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Management of the aphid, *Myzus persicae* (Sulzer) and the whitefly, *Bemisia tabaci* (Gennadius), using biorational on capsicum under protected cultivation in India

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Abstract

The peach aphid, *Myzus persicae* (Hemiptera: Aphididae) and silver leaf whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) are the major pests of capsicum under protected cultivation. The entomopathogenic fungi (EPF) are environmentally safe than the chemical pesticides. In the present study, different EPF formulations, *Beauveria bassiana* Balsamo (Vuillemin), *Lecanicillium lecanii* (Zimmerman) Viegas, *Metarhizium anisopliae* (Metschnikoff) Sorokin, were evaluated along with Azadirachtin 1% for the management of the aphid and the whitefly on capsicum under protected conditions. Result showed that talc formulation of *L. lecanii* MTCC 956 at 10 and 12 g/l caused 60.5 and 61.6% population reduction for aphid and 60.0 and 61.6% population reduction for whitefly, whereas Azadirachtin 1% at 4 and 5 ml/l caused 71.2 and 74.7% population reduction for aphid and 68.5 and 71.0% population reduction for whitefly after 3rd spray, respectively and were effective in reducing aphid and whitefly populations on capsicum recommending its organic production under protected cultivation and could be a part of integrated pest management program.

Keywords: Capsicum, Entomopathogenic fungi, *Myzus persicae*, *Bemisia tabaci*, Protected cultivation

Background

Capsicum is an annual herbaceous vegetable crop also known as sweet pepper and is broadly cultivated in India and all over the world as table food for its exquisite taste and good flavor. The active chemical component of sweet pepper called "capsaicin" has antioxidant, anti-carcinogenic, and anti-diabetic properties (Gupta et al. 2016). Temperature, relative humidity, and energy may influence the growth of sweet pepper under open field cultivation. Under protected cultivation, all these factors are maintained for its efficient productivity.

The aphids, *Myzus persicae* (Sulzer) and *Aphis gossypii* (Glover); whitefly, *Bemisia tabaci* (Gennadius); mite, *Polyphagotarsonemus lactus* (Banks); and thrips, *Scirthorips dorsalis* (Hood) are economic pests which infest crops under protected cultivation. They are sucking pests, which effect the growth and hence lead to reduction in crop yield. Among these, *M. persicae* (Hemiptera: Aphididae) and *B. tabaci* (Hemiptera: Aleyrodidae) are major insect pests, which cause vector borne viral diseases and their damage includes chlorosis, necrosis, wilting, stunting, flower and fruit abortion, leaf distortion, and

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defoliation (Sayed et al. 2019). *M. persicae* can reduce photosynthetic capability of plant by producing sugary honeydew and affect the quality and quantity of crop (Frantz et al. 2004).

Management of the sucking insect pests is mainly by chemical insecticides but their excessive and indiscriminate use has led to insecticide resistance and residue problems apart from health hazards (Pilkington et al. 2010 and Pappas et al. 2013). Various parasitoids, predators, pathogens, and botanicals are being exploited for management of these pests (Ali et al. 2017 and Ullah et al. 2019). Management of insect pests using entomopathogenic fungi (EPF) is regarded as an important alternative method for organic cultivation of vegetables under protected conditions(Manfrino et al. 2014 and Ali et al. 2018).

Entomopathogens are reported to control various crops insect pests. These EPF viz. *Beauveria bassiana* (Hypocreales: Cordycipitaceae), *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae), *Lecanicillium* spp., (previously *Verticillium lecanii*) (Hypocreales: Cordycipitaceae), and *Isaria fumosorosea* (Hypocreales: Clavicipitaceae) (previously *Paecilomyces fumosoroseus*) are reported to kill insect by nutritional deficiency, tissue degradation, and release of toxins. The EPF contain cuticle degrading enzymes like protease; lipase and chitinase which degrade the insect cuticle, followed by penetration of fungal germ tube into insect body and thereby releases several mycotoxins such as Beauvericin, Beauverolides, and Bassianolide to kill the insect (Gabarty et al. 2014). The fungus initiates infection by adherence of conidia to the cuticle of a susceptible host by hydrophobic or enzymatic mechanisms and kills the host due to depletion of their hemolymph nutrients. In modern era, with the increasing awareness about the safety and quality of foods, long-term sustainability of the system and accumulating evidences of being equally productive, the organic farming is gaining importance.

So, present study aimed to evaluate various mycoformulations along with botanical formulation Azadirachtin to manage *M. persicae* and *B. tabaci* on capsicum in organic production under protected cultivation.

Materials and methods

Fungal culture

One *Lecanicillium lecanii* isolate (MTCC 956) procured form Institute of Microbial Technology, Chandigarh, India, and one native isolate *Beauveria bassiana* (Bb-B1) were used in the present study. These isolates were grown and maintained on potato dextrose agar (PDA) (dextrose 2%, potatoes infusion form 20%, agar 5%, and chloramphenicol 0.5%) and stored at refrigeration temperature till further use.

Production of mycoformulations

These fungal isolates were inoculated and incubated on sterilized broken rice grains for 15 days at 25 ± 2 °C and formulated to talc formulation according to methodology of Kaur and Joshi (2014)**.**

Test biopesticides

Three entomopathogenic commercial mycoformulations viz. Bio-Catch (*L. lecanii* 1.50% liquid formulation), Biomagic (*M. anisopliae* 1.50% liquid formulation), Biopower (*B. bassiana* 1.50% liquid formulation) manufactured by T. Stanes & Company Limited, Tamil Nadu, India), and one botanical formulation Azadirachtin (Econeem plus(1.0%) from Margo Private Limited, Bengaluru and chemical malathion 50 EC (tusk) from Shivalik Company, Chandigarh, India, were used for the present study.

Experiment method

Capsicum crop was raised in polyhouse as per recommendation of Punjab Agricultural University Packages and Practices of Vegetable Crops. The capsicum hybrid variety "Indra" was transplanted on raised beds of 1.5 m width, with plant to plant and row to row spacing of 30 and 90 cm, respectively. The experiment for the management of *M. persicae* and *B. tabaci* on capsicum was conducted for 2 years. The pre-treatment data of the aphid and whitefly population was recorded from 3 leaves (top, middle, and bottom) per plant and 3 foliar applications of all mycoformulations (8, 10, and 12 g/l); Azadirachtin (@ 4 and 5 ml/l) were given at 10 days interval in the evening hours. The experiment was conducted in randomized block design (RBD) with each concentration of biopesticide as one treatment with 3 replications and 5 plants per replica. Apart from these biorational treatments, one chemical malathion 50 EC (4 ml/l) and untreated check was also maintained to compare the efficacy of treatments.

Aphid and whitefly counts

The aphid and whitefly populations were recorded from the randomly selected 3 leaves from top, middle, and bottom canopy of randomly selected plant before treatment and after 3, 7, and 10 days of spray, respectively. To compare the efficacy of different EPF, percent reduction in the population of the aphid and whitefly over control was calculated, using (Henderson and Tilton's 1955) formula.

$$\text{Corrected Mortality } \% = \left(1\text{-}\frac{\text{n in Co before treatment}*\text{n in T after treatment}}{\text{n in Co after treatment}*\text{n in T before treatment}}\right)*100$$

where n = insect population, T = treated, and Co = control.

Fruit yield

Capsicum fruits were harvested at regular interval and recorded for weight of fruits. Total yield was calculated in tons per hectare.

Statistical analysis

One-way ANOVA was conducted for all parameters, and means were compared by Duncan multiple range test (DMRT) at 5% level of significance using (SPSS

Table 1 Population dynamics of aphid, *Myzus persicae* (Sulzer) on capsicum plant treated with indigenous and commercial bioformulations under protected cultivation (2017, 2018)

Treatments	Dose (g or ml/l)	No. of aphid nymphs/plant*(mean ± SE)										Fruit yield (t/ha)
		Before spray	I spray			II spray			III spray			
			3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	
Beauveria bassiana Bb-B1	8	39.3 ± 0.4^{a}	36.0 ± 0.6^{c}	34.3 ± 0.6^{e}	33.6 ± 0.9^{d}	31.2 ± 1.2^{c}	29.5 ± 1.5^{c}	28.5 ± 1.7^{e}	26.0 ± 2.5^{e}	24.7 ± 2.7^{e}	23.7 ± 2.4^{e}	42.1 ± 1.1^{cd}
	10	39.8 ± 1.4^{a}	35.8 ± 0.2^{bc}	34.3 ± 0.2^{e}	33.6 ± 0.4^{d}	31.2 ± 0.4^{c}	29.3 ± 0.4^{c}	28.2 ± 0.6^{de}	25.7 ± 0.7^{e}	24.5 ± 1.0^{e}	23.5 ± 1.1^{e}	42.4 ± 0.9^{bcd}
	12	40.0 ± 2.2^{a}	35.5 ± 1.3^{bc}	34.0 ± 1.1^{e}	33.3 ± 0.9^{d}	30.7 ± 0.8^{c}	29.0 ± 0.8^{c}	28.0 ± 1.0^{de}	25.5 ± 1.7^{e}	24.2 ± 1.9^{de}	23.0 ± 1.7^{de}	42.8 ± 0.9^{bcd}
Lecanicillium lecanii MTCC 956	8	38.9 ± 0.6^{a}	33.7 ± 2.1^{abc}	31.5 ± 2.5^{bcd}	30.2 ± 2.4^{bcd}	26.7 ± 3.9^{bc}	24.3 ± 4.5^{abc}	22.3 ± 4.3^{abcde}	18.2 ± 3.5^{abcd}	16.0 ± 4.0^{abcd}	15.2 ± 3.6^{bcde}	42.6 ± 0.6^{bcd}
	10	38.4 ± 1.5^{a}	32.7 ± 2.2^{abc}	30.8 ± 2.3^{abcd}	29.5 ± 2.2^{bcd}	26.2 ± 3.2^{abc}	23.7 ± 3.7^{abc}	21.7 ± 3.7^{abcde}	17.7 ± 3.2^{abcd}	15.5 ± 3.8^{abc}	14.7 ± 4.5^{abcd}	42.9 ± 1.1^{bcd}
	12	38.7 ± 0.9^{a}	32.5 ± 2.5^{abc}	30.2 ± 3.3^{abcd}	29.0 ± 3.5^{abcd}	25.7 ± 3.5^{abc}	23.2 ± 3.7^{abc}	21.2 ± 3.2^{abcd}	16.8 ± 3.2^{abcd}	15.0 ± 3.7^{abc}	14.3 ± 4.9^{abc}	43.3 ± 0.7^{bcd}
Beauveria bassiana Commercial formulation	8	40.3 ± 0.5^{a}	35.5 ± 0.9^{bc}	33.5 ± 0.9^{cd}	32.3 ± 0.9^{cd}	28.8 ± 1.3^{bc}	27.0 ± 1.7^{bc}	25.7 ± 1.4^{cde}	21.7 ± 1.2^{de}	19.5 ± 1.3^{bcde}	18.2 ± 1.2^{cde}	41.9 ± 0.2^{cd}
	10	39.5 ± 0.9^{a}	34.3 ± 0.4^{bc}	32.3 ± 0.7^{bcd}	31.2 ± 0.7^{bcd}	27.7 ± 1.8^{bc}	25.8 ± 1.9^{bc}	24.5 ± 1.75^{bcde}	20.7 ± 1.4^{bcde}	18.5 ± 1.5^{bcde}	17.2 ± 1.6^{bcde}	42.5 ± 2.8^{bcd}
	12	39.5 ± 2.2^{a}	34.0 ± 1.7^{abc}	31.8 ± 1.6^{bcd}	30.7 ± 1.2^{bcd}	27.3 ± 2.0^{bc}	25.5 ± 2.0^{bc}	24.2 ± 2.04^{bcde}	20.3 ± 1.9^{bcde}	18.2 ± 2.2^{bcde}	16.8 ± 2.0^{bcde}	42.4 ± 2.1^{bcd}
Metarhizium anisopliae Commercial formulation	8	40.8 ± 1.9^{a}	36.0 ± 1.3^{c}	33.8 ± 0.9^{cd}	32.5 ± 0.8^{d}	29.0 ± 1.0^{bc}	26.8 ± 0.4^{bc}	25.3 ± 0.6^{cde}	22.0 ± 1.6^{de}	20.0 ± 2.1^{cde}	19.0 ± 2.4^{cde}	42.3 ± 0.8^{bcd}
	10	40.2 ± 2.1^{a}	35.2 ± 2.1^{bc}	32.8 ± 2.2^{bcd}	31.5 ± 2.2^{bcd}	28.0 ± 2.1^{bc}	25.8 ± 2.2^{bc}	24.3 ± 2.4^{bcde}	20.8 ± 2.7^{cde}	18.8 ± 2.8^{bcde}	17.8 ± 2.8^{bcde}	42.2 ± 2.2^{bcd}
	12	39.8 ± 0.7^{a}	34.2 ± 1.6^{abc}	32.0 ± 1.5^{bcd}	30.7 ± 1.6^{bcd}	27.0 ± 1.2^{bc}	24.8 ± 1.4^{bc}	23.3 ± 1.4^{bcde}	19.8 ± 0.7^{bcde}	17.7 ± 0.6^{bcde}	17.0 ± 0.9^{bcde}	42.6 ± 1.3^{bcd}
Lecanicillium lecanii Commercial formulation	8	39.1 ± 1.0^{a}	33.7 ± 0.7^{abc}	31.8 ± 0.3^{bcd}	30.7 ± 0.4^{bcd}	26.5 ± 0.8^{abc}	24.2 ± 0.7^{abc}	22.8 ± 1.0^{abcde}	18.7 ± 0.9^{bcd}	16.7 ± 1.7^{abcde}	16.0 ± 1.5^{bcde}	42.3 ± 1.1^{bcd}
	10	39.2 ± 2.6^{a}	33.3 ± 1.6^{abc}	31.5 ± 1.7^{bcd}	30.2 ± 1.9^{bcd}	26.0 ± 3.0^{abc}	23.5 ± 3.0^{abc}	22.3 ± 3.1^{abcde}	18.0 ± 3.0^{abcd}	16.0 ± 4.1^{abcd}	15.5 ± 3.3^{bcde}	43.1 ± 1.0^{bcd}
	12	39.0 ± 1.0^{a}	33.0 ± 1.2^{abc}	31.0 ± 1.5^{bcd}	29.8 ± 1.6^{bcd}	25.5 ± 1.3^{abc}	23.0 ± 2.0^{abc}	21.8 ± 1.8^{abcde}	17.7 ± 2.2^{abcd}	15.8 ± 3.1^{abcd}	15.2 ± 2.7^{bcde}	42.9 ± 1.0^{bcd}
Azadirachtin 1% (10,000 ppm)	4	38.3 ± 1.5^{a}	30.8 ± 1.3^{abc}	28.5 ± 1.0^{abc}	27.0 ± 1.2^{abc}	23.2 ± 1.0^{ab}	20.3 ± 0.7^{ab}	18.7 ± 0.7^{abc}	14.3 ± 0.7^{abc}	12.2 ± 0.3^{abc}	10.7 ± 0.4^{abc}	46.2 ± 2.0^{abc}
	5	38.8 ± 1.4^{a}	30.7 ± 1.1^{ab}	27.8 ± 0.9^{ab}	26.5 ± 1.1^{ab}	22.7 ± 1.6^{ab}	19.8 ± 1.2^{ab}	18.2 ± 1.1^{ab}	13.8 ± 1.2^{ab}	11.5 ± 1.0^{ab}	9.5 ± 0.8^{ab}	47.1 ± 1.6^{ab}
Chemical check (malathion 50 EC)	4	38.3 ± 1.2^{a}	29.2 ± 0.7^{a}	25.8 ± 1.0^{a}	24.2 ± 0.9^{a}	19.8 ± 1.0^{a}	17.2 ± 0.7^{a}	16.0 ± 0.3^{a}	11.7 ± 0.4^{a}	9.3 ± 0.4^{a}	6.7 ± 0.8^{a}	49.4 ± 0.8^{a}
Control		37.6 ± 3.6^{a}	41.1 ± 2.2^{d}	39.3 ± 2.0^{f}	39.3 ± 1.6^{e}	39.0 ± 2.6^{d}	37.0 ± 2.2^{d}	37.5 ± 1.0^{f}	37.2 ± 1.9^{f}	37.2 ± 3.0^{f}	36.3 ± 3.2^{f}	39.8 ± 2.0^{d}
$F_{(18,38)}$values		0.23	2.9	3.3	4.0	3.8	3.8	5.0	7.5	6.2	6.3	2.2
P		1.00	0.03	< 0.01	< 0.001	< 0.001	< 0.001	< 0 .001	< 0.001	< 0.001	< 0 .001	0.022

*Values represent means of 3 replicates

DAS days after spray

Means within each column bearing different letters are significantly different according to the Duncan test ($P = 0.05$)

Table 2 Percentage reduction of aphid, *Myzus persicae*, on capsicum plant treated with indigenous and commercial bioformulations under protected cultivation (2017, 2018)

Treatments	Dose (g or ml/l)	Percent reduction over control *(mean ± SE)								
		I spray			II spray			III spray		
		3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS
Beauveria bassiana Bb-B1	8	16.3 ± 3.9^{a}	16.6 ± 4.3^{b}	18.4 ± 5.0^{b}	23.7 ± 6.2^{c}	23.9 ± 4.9^{c}	27.4 ± 2.5^{e}	33.2 ± 1.4^{e}	36.6 ± 3.9^{e}	37.8 ± 4.7^{e}
	10	17.7 ± 7.6^{a}	17.7 ± 7.9^{b}	19.4 ± 8.5^{b}	24.6 ± 9.4^{c}	25.2 ± 8.8^{c}	29.2 ± 8.0^{e}	34.9 ± 5.8^{e}	37.8 ± 8.0^{e}	39.0 ± 7.1^{e}
	12	18.8 ± 6.2^{a}	18.8 ± 6.3^{b}	20.5 ± 7.4^{b}	26.2 ± 8.4^{c}	26.4 ± 7.5^{c}	30.0 ± 5.2^{de}	35.6 ± 3.1^{e}	38.9 ± 5.9^{de}	40.5 ± 5.8^{de}
Lecanicillium lecanii MTCC 956	8	21.0 ± 0.5^{a}	22.6 ± 2.1^{ab}	25.9 ± 1.2^{ab}	34.0 ± 5.1^{abc}	36.5 ± 7.6^{bc}	42.5 ± 6.3^{abcd}	52.8 ± 5.8^{abcd}	58.4 ± 5.4^{abcd}	59.7 ± 5.4^{abcd}
	10	22.3 ± 2.7^{a}	23.4 ± 4.4^{ab}	26.7 ± 5.1^{ab}	34.4 ± 6.4^{abc}	37.5 ± 6.2^{abc}	43.5 ± 3.1^{abc}	53.6 ± 3.0^{abcd}	59.3 ± 2.5^{abc}	60.6 ± 5.4^{abc}
	12	23.1 ± 2.0^{a}	25.5 ± 3.1^{ab}	28.4 ± 2.5^{ab}	36.1 ± 3.0^{abc}	39.2 ± 5.0^{abc}	45.2 ± 4.3^{abc}	56.0 ± 5.0^{abcd}	60.8 ± 4.5^{abc}	61.7 ± 6.6^{abc}
Beauveria bassiana Commercial formulation	8	19.4 ± 3.2^{a}	20.6 ± 3.5^{ab}	23.3 ± 4.1^{ab}	31.1 ± 3.9^{bc}	32.0 ± 2.4^{bc}	36.2 ± 3.1^{cde}	45.6 ± 3.5^{cde}	51.1 ± 6.1^{cde}	53.4 ± 6.0^{cde}
	10	20.5 ± 5.0^{a}	21.8 ± 4.4^{ab}	24.6 ± 5.4^{ab}	32.5 ± 3.2^{abc}	33.6 ± 2.3^{bc}	38.0 ± 6.4^{cde}	47.1 ± 7.0^{cde}	52.7 ± 8.2^{bcde}	55.1 ± 8.9^{bcde}
	12	21.3 ± 3.3^{a}	23.0 ± 3.7^{ab}	26.0 ± 5.3^{ab}	33.4 ± 2.5^{abc}	34.5 ± 2.3^{bc}	39.0 ± 5.6^{bcde}	48.0 ± 7.1^{bcde}	53.5 ± 9.5^{bcde}	56.0 ± 9.5^{bcde}
Metarhizium anisopliae Commercial formulation	8	19.2 ± 3.7^{a}	20.8 ± 3.1^{ab}	24.0 ± 4.0^{ab}	31.5 ± 3.2^{bc}	33.2 ± 3.0^{bc}	37.8 ± 4.3^{cde}	45.5 ± 6.8^{de}	50.4 ± 9.2^{cde}	51.8 ± 10.8^{cde}
	10	20.0 ± 3.5^{a}	22.0 ± 3.6^{ab}	25.2 ± 4.1^{ab}	33.0 ± 4.4^{abc}	34.8 ± 2.6^{bc}	39.4 ± 4.4^{bcde}	47.7 ± 5.4^{bcde}	52.7 ± 6.5^{bcde}	54.2 ± 7.1^{bcde}
	12	21.5 ± 5.3^{a}	23.3 ± 5.1^{ab}	26.5 ± 6.4^{ab}	34.7 ± 7.0^{abc}	36.7 ± 7.0^{bc}	41.3 ± 5.2^{bcde}	49.7 ± 4.1^{bcde}	55.2 ± 6.3^{bcde}	55.9 ± 5.3^{bcde}
Lecanicillium lecanii Commercial formulation	8	21.1 ± 5.0^{a}	22.2 ± 4.8^{ab}	25.0 ± 5.3^{ab}	34.6 ± 5.6^{abc}	37.2 ± 4.1^{bc}	41.4 ± 2.5^{bcde}	51.7 ± 1.7^{bcd}	56.9 ± 2.0^{bcde}	57.7 ± 2.3^{bcde}
	10	22.1 ± 4.4^{a}	23.2 ± 4.2^{ab}	26.4 ± 4.3^{ab}	36.1 ± 3.2^{abc}	39.1 ± 3.2^{abc}	42.9 ± 2.0^{abcd}	53.6 ± 0.9^{abcd}	58.7 ± 0.7^{abcd}	59.1 ± 1.1^{abcd}
	12	22.6 ± 3.2^{a}	24.1 ± 2.6^{ab}	27.0 ± 3.1^{ab}	37.0 ± 3.7^{abc}	40.1 ± 3.1^{abc}	43.9 ± 2.0^{abc}	54.2 ± 1.4^{abcd}	59.0 ± 1.0^{abcd}	59.8 ± 1.4^{abcd}
Azadirachtin 1% (10,000 ppm)	4	26.4 ± 4.1^{a}	29.0 ± 4.0^{ab}	32.7 ± 4.1^{ab}	41.8 ± 5.3^{abc}	46.2 ± 4.2^{ab}	51.2 ± 3.2^{abc}	62.2 ± 5.4^{abc}	67.9 ± 5.7^{abc}	71.2 ± 4.8^{abc}
	5	28.0 ± 4.0^{a}	31.5 ± 4.5^{ab}	34.8 ± 4.2^{ab}	43.8 ± 2.9^{ab}	48.2 ± 2.9^{ab}	53.1 ± 3.4^{ab}	64.0 ± 5.3^{ab}	70.1 ± 4.6^{ab}	74.7 ± 3.7^{ab}
Chemical check (malathion 50 EC)	4	30.4 ± 3.8^{a}	35.6 ± 5.1^{a}	39.8 ± 5.5^{a}	50.2 ± 5.1^{a}	54.5 ± 1.4^{a}	58.2 ± 3.6^{a}	69.2 ± 4.7^{a}	75.4 ± 3.3^{a}	82.0 ± 4.9^{a}
F values		0.7	1.1	1.1	1.6	2.5	3.2	4.1	3.3	3.5
P		0.8	0.4	0.4	0.1	0.01	0.01	0.01	0.01	0.01

Mean mortality (%) ± standard error of *M. persicae* recorded at different time intervals (*DAS*, days after spray) for bioassays performed with different commercial and indigenous strains

Treatment columns bearing different letters are significantly different from other treatments according to Duncan test ($P = 0.05$)

*Calculated as per Henderson and Tilton (1955) formula

2015). In order to correct mortality data in the treatment with that in the control, Henderson and Tilton's (1955) formula was used.

Results and discussion

Biopesticides against *M. persicae*

Under protected cultivation, *M. persicae* was recorded on capsicum plant for 2 consecutive years, 2017 and 2018. The pooled data presented in Table 1 depicted that the aphid individuals in the treatment control increased and decreased slightly, with maximum population density (41.1 aphids per 3 leaves). After 10 days of 1st spray, aphid individuals declined in all the mycoformulation treatments, 29.0–33.6 aphids per 3 leaves at the concentration of 1 × 10^8 cfu/ml, and in Azadirachtin, 26.5–27.0 aphids per 3 leaves at concentration of 1%. The aphid infestation decreased gradually throughout the experiment. Both commercial and indigenous bioformulation decreased the aphid individuals after 3rd spray. The aphid population in *L. lecanii* MTCC 956 at 12 g/l was 16.8, 15.0, and 14.3 aphids per 3 leaves with 56.0, 60.8, and 61.7% population reduction after 3, 7, and 10 days after spray (DAS), respectively and was non-significant with MTCC 956 at 10 g/l recorded 17.7, 15.5, and 14.7 aphids per 3 leaves with 53.6, 59.3, and 60.6% population reduction after 3, 7, and 10 DAS, respectively Table 2. Azadirachtin at 4 and 5 ml/l were non-significant with each other and with *L. lecanii* MTCC 956 formulation. Azadirachtin at 5 ml/l recorded aphid population 13.8, 11.5, and 9.5 with 64.0, 70.1, and 74.7% aphid population reduction after 3, 7, and 10 days after 3 sprays (Fig. 1). In the present studies, it was observed that Azadirachtin 1% at 4 and 5 ml/l and *L. lecani* bioformulation at 10 and 12 g/l were significantly better than all other fungal formulations in management of the aphid. Highest fruit yield (49.4 t/ha) was in chemical check malathion 50 EC at 4 ml/l and was non-significant with yield recorded in Azadirachtin at 5 ml/l (47.1 t/ha) and 4 ml/l (46.2 t/ha). So, bioformulations of *L. lecanii* and azadirachtin 1% against *M. persicae* resulted in a significant increase in the mortality of *M. persicae* under protected cultivation and also no plant damage was recorded during the experiment. The high mortality recorded in *L. lecanii* may be due to fact that it germinated well under a wide range of temperatures and humidity and thus made this fungus more virulent, whereas, the Azadirachtin affected the reproductive rate of sucking insect pests causing more nymphal mortality and thus reducing their survival period and fecundity. Obtained results are in corroboration with Vu et al. (2007) who evaluated 12 strains of EPF viz., *L. lecanii*, *P. farinosus*, *B. bassiana*, *M. anisopliae*, *Cordyceps scarabaeicola*, and *Nomuraea rileyi* (Hypocreales: Clavicipitaceae) against aphids on cabbage and cucumber under greenhouse conditions and recorded that *L. lecanii* 41185 strain was highly virulent than all other strains against *M. persicae* and *A. gossypii*. They also reported that *L. lecanii* 41185 strain germinated and grew well under wide range of temperature and humidity. This finding coincides with the results of Mohammed et al. (2018) who recorded *L. lecanii* better than *M. anisopliae* and *B. bassiana* against *M. persicae* and *A. gossypii* under laboratory and greenhouse cultivations and in which they evaluated 4 procured native isolates of *B. bassiana*, *M. anisopliae*, *L. lecanii*, and *Chaetomium globosum* and recorded their efficacy against the aphids *M. persicae* and *A. gossypii* and showed that *L. lecanii* showed the highest mortality than all 3 isolates against *M. persicae* and *A. gossypii* under laboratory as well as under greenhouse cultivation when applied at the concentration of 1 × 10^8 conidia/ml. Santos et al.

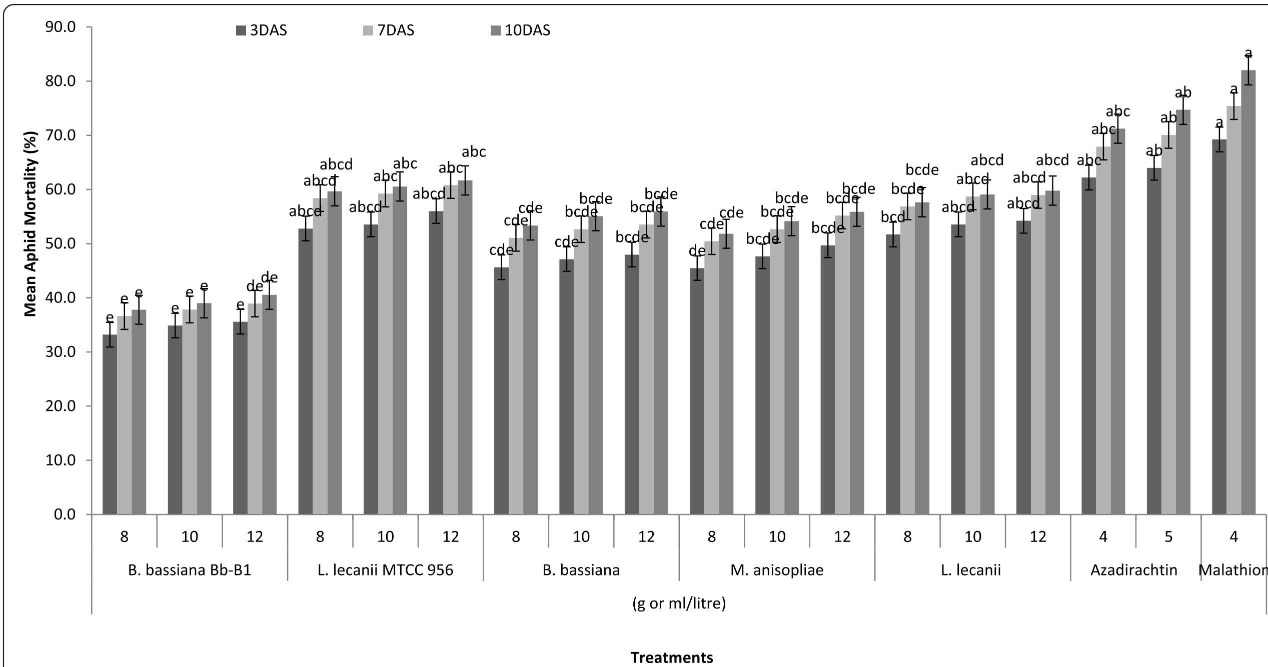

Fig. 1 Mean mortality (%) ± SE of *M. persicae* recorded at different time intervals (*DAS* days after spray). Treatment columns bearing different alphabets are significantly different from other treatments according to Duncan test (*P* = 0.05)

Table 3 Population dynamics of whitefly, *Bemisia tabaci* (Gennadius) on capsicum plant treated with indigenous and commercial bioformulations under protected cultivation (2017, 2018)

Treatments	Dose (g or ml/l)	No. of whitefly adults/plant*(mean ± SE)										Fruit yield (t/ha)
		Before spray	I spray			II spray			III spray			
			3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	
Beauveria bassiana Bb-B1	8	22.8 ± 2.9^{a}	20.5 ± 1.4^{abc}	19.3 ± 1.8^{ab}	18.7 ± 2.0^{ab}	17.0 ± 1.7^{bc}	16.0 ± 1.7^{c}	15.7 ± 2.0^{d}	14.0 ± 2.3^{d}	13.0 ± 2.1^{d}	12.3 ± 2.0^{d}	40.6 ± 1.3^{ab}
	10	22.7 ± 0.9^{a}	20.3 ± 1.8^{ab}	19.0 ± 1.7^{ab}	18.0 ± 1.7^{ab}	16.1 ± 1.0^{abc}	15.0 ± 1.1^{bc}	15.0 ± 0.6^{cd}	13.3 ± 0.3^{cd}	12.3 ± 0.3^{cd}	11.7 ± 0.7^{d}	41.0 ± 1.0^{ab}
	12	22.4 ± 0.9^{a}	20.0 ± 0.6^{ab}	18.0 ± 0.6^{ab}	17.0 ± 0.6^{ab}	15.1 ± 1.2^{abc}	14.3 ± 1.4^{abc}	14.0 ± 1.7^{bcd}	12.7 ± 1.2^{bcd}	11.7 ± 1.2^{cd}	11.0 ± 1.0^{d}	41.4 ± 1.4^{ab}
Lecanicillium lecanii MTCC 956	8	24.7 ± 3.3^{a}	20.3 ± 2.6^{ab}	18.7 ± 2.3^{ab}	17.8 ± 2.3^{ab}	16.3 ± 2.0^{bc}	14.3 ± 1.2^{abc}	13.0 ± 0.6^{abcd}	11.3 ± 0.3^{bcd}	10.3 ± 0.3^{bcd}	9.7 ± 1.2^{bcd}	41.9 ± 1.2^{ab}
	10	23.3 ± 0.9^{a}	19.0 ± 0.6^{ab}	17.3 ± 0.3^{ab}	16.3 ± 0.3^{ab}	14.0 ± 0.6^{abc}	12.3 ± 0.3^{abc}	11.3 ± 0.7^{abc}	10.0 ± 0.6^{abc}	8.7 ± 0.7^{abc}	8.5 ± 0.9^{abcd}	42.2 ± 1.7^{ab}
	12	23.7 ± 1.2^{a}	18.3 ± 0.9^{ab}	17.0 ± 0.6^{ab}	16.0 ± 0.6^{ab}	13.3 ± 1.2^{abc}	12.0 ± 1.1^{abc}	11.1 ± 1.1^{abc}	9.7 ± 0.9^{abc}	8.7 ± 0.9^{abc}	8.3 ± 0.9^{abcd}	42.4 ± 2.3^{ab}
Beauveria bassiana Commercial formulation	8	23.3 ± 1.8^{a}	20.7 ± 0.7^{abc}	19.3 ± 0.3^{ab}	19.0 ± 0.6^{b}	16.3 ± 0.9^{bc}	15.0 ± 1.0^{bc}	14.3 ± 0.9^{bcd}	12.7 ± 0.9^{bcd}	11.7 ± 1.2^{cd}	11.0 ± 1.1^{d}	40.9 ± 1.0^{ab}
	10	23.3 ± 0.9^{a}	20.5 ± 0.4^{abc}	19.1 ± 0.5^{ab}	18.7 ± 0.3^{ab}	16.1 ± 0.7^{abc}	14.7 ± 1.2^{bc}	14.0 ± 1.5^{bcd}	12.3 ± 1.2^{bcd}	11.3 ± 0.3^{bcd}	10.7 ± 1.2^{cd}	40.7 ± 1.0^{ab}
	12	23.4 ± 1.4^{a}	20.5 ± 0.3^{abc}	18.9 ± 0.5^{ab}	18.3 ± 0.7^{ab}	15.7 ± 0.3^{abc}	14.0 ± 0.6^{abc}	13.3 ± 1.2^{abcd}	11.7 ± 1.2^{bcd}	11.0 ± 1.5^{bcd}	10.3 ± 1.4^{bcd}	41.2 ± 0.9^{ab}
Metarhizium anisopliae Commercial formulation	8	24.7 ± 5.2^{a}	22.0 ± 3.6^{bc}	20.7 ± 2.9^{b}	20.0 ± 2.9^{b}	17.3 ± 1.8^{c}	16.0 ± 1.5^{c}	14.9 ± 1.5^{cd}	13.3 ± 1.8^{cd}	13.0 ± 2.1^{d}	12.3 ± 1.8^{d}	40.5 ± 1.0^{ab}
	10	21.4 ± 0.9^{a}	19.0 ± 0.6^{ab}	17.7 ± 0.3^{ab}	17.0 ± 0.6^{ab}	14.7 ± 1.2^{abc}	13.7 ± 0.7^{ab}	12.7 ± 0.7^{abcd}	11.3 ± 0.3^{bcd}	11.0 ± 1.5^{bcd}	10.3 ± 1.8^{bcd}	40.6 ± 1.6^{ab}
	12	22.7 ± 1.2^{a}	20.0 ± 0.6^{ab}	18.7 ± 0.7^{ab}	17.9 ± 0.6^{ab}	15.3 ± 0.9^{abc}	14.0 ± 0.6^{abc}	13.3 ± 0.7^{abcd}	11.7 ± 0.9^{bcd}	11.3 ± 0.9^{bcd}	10.7 ± 1.2^{cd}	41.2 ± 1.5$^{ab\backslash}$
Lecanicillium lecanii Commercial formulation	8	24.7 ± 3.2^{a}	21.0 ± 2.6^{abc}	19.0 ± 2.6^{ab}	18.2 ± 2.6^{ab}	16.7 ± 2.3^{bc}	14.7 ± 1.4^{bc}	13.3 ± 0.9^{abcd}	11.7 ± 0.7^{bcd}	10.7 ± 0.3^{bcd}	10.0 ± 1.5^{bcd}	41.5 ± 1.0^{ab}
	10	23.3 ± 0.9^{a}	19.7 ± 0.7^{ab}	17.7 ± 0.7^{ab}	16.7 ± 0.3^{ab}	14.3 ± 0.7^{abc}	12.7 ± 0.3^{abc}	11.7 ± 0.3^{abc}	10.3 ± 0.3^{abcd}	9.7 ± 0.9^{bcd}	9.2 ± 1.5^{bcd}	42.1 ± 0.7^{ab}
	12	23.7 ± 1.2^{a}	19.3 ± 0.7^{ab}	17.3 ± 0.7^{ab}	16.3 ± 0.7^{ab}	14.0 ± 0.6^{abc}	12.7 ± 0.7^{abc}	11.4 ± 0.8^{abc}	10.0 ± 1.0^{abc}	9.3 ± 0.3^{abcd}	8.7 ± 1.2^{bcd}	41.8 ± 1.2^{ab}
Azadirachtin 1% (10,000 ppm)	4	23.1 ± 1.7^{a}	17.7 ± 0.9^{ab}	16.3 ± 0.9^{ab}	15.3 ± 0.9^{ab}	12.7 ± 0.3^{ab}	11.7 ± 0.3^{ab}	11.0 ± 0.6^{abc}	9.0 ± 0.6^{ab}	7.7 ± 0.3^{ab}	6.7 ± 0.3^{abc}	44.0 ± 1.7^{ab}
	5	24.2 ± 0.4^{a}	17.7 ± 1.3^{ab}	16.0 ± 1.0^{a}	15.3 ± 1.2^{ab}	13.0 ± 0.6^{abc}	11.7 ± 0.3^{ab}	10.7 ± 0.3^{ab}	9.0 ± 0.6^{ab}	7.7 ± 0.3^{ab}	6.4 ± 0.6^{ab}	44.4 ± 4.4^{ab}
Chemical check (malathion 50 EC)	4	23.3 ± 1.85^{a}	16.7 ± 1.7^{a}	15.0 ± 1.0^{a}	14.2 ± 0.9^{a}	11.7 ± 1.2^{a}	10.3 ± 0.9^{a}	9.7 ± 0.9^{a}	7.1 ± 0.5^{a}	6.0 ± 0.6^{a}	4.7 ± 0.3^{a}	46.3 ± 3.0^{a}
Control		24.0 ± 2.1^{a}	25.3 ± 1.3^{c}	25.0 ± 1.1^{c}	25.3 ± 1.4^{c}	24.3 ± 2.8^{d}	23.9 ± 2.9^{d}	24.0 ± 2.5^{e}	24.7 ± 2.1^{e}	23.0 ± 1.5^{e}	22.0 ± 0.6^{e}	40.0 ± 1.0^{b}
$F_{(18)}$ values		0.16	1.5	2.5	3.0	3.9	5.5	6.8	10.3	10.2	8.1	0.8
P		1.00	> 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.7

*Values represent means of 3 replicates
DAS days after spray
Means within each column bearing different letters are significantly different according to the Duncan test (P = 0.05)

(2004) evaluated neem extract against the aphid *A. gossypii* pest on cotton and reported that aqueous extract of neem effected development, survival, and fecundity of *A. gossypii* thus causing high nymphal mortality.

Biopesticide against *B. tabaci*

The data presented in Table 3 showed that the whitefly population in the treatment control increased and decreased slightly with a maximum population density of 25.3 whiteflies per 3 leaves. After 10 days of 1st spray,

Table 4 Percentage reduction of whitefly, *Bemisia tabaci*, on capsicum plant treated with indigenous and commercial bioformulations under protected cultivation (2017, 2018)

Treatments	Dose (g or ml/l)	Percent reduction over control*(mean ± SE)								
		I Spray			II Spray			III Spray		
		3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS
Beauveria bassiana Bb-B1	8	14.5 ± 6.0^{a}	18.5 ± 8.2^{c}	22.3 ± 8.3^{b}	26.3 ± 3.1^{c}	29.4 ± 3.0^{d}	31.2 ± 5.4^{e}	40.2 ± 7.9^{e}	40.4 ± 9.5^{e}	40.9 ± 12.0^{d}
	10	15.0 ± 9.0^{a}	19.5 ± 8.0^{bc}	24.8 ± 8.7^{ab}	30.0 ± 10.7^{bc}	33.5 ± 10.0^{cd}	33.8 ± 7.9^{de}	42.7 ± 6.4^{de}	43.2 ± 4.9^{de}	43.8 ± 6.4^{d}
	12	15.6 ± 5.4^{a}	23.0 ± 7.3^{abc}	28.2 ± 6.3^{ab}	33.6 ± 9.4^{abc}	35.8 ± 8.8^{bcd}	37.6 ± 11.1^{cde}	45.1 ± 8.1^{cde}	45.8 ± 8.5^{de}	46.5 ± 9.7^{d}
Lecanicillium lecanii MTCC 956	8	21.9 ± 5.2^{a}	27.3 ± 3.8^{abc}	31.3 ± 4.4^{ab}	34.7 ± 5.4^{abc}	41.6 ± 1.2^{abcd}	47.3 ± 0.5^{abcde}	55.3 ± 1.2^{abcde}	56.3 ± 4.0^{abcde}	57.2 ± 0.9^{abcd}
	10	23.0 ± 4.0^{a}	29.0 ± 2.0^{abc}	33.7 ± 2.6^{ab}	40.8 ± 3.8^{abc}	46.8 ± 1.8^{abc}	51.4 ± 0.6^{abc}	58.3 ± 1.5^{abcd}	61.2 ± 3.2^{abcd}	60.0 ± 4.8^{abcd}
	12	26.6 ± 7.4^{a}	31.0 ± 6.4^{abc}	35.9 ± 5.4^{ab}	44.4 ± 2.7^{abc}	49.0 ± 3.6^{ab}	53.1 ± 2.5^{abc}	60.3 ± 3.0^{abcd}	61.8 ± 3.8^{abcd}	61.6 ± 4.7^{abcd}
Beauveria bassiana Commercial formulation	8	16.1 ± 2.1^{a}	20.4 ± 4.8^{abc}	22.8 ± 5.8^{b}	30.9 ± 2.5^{bc}	35.4 ± 2.6^{bcd}	38.6 ± 3.3^{bcde}	47.2 ± 4.0^{bcde}	47.9 ± 3.9^{cde}	48.6 ± 5.4^{cd}
	10	16.5 ± 5.0^{a}	21.3 ± 3.4^{abc}	24.2 ± 2.4^{ab}	31.8 ± 2.6^{abc}	36.8 ± 3.6^{bcd}	39.6 ± 7.1^{bcde}	48.6 ± 6.3^{bcde}	49.3 ± 2.7^{bcde}	50.2 ± 5.1^{bcd}
	12	16.9 ± 8.6^{a}	22.7 ± 7.2^{abc}	25.9 ± 6.0^{ab}	34.1 ± 11.5^{abc}	40.0 ± 9.3^{bcd}	43.1 ± 11.8^{abcde}	51.6 ± 12.7^{bcde}	51.1 ± 12.8^{bcde}	52.0 ± 11.8^{bcd}
Metarhizium anisopliae Commercial formulation	8	15.5 ± 3.5^{a}	19.6 ± 6.5^{c}	23.2 ± 6.6^{b}	30.7 ± 2.7^{bc}	34.8 ± 3.6^{cd}	40.0 ± 3.5^{bcde}	47.4 ± 0.7^{bcde}	45.0 ± 1.9^{de}	45.4 ± 3.0^{d}
	10	16.0 ± 2.1^{a}	21.0 ± 0.5^{abc}	24.9 ± 3.5^{ab}	32.5 ± 2.6^{abc}	36.0 ± 4.0^{bcd}	40.9 ± 3.8^{abcde}	48.6 ± 6.0^{bcde}	46.5 ± 10.3^{de}	47.4 ± 11.0^{cd}
	12	16.4 ± 3.3^{a}	21.0 ± 4.2^{abc}	25.2 ± 4.4^{ab}	33.3 ± 6.9^{abc}	37.9 ± 4.5^{bcd}	41.2 ± 5.1^{abcde}	50.0 ± 5.8^{bcde}	47.8 ± 4.7^{cde}	48.7 ± 4.6^{cd}
Lecanicillium lecanii Commercial formulation	8	19.3 ± 4.4^{a}	26.0 ± 4.2^{abc}	30.0 ± 4.9^{ab}	33.4 ± 6.7^{abc}	40.2 ± 2.4^{abcd}	45.9 ± 1.4^{abcde}	54.0 ± 1.1^{abcde}	54.8 ± 2.8^{bcde}	55.8 ± 2.0^{abcd}
	10	20.1 ± 3.8^{a}	27.3 ± 2.6^{abc}	32.3 ± 2.7^{ab}	39.4 ± 5.3^{abc}	45.5 ± 3.4^{abcd}	50.0 ± 1.1^{abcd}	57.0 ± 1.8^{abcde}	56.7 ± 4.5^{abcde}	57.0 ± 7.0^{abcd}
	12	22.6 ± 6.2^{a}	29.7 ± 6.2^{abc}	34.6 ± 5.4^{ab}	41.6 ± 0.7^{abc}	46.2 ± 2.4^{abc}	51.6 ± 1.5^{abc}	59.0 ± 4.1^{abcd}	58.9 ± 0.9^{abcde}	60.1 ± 5.7^{abcd}
Azadirachtin 1% (10,000 ppm)	4	27.6 ± 2.4^{a}	32.2 ± 1.2^{abc}	37.1 ± 1.8^{ab}	46.0 ± 2.7^{abc}	49.3 ± 2.4^{ab}	52.4 ± 1.4^{abc}	62.1 ± 2.8^{abc}	65.4 ± 0.7^{abc}	68.5 ± 2.0^{abc}
	5	30.9 ± 8.3^{a}	36.6 ± 6.5^{ab}	40.0 ± 7.0^{ab}	47.0 ± 6.5^{ab}	51.6 ± 4.1^{ab}	56.0 ± 4.2^{ab}	63.8 ± 3.7^{ab}	67.1 ± 1.1^{ab}	71.0 ± 1.6^{ab}
Chemical check (malathion 50 EC)	4	32.3 ± 4.9^{a}	38.3 ± 3.3^{a}	42.2 ± 4.4^{a}	50.7 ± 3.6^{a}	55.5 ± 3.1^{a}	58.6 ± 2.1^{a}	70.4 ± 2.2^{a}	73.2 ± 0.3^{a}	78.2 ± 2.8^{a}
F values		1.1	1.3	1.4	1.5	2.4	2.4	2.3	2.8	2.5
P		0.40	0.22	0.20	0.14	0.01	0.01	0.01	0.01	0.01

Mean mortality (%) ± standard error of *B. tabaci* recorded at different time intervals (*DAS* days after spray) for bioassays performed with different commercial and indigenous strains

Treatment columns bearing different alphabets are significantly different from other treatments according to Duncan test ($P = 0.05$)

*Calculated as per Henderson and Tilton (1955) formula

whitefly population declined in all the mycoformulation treatments (16.0–18.7 whiteflies per 3 leaves) and in Azadirachtin 1% (15.3 whiteflies per 3 leaves). The whitefly population infestation decreased gradually throughout the experiment. Both commercial and indigenous bioformulation decreased the whitefly population after 3rd spray. The whitefly population in *L. lecanii* MTCC 956 at 12 g/l was 9.7, 8.7, and 8.3 with 60.3, 61.8, and 61.6% population reduction after 3, 7, and 10 days after spray (DAS), respectively and was non-significant with MTCC 956 at 10 g/l which recorded 10.0, 8.7, and 8.5 whiteflies per 3 leaves with 58.3, 61.2, and 60.0% population reduction after 3, 7, and 10 DAS, respectively (Table 4). Azadirachtin at 4 and 5 ml/l were non-

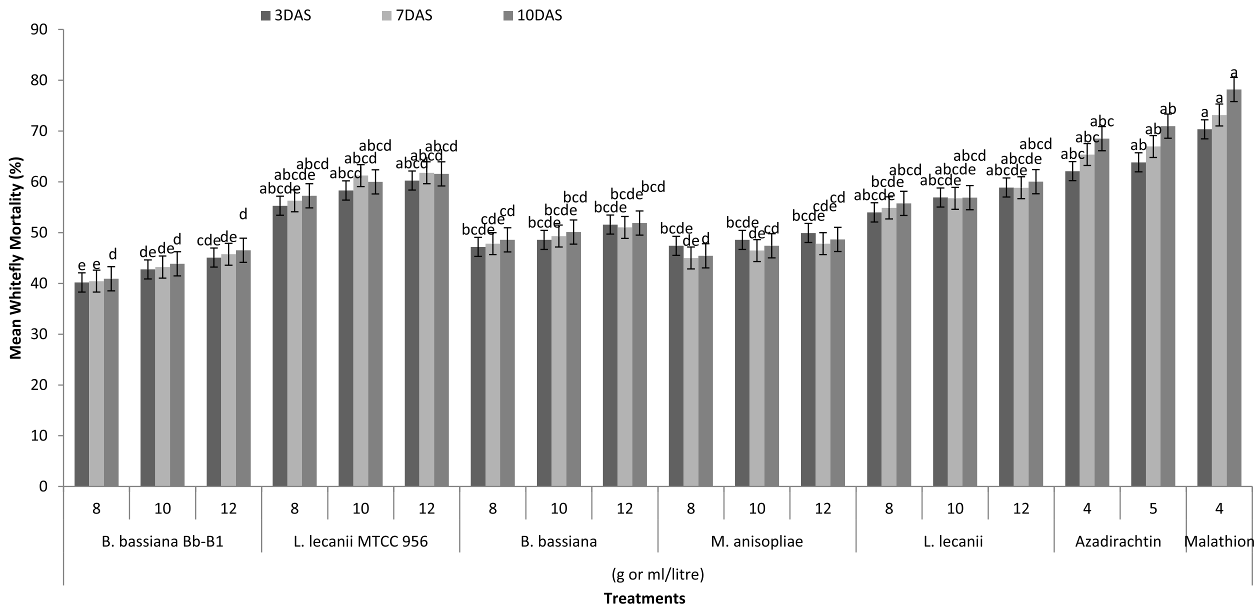

Fig. 2 Mean mortality (%) ± SE of *B. tabaci* recorded at different time intervals (*DAS* days after spray). Treatment columns bearing different alphabets are significantly different from other treatments according to Duncan test (P = 0.05)

significant with each other and with *L. lecanii* MTCC 956 formulation. Azadirachtin 5 ml/l recorded whitefly population of 9.0, 7.7, and 6.4 whiteflies per 3 leaves per plant with 63.8, 67.1, and 71.0% whitefly population reduction after 3, 7, and 10 days after 3rd spray (Fig. 2). In the present study, it was observed that Azadirachtin 1% at 4 and 5 ml/l and *L. lecanii* bioformulation at 10 and 12 g/l was significantly better than all other fungal formulations in management of whitefly. So, we conclude that bioformulations of *L. lecanii* and azadirachtin 1% against *B. tabaci* resulted in a significant increase in the mortality of *B. tabaci* population under protected cultivation. The highest fruit yield was in all treatments were at par with each other. Other scientists' work (Cuthbertson and Walters, 2005) demonstrated that the pathogenicity of commercial EPF *Lecanicillium muscarium* (Mycotal, Koppert Biological Systems Ltd., UK) against sweet potato whitefly *B. tabaci* under laboratory and glasshouse cultivation and recorded that the application of *L. muscarium* against *B. tabaci* resulted in a significant increase in the mortality of *B. tabaci* under glasshouse cultivation and also no plant damage was recorded during the experiment. Budha et al. 2015 tested the efficacy of bio-pesticide against whitefly *B. tabaci* on tomato plant and they observed the efficacy test of some bio-pesticides on tomato plants to control nymphs of Tobacco whitefly *B. tabaci*, thus concluded that biopesticides viz. Bio Magic (91.64%), Mealikil (93.55%), and Biopower (88.91) were highly effective in killing nymphal whitefly population over control after 3rd spray. The most effective EPF that reduced the pest population were *B. bassiana*, *V. lecanii*, and *M. anisopliae*. These studies are in accordance with the present work where *L. lecanii* was recorded most effective against *B. tabaci*. Abdel-Rahim and Ahmed (2017) evaluated the EPF, *M. anisopliae*, *B. bassiana*, and *V. lecanii* at three different concentrations (1×10^7, 1×10^8, and 1×10^9 spores/ml) against *B. tabaci* in laboratory and field cultivation, respectively. They reported that higher concentration (1×10^9 spores/ml) of the 3 EPF was highly toxic to adults of *B. tabaci* than the other 2 concentrations. Under field cultivation also higher concentration (1×10^9) of *V. lecanii* was best in managing adult whitefly population; similar trend was found in this study also.

Conclusion

Obtained results showed that EPF, *L. lecanii* MTCC956 formulation was virulent to both *M. persicae* and *B. tabaci* on capsicum under protected cultivation when applied at 10 and 12 g/l. Similarly, botanical formulation Azadirachtin 1% at 4 and 5 ml/l was most effective in reducing *M. persicae* and *B. tabaci* on capsicum under protected cultivation. These results suggest that these biorationals can be included in integrated pest management programs designed for controlling the aphid and whitefly population on capsicum under protected conditions.

Abbreviations

PDA: Potato dextrose agar; RBD: Randomized block design; EC: Emulsifiable concentrate; N: Insect population; T: Treated; Co: Control; ANOVA: Analysis of variance; DMRT: Duncan multiple range test; cfu: Colony forming unit; DAS: Days after spray; MTCC: Microbial type culture collection and gene bank; LSD: Least significant difference

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Ethical approval and consent to participate
Not applicable

Authors' contributions
H S carried out the experiments, recorded data, interpreted the results, and wrote the manuscript. N J designed and supervised the experiments, provided technical guidance, and edited manuscript. All authors read and approved the final manuscript during present study.

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The authors declare that they have no competing interests.

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