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Effectiveness of *Beauveria bassiana* Against Cotton Whitefly, *Bemisia tabaci* (Gennadius) (Aleyrodidae: Homoptera) on Different Host Plants

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ABSTRACT

Bemisia tabaci is an important polyphagous sucking insect pest and vector for plant diseases. Due to indiscriminate use of insecticides, whitefly has developed resistance against different groups of insecticides. There is a need of effective alternative and an environmentally safe pest management strategy. Among different management programs the use of entomopathogenic fungi, or the microbial control is ecofriendly and safe for life. This study was primarily based on the application of different isolates of entomopathogenic fungi, *Beauveria bassiana* against different life stages of *B. tabaci* on different host plants *i.e. Gossypium hirsutum, Lycopersicum esculentum, Solanum melongena* and *Capsicum annum*. The results showed *B. bassiana* isolate (Bb-01) to be the most effective with LC_{50} value (2.4×10^7 spores/ml) which caused highest mortality of eggs (65.30%) and nymphs (88.82%) with LC_{50} value (2.7×10^6 spores/ml) and LT_{50} 5.40 at 2×10^8 on *G. hirsutum* in comparison to other hosts. In addition, the different plant hosts *i.e., G. hirsutum, L. esculentum, S. melongena* and *C. annum* affected the egg and nymphs as response was concentration dependent and mortality rates were highly significant.

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SF designed the experiments and supervised the works. JZ performed the experiments and wrote the article. BAK and MF analyzed the data.

Key words

Bemisia tabaci, Beauveria bassiana, Gossypium hirsutum, Lycopersicum esculentum, Solanum melongena, Capsicum annum.

INTRODUCTION

Cotton whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), is a widespread insect pest (Landa *et al*., 1994; Nomikou *et al*., 2001) causing economic damages in essential green houses and field crops (Byrne *et al*., 1990; Fransen, 1994; Kogan, 1995). Whitefly being polyphagous insect pest of crops in all subtropical and tropical regions of the world including Pakistan (Amjad *et al*., 2009) causes losses directly and indirectly, either by sucking cell sap or secretion of honeydew but also vectoring cotton leaf curl virus (CLCV) (Ahmad *et al*., 2002; Nelson *et al*., 1998).

The favorable hosts that support the *B. tabaci* population include cotton (*Gossypium hirsutum* L.), cabbage (*Brassica oleracea* L.), tomato (*Lycopersicum esculentum* L.), eggplant (*Solanum melongena* L.), okra (*Abelmoschus esculentus* L.), cucumber (*Cucumis sativus* L.), squash (*Cucurbita moschata* Duch.), melon (*Cucumis melo* L.) and many ornamentals (Brown and Bird, 1992). Worldwide use of synthetic insecticides is a dynamic factor of whitefly management programs (Ellsworth and Martinez-Carrillo, 2001). However, the consumption of insecticides has been negotiated predominantly because of the rapid development of resistance to different groups of insecticides, especially organophosphates, cyclodienes and pyrethroids (Cahill *et al*., 1995). Owing to the draw backs of insecticides usage, the need of biological control methods has increased as compared to the previous years (Torrado-Leon *et al*., 2006).

Entomopathogenic fungi have been identified as potential control agents against *B. tabaci* (Saito and Sugiyama, 2005). *Beauveria bassiana* (Hypocreales: Cordycipitaceae) (Balsamo) Vuillemin is a key tool for the management of various agricultural insect pests, including whiteflies, mealy bugs, aphids, thrips, psyllids and weevils in outdoor and greenhouse crops (Akmal *et al*., 2013; Shah and Goettel, 1999; Wraight *et al*., 2000; Vestergaard *et al*., 2003; Torrado-Leon *et al*., 2006; Daniel and Wyss, 2010). Several studies have been reported on the efficacy of entomopathogenic fungi against different life stages of whitefly *i.e.*, eggs and nymphal instars (Wraight *et al*., 1998; Saito and Sugiyama, 2005; Park and Kim, 2010; Norhelina *et al*., 2013).

Owing to the increasing threats of whitefly in the region and indirect loss by the injudicious use of chemical insecticides, a study was carried out to evaluate the virulence of different isolates of entomopathogenic fungi *B. bassiana* on different developmental stages of whitefly on different host plants.

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MATERIALS AND METHODS

Collection and rearing of insects

The whitefly, *B. tabaci* was collected from cotton fields of Bahauddin Zakariya University Multan with help the of manual aspirator, which were later released in rearing cages ($60\times60\times60cm^3$) containing host plants. Adults were allowed to settle and feed on the host plants. Temperature was maintained at 28±2°C with photoperiod of 14:10 h, while 60-70% relative humidity was maintained with adequate supply of water. After 48-72 h plants were monitored for eggs. The plants containing eggs were kept in separate cages for hatching and to obtain uniform generation of whiteflies.

Entomopathogenic fungi

Different isolates of *B. bassiana* Bb-01, Bb-08 and Bb-10 acquired from Laboratory of Insect Microbiology were tested against different life stages of whitefly. For this purpose the slants of monoconidial cultures of the strain already grown on PDA at 25°C in darkness and then stored at 4°C were used. For further propagation the spores from these slants were spread on to the PDA plates (9 cm diameter) and these plates were kept at 25°C in darkness at 70-75% RH for 14 days. After 14 days of growth of the fungus the spores were used to treat the insects or were stored at 4°C until used for insect bioassay.

Preparation of fungal concentrations

For bioassay, different fungal concentrations were prepared by scrapping spores in flask containing Tween 80 (0.05%) solution. The number of spores were counted with the help of haemocytometer and concentration of stock solution was determined. The required concentrations *i.e.*, 1×10^6, 1×10^7, 1×10^8, 2×10^8 were further prepared from stock solution by serial dilution.

Host plants

Four different plants (40-60 days old) i.e. cotton (*G. hirsutum*), tomato (*L. esculentum*), chillies (*Capsicum annum* L.) and eggplant (*S. melongena*) were used as host plants. The plants were grown in 25 cm (length) pots. Mixture of soil and farm yard manure was used as growth media.

Bioassay

The experiment was conducted under the Completely Randomized Design (CRD) with four replications in each treatment at 28±1°C with 50-60 RH (relative humidity) and photoperiod of 14 h. Five leaves on each plant (one replication) were covered with the zip lock pouches and 50 adults (sex ratio 1:1) of *B. tabaci* were released in each replication. After 72 h the plants were checked for egg laying, which were then counted on leaves. The plant leaves were then sprayed by using hand sprayer with different concentrations and different isolates of *B. bassiana*. The cage containing control plants were sprayed with Tween 80 (0.05%) solution only, while similar procedure was applied separately for nymphs.

Data collection

The plants were daily examined under the microscope and percent mortality data was recorded for eggs and nymphs, separately. The eggs with blackish appearance after the application of fungi were considered and counted as dead, while percent mortality of nymphs was accounted on 3rd, 5th and 7th day after the application of fungus. The reddish black nymphs were considered dead as a result of fungus application.

Data analysis

The mortality data was corrected by using Abbott's formula (Abbott, 1925) while LC_{50} values of each isolate were calculated for eggs and nymphs on all host plants separately by using probit analysis (Finney, 1971). In addition to this, the lethal time to kill more than 50 percent of the population was also calculated. Means were analyzed and compared by LSD test with the help of Statistix vseriosn 8.1 (Tallahassee, 2005).

RESULTS

Effect of fungus on eggs

Virulence of three isolates of *B. bassiana* was tested on eggs of whitefly on cotton (*G. hirsutum*) tomato (*L. esculentum*), *chillies* (*C. annum*) and brinjal (*S. melongena*). Mortality percentage was significantly different for isolates of *B. bassiana* on all hosts. *B. bassiana* (Bb-01) showed the least LC_{50} values (2.4×10^7 spores/ml) on *G. hirsutum*, *L. esculentum* (3.7×10^7 spores/ml), *C. annum* (5.2×10^7 spores/ml) and *S. melongena* (7.6×10^7 spores/ml) proving to be highly effective against the eggs of whitefly. In addition, the LC_{50} values of all three isolates on different hosts are represented in Table I.

The virulence of three isolates of *B. bassiana* (Bb-01, Bb-08 and Bb-10) was evaluated against eggs of whitefly on *G. hirsutum, L. esculentum, C. annum* and *S. melongena* plants. The mortality rates were highly significant and response was concentration dependent for each isolate. For Bb-01 the highest percent mortality of eggs (65.30±0.98) was noted on *G. hirsutum* followed by *L. esculentum* (61.42±2.06) and *S. melongena* (59.56±2.68) at concentration level of 2×10^8 spores/ml.

Table I.- LC_{50} (spores/ml) values of *B. bassiana* isolates against whitefly eggs on different hosts.

Host	Fungi isolate	LC_{50} (spores/ml)	FD[a]	Slope
Gossypium hirsutum	Bb-01	2.4×10^7	1.3×10^7-4.4×10^7	0.33 ± 0.05
	Bb-08	6.5×10^7	3.3×10^7-1.2×10^8	0.36 ± 0.05
	Bb-10	1.0×10^8	5.2×10^7-2.0×10^8	0.38 ± 0.05
Lycopersicum esculentum	Bb-01	3.7×10^7	1.5×10^7-8.9×10^7	0.25 ± 0.05
	Bb-08	2.2×10^8	6.8×10^8-7.6×10^8	0.27 ± 0.06
	Bb-10	2.6×10^8	8.1×10^7-8.7×10^8	0.29 ± 0.06
Capsicum annum	Bb-01	5.2×10^7	1.9×10^7-1.3×10^8	0.25 ± 0.06
	Bb-08	1.8×10^8	5.8×10^7-6.0×10^8	0.28 ± 0.06
	Bb-10	2.5×10^8	6.9×10^7-9.4×10^8	0.28 ± 0.06
Solanum melongena	Bb-01	7.6×10^7	2.9×10^7-2.0×10^8	0.22 ± 0.06
	Bb-08	1.8×10^8	4.5×10^7-7.6×10^8	0.26 ± 0.06
	Bb-10	2.5×10^8	6.1×10^7-9.9×10^8	0.28 ± 0.07

a: Fudicial limit

The lowest mortality (36.22±4.17) was observed in the case of *G. hirsutum* at concentration level of 1×10^6 spores/ml (F=0.2, P=0.003) (Table II). In the case of Bb-08 highest percent mortality of eggs (58.98±7.25) was noted on *G. hirsutum* followed by *S. melongena* (55.29±3.85) and *C. annum* (54.66±6.78) at concentration level of 2×10^8 spores/ml (F=0.19, P=0.0021) (Table II), while for Bb-10, the highest percent egg mortality (55.00±7.30) was observed on *G. hirsutum* followed by *S. melongena* (52.73±3.05) at 2×10^8 spores/ml concentration level (F=0.13, P=0.0001) (Table II).

Effect of fungus on 2nd instar nymphs

Virulence of three isolates of *B. bassiana* was tested on nymphs of whitefly on different host plants. Mortality percentage was significantly different for all isolates of *B. bassiana* on all hosts. *B. bassiana* (Bb-01) showed the least LC_{50} values (2.7×10^6 spores/ml) on *G. hirsutum, L. esculentum* (4.3×10^6 spores/ml), *C. annum* (9.3×10^6 spores/ml) and *S. melongena* (9.3×10^6 spores/ml) plants proving to be highly effective against the nymphs of the whitefly. In addition, the LC_{50} values of all three isolates on different hosts are represented in Table III.

The virulence of different isolates of *B. bassiana* was evaluated against 2nd instar nypmhs of *B. tabaci* on *G. hirsutum* and *L. esculentum* plants. The mortality rate was highly significant and response was concentration dependent for each isolate. For *G. hirsutum*, the highest percent mortality (88.82±1.68) was recorded by Bb-01 by killing more than 50 percent of population in lethal time of 5.40 (2.79-10.46) days at concentration level of 2×10^8 spores/ml (F=78.0, P=0.000) (Table IV).

Similar trend was observed for the mortality percentage of nymphs on *L. esculentum* as for *G. hirsutum*. The highest percent mortality (80.66±3.88) was caused by Bb-01 with lethal time (LT_{50}) of 5.81 (4.08-8.25) days at concentration level of 2×10^8 spores/ml (F=37.20, P=0.000) (Table IV).

The pathogenicity of different isolates of *B. bassiana* was evaluated against 2nd instar nypmhs of whitefly on *C. annum* and *S. melongena* plants. Bb-01 caused highest percent mortality (75.90±6.56) by killing more than 50 percent of population in lethal time (LT_{50}) of 6.02 (2.46-14.74) days at concentration level of 2×10^8 spores/ml. Similar pattern was observed for the mortality percentage for *G. hirsutum* and *L. esculentum.* (F=28.4, P=0.000) (Table 5), while for *S. melongena*, the highest mortality (76.91±2.59) was caused by Bb-01 with lethal time (LT_{50}) of 5.76 (4.08-8.10) days at concentration level of 2×10^8 spores/ml. The mortality rates were highly significant and response was concentration dependent for each isolate. Similar trend was observed in the mortality percentage for *G. hirsutum, L. esculentum* and *C. annum* (F=63.7, P=0.000) (Table V).

DISCUSSION

Microbial control and the use of pathogens for the management of Alyerodidae are limited to entomopathogenic fungi as it can penetrate and infect the insect cuticle effectively. Several insect pathogenic fungi have been identified earlier as potential bio control agents for *B. tabaci.* Out of these insect pathogenic fungi,

Table II.- Percent mortality of whitefly eggs against *B. bassiana* isolates on different hosts

Concentrations	*Gossypium hirsutum*	*Lycopersicum esculentum*	*Capsicum annum*	*Solanum melongena*
Bb-01				
2×10^8	65.30±0.98a	61.42±2.06ab	59.04±3.98ab	59.56±2.68ab
1×10^8	58.33±5.22abc	53.70±6.19abcd	52.87±8.82abcde	49.28±9.53bcdef
1×10^7	46.08±6.26cdef	46.56±8.02bcdef	40.25±5.82def	42.42±3.66def
1×10^6	36.22±4.17f	38.67±4.12ef	37.80±4.89f	38.19±2.79f
Control	4.55±0.84g	4.95±1.24g	3.21±0.39g	3.82±1.53g
F-value	0.2			
P-value	0.003			
LSD-value	14.08			
Bb-08				
2×10^8	58.98±7.25a	52.91±2.85ab	54.66±6.78ab	55.29±3.85ab
1×10^8	49.65±8.84ab	44.83±4.68abcd	47.69±8.56abc	42.44±6.54bcde
1×10^7	41.12±5.99bcdef	39.25±4.27bcdef	35.29±9.07cdef	36.13±3.39cdef
1×10^6	29.08±5.11def	28.48±6.16def	29.30±3.16def	31.40±2.28def
Control	3.85±2.00g	3.41±0.68g	2.56±0.28g	2.29±0.73g
F-value	0.19			
P-value	0.021			
LSD-value	16.27			
Bb-10				
2×10^8	55.00±7.30a	51.92±2.48ab	51.27±8.24ab	52.73±3.05ab
1×10^8	46.14±9.75abc	42.34±5.03abcd	43.58±7.19abcd	40.83±11.35abcde
1×10^7	36.90±9.46bcdef	35.80±4.41bcdef	32.68±9.08bcdef	33.61±1.54cdef
1×10^6	23.13±8.41ef	25.79±10.26ef	28.03±3.88def	28.10±3.14def
Control	1.65±0.67g	1.73±0.19g	1.28±0.64g	1.53±0.76g
F-value	0.13			
P-value	0.001			
LSD-value	17.36			

Means followed by the same letters in rows and columns are not statistically different at 5 % level of significance.

Table III.- LC_{50} (spores/ml) values of *B. bassiana* isolates against 2nd instar of whitefly on different hosts

Host	Fungi isolate	LC_{50} (spores/ml)	FD[a]	Slope
Gossypium hirsutum	Bb-01	2.7×10^6	1.5×10^5-4.9×10^7	0.51 ± 0.12
	Bb-08	5.5×10^6	3.1×10^6-9.7×10^6	0.42 ± 0.05
	Bb 10	1.6×10^7	8.7×10^6-3.1×10^7	0.32 ± 0.05
Lycopersicum esculentum	Bb-01	4.3×10^6	2.4×10^6-8.0×10^6	0.45 ± 0.05
	Bb-08	1.4×10^7	6.2×10^6-3.1×10^7	0.27 ± 0.05
	Bb-10	4.5×10^7	1.9×10^7-1.0×10^8	0.25 ± 0.05
Capsicum annum	Bb-01	9.3×10^6	5.1×10^6-1.7×10^7	0.41 ± 0.06
	Bb-08	8.5×10^7	4.2×10^6-1.7×10^7	0.36 ± 0.06
	Bb-10	1.8×10^7	8.4×10^6-3.9×10^7	0.30 ± 0.06
Solanum melongena	Bb-01	9.3×10^6	5.2×10^6-1.6×10^7	0.46 ± 0.06
	Bb 08	1.2×10^7	5.1×10^6-3.0×10^7	0.29 ± 0.06
	Bb-10	2.0×10^7	9.8×10^6-4.3×10^7	0.34 ± 0.06

a: Fudicial limit

Table IV.- Percent mortality and lethal time LT_{50} of whitefly nymphs against *B. bassiana* isolates on *Gossypium hirsutum and Lycopersicum esculentum*

Fungi	Concentration	% Mortality	LT_{50}	FD[a]	Slope
Gossypium hirsutum					
Bb-01	2×10^8	88.82±1.68a	5.4	2.79-10.46	6.09 ± 1.59
	1×10^8	73.04±3.49b	5.87	4.99-6.89	5.05 ± 0.63
	1×10^7	60.80±5.98c	6.95	5.38-8.99	4.72 ± 0.73
	1×10^6	45.11±4.00d			
	Control	3.50±1.14e			
	F	43.4			
	P	<0.0001			
	LSD-value	13.38			
Bb-08	2×10^8	77.77±2.08a	5.71	4.37-7.46	5.32 ± 0.87
	1×10^8	69.08±5.18a	6.11	5.31-7.03	4.93 ± 0.59
	1×10^7	51.89±7.47b	7.93	6.12-10.28	3.77 ± 0.53
	1×10^6	42.88±3.32b			
	Control	2.73±0.73c			
	F	43.4			
	P	<0.0001			
	LSD-value	13.38			
Bb-10	2×10^8	69.30±3.61a	5.95	5.67-6.25	4.63 ± 0.31
	1×10^8	55.63±4.45a	6.81	6.39-7.25	4.53 ± 0.36
	1×10^7	48.13±6.99ab			
	1×10^6	38.48±4.88bc			
	Control	2.24±1.00c			
	F	30.0			
	P	<0.0001			
	LSD-value	13.91			
Lycopersicum esculentum					
Bb-01	2×10^8	80.66±3.88a	5.81	4.08-8.25	5.47 ± 1.07
	1×10^8	71.28±7.49ab	6.1	5.07-7.35	5.04 ± 0.70
	1×10^7	60.58±4.31b	6.79	5.12-9.00	4.82 ± 0.82
	1×10^6	40.22±6.25c			
	Control	2.67±0.38d			
	F	37.20			
	P	<0.0001			
	LSD-value	15.31			
Bb-08	2×10^8	66.30±5.63a	6.43	5.07-8.71	5.02 ± 0.80
	1×10^8	57.90±4.75a	7.19	5.75-8.99	4.33 ± 0.63
	1×10^7	52.66±4.07ab	7.68	6.09-9.69	3.96 ± 0.57
	1×10^6	39.97±5.95b			
	Control	3.26±0.51c			
	F	28.7			
	P	<0.0001			
	LSD-value	13.91			
Bb-10	2×10^8	61.25±6.37a	6.77	5.68-8.07	4.68 ± 0.62
	1×10^8	52.20±4.31ab	7.57	6.26-9.16	4.14 ± 0.53
	1×10^7	43.64±4.03bc			
	1×10^6	36.86±4.38c			
	Control	2.10±0.82d			
	F	27.0			
	P	<0.0001			
	LSD-value	13.16			

a: Fudicial limit; Means followed by the same letters in columns are not statistically different at 5 % level of significance.

Table V.- Percent mortality and lethal time LT_{50} of whitefly nymphs against *B. bassiana* isolates on *Capsicum annum and Solanum melongena*

Fungi	Concentration	% Mortality	LT_{50}	FD[a]	Slope
Capsicum annum					
Bb-01	2×10^8	75.90±6.56a	6.02	2.46-14.74	5.89 ± 1.99
	1×10^8	66.29±6.44ab	6.51	5.23-8.10	4.59 ± 0.69
	1×10^7	51.24±7.17bc	7.21	6.68-7.78	4.63 ± 0.42
	1×10^6	38.59±1.53c			
	Control	3.87±0.74d			
	F	28.4			
	P	<0.0001			
	LSD-value	15.88			
Bb-08	2×10^8	73.36±3.14a	6.22	3.77-10.25	5.48 ± 1.36
	1×10^8	65.48±6.47a	6.63	5.48-8.02	4.67 ± 0.67
	1×10^7	51.24±7.17b	7.57	6.11-9.38	4.38 ± 0.65
	1×10^6	40.66±1.84b			
	Control	3.51±0.98c			
	F	34.7			
	P	<0.0001			
	LSD-value	13.92			
Bb-10	2×10^8	67.52±2.03a	6.41	4.62-8.90	5.17 ± 1.02
	1×10^8	55.94±4.44b	7.06	6.53-7.65	4.23 ± 0.37
	1×10^7	47.31±6.01bc			
	1×10^6	37.92±2.10c			
	Control	1.33±0.84d			
	F	47.0			
	P	<0.0001			
	LSD-value	10.95			
Solanum melongena					
Bb-01	2×10^8	76.91±2.59a	5.76	4.08-8.10	5.64 ± 1.18
	1×10^8	67.04±4.00a	6.4	5.17-7.92	5.15 ± 0.83
	1×10^7	55.49±5.54b	6.96	6.43-7.54	4.35 ± 0.41
	1×10^6	35.19±3.45c			
	Control	3.86±0.89d			
	F	63.7			
	P	<0.0001			
	LSD-value	10.96			
Bb-08	2×10^8	69.49±5.49a	6.37	4.94-8.22	4.92 ± 0.86
	1×10^8	61.73±9.60a	6.75	6.28-7.25	4.68 ± 0.43
	1×10^7	52.78±5.63ab	7.27	6.64-7.96	4.15 ± 0.40
	1×10^6	39.88±1.89b			
	Control	3.89±0.87c			
	F	63.7			
	P	<0.0001			
	LSD-value	10.96			
Bb-10	2×10^8	63.25±5.12a	6.73	5.17-8.76	4.67 ± 0.82
	1×10^8	55.63±8.59ab	7.2	6.60-7.85	4.31 ± 0.42
	1×10^7	43.04±0.75bc			
	1×10^6	36.36±3.46c			
	Control	2.33±0.79d			
	F	24.6			
	P	<0.0001			
	LSD-value	14.35			

a: Fudicial limit; Means followed by the same letters in columns are not statistically different at 5 % level of significance.

B. bassiana is of great importance (Feng *et al*., 1994; Wraight *et al*., 2000; Torrado-Leon *et al*., 2006; Daniel and Wyss, 2010) as it penetrates through cuticle and propagates in the haemocoel to kill insect pests (Toledo *et al*., 2010).

In the current study, *B. tabaci* was reared on several host plants in the laboratory and its different life stages were assessed with number of isolates of *B. bassiana* for their susceptibility at various hosts. The findings of the current research showed that mortality percentage of *B. tabaci* eggs on different hosts was concentration dependent. Similar results were observed in case of the nymphal mortality. In addition, the lethal time (LT_{50}) decreased with the increase in nympal mortality in response to higher concentrations of fungi. The whitefly eggs mortality was assessed on four different hosts against the three isolates of *B. bassiana.* Out of four host and three fungal isolates, the highest percent egg mortality (65.30±0.98) (F=33.1, P=0.0000) was caused by Bb-01 on *G. hirsutum* with LC_{50} of 2.4×10^7 spores/ml. The findings of current work are in favour of Chan-cupul *et al*. (2013) who evaluated the virulence of *I. fumosorosea* on whitefly eggs and observed native isolate to have least LC_{50} (5.5×10^4 conidia mL^{-1}) and proved to be effective against *B. tabaci* eggs.

In addition, 2nd nymphal instar of *B. tabaci* was also evaluated for its virulence against three isolates of *B. bassiana* on four different hosts. The 2nd nymphal instar showed high mortality as a result of fungal infection caused by isolates of *B. bassiana* and lies in agreement with the previous studies. High pathogenic activity of *B. bassiana* was reported against the *B. argentifolii* (Wright *et al*., 1998). In addition, excellent control of *T. vaporariorum* nymphs by *P. fumosorosea* was reported earlier by Poprawski *et al*. (2000). Moreover, different isolates of *M. anisopliae* have showed high virulence against *B. tabaci* nymphs on brinjal (Norhelina *et al*., 2013).

Pathogenicity of different isolates of *B. bassiana* was evaluated by Santiago-alvarez *et al*. (2006) on the fourth instar nymphs of whitefly and was highly dependent on the host plant. The mortality of nymphs differed significantly among 10 host plant species. In the current study, the susceptibility of 2nd nymphal instar to *B. bassiana* was significantly affected by the host plant and virulence of *B. bassiana* was highly dependent on host plant species. *P. fumosoroseus* showed efficacy against nymphs of *T. vaporariorum* reared on cucumber while less effective against nymphs reared on tomato (Bolckmans *et al*., 1995). In addition, significant differences in susceptibility of *L. decemlineata* to *B. bassiana* were observed, when reared on four different *Solanaceae* species (Hare and Andreadis, 1983). However, the results of current study are contrary to findings of Vidal *et al*. (1998) where infection potential of *P. fumosoroseus* to *B. agrentifolli* was not affected by host plant species. In addition, no effect was observed on potato and tomato to susceptibility of *L. decemlineata* to *B. bassiana* (Costa and Gaugler, 1989).

Infection rate and susceptibility of insects to insect pathogenic fungi which differ on host plants can be recognized as effects of host plants both physically and chemically. The physical aspects may include physical structure such as presence or absence and distribution of hairs on the lower surface of the leaves. Hairs of plant surface increase the surface area for attachment of conidia especially on the lower surface of leaves where nymphs are located. It will result in increased spores attachment to the insect and ultimately increase the infection opportunity. For this reason plant type must be taken in account for foliar application of *B. bassiana* (Kouassi *et al*., 2003).

In the current study, pathogenecity of isolates of entomopathogenic fungi was variable and factors which cause variation often remain unclear. However, these differences may be due to genotype of isolate either it produces large quantity of toxin or more energy was consumed during vegetative phase of growth. In addition, physical aspects of plants such as pubescence may also have an effect in this case *G. hirsutum* has more number of hairs as compared to others it possibly increased the infection opportunity and resulted in high mortality.

Microclimate conditions are very much important for the germination and growth of fungal spores. Leaves play an important part in providing humidity around the spores. Infection rates of *B. agrentifolli* by *P. fumosoroseus* and *B. bassiana* were slightly affected by ambient humidity due to microclimate by leaves and adequate humidity could be supplied by leaf and insect (Wraight *et al*., 2000). Porous plants can limit water transpiration and affecting the process of fungal infection (Olleka *et al*., 2009).

Secondary compounds produced by plants may also influence fungal infection that is transferred to insect through feeding (Poprawski *et al*., 2000). Several cases have been reported where secondary compounds produced by plants had significant effect on the infection rates by insect pathogenic fungi (Lacey and Mercadier, 1998; Inyang *et al*., 1999; Klingen *et al*., 2002).

In the current study whitefly had shorter survival duration on host plants where it was more susceptible to insect pathogenic fungi. The virulence of *B. bassiana* (Bb-01) was found highest on *G. hirsutum.* It is suggested that *B. bassiana* isolate Bb-01 could be used as biocontrol

agent for *B. tabaci* with respect to different host species. However, further detailed research is needed to focus the application of virulent isolate of *B. bassiana* (Bb-01) in glass house and field conditions.

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