* @ FR dose	0.50 g + 2.00 g
T_{13}	Acephate @ 0.5 X FR dose + *B.bassiana* @ 0.5 X FR dose	0.50 g + 1.00 g
T_{14}	Buprofezin alone @ FR dose	1.00 ml
T_{15}	Buprofezin @ FR dose + *B.bassiana* @ FR dose	1.00 ml + 2.00g
T_{16}	Buprofezin @ 0.5 X FR dose + *B.Bassiana* @ FR dose	0.50 ml + 2.00 g
T_{17}	Buprofezin @ 0.5 X FR dose + *B. Bassiana* @ 0.5 X FR dose	0.50 ml + 1.00 g
T_{18}	Azadirachtin alone @ FR dose	5.00 ml
T_{19}	Azadirachtin @ FR dose + *B. Bassiana* @ FR dose	5.00 ml + 2.00 g
T_{20}	Azadirachtin @ 0.5 X FR dose + *B.bassiana* @ FR dose	2.50 ml + 2.00 g
T_{21}	Azadirachtin @ 0.5 X FR dose + *B.bassiana* @ 0.5 X FR dose	2.50 ml + 1.00 g
T_{22}	Untreated control	-

Table.2 Efficacy of *B. bassiana* in combination with selected insecticides against whiteflies after first spray in sunflower during *rabi* 2018

Treat. No.	Treatments	Dosages (g or ml/l)	Number of whiteflies/6 leaves/plant					
			1 DBS	1 DAS	5 DAS	10 DAS	Mean	% reduction over control
T_1	Thiamethoxam	0.2 g	13.17 (3.76)*	7.51 (2.91)	3.73 (2.17)	1.48 (1.57)	4.24 (2.28)	74.07
T_2	*Beauveria bassiana*	2 g	11.44 (3.52)	10.91 (3.45)	8.78 (3.12)	4.19 (2.27)	7.96 (2.99)	51.36
T_3	Thiamethoxam + *B. bassiana*	0.2 g + 2 g	14.13 (3.88)	2.07 (1.75)	1.12 (1.45)	0.77 (1.33)	1.32 (1.52)	91.92
T_4	Thiamethoxam + *B. bassiana*	0.1 g + 2 g	13.74 (3.83)	4.11 (2.26)	3.33 (2.08)	1.51 (1.58)	2.98 (1.99)	81.75
T_5	Thiamethoxam + *B. bassiana*	0.1 g + 1 g	16.64 (4.20)	6.10 (2.66)	5.50 (2.54)	2.40 (1.84)	4.66 (2.37)	71.49
T_6	Flonicamid	0.4 g	15.66 (4.08)	6.82 (2.79)	5.66 (2.58)	1.82 (1.67)	4.76 (2.40)	70.87
T_7	Flonicamid + *B. bassiana*	0.4 g + 2 g	14.67 (3.95)	2.16 (1.77)	1.13 (1.45)	0.96 (1.40)	1.41 (1.55)	91.34
T_8	Flonicamid + *B. bassiana*	0.2 g + 2 g	15.73 (4.09)	4.59 (2.36)	3.41 (2.10)	1.56 (1.60)	3.18 (2.04)	80.53
T_9	Flonicamid + *B. bassiana*	0.2 g + 1 g	16.59 (4.19)	6.80 (2.79)	6.40 (2.72)	2.80 (1.94)	5.33 (2.51)	67.42
T_{10}	Acephate	1 g	15.79 (4.09)	7.27 (2.87)	5.77 (2.60)	2.65 (1.91)	5.23 (2.49)	68.04
T_{11}	Acephate + *B. bassiana*	1 g + 2 g	15.81 (4.10)	2.57 (1.88)	1.14 (1.46)	1.20 (1.48)	1.63 (1.62)	90.00
T_{12}	Acephate + *B. bassiana*	0.5 g + 2 g	15.35 (4.04)	5.34 (2.51)	4.24 (2.28)	1.65 (1.62)	3.74 (2.17)	77.13
T_{13}	Acephate + *B. bassiana*	0.5 g + 1 g	15.84 (4.10)	7.10 (2.84)	6.80 (2.79)	3.20 (2.04)	5.70 (2.58)	65.18
T_{14}	Buprofezin	1 ml	14.22 (3.90)	7.63 (2.93)	6.64 (2.76)	2.37 (1.83)	5.54 (2.55)	66.10
T_{15}	Buprofezin + *B. bassiana*	1 ml + 2 g	15.84 (4.10)	4.14 (2.26)	2.08 (1.75)	1.30 (1.51)	2.50 (1.87)	84.68
T_{16}	Buprofezin + *B. bassiana*	0.5 ml + 2 g	13.37 (3.79)	6.83 (2.79)	4.47 (2.33)	1.72 (1.64)	4.34 (2.31)	73.48
T_{17}	Buprofezin + *B. bassiana*	0.5 ml + 1g	14.37 (3.92)	7.50 (2.91)	7.40 (2.89)	3.60 (2.14)	6.16 (2.67)	62.32
T_{18}	Azadhirachtin	5 ml	14.75 (3.96)	8.83 (3.13)	5.44 (2.53)	3.80 (2.19)	6.02 (2.64)	63.17
T_{19}	Azadhirachtin + *B. bassiana*	5 ml + 2 g	15.55 (4.06)	5.15 (2.47)	2.23 (1.79)	1.63 (1.62)	3.00 (2.00)	81.64
T_{20}	Azadhirachtin + *B. bassiana*	2.5 ml + 2 g	14.52 (3.93)	7.28 (2.87)	4.50 (2.34)	2.53 (1.87)	4.77 (2.40)	70.86
T_{21}	Azadhirachtin + *B. bassiana*	2.5 ml + 1 g	15.01 (4.00)	7.80 (2.96)	7.80 (2.96)	3.90 (2.21)	6.50 (2.73)	60.29
T_{22}	Untreated control	00	16.09 (4.07)	14.02 (3.81)	16.50 (4.12)	18.60 (4.37)	16.37 (4.10)	-
	S. Em. ±		**0.26**	**0.13**	**0.09**	**0.08**	**0.13**	
	C. D. at 5 %		**0.73**	**0.37**	**0.27**	**0.22**	**0.38**	

DBS- day before spraying, DAS- days after spraying, *Figures in the parentheses are square root transformed values

Table.3 Efficacy of *B. bassiana* in combination with selected insecticides against whiteflies after second spray in sunflower during *rabi* 2018

Treat. No.	Treatments	Dosages (g or ml/l)	Number of whiteflies/ 6 leaves/plant					
			1 DBS	1 DAS	5 DAS	10 DAS	Mean	% reduction over control
T_1	Thiamethoxam	0.2 g	12.17 (3.62)*	7.43 (2.90)	4.41 (2.32)	1.04 (1.42)	4.29 (2.30)	73.21
T_2	*Beauveria bassiana*	2 g	11.77 (3.57)	11.58 (3.54)	9.23 (3.19)	5.23 (2.49)	8.68 (3.11)	45.87
T_3	Thiamethoxam + *B. bassiana*	0.2 g + 2 g	13.79 (3.84)	1.33 (1.52)	1.26 (1.50)	0.61 (1.26)	1.06 (1.43)	93.34
T_4	Thiamethoxam + *B. bassiana*	0.1 g + 2 g	12.74 (3.70)	4.72 (2.39)	2.65 (1.91)	1.03 (1.42)	2.80 (1.94)	82.54
T_5	Thiamethoxam + *B. bassiana*	0.1 g + 1 g	15.30 (4.03)	7.00 (2.82)	5.10 (2.46)	2.50 (1.87)	4.86 (2.42)	69.65
T_6	Flonicamid	0.4 g	15.32 (4.03)	9.06 (3.17)	5.21 (2.49)	0.98 (1.40)	5.08 (2.46)	68.28
T_7	Flonicamid + *B. bassiana*	0.4 g + 2 g	14.03 (3.87)	1.81 (1.67)	1.53 (1.59)	0.74 (1.31)	1.36 (1.53)	91.52
T_8	Flonicamid + *B. bassiana*	0.2 g + 2 g	15.42 (4.05)	4.83 (2.41)	2.81 (1.95)	1.10 (1.44)	2.91 (1.97)	81.83
T_9	Flonicamid + *B. bassiana*	0.2 g + 1g	14.86 (3.98)	7.30 (2.88)	6.10 (2.66)	3.90 (2.21)	5.76 (2.60)	64.04
T_{10}	Acephate	1 g	15.25 (4.03)	9.21 (3.19)	5.76 (2.60)	1.53 (1.59)	5.50 (2.54)	65.67
T_{11}	Acephate + *B. bassiana*	1 g + 2 g	14.31 (3.91)	3.07 (2.01)	2.20 (1.78)	0.76 (1.32)	2.01 (1.73)	87.46
T_{12}	Acephate + *B. bassiana*	0.5 g + 2 g	15.35 (4.04)	5.16 (2.48)	3.33 (2.08)	1.19 (1.47)	3.22 (2.05)	79.86
T_{13}	Acephate + *B. bassiana*	0.5 g + 1 g	11.24 (3.49)	7.80 (2.96)	6.90 (2.81)	4.20 (2.28)	6.30 (2.70)	60.72
T_{14}	Buprofezin	1 ml	13.16 (3.76)	10.12 (3.33)	5.07 (2.46)	2.98 (1.99)	6.06 (2.65)	62.20
T_{15}	Buprofezin + *B. bassiana*	1 ml + 2 g	11.70 (3.56)	3.27 (2.06)	2.29 (1.81)	0.86 (1.36)	2.14 (1.77)	86.64
T_{16}	Buprofezin + *B. bassiana*	0.5 ml + 2 g	12.35 (3.65)	5.24 (2.49)	4.09 (2.25)	1.43 (1.55)	3.58 (2.14)	77.62
T_{17}	Buprofezin + *B. bassiana*	0.5 ml + 1 g	15.13 (4.01)	8.20 (3.03)	7.00 (2.82)	4.50 (2.34)	6.56 (2.74)	59.06
T_{18}	Azadhirachtin	5 ml	13.64 (3.82)	10.22 (3.34)	5.10 (2.46)	1.98 (1.72)	5.76 (2.60)	64.04
T_{19}	Azadhirachtin + *B. bassiana*	5 ml + 2 g	14.67 (3.95)	3.54 (2.13)	2.40 (1.84)	1.83 (1.68)	2.59 (1.89)	83.83
T_{20}	Azadhirachtin + *B. bassiana*	2.5 ml + 2 g	10.77 (3.43)	5.43 (2.53)	4.22 (2.28)	2.20 (1.78)	3.95 (2.22)	75.37
T_{21}	Azadhirachtin + *B. bassiana*	2.5 ml + 1 g	13.85 (3.85)	8.40 (3.06)	7.30 (2.88)	4.80 (2.40)	6.83 (2.79)	57.39
T_{22}	Untreated control	00	13.78 (3.77)	15.36 (3.98)	15.87 (4.04)	16.89 (4.17)	16.04 (4.06)	-
	S. Em. ± **C. D. at 5 %**		**0.20** **0.57**	**0.13** **0.36**	**0.11** **0.33**	**0.10** **0.29**	**0.14** **0.40**	

DBS- day before spraying, DAS- days after spraying, *Figures in the parentheses are square root transformed values

Table.4 Per cent reduction of whitefly population over untreated control in sunflower during *rabi* 2018

Treat. No.	Treatments	Dosage (g or ml/l)	Reduction (%) of whiteflies		
			First spray	Second spray	Mean
T_1	Thiamethoxam	0.2 g	74.07 (59.38)*	73.21 (58.82)	72.40
T_2	*Beauveria bassiana*	2 g	51.36 (45.77)	45.87 (42.63)	46.95
T_3	Thiamethoxam + *B. bassiana*	0.2 g + 2 g	91.92 (73.48)	93.34 (75.04)	91.87
T_4	Thiamethoxam + *B. bassiana*	0.1 g + 2 g	81.75 (64.70)	82.54 (65.30)	80.96
T_5	Thiamethoxam + *B. bassiana*	0.1 g + 1 g	71.49 (57.72)	69.65 (56.57)	67.96
T_6	Flonicamid	0.4 g	70.87 (57.33)	68.28 (55.72)	68.76
T_7	Flonicamid + *B. bassiana*	0.4 g + 2 g	91.34 (72.88)	91.52 (73.06)	90.47
T_8	Flonicamid + *B. bassiana*	0.2 g + 2 g	80.53 (63.81)	81.83 (64.76)	79.96
T_9	Flonicamid + *B. bassiana*	0.2 g + 1 g	67.42 (55.19)	64.04 (53.15)	64.21
T_{10}	Acephate	1 g	68.04 (55.57)	65.67 (54.13)	66.60
T_{11}	Acephate + *B. bassiana*	1 g + 2 g	90.00 (71.56)	87.46 (69.26)	87.40
T_{12}	Acephate + *B. bassiana*	0.5 g + 2 g	77.13 (61.43)	79.86 (63.33)	77.25
T_{13}	Acephate + *B. bassiana*	0.5 g + 1 g	65.18 (53.83)	60.72 (51.19)	61.07
T_{14}	Buprofezin	1 ml	66.10 (54.39)	62.20 (52.06)	64.79
T_{15}	Buprofezin + *B. bassiana*	1 ml + 2 g	84.68 (66.95)	86.64 (68.56)	86.09
T_{16}	Buprofezin + *B. bassiana*	0.5 ml + 2 g	73.48 (59.00)	77.62 (61.76)	73.59
T_{17}	Buprofezin + *B. bassiana*	0.5 ml + 1 g	62.32 (52.13)	59.06 (50.21)	58.58
T_{18}	Azadhirachtin	5 ml	63.17 (52.63)	64.04 (53.15)	63.95
T_{19}	Azadhirachtin + *B. bassiana*	5 ml + 2 g	81.64 (64.62)	83.83 (66.28)	82.25
T_{20}	Azadhirachtin + *B. bassiana*	2.5 ml + 2 g	70.86 (57.32)	75.37 (60.24)	70.74
T_{21}	Azadhirachtin + *B. bassiana*	2.5 ml + 1 g	60.29 (50.93)	57.39 (49.24)	56.46
T_{22}	Untreated control	00	-	-	-
	S. Em. ± **C. D. at 5 %**		**0.85** **2.42**	**0.88** **2.51**	

DBS- day before spraying, DAS- days after spraying, *Figures in the parentheses are arcsine transformed values

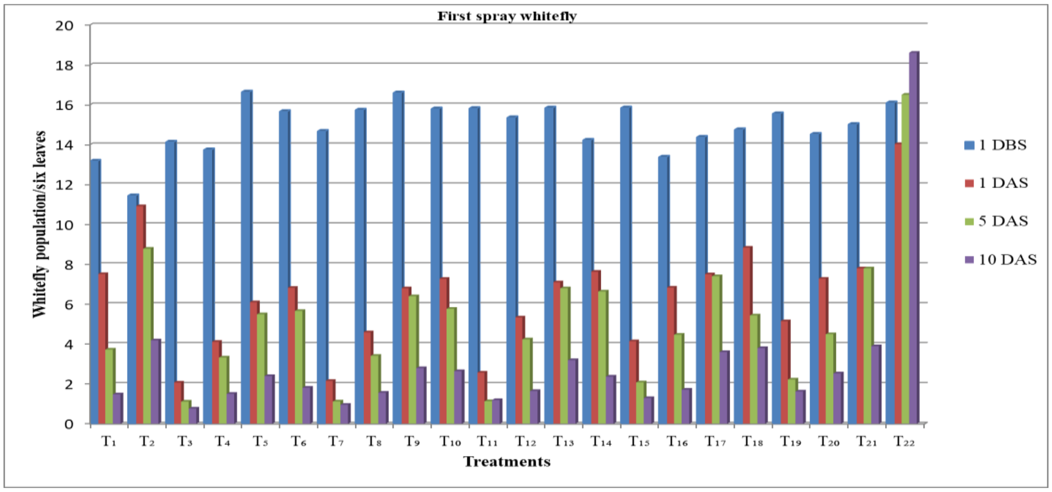

Figure.1 Efficacy of *B. bassiana* in combination with selected insecticides against whiteflies after first spray in sunflower during *rabi* 2018

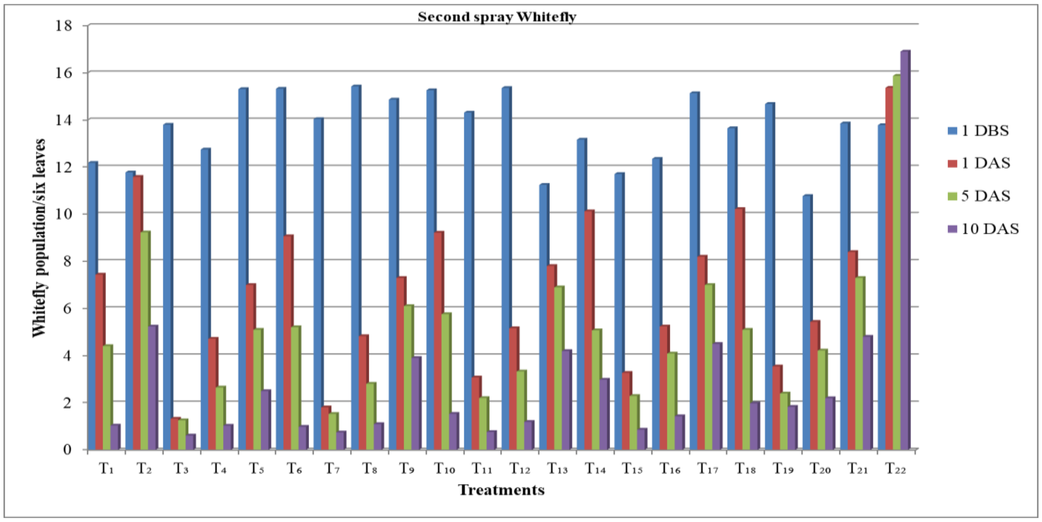

Figure.2 Efficacy of *B. bassiana* in combination with selected insecticides against whiteflies after second spray in sunflower during *rabi* 2018

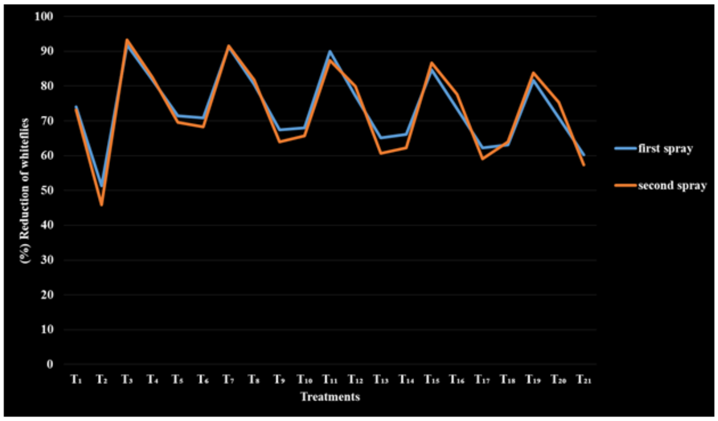

Figure.3 Per cent reduction of whitefly population over untreated control in sunflower during *rabi* 2018

Due to the lack of availability of literature on combined effect of thiamethoxam, flonicamid, buprofezin, acephate and azadirachtin with *B. bassiana* for the management of sucking pest *viz.*, whiteflies, we have quoted similar research studies conducted by different authors for the management of various insect pests, where the combined effect of entomopathogenic fungi and insecticides gave synergist effect and comparatively more effective than those of individual application.

Our results are supported by Islam *et al.*, (2010) who reported that highest adult deterrence index (80.15) and oviposition deterrence index (88.25) occurred when 1.0 % neem (azadirachtin 0.3 % EC) was combined with 10^8 conidia/ml of *B. bassiana* and reported that soil application of neem along with foliar application of *B. bassiana* was useful for the control of *B. tabaci* on brinjal. Combined application of azadirachtin and *B. bassiana* showed synergist effect for whiteflies control. This synergistic interaction may be due to less than 5 per cent concentration of emulsible neem oil that did not cause significant fungi toxic effects and also no inhibition in growth parameters of *B. bassiana*. Anderson *et al.*, (1989) reported that adjuvants present in the neem formulation showed enhancing effect of insecticide formulation on fungal growth and also antifeedant nature of neem revealed no egg deposition by sweet potato whitefly.

The results obtained in the present study showed that the combined application of buprofezin and *B. bassiana* at recommended concentration showed 85.54 per cent reduction of leafhopper population at both sprays of 30 and 50 days after spraying. Our results are in similarity with the study conducted by Jin *et al.*, (2011) who reported significant plant hopper control (54 - 60 %) achieved by biweekly sprays of two fungal strains (Ma 456 and Ma 576) at 1.5×10^{13} conidia/ha and 80 - 83 per cent brown plant hopper control by incorporating 30.8 g *a.i.* buprofezin/ha into the fungal sprays. These reports showed that combined application of entomopathogens with chemical insecticides at recommended dose gave significantly highest pest reduction over an individual application of chemical insecticides and fungal pathogens.

The present study field results are in line with the findings of Islam and Omar (2012) who reported that combined effect of *B. bassiana* and neem produces more rapid mortality response in *B. tabaci* nymphs than individual treatments of *B. bassiana* and neem alone, this synergistic effect may be due to the active ingredients and formulations present in the neem which enhanced the fungal development and made insect more susceptible to *B. bassiana*.

For the management of sunflower whitefly, eco-friendly approaches need to be followed. Since the sunflower crop attracts several species of beneficial insect fauna, hence attention needs to be focused on conservation of activity of promising biocontrol agents and pollinators by adopting eco-friendly approaches like use of bio-pesticides, and sometimes addition of compatible insecticides to increase efficacy of bio pesticide, which play very important role in reducing pest load without affecting beneficial insect fauna.

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How to cite this article:

Rajeshwari Hiremath, Vijaykumar N. Ghante, Arunkumar Hosamani, Shivaleela and Amaresh, Y. S. 2020. Combined Effect of *Beauveria bassiana* (Balsamo) and Selected Chemical Insecticides against Sunflower Whitefly *Bemisia tabaci* Gennadius. *Int.J.Curr.Microbiol.App.Sci.* 9(11): 3694-3704. doi: https://doi.org/10.20546/ijcmas.2020.911.443