Effect of entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, on *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) populations in different onion cultivars

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**Abstract**

**Background:** *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) is the key pest of onions that causes economic yield losses in commercial onion production in Pakistan. In this study, potential of the entomopathogenic fungi (EPF), *Beauveria bassiana* and *Metarhizium anisopliae*, as a bio agent was evaluated to manage buildup of thrips population on onion crop.

**Results:** Efficacy tests for EPF were conducted against *T. tabaci* infesting 3 different onion varieties (Phulkara, Swat 1, and Virio 7). Commercial formulations of *B. bassiana* strain GHA and *M. anisopliae* strain ESC-1, were evaluated at 4 different concentrations (10^8, 10^9, 10^10, and 10^11 conidia/ml) under field conditions for 2 years. The efficacy was assessed 3, 5, 7, and 10 days after spray application of the whole onion plant. Efficacy expressed as *T. tabaci* (nymphs and adults) percent population reduction in comparison to controls. Maximum corrected percent population reduction was observed in onion plants treated with *B. bassiana* 10^11 conidia/ml, i.e., 86.62, 84.59, and 86% in Phulkara, Swat 1, and Virio 7 onion varieties respectively, after 10 days of spray application. While onion plants treated with *M. anisopliae* 10^8 conidia/ml showed minimum corrected percent population reduction, i.e., 69.42, 68.45, and 69.11% in Phulkara, Swat 1, and Virio 7 onion varieties respectively, after 10 days of spray.

**Conclusions:** *Beauveria bassiana* could significantly reduce thrips population and could provide a better long-term management of *T. tabaci* on onion. *B. bassiana* had a high toxic effect against offspring production of the *T. tabaci* under field conditions than *M. anisopliae*.

**Keywords:** *Beauveria bassiana*, *Metarhizium anisopliae*, *Thrips tabaci*, Onion, Biological control
In Pakistan, sucking insect pests is the major reason of decrease in onion production. These pests include thrips as major pest and onion maggot (Delia antiqua), leaf minors (Lyriomyza spp.), and cutworm (Agrotis ipsilon) as minor pests (Khan et al. 2015). The demand for organic horticulture products that are safe for environment and consumers is increasing. Non-chemical methods such as biotechnical methods and intercropping (Trdan et al. 2006), late planting, physical barriers, and mulching are identified control methods for T. tabaci on onion crop (Gawande et al. 2010). However, all the above tactics could form one component of integrated pest management. Biological control in onion fields faces an immense difficulty because onion is treated intensively with insecticides. In organic horticulture, biological control is recognized as a basic component of IPM in which microbial control is a preferred technique due to its positive attributes such as amenable to production, broad spectrum effectiveness, and long-term storage (Dinesh 2017).

Among entomopathogenic microbial agents, fungal pathogens EPF isolated from different thrips species and proven to be pathogenic to T. tabaci include Metarhizium anisopliae (Metschn.) Sorokin., Beauveria bassiana (Bals.) Vuill., Neozygites cucumeriformis, Zoophthora radicans, Entomophthora thripidium, Verticillium lecanii, and Paecilomyces fumosoroseus (Butt and Brownbridge 1997). EPF are developed for the management of onion thrips T. tabaci, western flower thrips Frankliniella occidentalis and legume thrips Megalurothrips sjostedti in leguminous crops, ornamental plants, and vegetables (Maniania et al. 2002). Biopesticide usage for integrated crop pest management has increased in last few years (Sahayaraj and Namasivayam 2008). Various EPF have been industrialized as formulated products such as (i) Beauveria as BotaniGard® ES, Beauverin®, and Mycotrol® WPO, Betel®; (ii) M. anisopliae as Met52® EC, Bio-Catch-M® SL, and Green Muscle® SU; (iii) M. flavoviride as Biogreen® L; and (iv) Isaria fumosorosea as Preferal® WG and Priority® WP (Faria and Wraight 2007). These formulated products are being used to manage a wide range of pests such as thrips, whiteflies, aphids, mealybugs, psyllids, plant bugs, scarab beetles, and weevils (Copping 2009). These EPF have potential to be used in integrated insect pest management programs due to their less persistent nature, low mammalian toxicity, and natural occurrence (Lee et al. 2016). Although EPF formulated products have been developed, there is a little or no information about their evaluation in Pakistan farmer’s greenhouse and field conditions.

The present study focused on determining the efficacy of these EPF against T. tabaci under field conditions, in order to generate knowledge for their use as a component in organic farm production.

Methods

Experimental site
Field trials were conducted at Chak Shahzad, Islamabad, where vegetables are grown through the year. This site is situated at longitude 33° 40’ N, latitude 73° 8.9’ E and with elevation 499 meters ASL. The minimum and maximum average temperature of the area is 10 and 38 °C, respectively. Crops grown in the surroundings of the experimental area were wheat in the South, brassica and canola in the West, cabbage in the East, and bamboos in the North.

Nursery sown
Seeds of onion varieties (Phulkara, Swat 1, and Virio 7) were acquired from Ayub Agriculture Research Institute, Faisalabad. Nursery of these three varieties was raised after soil preparation during the October 2018 and 2019. Fertilizer was applied in 3 split concentrations: at the time of nursery raising, at transplanting stage, and at bulb initiation stage for better yield. Nursery was transplanted in December 2018 and 2019 for the winter season at 4-5 leaf stage after 8 weeks of emergence.

Experimental layout
The plot layout was a randomized complete block design for onion varieties Phulkara, Swat 1, and Virio 7 with 3 replications. Each experimental plot consisted of (3 m × 3 m) with distance of 10 cm between seedlings with 30 cm distance between rows. To avoid contamination and drift hazards among treatments, each experimental plot was separated by a distance of 1.5 m.

Formulations of entomopathogenic fungi
The B. bassiana WP and M. anisopliae WP formulations contained active ingredient based on 2.01 × 10^10 cfu/g of product. Commercial formulations of B. bassiana strain GHA and M. anisopliae strain ESC-1 were added in distilled water to make spray solution (Maniania et al. 2003). Spore germination rates of these EPF were tested on PDA at 25 °C after 24 h for 80% germination. The conidial concentration of EPF was determined by a hemocytometer.

EPF were applied after the 7th week of transplantation. Treatments were sprayed to onion plants infested with thrips with the help of Solo 418-One Hand Pressure Sprayer. Surfactant (0.02% tween 80) was mixed to the spray solution to enhance the adjuvant ability of solution and for better spread of entomopathogens. Treatments were sprayed during the evening times to lessen the ultraviolet radiation adverse effects on spore germination (Morley et al. 1996) and providing better conditions regarding humidity and temperature for fungal growth. Experimental plots were irrigated before spray of EPF to maintain relative humidity. Entomopathogens and
insecticide were sprayed with the help of separate hand sprayer to avoid contamination. Five randomly selected onion plants were observed for thrips population density in each experimental plot before and after application of treatments. Following experimental treatments were prepared:

| Treatments | Entomopathogenic fungi | Concentrations (conidia/ml) |
|------------|------------------------|-----------------------------|
| T1         | M. anisopliae          | $1 \times 10^8$             |
| T2         | B. bassiana            | $1 \times 10^9$             |
| T3         | M. anisopliae          | $1 \times 10^8$             |
| T4         | B. bassiana            | $1 \times 10^9$             |
| T5         | M. anisopliae          | $1 \times 10^{10}$          |
| T6         | B. bassiana            | $1 \times 10^{10}$          |
| T7         | M. anisopliae          | $1 \times 10^{11}$          |
| T8         | B. bassiana            | $1 \times 10^{11}$          |
| T9         | Bifenthrin 10 EC       | 330 ml/acre                 |
| T10        | Untreated control      | 1.5 l + 0.02% tween 80 surfactant |

Control plants were sprayed by water and surfactant as a negative control and recommended insecticide (Bifentrin) as positive control. Entomopathogens were applied in the evening.

**Statistical analysis**
Conidial application of these EPF was made 3 times at 10 days interval as experiment replication. The results were presented as onion thrips (%) population reduction pooled means of these replications. Thrips population reduction percentage in comparison to control treatments were calculated by the Henderson-Tilton’s formula (Henderson and Tilton 1955).

Thrips counts before treatment application were used in population reduction percentage calculation by Henderson-Tilton’s formula for each treatment. Pre-treatment and post-treatment means were analyzed by using the statistical software (Statistix 8.1) for ANOVA. Means were compared at 0.05 probability levels by Tukey’s Honest Significant Difference test (HSD).

**Results**
The present study was carried out, using 2 EPF, with 4 different concentrations on 3 onion varieties, i.e., Phulkara, Swat 1, and Virio 7. Effect of EPF on thrips population percentage in 3 different onion varieties is shown in Fig. 1. Maximum thrips population reduction percentages were recorded in Swat 1 onion variety after application.

**Onion thrips corrected population reduction percentage on Phulkara variety**
Effect of EPF on thrips population reduction percentage during 2019 at Phulkara onion variety is presented in Table 1. High corrected population reduction percentage was recorded in case of high concentrations of EPF. Among all the treated onion plots, the highest reduction in thrips population (89.14 %) was observed in bifenthrin-treated plots. Results revealed that B. bassiana treatment of onion plots at the concentration of $10^{11}$ conidia/ml showed the highest thrips population reduction (22.03%), which is at par with *M. anisopliae* at

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**Fig. 1** Entomopathogenic effects on thrips population reduction percentage in three different onion varieties
Thrips population significantly reduced after 5 to 7 days of EPF application. After 5 days, all the fungal treatments significantly reduced onion thrips population in comparison to control plots. Population reductions between 35.47 and 41.15% were observed in the treatments *M. anisopliae* 10^10 and *B. bassiana* 10^11 conidia/ml, respectively. After 7 days of EPF application, the highest reduction in populations was observed in *B. bassiana* at the concentration of 10^11 conidia/ml (73.33%) treated onion plots.

Significant differences (F = 5.21; P = 0.00) were observed among treatments after 7 days of EPF application. After 10 days, the highest population reduction percentage was observed in *B. bassiana* at the concentration of 10^11 conidia/ml (73.33%) treated onion plots.

10^10 conidia/ml (21.92%) after 3 days of application. Thrips population significantly reduced after 5 to 7 days of EPF application. After 5 days, all the fungal treatments significantly reduced onion thrips population in comparison to control plots. Population reductions between 35.47 and 41.15% were observed in the treatments *M. anisopliae* 10^10 and *B. bassiana* 10^11 conidia/ml, respectively. After 7 days of EPF application, the highest reduction in populations was observed in *B. bassiana* at the concentration of 10^11 conidia/ml (73.33%) treated onion plots.

Significant differences (F = 5.21; P = 0.00) were observed among treatments after 7 days of EPF application. After 10 days, the highest population reduction percentage was observed in *B. bassiana* at the concentration of 10^11 conidia/ml (73.33%) treated onion plots.

### Table 1 Entomopathogenic fungi on thrips population reduction percentage on Phulkara onion variety during 2019

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|--------------------------------|
|                         | (3rd day) | (5th day) | (7th day) | (10th day) |
| *Metarhizium anisopliae* 10^8 | 13.43d | 24.65c | 40.32b | 69.42d |
| *M. anisopliae* 10^9 | 15.96cd | 26.14c | 56.11ab | 72.61cd |
| *M. anisopliae* 10^10 | 14.16d | 30.28bc | 44.76b | 72.75cd |
| *M. anisopliae* 10^11 | 18.00bcd | 33.92bc | 62.20ab | 77.72bc |
| *Beauveria bassiana* 10^8 | 16.15cd | 34.33bc | 56.26ab | 74.07cd |
| *B. bassiana* 10^9 | 19.85bc | 38.32b | 67.29a | 81.31ab |
| *B. bassiana* 10^10 | 21.92b | 35.47bc | 61.71ab | 81.66ab |
| *B. bassiana* 10^11 | 22.03b | 38.67b | 58.1a | 69.52ab |
| Bifenthrin | 89.14a | 79.62a | 54.73ab | 38.58e |
| HSD value | 5.6 | 11.0 | 13.49 | 6.68 |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)

### Table 2 Entomopathogenic fungi on thrips population reduction percentage on Phulkara onion variety during 2020

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|--------------------------------|
|                         | (3rd day) | (5th day) | (7th day) | (10th day) |
| *Metarhizium anisopliae* 10^8 | 24.08b | 31.21b | 44.4b | 60.01ab |
| *M. anisopliae* 10^9 | 25.10b | 36.60b | 56.43a | 67.55ab |
| *M. anisopliae* 10^10 | 18.32b | 38.67b | 58.1a | 69.52ab |
| *M. anisopliae* 10^11 | 21.47b | 40.19b | 65.63a | 71.76ab |
| *Beauveria bassiana* 10^8 | 15.27b | 36.49b | 62.2a | 73.49ab |
| *B. bassiana* 10^9 | 22.13b | 40.78b | 70.63a | 76.05ab |
| *B. bassiana* 10^10 | 23.68b | 30.12b | 67.79a | 77.16a |
| *B. bassiana* 10^11 | 35.48b | 37.64b | 74.20a | 79.19a |
| Bifenthrin | 75.43a | 67.99a | 53.95a | 49.47b |
| HSD value | 24.55 | 24.25 | 22.01 | 27.44 |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)
Reduction of thrips population was recorded up to 35.48% by the application of *B. bassiana* at the concentration of $10^{11}$ conidia/ml. Thrips population further reduced after 5 and 7 days of EPF application. *B. bassiana* $10^{11}$ conidia/ml induced the population reduction (74.20%), followed by *B. bassiana* $10^{10}$ conidia/ml (70.63%) and *M. anisopliae* $10^{11}$ conidia/ml (67.79%) after 7 days of EPF application (F = 0.59; P = 0.77). Maximum reduction in thrips population was observed after 10 days of EPF application. For treated onion plots, *B. bassiana* at the concentration of $10^{11}$ conidia/ml showed the highest thrips population reduction 79.19% which is at par with *M. anisopliae* $10^{11}$ conidia/ml (77.16%) (F = 2.46; P = 0.06) after 10 days of EPF application.

Population counts were undertaken before treatment application ranged between 69 and 135 thrips per 5 plants. Thrips densities reduced in both insecticide- and EPF-treated plots in comparison to untreated control plots during the trials (Table 2).

**Onion thrips population reduction percentage on Swat 1 variety**

The population reduction percentage after the application of EPF on Swat 1 variety during 2019 is presented in Table 3 and Fig. 1. After 3 days of EPF application, the highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (24.43%), followed by *B. bassiana* $10^{10}$ conidia/ml (22.36%) treatments. Significant difference in population reduction percentage of onion thrips was observed after 5 days of spray. The highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (40.83%) followed by *B. bassiana* $10^{10}$ conidia/ml (37.04%) and *M. anisopliae* $10^{11}$ conidia/ml (36.45%) treatment (F = 7.91; P = 0.00) after 5 days of spray. Significant differences were observed among treatments after 7 days of application. After 7 days, the highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (76.50%), followed by *B. bassiana* $10^{10}$ conidia/ml (65.22%) treatments. After 10 days of EPF application, the highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (84.16%) and *M. anisopliae* $10^{11}$ conidia/ml (82.90%) treatments (F = 6.38; P = 0.00). A significant difference in population reduction percentage was observed at all the treatments at different level of concentrations for *T. tabaci*. After EPF applications, thrips numbers were reduced in treated plots than the untreated control plots. However, significant differences were observed in the treatments applied at different concentration.

Significant differences (F = 21.68; P = 0.00) in corrected population reduction percentage of onion thrips were observed after 3 days of treatment application on Swat 1 variety (Table 4). The highest population reduction percentage (89.46%) was observed in 3 days after spraying with bifenthrin. After 5 days, the highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (60.62%), followed by *B. bassiana* $10^{10}$ conidia/ml (59.89 %) treatments. After 7 days, the highest population reduction percentage observed was induced by *B. bassiana* $10^{11}$ conidia/ml (87.92%), followed by *B. bassiana* $10^{10}$ conidia/ml (81.22%) and *M. anisopliae* $10^{11}$ conidia/ml (78.70%) treatments (F = 3.62; P = 0.01). After 10 days of entomopathogenic application, the highest percent population reduction observed was induced by *B. bassiana* $10^{11}$ conidia/ml (76.58%) followed by *B. bassiana* $10^{10}$ conidia/ml (75.76%) treatment (F = 9.61; P = 0.04). A significant difference in population reduction percentage was observed for all the treatments at different level of doses for *T. tabaci* on Swat 1 onion variety.

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|-------------------------------|
|                         | (3rd day)                     |
|                         | (5th day)                     |
|                         | (7th day)                     |
|                         | (10th day)                    |
| **Metarhizium anisopliae** | 14.25e                        |
| $10^8$                  | 20.62f                        |
| $10^9$                  | 41.65f                        |
| $10^{10}$               | 68.45c                        |
| $10^{11}$               |                                |
| **M. anisopliae**       | 16.49de                       |
| $10^8$                  | 27.36e                        |
| $10^9$                  | 53.25de                       |
| $10^{10}$               | 70.82c                        |
| $10^{11}$               |                                |
| **M. anisopliae**       | 15.06e                        |
| $10^8$                  | 28.14de                       |
| $10^9$                  | 46.36ef                       |
| $10^{10}$               | 75.12bc                       |
| $10^{11}$               |                                |
| **M. anisopliae**       | 17.75de                       |
| $10^8$                  | 34.35cd                       |
| $10^9$                  | 60.62bcd                      |
| $10^{10}$               | 77.99abc                      |
| $10^{11}$               |                                |
| **Beauveria bassiana**  | 16.35de                       |
| $10^8$                  | 33.96cd                       |
| $10^9$                  | 57.39bcd                      |
| $10^{10}$               | 80.64abc                      |
| $10^{11}$               |                                |
| **B. bassiana**         | 22.36bc                       |
| $10^8$                  | 37.04bc                       |
| $10^9$                  | 65.22bc                       |
| $10^{10}$               | 82.90a                        |
| $10^{11}$               |                                |
| **B. bassiana**         | 19.36cd                       |
| $10^8$                  | 36.45bc                       |
| $10^9$                  | 63.72bc                       |
| $10^{10}$               | 84.16a                        |
| $10^{11}$               |                                |
| **B. bassiana**         | 24.43b                        |
| $10^8$                  | 40.83b                        |
| $10^9$                  | 76.50a                        |
| $10^{10}$               | 84.59a                        |
| $10^{11}$               |                                |
| Bifenthrin              | 81.01a                        |
| $10^8$                  | 76.63a                        |
| $10^9$                  | 52.60cde                      |
| $10^{10}$               | 39.31d                        |
| $10^{11}$               |                                |
| HSD value               | 3.99                          |
|                         | 6.48                          |
|                         | 9.92                          |
|                         | 6.69                          |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)
Thrips population before spray ranged between 65 and 170 thrips/5 plants. After 1 week of treatment applications, decline in thrips population density was more in EPF treatments than in insecticide-treated plots (Table 4). Average hourly temperature and RH measurements ranged from 23.2 to 31.3 °C and 28 to 76%, respectively, during the study.

Onion thrips population reduction percentage on Virio 7 variety
A high population reduction percentage was recorded at high concentrations of EPF during 2019 (Table 5). Results revealed that the maximum population reductions were 23.74% and 40.97% after 3 and 5 days of B. bassiana 10^11 conidia/ml application, respectively. Further population reduction of thrips was observed after 7 days of spray. B. bassiana at the concentration of 10^{11} conidia/ml treated onion plants showed the highest population reduction 71.91% which is at par with M. anisopliae 10^{11} conidia/ml (67.14%) (F = 20.40; P = 0.00). Significant differences were observed in treatments after 7 days of application. After 10 days, the highest population reduction percentage observed was induced by B. bassiana 10^{11} conidia/ml (86.00%), followed by M. anisopliae 10^{11} conidia/ml (82.70%) and B. bassiana 10^{10} conidia/ml (80.58%) treatments (F = 6.97; P = 0.00). A significant difference in population reduction percentage was observed at all the treatments at different level of doses for T. tabaci.

Significant difference in population reduction percentage of onion thrips was observed after 3 days of application on Virio 7 variety (Table 6). The highest population reduction percentage (80.78%) observed was induced by bifenthrin (F = 7.47, P = 0.00) after 3 days of spray. After 5 days, the highest population reduction percentage observed was induced by B. bassiana 10^{11} conidia/ml (49.93%) followed by M. anisopliae 10^{11} conidia/ml (45.53%) treatment (F = 0.92; P = 0.52). Thrips generations showed peak populations after 5 to 6 weeks in control treatments. There were significant differences

### Table 4
Entomopathogenic fungi on thrips population reduction percentage on Swat 1 onion variety during 2020

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|--------------------------------|
|                         | (3rd day)                      |
|                         | (5th day)                      |
|                         | (7th day)                      |
|                         | (10th day)                     |
| Metarhizium anisopliae 10^8 | 17.85b                         |
| M. anisopliae 10^9      | 18.29bc                        |
| M. anisopliae 10^{10}   | 20.09bc                        |
| M. anisopliae 10^{11}   | 28.48bc                        |
| Beauveria bassiana 10^9 | 6.19c                          |
| B. bassiana 10^9        | 16.40bc                        |
| B. bassiana 10^{10}     | 19.11b                         |
| B. bassiana 10^{11}     | 21.68bc                        |
| Bifenthrin              | 89.46a                         |
| HSD value               | 26.17                          |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)

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### Table 5
Entomopathogenic fungi on thrips population reduction percentage on Virio 7 onion variety during 2019

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|--------------------------------|
|                         | (3rd day)                      |
|                         | (5th day)                      |
|                         | (7th day)                      |
|                         | (10th day)                     |
| Metarhizium anisopliae 10^8 | 14.68f                         |
| M. anisopliae 10^9      | 16.37ef                        |
| M. anisopliae 10^{10}   | 17.89de                        |
| M. anisopliae 10^{11}   | 18.26cde                       |
| Beauveria bassiana 10^9 | 19.93cd                        |
| B. bassiana 10^9        | 21.01bc                        |
| B. bassiana 10^{10}     | 20.86bc                        |
| B. bassiana 10^{11}     | 23.74b                         |
| Bifenthrin              | 78.14a                         |
| HSD value               | 3.22                           |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)
observed in treatments after 5 days of application. After 7
days of application, the highest population reduction
percentage was induced by *B. bassiana* $10^{11}$ conidia/ml
(68.65%) followed by *M. anisopliae* $10^{11}$ conidia/ml
(65.51%) treatment..

**Discussion**

Obtained results highlighted the prospective of EPF for
controlling onion thrips. In particular, more than 80%
thrips population reduction was recorded by *B. bassiana*
and *M. anisopliae* application field trials.

The EPF species used against *T. tabaci* varied in their ef-
cfficacy to reduce pest’s populations. *B. bassiana* concentra-
tion ($1 \times 10^{11}$ conidia/ml) tested was more effective than
any *M. anisopliae* treatments. The results are in agree-
ment with Neves and Alves (2000). *B. bassiana* is an effi-
cient alternative method for use in biocontrol against the
onion thrips (Maniania et al. 2003). In this study, *B. bassi-
ana* showed 86.62 ± 1.43 population reduction percentage
after 10 days of treatment application which are similar to
Ansari et al. (2008) who stated that *Beauveria* spp. were
the most efficient, causing 54-84% onion thrips corrected
population reduction percentage after 11 days of applica-
tion. Low population reduction percentage by *M. aniso-
pliae* application might be due to the more time required
for conidial germination on insect body as compared with
filtrate. Some other factors like viability of conidia, rate of
germination, hyphae growth rate, and environmental fac-
tors such as temperature, humidity, and UV light could
also affect spore production and virulence of fungal iso-
lates on different insects (Molenaar 1984).

Results showed that EPF induce an immediate effect
on thrips populations to obtain 2-3 thrips/onion leaf
(Diaz-Montano et al. 2011) economic threshold levels in
field conditions. However, a lot of variations in thrips
counts were observed during the field trial. Environmen-
tal factors like rainfall had a significant effect on the
population densities of thrips by washing or dislodging
them from the plants. Results also showed that thrips
populations were reduced at insecticidal-treated plots,
which is in agreement with Ghelani et al. (2014) find-
ings. Although EPF formulations were efficient in redu-
cing the thrips numbers, they caused moderate
population reduction as compared to insecticides. The
highest efficacy of *B. bassiana* against thrips is in ac-
cordance with Boopathi et al. (2011) who stated that
among different EPF *B. bassiana* gave better results in
reducing the population of thrips. For maximum bene-
fits, therefore, this approach should be integrated with
other thrips management strategies, such as the use of
resistant varieties, polythene mulches, proper sanitation,
sticky traps, and botanicals (Maniania et al. 2003).

*T. tabaci* population on vegetables may be controlled
well with entomopathogens at concentration of $1 \times 10^{11}$
conidia/ha in field crops. But there is one limitation in
the use of these EPF that they are relatively less persist-
ent (Inglis et al. 1997). Results showed that these EPF
were able to persist for 10 days under the field condi-
tions. The present results showed also that *B. bassiana*,
*M. anisopliae*, and bifenthrin had great potentials for
use as important component in developing integrated in-
sect pest management packages against thrips on onion
(Nyasani et al. 2015). Further studies are required to
standardize concentrations of these EPF at different
stages of onion thrips infestations under field conditions.

**Conclusion**

Entomopathogenic fungi *B. bassiana* and *M. anisopliae*
significantly reduced thrips population build up in onion
crop after 7-10 days post applications. The fungal species
used against *T. tabaci* varied in their ability to reduce its
populations. *B. bassiana* as EPF was much against the
onion thrips than the *M. anisopliae*. Use of EPF to control
thrips populations could reduce the application of

| Treatments (conidia/ml) | Reduction (%) of onion thrips |
|-------------------------|-------------------------------|
|                         | (3rd day)         | (5th day)         | (7th day)         | (10th day)        |
| *Metarhizium anisopliae* $10^{8}$ | 16.63b          | 32.04a          | 51.0a           | 61.68ab          |
| *M. anisopliae* $10^{9}$ | 20.57b          | 33.92a          | 58.93a          | 62.59ab          |
| *M. anisopliae* $10^{10}$ | 22.27b         | 37.04a          | 57.07a          | 67.12ab          |
| *M. anisopliae* $10^{11}$ | 33.75b         | 38.09a          | 57.77a          | 71.14ab          |
| *Beauveria bassiana* $10^{9}$ | 21.28b         | 36.43a          | 55.12a          | 74.97a           |
| *B. bassiana* $10^{9}$ | 25.61b         | 41.47a          | 56.00a          | 76.96a           |
| *B. bassiana* $10^{10}$ | 26.42b         | 45.53a          | 65.51a          | 77.95a           |
| *B. bassiana* $10^{11}$ | 26.70b         | 49.93a          | 68.65a          | 79.41a           |
| Bifenthrin               | 80.78a         | 66.81a          | 54.77a          | 35.21b           |
| HSD value                | 34.77          | 56.4            | 36.14           | 38.54            |

Columns having same letter are not statistically different (P ≥ 0.05, ANOVA)
insecticide thereby preventing and/or delaying the population buildup of resistant thrips progenies. It is suggested that EPF can provide a better long-term management of *T. tabaci* on onion under field conditions.

**Abbreviations**

*T. tabaci*: Thrips tabaci; *B. bassiana*: Beauveria bassiana; *M. anisopliae*: Metarhizium anisopliae; EPF: Entomopathogenic fungi

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**Authors’ contributions**

Q and AM conceived, planned, and carried out the experiments, while MN helped shape the research, analysis and manuscript. The authors read and approved the final manuscript.

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**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

Not applicable

**Consent for publication**

Not applicable

**Competing interests**

The authors declare that they have no competing interests.

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