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Study on efficacy of *Beauveria bassiana* (Bb 112) formulations and validation of delivery equipments against *Aphis gossypii* on tomato

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Abstract

Bioefficacy of three different formulations of *Beauveria bassiana* (Balsamo) Vuillemin (Ascomycota: Hypocreales: Clavicipitaceae) Bb 112 isolate were assessed against aphid, *Aphis gossypii* (Aphididae: Hemiptera) in tomato. Based on the experimental results, effective formulation of *B. bassiana* (Bb 112) was selected and its bioefficacy was tested against aphids under field condition using different delivery equipments. Two sprays at 14 days interval were given and the cumulative reduction in aphid population was taken into account. The microplot study revealed that the oil formulation of *B. bassiana* (Bb 112) recorded maximum control of aphids with highest population reduction of 45.50 % when compared to talc and crude formulations. Under field condition also, oil formulation of *B. bassiana* (Bb 112) sprayed with Controlled Droplet Applicator (CDA) recorded highest population reduction of aphid (41.02 and 46.31 %). Hence, the present study entails that the improved formulations applied using improved delivery systems can thereby reform the biopesticide utility.

Key words: *Beauveria bassiana,* Bb 112, *Aphis gossypii,* CDA, bioefficacy

Introduction

Tomato, *Solanum lycopersicum* L. is one of the most widely grown solanaceous vegetables in the world which accounts for more than 65 % of global vegetable production. This crop is attacked by a large number of insect pests, out of which cotton aphid, *Aphis gossypii* and fruit borer, *Helicoverpa armigera* cause considerable losses (20 to 60 %). Aphids cause damage directly through sucking the cell contents from leaves, stems, flowers and surface of fruits, thereby causing various symptoms in plants and indirectly through the transmission of lethal plant viruses. Because of their ubiquitous nature, the characteristic damage they cause, such as leaf crinkling or flower drop, can be mistaken for virus diseases or physiological disorders. Severe infestation can kill entire plant.

Entomopathogenic fungi are potentially the most versatile biological control agent against aphids, due to their wide host range that often results in natural epizootics. Fungi unlike bacteria or viruses directly infect through insect cuticle and do not require ingestion for infection and thereby it offers great potential for the management of sucking pests (Ramanujam, 2004). Fungal formulations developed as microbial insecticides should possess good fluid stability and shelf life. Hence, present study was carried out to evaluate the effective fungal formulation and its efficacy against *A. gossypii* using different delivery equipments.

Materials and methods

Selection of fungal isolate: Hemalatha *et al.* (2016) isolated and evaluated fungal isolates belonging to *Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii and M. flavoviride* against chilli thrips. LC_{50} values of fungal isolates against *Scirtothrips dorsalis* indicated that *B. bassiana* isolate Bb 112 had the highest virulence with lowest LC_{50} values of 0.6 x 10^6 spores mL^{-1}. The time mortality response of *S. dorsalis* to fungal pathogens indicated that isolate Bb 112 had the lowest LT_{50} value of 97.68 h. In pot culture experiment also, among the other fungal isolates, application of Bb 112 at 10^8 spores mL^{-1} had highest cumulative mean thrips population reduction. Hence, the promising isolate Bb 112 was selected for further testing of efficacy against tomato aphids, *A. gossypii* using different delivery equipments.

Formulations of *B. bassiana* (Bb 112): Different formulations of *B. bassiana* (Bb 112) *viz.*, crude, talc and oil based formulations were prepared as per the protocol formed by Sangamithra (2015).

Evaluation of formulations under microplot: Studies were conducted in microplots at the insectary of Department of Agricultural Entomology, TNAU, Coimbatore in 2016 to evaluate the efficacy of different formulations of *B. bassiana* (Bb 112) at 10^8 spores mL^{-1} against aphids (*Aphis gossypii*) on tomato in comparison with talc formulation of *B. bassiana* (B2) available in the Department of Plant Pathology, TNAU and standard insecticide checks (imidacloprid 17.8 SL and dimethoate 30 EC). Tomato seedlings (cv. PKM 1) were raised in protrays. After 15 days of sowing, tomato seedlings were transferred to the microplots of size 12 m^2 (4x3 m^2). The experiment included seven treatments with four replications.

Treatments were imposed twice at fortnightly interval with the help of a hand sprayer. The pre and post treatment observations on live aphid population were assessed on 0, 3, 5, 7, 10 and 14

days after application. Three leaves, one each from top, middle and bottom canopies of each plant were assessed for the live aphids on the undersurface of the leaves. The observations were made randomly on the place where maximum population was noticed. The treatment details are as follows.

Treatments	Dosage
B. bassiana (Bb 112) (Oil formulation)	10^8 Spores mL^{-1}
B. bassiana (Bb 112) (Talc formulation)	10^8 Spores mL^{-1}
B. bassiana (Bb 112) (Crude formulation)	10^8 Spores mL^{-1}
B. bassiana (B 2) 5 g L^{-1} (Commercial talc formulation)	10^8 Spores mL^{-1}
Dimethoate 30 EC	0.7 mL L^{-1}
Imidacloprid 17.8 SL	0.5 mL L^{-1}
Control (Water spray)	-

Evaluation of effective formulation against *A. gossypii* using different delivery equipments under field condition: Field experiments were conducted to evaluate the performance of different delivery equipments for the application of novel formulation of *B. bassiana* (Bb 112) against *A. gossypii* on tomato. Trials were conducted at Kumarapalayam, Coimbatore district and at Ambillikai, Dindigul district. The experiments were carried out in a randomized block design with the plot size of 4m x 5m with three replications. The treatment details are furnished below.

Treatment	Delivery equipments	Dosage
B. bassiana (Bb 112) Oil formulation – 4 mL L^{-1}	ASPEE Maruyama Engine sprayer	10^8 spores mL^{-1}
	Avenger ULV sprayer	10^8 spores mL^{-1}
	ASPEE Battery sprayer	10^8 spores mL^{-1}
	ASPEE Knapsack hand sprayer	10^8 spores mL^{-1}
	ASPEE Hitech hand sprayer	10^8 spores mL^{-1}
	CDA sprayer	10^8 spores mL^{-1}
B. bassiana (B 2) Talc based formulation - 5 g L^{-1}	Knapsack hand sprayer	10^8 spores mL^{-1}
Dimethoate 30 EC	Knapsack hand sprayer	0.7 mL L^{-1}
Imidacloprid 17.8 SL	Knapsack hand sprayer	0.5 mL L^{-1}
Control (Water spray)	Knapsack hand sprayer	-

Results

Evaluation of effective formulation of *B. bassiana* (Bb 112) against *Aphis gossypii* on tomato: Talc, paraffin oil, crude formulations of *B. bassiana* (Bb 112) were evaluated for their efficacy in microplots against *Aphis gossypii*.

The pretreatment population of aphids was uniform and not significant among the treatments and ranged from 31.03 to 33.68 per leaf. After the first round of spraying, the oil based formulation of *B. bassiana* (Bb 112) was found significantly superior to other *B. bassiana* treatments and recorded the lowest aphids population of 21.52, 17.76, 15.49, 19.73 and 20.89 numbers per leaf at 3, 5, 7, 10 and 14 days after treatment, respectively with the highest reduction of 41.18 %. This was followed by the talc based formulation of *B. bassiana* (Bb 112) with a reduction of 29.57 % (Table 1). Standard insecticide checks, imidacloprid 17.8 SL (0.5 mL L^{-1}) and dimethoate 30 EC (0.7 mL L^{-1}) were significantly superior to all other treatments and with the population reduction of 62.38 and 61.26 %, respectively.

After the second round of treatments, a similar trend was observed (Table 2). Application of oil based formulation of *B. bassiana* (Bb 112) was highly effective with a cumulative mean aphids population reduction of 45.50 % after two rounds of spraying. This was followed by talc based and crude formulations of *B. bassiana* (Bb 112), which recorded the cumulative mean reduction of 34.04 and 25.22 % over control, respectively. The standard insecticide check, imidacloprid 17.8 SL (0.5 mL L^{-1}) and dimethoate 30 EC (0.7 mL L^{-1}) were significantly superior to all other treatments with the highest cumulative mean reduction of 70.94 and 69.28 %, respectively. The standard biocontrol agent, *B. bassiana* (B2) commercial talc formulation recorded cumulative mean reduction of 38.95 only.

Field evaluation of delivery equipments for effective delivery of oil based formulation of *B. bassiana* (Bb 112) against *A. gossypii* on tomato.

Trial I (Location: Kumarapalayam): From Table 3, results revealed that the pretreatment population of aphids uniformly

Table 1. Efficacy of *B. bassiana* (Bb 112) formulations against *Aphis gossypii* in tomato (cv. PKM 1) in microplot

Treatments	PTC (No. of aphids / leaf)	Days after first spraying (Number of aphids / leaf)					Mean no. of aphids/ leaf	Reduction over control (%)
		3	5	7	10	14		
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (oil formulation)	33.68	21.52 (4.64)^b	17.76 (4.21)^b	15.49 (3.94)^b	19.73 (4.44)^b	20.89 (4.57)^b	19.08	41.18
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (talc formulation)	32.13	27.47 (5.24)^d	20.82 (4.56)^d	18.78 (4.33)^{cd}	22.25 (4.72)^d	24.90 (4.99)^d	22.84	29.57
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (crude formulation)	33.17	29.45 (5.43)^e	25.39 (5.04)^e	22.19 (4.71)^d	24.83 (4.98)^e	28.18 (5.31)^e	26.01	19.82
B. bassiana (B 2) - 10^8 spores ml^{-1} (talc formulation)	32.25	25.38 (5.04)^c	18.87 (4.34)^c	17.42 (4.17)^c	20.96 (4.58)^c	22.47 (4.74)^c	21.20	35.20
Dimethoate 30 EC 0.7 mL L^{-1}	31.03	17.25 (4.15)^a	13.05 (3.61)^a	11.17 (3.34)^a	9.22 (3.04)^a	12.14 (3.48)^a	12.57	61.26
Imidacloprid 17.8 SL 0.5 mL L^{-1}	32.50	16.98 (4.12)^a	12.83 (3.58)^a	10.71 (3.27)^a	8.64 (2.94)^a	11.86 (3.44)^a	12.20	62.38
Control (water spray)	31.87	30.02 (5.48)^f	32.18 (5.67)^f	32.69 (5.72)^e	33.48 (5.79)^f	33.81 (5.81)^f	32.44	-
SE (d)	NS	0.18	0.13	0.24	0.32	0.21	-	-
C.D (P=0.05)	-	0.37	0.28	0.52	0.65	0.43	-	-

Values are means of three replications. PTC- Pretreatment count. Figures in the parentheses are transformed values. Means followed by the common letter (s) are not significant at P=0.05 level by LSD

Table 2. Efficacy of *B. bassiana* (Bb 112) formulations against *Aphis gossypii* in tomato (cv. PKM 1) in microplot

Treatments	Days after second spraying (No. of aphids / leaf)					Mean no. of aphids/ leaf	Reduction over control	Pooled mean (No/leaf)	Cumulative reduction (%) over control
	3	5	7	10	14				
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (oil formulation)	18.67 (4.32)^{b}	17.41 (4.17)^{b}	15.85 (3.98)^{b}	17.49 (4.18)^{b}	19.01 (4.36)^{c}	17.69	49.82	18.38	45.50
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (talc formulation)	22.81 (4.78)^{d}	20.74 (4.55)^{cd}	19.61 (4.43)^{cd}	22.17 (4.71)^{d}	23.05 (4.80)^{e}	21.68	38.50	22.26	34.04
B. bassiana (Bb 112) - 10^8 spores mL^{-1} (crude formulation)	23.49 (4.85)^{e}	22.62 (4.76)^{e}	20.71 (4.55)^{d}	27.53 (5.25)^{e}	27.92 (5.28)^{f}	24.45	30.62	25.23	25.22
B. bassiana (B 2) - 10^8 spores mL^{-1} (talc formulation)	20.87 (4.57)^{c}	19.91 (4.46)^{c}	18.33 (4.28)^{c}	20.48 (4.53)^{c}	21.38 (4.62)^{d}	20.19	42.71	20.61	38.95
Dimethoate 30 EC 0.7 mL L^{-1}	9.72 (3.13)^{a}	7.32 (2.71)^{a}	6.01 (2.45)^{a}	5.31 (2.35)^{a}	11.64 (3.41)^{b}	8.00	77.30	10.28	69.28
Imidacloprid 17.8 SL 0.5 mL L^{-1}	9.18 (3.04)^{a}	6.98 (2.64)^{a}	5.62 (2.37)^{a}	4.93 (2.22)^{a}	9.41 (3.07)^{a}	7.22	79.50	9.71	70.94
Control (water spray)	34.79 (5.90)^{e}	34.97 (5.91)^{f}	35.28 (5.94)^{e}	35.41 (5.95)^{f}	35.78 (5.98)^{e}	35.25	-	33.84	-
SE (d)	0.27	0.18	0.21	0.19	0.16	-	-	-	-
C.D (P=0.05)	0.56	0.37	0.43	0.41	0.33	-	-	-	-

Values are means of three replications. Figures in the parentheses are $\sqrt{x + 0.5}$ transformed values. Means followed by the common letter (s) are not significant at P=0.05 level by LSD.

Table 3. Efficacy of oil formulation of *B. bassiana* (Bb 112) against *Aphis gossypii* in tomato (Hyb. Sagar) using different delivery equipments – Trial I (Kumarapalayam)

Treatment	Dose	Delivery equipments	PTC (No. of aphids / leaf)	Days after first spraying (No. of aphids / leaf)				Mean no. of aphids / leaf	Reduction (%) over control
				3	7	10	14		
B. bassiana (Bb 112)- oil based formulation - 10^8 spores mL^{-1}	4 mL L^{-1}	Aspee Maruyama engine sprayer	39.09	29.81 (5.46)^{d}	26.73 (5.17)^{d}	24.66 (4.97)^{d}	28.40 (5.33)^{de}	27.40	30.02
	4 mL L^{-1}	Avenger ULV sprayer	38.45	28.57 (5.35)^{c}	25.55 (5.05)^{c}	23.08 (4.80)^{cd}	27.97 (5.29)^{d}	26.29	32.85
	4 mL L^{-1}	Aspee battery sprayer	38.62	33.45 (5.78)^{fg}	30.11 (5.49)^{f}	27.62 (5.26)^{f}	32.18 (5.67)^{g}	30.84	21.24
	4 mL L^{-1}	Aspee Knapsack hand sprayer	39.19	31.29 (5.59)^{e}	28.81 (5.37)^{e}	25.35 (5.03)^{de}	29.35 (5.42)^{e}	28.70	26.70
	4 mL L^{-1}	Aspee Hitech hand sprayer	39.25	32.74 (5.72)^{f}	29.22 (5.41)^{ef}	26.67 (5.16)^{e}	30.90 (5.56)^{f}	29.88	23.68
	4 mL L^{-1}	CDA sprayer	38.35	27.74 (5.27)^{b}	21.33 (4.62)^{b}	22.69 (4.76)^{c}	26.52 (5.15)^{c}	24.57	37.25
B. bassiana (B2) – Talc based formulation - 10^8 spores mL^{-1}	5 g L^{-1}	Knapsack hand sprayer	38.78	35.98 (6.00)^{g}	31.45 (5.61)^{g}	29.56 (5.44)^{g}	33.69 (5.80)^{h}	32.67	16.56
Dimethoate 30 EC	0.7 mL L^{-1}	Knapsack hand sprayer	38.59	18.09 (4.25)^{a}	13.15 (3.63)^{a}	10.09 (3.18)^{b}	18.91 (4.35)^{b}	15.06	61.54
Imidacloprid 17.8 SL	0.5 mL L^{-1}	Knapsack hand sprayer	39.05	17.76 (4.21)^{a}	12.88 (3.59)^{a}	8.80 (2.97)^{a}	15.43 (3.93)^{a}	13.72	64.97
Control (water spray)		-	38.25	38.46 (6.20)^{h}	38.75 (6.22)^{h}	39.49 (6.28)^{h}	39.92 (6.32)^{i}	39.16	-
SE (d)			NS	0.17	0.15	0.11	0.13	-	-
C.D (P=0.05)			-	0.36	0.31	0.21	0.27	-	-

Values are means of three replications ; PTC- Pretreatment count. Figs. in the parentheses are $\sqrt{x + 0.5}$ transformed values ;
Means followed by the common letter (s) are not significantly different at P=0.05 level by LSD

ranged from 38.25 to 39.25 numbers per leaf in all the plots. After first round of spraying, there was significant reduction in aphids population up to 10 days after treatment in all the treatments. In first round of treatment, Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer was significantly superior to all *B. bassiana* treatments and recorded the lowest aphids population of 27.74, 21.33, 22.69 and 26.52 on 3, 7, 10 and 14 days after treatment, respectively and recorded 37.25 % mean reduction in aphids population. Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Avenger ULV sprayer registered 32.85 % mean reduction in aphids population. This was followed by Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Aspee Maruyama engine sprayer, Aspee Knapsack hand sprayer and Aspee Hi tech hand sprayer with 30.02, 26.70 and 23.68 % reduction in aphid population, respectively. Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Aspee battery sprayer was less effective against *A. gossypii* and recorded the least reduction of 21.24 %. After the second round of spraying, Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer recorded the lowest aphids population and the highest reduction of 44.78 % (Table 4). The standard biocontrol agent *B. bassiana* (B2) commercial talc formulation as check recorded 28.01 %.

After two rounds of treatments, the cumulative mean % reduction

Table 4. Efficacy of oil formulation of *B. bassiana* (Bb 112) against *Aphis gossypii* in tomato (Hyb. Sagar) using different delivery equipments – Trial I (Kumarapalayam)

Treatment	Dose	Delivery equipments	Days after second spraying (No. of aphids / leaf)				Mean no. of aphids / leaf	Reduction (%) over control	Pooled mean (No/ leaf)	Cumulative % reduction
			3	7	10	14				
B. bassiana (Bb 112)- oil based formulation - 10^8 spores mL^{-1}	4 mL L^{-1}	Aspee Maruyama engine sprayer	23.61 (4.86)^{d}	21.38 (4.62)^{cd}	23.59 (4.86)^{e}	25.98 (5.10)^{e}	23.64	38.36	26.15	34.19
	4 mL L^{-1}	Avenger ULV sprayer	22.38 (4.73)^{c}	20.65 (4.54)^{c}	22.43 (4.74)^{d}	24.89 (4.99)^{d}	22.59	41.10	25.13	36.98
	4 mL L^{-1}	Aspee battery sprayer	26.32 (5.13)^{ef}	24.79 (4.98)^{f}	26.18 (5.12)^{fg}	27.35 (5.23)^{fg}	26.16	31.79	28.75	26.51
	4 mL L^{-1}	Aspee Knapsack hand sprayer	24.42 (4.94)^{de}	22.53 (4.75)^{d}	24.87 (4.99)^{f}	26.12 (5.11)^{ef}	24.49	36.15	27.10	31.43
	4 mL L^{-1}	Aspee Hitech hand sprayer	25.97 (5.10)^{e}	23.56 (4.85)^{e}	25.71 (5.07)^{fg}	26.90 (5.19)^{f}	25.54	33.42	29.10	28.55
	4 mL L^{-1}	CDA sprayer	21.13 (4.60)^{b}	19.38 (4.40)^{b}	21.02 (4.58)^{c}	23.17 (4.81)^{c}	21.18	44.78	24.00	41.02
B. bassiana (B2) – Talc based formulation - 10^8 spores mL^{-1}	5g L^{-1}	Knapsack hand sprayer	27.78 (5.27)^{f}	26.42 (5.14)^{g}	27.49 5.24)^{g}	28.74 (5.36)^{g}	27.61	28.01	31.51	22.29
Dimethoate 30 EC	0.7 mL L^{-1}	Knapsack hand sprayer	14.03 (3.75)^{a}	10.14 (3.18)^{a}	7.98 (2.82)^{b}	17.23 (4.15)^{b}	12.35	67.81	14.86	64.67
Imidacloprid 17.8 SL	0.5 mL L^{-1}	Knapsack hand sprayer	13.78 (3.71)^{a}	9.91 (3.15)^{a}	7.43 (2.73)^{a}	15.91 (3.99)^{a}	11.76	69.34	14.28	67.15
Control (water spray)		-	38.35 (6.19)^{g}	37.10 (6.09)^{h}	38.59 (6.21)^{h}	39.36 (6.27)^{h}	38.35	-	40.25	-
SE (d)			0.14	0.12	0.17	0.19	-	-	-	-
C.D (P=0.05)			0.29	0.25	0.36	0.38	-	-	-	-

Values are means of three replications. Figs. in the parentheses are $\sqrt{x + 0.5}$ transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by LSD

Table 5. Efficacy of oil formulation of *B. bassiana* (Bb 112) against aphid *Aphis gossypii* in tomato (Hyb. Sivam) using different delivery equipments –Trial II (Ambillikai)

Treatment	Dose	Delivery equipments	PTC (No. of aphids / leaf)	Days after first spraying (No. of aphids / leaf)				Mean no. of aphids / leaf	Reduction (%) over control
				3	7	10	14		
B. bassiana (Bb 112)- oil based formulation - 10^8 spores mL^{-1}	4 mL L^{-1}	Aspee Maruyama engine sprayer	41.41	32.87 (5.73)^{d}	27.31 (5.23)^{d}	28.16 (5.31)^{d}	30.87 (5.56)^{e}	29.80	32.81
	4 mL L^{-1}	Avenger ULV sprayer	41.84	31.69 (5.63)^{c}	25.28 (5.03)^{c}	26.08 (5.11)^{c}	29.79 (5.46)^{d}	28.21	36.40
	4 mL L^{-1}	Aspee battery sprayer	42.32	35.48 (5.96)^{f}	32.34 (5.69)^{g}	32.83 (5.73)^{fg}	34.13 (5.84)^{g}	33.70	24.03
	4 mL L^{-1}	Aspee Knapsack hand sprayer	41.66	33.23 (5.76)^{de}	28.58 (5.35)^{e}	29.76 (5.46)^{e}	31.42 (5.61)^{ef}	30.75	30.68
	4 mL L^{-1}	Aspee Hitech hand sprayer	42.58	34.32 (5.86)^{e}	30.96 (5.56)^{f}	31.81 (5.64)^{f}	33.04 (5.75)^{f}	32.53	26.65
	4 mL L^{-1}	CDA sprayer	41.76	29.81 (5.46)^{b}	23.79 (4.88)^{b}	24.63 (4.96)^{b}	28.55 (5.34)^{c}	26.70	39.82
B. bassiana (B2) – Talc based formulation - 10^8 spores mL^{-1}	5g L^{-1}	Knapsack hand sprayer	41.52	36.56 (6.05)^{g}	34.60 (5.88)^{h}	34.21 (5.85)^{g}	35.66 (5.97)^{gh}	35.26	20.51
Dimethoate 30 EC	0.7 mL L^{-1}	Knapsack hand sprayer	42.67	26.21 (5.12)^{a}	18.17 (4.26)^{a}	16.48 (4.06)^{a}	23.05 (4.80)^{b}	20.98	52.71
Imidacloprid 17.8 SL	0.5 mL L^{-1}	Knapsack hand sprayer	40.92	25.63 (5.06)^{a}	17.88 (4.23)^{a}	15.91 (3.99)^{a}	21.76 (4.66)^{a}	20.30	54.24
Control (water spray)		-	42.60	42.72 (6.54)^{h}	44.58 (6.68)^{i}	44.94 (6.70)^{h}	45.18 (6.72)^{h}	44.36	-
SE (d)			NS	0.32	0.17	0.24	0.22	-	-
C.D (P=0.05)			-	0.65	0.35	0.49	0.45	-	-

Values are means of three replications. PTC- Pretreatment count. Figs. in the parentheses are $\sqrt{x + 0.5}$ transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by LSD

in aphids population showed that (Table 4), Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer was significantly superior to other *B. bassiana* treatments with 41.02 % reduction. The next in the order of efficacy were Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Avenger ULV sprayer, Aspee Maruyama engine sprayer, Aspee Knapsack hand sprayer, Aspee Hitech hand sprayer and Aspee battery sprayer with the corresponding cumulative mean reduction of 36.98, 34.19, 31.43, 28.55 and 26.51 %, respectively. *Beauveria bassiana* (B2) commercial talc formulation as check recorded cumulative mean reduction of 22.29 % which was the lowest compared to oil based formulation of Bb 112 sprayed with different types of sprayers.

However, the standard insecticide checks imidacloprid 17.8 SL at 0.5 mL L^{-1} and dimethoate 0.7 mL L^{-1} recorded the lowest aphids population (12.74 and 13.70 numbers/ leaf) and effected a cumulative mean reduction of 67.15 and 64.67 % after two rounds of sprays.

Trial II (Location: Ambillikai): Results of the second trial also showed similar trend as that of first trial conducted at Kumarapalayam against tomato aphids (Table 5).

After the first round of spraying, Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer showed the highest % reduction in aphids population (39.82 %). This was followed by Avenger ULV sprayer, Aspee Maruyama engine sprayer, Aspee Knapsack hand sprayer and Aspee Hitech hand sprayer which recorded mean per cent reduction of 36.40, 32.81, 30.68 and 26.65, respectively. Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Aspee battery sprayer was the least effective treatment with the % reduction of 24.03. The standard insecticide checks imidacloprid 17.8 SL at 0.5 mL L^{-1} and dimethoate at 0.7 mL L^{-1} were significantly superior to all other treatments and recorded higher reduction in the aphids population (54.24 and 52.71 %). *B. bassiana* (B2) commercial talc formulation as check recorded lowest mean reduction of 20.51 %.

Similar trend was observed after second round of spraying also (Table 6). Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer was effective in reducing the aphids population to the extent of 52.80 %. Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Avenger ULV sprayer (49.20 %) and Aspee Maruyama engine sprayer (46.05 %) were next in order of their efficacy. The cumulative mean reduction over control showed that, Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with CDA sprayer was significantly superior in reducing the aphids population by 46.31 %. The next in the order of efficacy were; Bb 112 @ 10^8 spores mL^{-1} in oil based formulation sprayed with Avenger ULV sprayer (42.80 %) > Aspee Maruyama engine sprayer (39.43 %) > Aspee Knapsack hand sprayer (37.43 %) > Aspee Hitech hand sprayer (33.82 %) > Aspee battery sprayer (31.39 %). Imidacloprid 17.8 SL 0.5 mL L^{-1} and dimethoate 30 EC 0.7 mL L^{-1} were significantly superior to all other treatments and recorded higher reduction in the aphids population (62.11 and 60.75 %). Biocontrol agent *B. bassiana* (B2) commercial talc formulation as check recorded the lowest cumulative mean reduction of 26.95 %.

Discussion

Higher efficacy of oil formulations of *B. bassiana* (Bb 112) in the present investigation might be due to the fact that the oil could coat the dry, dusty type of conidia allowing them to suspend easily in oil and spread rapidly over the surface of leaves which helps better contact of conidia with insect cuticle. The variation in virulence may be attributed to the number of conidia received by the individual pest (Bateman *et al.,* 1993). who reported that

Table 6. Efficacy of oil formulation of *B. bassiana* (Bb 112) against *Aphis gossypii* in tomato (Hyb. Sivam) using different delivery equipments - Trial II (Ambillikai)

Treatment	Dose	Delivery equipments	Days after second spraying (No. of aphids / leaf)				Mean no. of aphids / leaf	Reduction (%) over control	Pooled mean (No/leaf)	Cumulative reduction (%)
			3	7	10	14				
B. bassiana (Bb 112)- oil based formulation - 10^8 spores mL^{-1}	4 mL L^{-1}	Aspee Maruyama engine sprayer	25.09 (5.01)^{d}	23.77 (4.88)^{d}	27.63 (5.26)^{e}	28.74 (5.36)^{de}	26.31	46.05	28.06	39.43
	4 mL L^{-1}	Avenger ULV sprayer	23.31 (4.83)^{c}	21.53 (4.64)^{c}	26.37 (5.14)^{d}	27.89 (5.28)^{d}	24.78	49.20	26.49	42.80
	4 mL L^{-1}	Aspee battery sprayer	28.68 (5.36)^{f}	26.04 (5.10)^{fg}	32.14 (5.67)^{g}	32.61 (5.71)^{g}	29.87	38.75	31.78	31.39
	4 mL L^{-1}	Aspee Knapsack hand sprayer	25.97 (5.10)^{de}	24.46 (4.95)^{de}	28.62 (5.35)^{ef}	29.84 (5.46)^{e}	27.22	44.18	28.99	37.43
	4 mL L^{-1}	Aspee Hitech hand sprayer	27.12 (5.21)^{e}	25.63 (5.06)^{f}	30.78 (5.55)^{f}	31.58 (5.62)^{f}	28.78	40.99	30.66	33.82
	4 mL L^{-1}	CDA sprayer	21.82 (4.67)^{b}	19.61 (4.43)^{b}	23.92 (4.89)^{c}	26.71 (5.17)^{c}	23.02	52.80	24.86	46.31
B. bassiana (B2) –Talc based formulation - 10^8 spores mL^{-1}	5g L^{-1}	Knapsack hand sprayer	31.84 (5.64)^{g}	31.20 (5.59)^{g}	33.38 (5.78)^{gh}	33.52 (5.79)^{h}	32.49	33.38	33.87	26.95
Dimethoate 30 EC [1]	0.7 mL L^{-1}	Knapsack hand sprayer	16.07 (4.01)^{a}	13.23 (3.64)^{a}	11.39 (3.37)^{b}	20.17 (4.49)^{b}	15.22	68.80	18.10	60.75
Imidacloprid 17.8 SL	0.5 mL L^{-1}	Knapsack hand sprayer	15.74 (3.97)^{a}	12.88 (3.59)^{a}	10.73 (3.28)^{a}	19.22 (4.38)^{a}	14.52	69.97	17.47	62.11
Control (water spray)		-	46.36 (6.81)^{h}	48.12 (6.94)^{h}	49.47 (7.03)^{i}	51.11 (7.15)^{i}	48.77	-	46.56	-
SE (d)			0.18	0.21	0.16	0.19	-	-	-	-
C.D (*P*=0.05)			0.37	0.43	0.34	0.38	-	-	-	-

Values are means of three replications. Figures in the parentheses are $\sqrt{x + 0.5}$ transformed values. Means followed by the common letter (s) are not significantly different at *P*=0.05 level by LSD

the use of oil formulation of *M. anisopliae* in ultra-low volumes (ULV) was highly effective against locusts in Africa. The present findings are also in accordance with Nugroho and Ibrahim (2007) who reported significant reduction in the population of *P. latus* sprayed with *B. bassiana* and *P. fumosoroseus*.

Being non-evaporative, oil formulation of mycoinsecticides is readily compatible with ultra-low volume (ULV) application techniques for spraying at low relative humidities (Bateman, 1997). According to Bateman and Alves (2000) CDA represents a very specialised delivery system for oil formulations which can only be used with specialised application equipments (often rotary atomisers). Patil *et al*. (1992) compared ultra-low volume, high volume and low volume spray application of mycopathogen for the management of cotton bollworms and recorded that ultra-low volume spraying significantly reduced the bollworms than high volume and low volume spraying. Ultra low volume application technique produces small droplets and has been used for spray application of entomopathogenic fungus on a large-scale (Munthali and Wyatt, 1986; Chapple *et al.*, 1994).

The study microplot conditions revealed that the oil formulation of *B. bassiana* (Bb 112) recorded better control of aphids with highest population reduction of 45.50 % as compared to talc and crude formulations. Under field condition also, oil formulation of *B. bassiana* (Bb 112) sprayed with Controlled Droplet Applicator (CDA) recorded highest population reduction of aphid. Therefore, improved formulations applied using improved delivery systems can ensure better biopesticide utility.

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