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Efficacy of Entomopathogenic Fungi *Paecilomyces* spp. against Rice Stem Borer (*Scirpophaga incertulas* L.) and Leaf Folder (*Cnaphalocrocis medinalis* L.) under Natural Field condition

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ABSTRACT: Entomopathogenic fungi are considered the most versatile groups of bioagents which reduce the insect's population as well as safe guard to environments by considering these facts the EPF was isolated from soils and insects. A field experiment was conducted at research farm of BTC College of Agriculture and Research Station, Bilaspur, (C.G.) during Kharif -2021-2022, to test the efficacy of isolates fungi, among them two most effective isolates of *Paceliomyces* spp. and combination with other bioagents was tested under natural field condition against two rice insects i.e. rice leaf hopper (*Cnaphalocrocis medinalis*) and rice stem borer (*Scirpophaga incertulas*) in two different rice var. Rajeshwari and Swarna. Three different spore suspension loads (1×10^7, 1×10^8 and 1×10^9 spore^{ml}) of *Paecilomyces* spp. and combination with other bioagents i.e. *Beauveria bassiana* and BT were sprayed @10ml^l with Standard check chemical insecticides. Standard check chemical insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) observed most effective among all treatments when use @1.65ml^l and reduced rice leaf folder population (87.58% & 86.01%) and stem borer reduced 91.42 and 91.04%, While, *Paecilomyces* isolate 1 with spore load 1×10^9 was most superior after insecticide and among all EPF for controlling rice insect leaf folder (73% and 66%) and stem borer 81.71%, 82.92%, respectively for Rajeswari and Swarna var.

Keywords: *Paecilomyces*, leaf folder, stem borer, *Scirpophaga incertulas, Cnaphalocrocis medinalis.*

INTRODUCTION

The use of modern farming such as enhanced irrigation, high-yielding varieties, agrochemicals and farm mechanization has significantly contributed to increasing food production. On the other hand intensive cultivation of high-yielding cultivars, mono culture of commercially significant crops, overlapping cropping seasons and overuse of agrochemicals, have resulted in high pest and disease occurrences. Crop loss due to pest becoming a key obstacle to agricultural productivity and production. Cotton has the biggest market share of pesticide use in India, with 45 % followed by rice 22%, vegetables 9% plantations 7%, wheat 4% and other crops 9% (David, 2008). The states of Karnataka, Andhra Pradesh, Maharashtra, and Punjab consume 38.14 % of all pesticides used in the country (Agnihotri, 2000). These states, also known as pesticide use prominent areas, sometimes also known as pesticide hot spots'. To reduce pest damage to crops, farmers frequently use insecticide mixtures, which leave hazardous residues in food and have negative impacts on related natural enemies Pest-related losses account for 14% of total agricultural output. Actual losses are reported to be 51% in rice, 37% in wheat, 38% in maize, 41% in potato, 38% in cotton, 32% in soybean, 32% in barley and 29% in coffee (Sharma *et al*., 2001). On the other hand bio Pesticides are a non-toxic alternative to chemical pesticides. Bio-pesticides are biological pest control agents that are applied in a similar way as chemical pesticides. The most advantageous feature of bio-pesticides is that no hazardous residues are left behind (Kaushik and Nirmalkar 2021).

Rice is the primary staple food for almost 65 % of the Indian population with the cultivated area 43.78 million hectare and total production of rice during 2019-20 is estimated at 118.43 million tones. It is 8.67 million tons higher than the last five years' average production of 109.76 million tones (Annual report 2020-2021), Department of agriculture Cooperation & Farmer's Welfare). Total geographical area of the Chhattisgarh state is 13.79 million hectares of which 5.64 million hectares is the gross cropped area with a cropping intensity of 121.3 %. The net sown area approx 33.73% of the total geographical area. The net irrigated area is 1.476 million hectares. In Chhattisgarh, Paddy is the main crop and grown about 77% of the net sown area (Singh *et al*., 2018). Insect infestations are one of the biotic stressors that cause 10-15% output losses. Rice yield losses are predicted to range from 21% to 51%.

Yellow stem borer, leaf folder, brown plant hopper, mealy bug and gall midge were the most common rice pests, resulting in crop losses of 25-30%, 10-70%, and 15-60%, respectively (Sain and Prakash 2008; Kaushik and Nirmalkar 2020). Stem borer and leaf folder cause 10 to 48% crop damage after sixty days of transplanting. *S. incertulas*, the yellow stem borer, causes an annual loss of 10-15% of rice crops, with local catastrophic outbreaks inflicting up to 60% damage (Daryaei, 2005; Nirmalkar *et al.*, 2016). On the above facts there is need to evaluate entomopathogenic fungi and their combination to find out best alternative option which is safer to environments. Rice stem borer and leaf folder has a negative impact on the quality and quantity of rice, resulting in significant market value losses. In order to reduce the economic loss of rice crop, it is important to check the most effective isolate of *Paecilomyces* spp. for management.

MATERIALS AND METHODS

The experiment was conducted at BTC CARS Bilaspur C.G. latitude 22.1032601 and longitude 82.1389713 during kharif, 2021-2022 to evaluate the bio efficacy of *Paecilomyces* spp. against rice stem borer (*Scirpophaga incertulas*) and leaf folder (*Cnaphalocrocis medinalis*). The cultivars Rajeshwari and Swarna were grown in plot size of 2×3m and 2m × 1m, respectively with proper spacing 20x15cm each treatment. Good agronomic practice was followed during experiments. The details of treatment are as follow:

T_1 = *Paecilomyces* (isolates Pl1) L (1×10^7) -1.5% concentration
T_2 = *Paecilomyces* (isolates Pl1) L (1×10^8) -5% concentration
T_3 = *Paecilomyces* (isolates Pl1) L (1×10^9)- 10% concentration
T_4 = *Beauveria* + *Paecilomyces* L - L (1×10^9)- 10% concentration
T_5 = *Paecilomyces* (isolates Pl 2) L (1×10^7) -1.5% concentration
T_6 = *Paecilomyces* (isolates Pl 2) L (1×10^8)- 5% concentration
T_7 = *Paecilomyces* (isolates Pl2) L (1×10^9)-10% concentration
T_8 = *Paecilomyces* + BT L - 10% concentration)
T_9 = Novaluron 5.25% + Indoxacarb 4.5% SC 1.65 ml[l]
T_{10} = Control (untreated)

First foliar spray was done when reached ETL level of stem borer and leaf folder. The efficacy of entomopathogens was compared with the standard check insecticide and control plot, which was water spray only. For the observation, five plants from each of the treatment was randomly selected and tagged. Observation pertaining to stem borer and leaf folder per row meter intensity was recorded under each treatment at 5th, 7th and 10th days of foliar spray, percent leaf folder, WE (White ear) and based on percent reduction was calculated.

Stem borer damage assessment. The effectiveness of treatments against rice stem borer was assessed on the basis of total number of white ears. Stem borer damage was recorded at the harvesting stage as white ear (WE) in row meter. The following formula was used to calculate the percentage of damage (Nirmalkar *et al.*, 2016).

$$\text{Per cent white ear} = \frac{\text{number of whiteears}}{\text{number of productivetillers}} \times 100$$

Leaf folder damage assessments. The observation was made during the panicle initiating stage (reproductive period) by assessing the number of infected leaves (scarping and rolled green tissue of leaves) and healthy leaves. Their percentage of damage had been calculated using the formula below

$$\text{Percent of damaged leaves} = \frac{\text{Number of damaged leaves per hill}}{\text{Total number of leaves per hill (damaged + healthy)}} \times 100$$

Statistical analysis. To compare different numerical observation, data was statically analyzed using appropriate design i.e. CRD, factorial CRD, RBD with desired transformation as applicable.

RESULTS AND DISCUSSION

A field experiments was conducted to determine the effect of *Paecilomyces* at three concentrations (10^7, 10^8, and 10^9 cfu g^{-1}) @ $10g^{-1}$. The data presented in Table 1 and shows that different treatments have different population of leaf folder ranged from 12.22% to 17.7%.

Average mean mortality of *Cnaphalocrosis medinalis.* The % reduction of leaf folder was observed and data was recorded. The mean mortality was maximum in 10th days after spray (68.30%) and among the different concentration maximum mean mortality was observed in T_9 insecticides (Novaluron 5.25% + Indoxacarb 4.5% SC) 87.58% followed by T_3 (73.98%) and T_7 (67.10%) while, the least mortality was observed in T_1(33.69%) over the control and found all the treatments were significantly differ from each other.

Percent reduction 5th days after spray. Data on percent reduction of leaf folder infestation was recorded 5 days after spray from different treatments. All treatments showed significant effect to control the rice leaf folder among the different treatments over untreated control. Table 1 revealed that after 5th days of spray the standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) was found superior over all treatment and significantly differ with all other treatment and recorded 82.48% per cent reduction over control followed by T_3 *Paecilomyces*-1, 10% (54.80%),

T_7 *Paecilomycesl*-2, 10% (49.15%) and T_4 *Beauveria bassiana* 50% + *Paecilomyces* 50% (38.94%). Where T_7*Paecilomyces*-2, 10% (49.15%) and T_4 *B. bassiana* 50% + *Paecilomyces* 50% (38.94%) was significantly at par with each other. Although T_1 *Paecilomyces*-1, 1.5% (22.03%) was least effective compare to other treatments. Treatment T_2 *Paecilomyces*-1, 5% (30.20%), T_8*Paecilomyces* 50% +BT 50%, (35.02%) was at par with each other.

Among the entomopathogens and their combinations T_3 (54.80%) was highly effective against rice leaf folder compared to other treatments, followed by T_7 (49.15%), T4 (38.94%) and T_8 (35.02%). Treatment T_3 showed significantly at par with T_7 while differ with rest other. The minimum effective in reduction percent over control was recorded in T_1 (22.03%) was least effective to control rice leaf folder. However, T_2 (30.20%) showed significantly at par with T_8 (35.02%).

Reduction at 7th day after spray. Percent reduction of leaf folder infestation was also recorded 7th days after spray from different treatments. Table no.1 showed that reduction percent was maximum in T_9 standard check insecticide (87.2%) and found significantly differ from other treatments followed by T_3 *Paecilomyces*-1, 10% (79.48%), T_7 *Paecilomyces*-2, 10% (67.34%) and T_4*B. bassiana* 50% + *Paecilomyces* 50% (54.08%). whereas, T_4 (54.08%) and T_8 (52.04%) was significantly at par to each other. Least effective treatments was T_1 *Paecilomyces*-1, 1.5% (32.14%) followed by T_5 *Paecilomyces*- 2, 1.5% (34.18%) while, T_1 (32.14%), T_2 (44.89%) and T_5 (34.18%) were at par to each other, it means there was less difference among three treatments.

Amongst the entomopathogens, T_3 *Paecilomyces*-1, 10% was most efficacious treatment and found 79.48 % reduction compared to other bio entomopathogen treatments, followed by T_7 *Paecilomyces*-2, 10% (67.34%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (54.08%). Whereas, T_4 (54.08%) and T_7 (67.34%) was at par with each other. Mean while, T_3 (79.48%) was most effective treatment and at par with standard (Novaluron 5.25% + Indoxacarb 4.5% SC) (87.2%). Treatments with the lowest percent mortality was T_1*Paecilomyces*-1, 1.5% (32.14%) which showed the lowest percent reduction against leaf folder followed by T_5 *Paecilomyces*-2, 1.5% (34.18%). While,T_4 *Beauveria* 50% + *Paecilomyces* 50% (54.08%), T_8 *Paecilomyces* 50% + *BT* 50% (52.04) and T_6 *Paecilomyces*-2, 5% (45.91%) were at par with each other.

Reduction % at 10th days after spray. Data on percent reduction of leaf folder was obtained after 10 days of spraying from various treatments and showed all treatments were significant reduction over untreated control. However, the individual treatment was significantly more effective in controlling insect infestations than the combination of treatments. In all the treatments the maximum percent reduction was found in T_{10} standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (93.08%) over all treatments and found significantly differ from with all the treatments followed by T_3 *Paecilomyces*-1, 10% (87.67%) and T_7*Paecilomyces*-2, 10% (84.83%) were effective to control rice leaf folder compared with other treatments while, T_3 (87.67%), T_7 (84.83%) and T_9 (93.08%) was at par to each other. Lowest effective treatment against rice leaf folder in all over treatments was T_1 *Paecilomyces*-1, 1.5% (46.91%) followed by T_5 *Paecilomyces*-2, 1.5% (48.34%) while, T_1 (46.91%), T_2 (54.97%) and T_5 (48.34%) and T_6 (59.71%) were at par to each other, it means there was less difference among these treatments.

In comparison to all other entomopathogen treatments the most efficacious treatment was T_3 *Paecilomyces*-1, 10% (87.67%) more effective over all bio-control treatments followed by T_7 *Paecilomyces*-2, 10% (84.83%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (71.5%) whereas T_9 (93.08%), T_3 (87.67%) and T_7 (84.83%) were at par to each other. While, T_1 *Paecilomyces*-1, 1.5% (46.91%) was least effective over all entomopathogen treatments, followed by T_5 *Paecilomyces*-2, 1.5% (48.34%) mean while, T_5 (48.34%), T_1 (46.91%) and T_2(54.97%), T_6 (59.71%) were found at par with each other.

The current study was on effect of entopathogen *Paecilomyces* spp. isolates (Pl-1 and Pl-2) against % reduction of leaf folder infestation and revealed that all treatments were significantly effective in reducing the rice leaf folder insect compared to control. Among all bio-control agents and their combinations, T_3 (87.675) singly proved to be the most effective treatments for controlling the rice leaf folder and as effective as standard check chemical insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (93.08%). Other treatments i.e. T_7 (84.83%) alone significant effective against rice leaf folder and combination of two bio-control agent, T_4 *Beauveria* 50% + *Paecilomyces* 50% (71.5%) and T_8*Paecilomyces* 50% + *BT* 50% were also comparatively more effective to control and can be used for rice leaf folder management.

Grain yield – The highest grain yield 49.54 q^{ha} was recorded in T_9 , which is higher over all treatments followed by treatment T_3 (46.72) and T_7 (45.39 q^{ha}), whereas all this treatments T_9,T_3 and T_7 was statistically at par with each other. The lowest yield (35.26 q^{ha}) was recorded in control T_{10}.While, rest treatments show intermediate result and statistically at par with each other.

Rice leaf folder infestation in variety Swarna. A field experiments was carried out to assessing the effectiveness of various concentrations (10^7, 10^8, and 10^9 cfu g^{-1}) @ 10 g^{-1}. Table no.2 shows that the population of insect was recorded from different plots ranged from 12 % to 16.66 %.

At 5th days after spray. Data on percent reduction of insect population was recorded at 5th days after spray. All the treatments were significantly effective in controlling rice leaf folder. The plot treated with standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (77.10%) was most effective and significantly differ from all treatments followed by treatment T_3 *Paecilomyces*-1, 10% (50%) and T_7 *Paecilomyces*-2, 10% (45.78%) whereas, treatment T_3 (50%) and T_7 (45.78%) was found significantly at par to each other.

Amongst the bio-control treatments T_3 *Paecilomyces*-1, 10% (50%) was most effective against rice leaf folder as comparison to other entomopathogens treatments followed by T_7 *Paecilomyces*-2, 10% (45.78%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (30.72%) where, T_3 (50%) and T_7 (45.78%) was at par with each other. Mean while, the lowest percent reduction was recorded from treatments T_1 *Paecilomyces*-1, 1.5% (18.07%). It was least effective compare to other treatments followed by T_5 *Paecilomyces*-2, 1.5% (21.08%) and found at par with each other while, treatment T_8 *Paecilomyces* 50% + *BT* 50% (28.91), T_6 *Paecilomyces*-2, 5% (27.71%) and T_2 *Paecilomyces*-1, 5% (22.89%) with T_5 *Paecilomyces*-2, 1.5% (21.08%) were found at par with each other.

At 7th days after spray. Data on percent reduction was recorded at 7th days after spray. All the treatments showed significant effective over the untreated control. Among all the treatments, standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (88.39%) was most effective and found significant differ from over all treatments followed by T_3 *Paecilomyces*-1, 10% (63.53%) and T_7 *Paecilomyces*-2, 10% (56.35%) both treatments were very effective treatment to control rice leaf folder. Whereas, T_3 (63.53%) and T_7 (56.35%) was found significantly at par with each other.

Amongst the entomopathogen treatments the most effective treatment was T_3 *Paecilomyces*-1, 10% (63.53%) followed by T_7 *Paecilomyces*-2, 10% (56.35%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (48.61%) where, T_7 (56.35 %) was found significantly at par with T_4 (48.61%). The least effective treatment on rice leaf folder was T_1 *Paecilomyces*-1, 1.5% (29.28%) followed by T_5 *Paecilomyces*-2, 1.5% (35.91%) while, T_6 *Paecilomyces*-2, 5% (41.43%) and T_2 *Paecilomyces*-1, 5% (40.33%) was found significantly at par with each other.

At 10th days after spray. Percent reduction of leaf folder population was recorded at 10th days after spray. Table no.2 showed the significant effect of all the treatments over control. The most effective treatments over all the treatments was T_9 standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) and showed 92.55% reduction followed by T_3 *Paecilomyces*-1, 10% (86.51%) and T_7 *Paecilomyces*-2, 10% (84.65%). Both treatments were effective to control rice leaf folder after chemical insecticide whereas T_9 (92.55%) was found significantly at par with T_3 (86.51%) and T_7 (84.65%).

Amongst the entomopathogen treatments *Paecilomyces*-1, 10% (86.51%) was the most effective treatments compared to all other entomopathogen treatments and showed significantly effective over control, followed by T_7 *Paecilomyces*-2, 10% (84.65%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (72.09%). Where, T_3 (86.51%) and T_7 (84.65%) was significantly at par with each other. While, T_1 *Paecilomyces*-1, 1.5% (47.44%) was the least effective among all entomopathogen treatments. T_5 *Paecilomyces*-2, 1.5% (50.53%) was second lowest effective treatment over other entomopathogen treatments. Moreover, T_1 *Paecilomyces*-1, 5% (54.41%) and T_6 *Paecilomyces*-2, 5% (58.13%) was at par with each other. The current study on the efficacy of entomopathogen treatments found significantly more effective at reducing the rice leaf folder population than the water spray control. Amongst the bio-control agents *Paecilomyces*-1, 10% and *Paecilomyces*-2, 10% alone found the most efficacious treatments over other entomopathogen treatments. Chemical insecticide and entomopathogen alone gives the best effect on control of rice leaf folder compared to combination of two entomopathogen treatments *Beauveria* 50% + *Paecilomyces* 50% and *Paecilomyces* 50% + *BT* 50.

Grain yield. The highest grain yield 47.42 q^{ha} was recorded in T_9, which is higher over all treatments followed by treatment T_3 (45.58) and T_7 (44.82 q^{ha}), whereas treatments T_9,T_3 and T_7 was statistically at par with each other. The lowest yield (34.26 q^{ha}) was recorded in control T_{10}. While, rest treatments show intermediate result and statistically at par with each other.

Stem borer infestation in variety Rajeshwari. Field experiments was conducted to determine the efficacy of different concentration (10^7, 10^8 and 10^9 cfu g^{-1}) @ 10 g^{-1} The data in Table 3 showed that different treatments was different population of rice stem borer and recorded from different plots ranging from 11.3 % to 17.5%. The percentage inhibition was showed significantly different.

Overall mortality at 7th days after spray. Data on percent reduction of population from various treatments were recorded 7th days after spraying. Significant variation was found in all the studied treatments. Among all the treatments T_9 standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) was found superior over all treatments and observed 91.42% reduction followed by T_3 *Paecilomyces*-1, 10% (81.71%) was the next best effective treatment for insect leaf folder and T_7 *Paecilomyces*-2, 10% (79.42%) where, treatment T_3 (81.71%) showed significantly at par with treatment T_9 (91.42%). Meanwhile the lowest reduction percent was found in T_5 *Paecilomyces*-2, 1.5% (31.42%) and also showed at par with T_1(34.28%) whereas, treatment T_2 (54.28%) showed significantly at par with T_6 (48%).

Amongst the entomopathogen treatments T_3 *Paecilomyces*-1, 10% (87.71%) was most effective treatments for rice stem borer followed by T_7 *Paecilomyces*-1, 10% (79.42%) and T_4 *Beauveria* 50% + *Paecilomyces* 50% (73.14%) these treatments were significantly effective in comparison to other treatments. Where, treatment T_3 (87.71%) and T_7 (79.42%) was found significantly at par with each other and T_4 (73.14%) found significantly at par with T_8 (70.28%). Besides, the least percent reduction was found in treatment T_5 *Paecilomyces*-2, 1.5% (31.42%) followed by T_1 *Paecilomyces*-1, 1.5% (34.28%) also found significantly at par with each other.

The current study's findings on the efficacy of entomopathogen on rice stem borer and reported that all treatments were significantly effective over control. Amongst entomopathogens and their combination T_3 (81.71%) and T_7 (79.42%) alone proved to the most

effective treatment for control of rice stem borer almost equivalent to standard check chemical insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (91.42%). Other treatments which are combination of two entomopathogen *Beauveria* 50% + *Paecilomyces* 50% (73.14%) and *Paecilomyces* 50% + *BT* 50% (70.28%) were also significantly effective over control and can be used for management of rice stem borer.

Grain yield. The highest grain yield 49.54 q^{ha} was recorded in T_9, which is higher over all treatments followed by treatment T_3 (46.72) and T_7 (45.39 q^{ha}), whereas all this treatments T_9, T_3 and T_7 was statistically at par with each other. The lowest yield (35.26 q^{ha}) was recorded in control T_{10}. While, rest treatments show intermediate result and statistically at par with each other.

Stem borer infestation in variety swarna. A field experiment was conducted to determine the efficacy of *Paecilomyces* at three concentration (10^7, 10^8 and 10^9 cfu^{-1}) @ 10 g^{-1}. Data presented in Table 3 showed that population of stem borer was recorded and ranged from 8.3% to 12.3% which showed non - significant from each other.

Overall mortality at 7th days after spray. Data on percent reduction was recorded at 7th days after spray. All the treatments were significant different from each other. Among all the treatments standard check insecticide (Novaluron 5.25% + Indoxacarb 4.5% SC) (91.05%) was most effective treatment over the other treatments followed by T_3 *Paecilomyces*-1, 10% (82.92%) and T_7 *Paecilomyces*-2, 10% (79.67%). Whereas, T_9 (93.08%) was found significantly at par with treatment T_3 (82.92%).

Among all the entomopathogen treatments, the most efficacious treatments was *Paecilomyces*-1, 10% (82.92%) followed by *Paecilomyces*-2, 10% (79.67%) and *Paecilomyces* 50% + *BT* 50% (74.79%). However *Paecilomyces*-1, 10% (82.92%) and *Paecilomyces*-2, 10% (79.67%) were at par with each other. The least effective treatment was *Paecilomyces*-1, 1.5% (34.95%) followed by *Paecilomyces*-2, 1.5% (39.02%). Although *Beauveria* 50% + *Paecilomyces* 50% (69.10%) and *Paecilomyces* 50% + *BT* 50% (74.79%) were significantly at par with each other.

Grain yield. The highest grain yield 47.42 q^{ha} was recorded in T_9, which is higher over all treatments followed by treatment T_3 (45.58) and T_7 (44.82 q^{ha}), whereas treatments T_9, T_3 and T_7 was statistically at par with each other. The lowest yield (34.26 q^{ha}) was recorded in control T_{10}. While, rest treatments show intermediate result and statistically at par with each other.

Result obtained from current study showed that *Paecilomyces*-1, 10% and *Paecilomyces*-2, 10% were alone most effective treatments against rice insects and can be used as the most efficacious treatment against rice insect stem borer. However, the combination of two bio-control agents i.e. *Beauveria* 50% + *Paecilomyces* 50% and *Paecilomyces* 50% + *BT* 50% were also very effective against rice stem borer compared to other bio-control treatment. Hashim and Ibrahim 2003 reported their finding on field efficacy of *Paecilomyces fumosoroseus* against cabbage-heart caterpillar. At exceeding the concentration of *Paecilomyces fumosoroseus* larval mortality was excess. Feng *et al.* (2004) reported their findings that *Paecilomyces* spp. combination with other bioagents *Beauveria bassiana* are effective against whitefly and cause 90% mortality.

Table 1: Field efficacy of *Paecilomyces* spp. against rice leaf folder (*Cnaphalocrosis medinalis*) in variety Rajeshwari.

Treatments	Dose g^{-1} or ml^{-1}	Cfu g^{-1}	Percent infestation $plant^{-1}$ (BS)	Reduction % of leaf folder infestation over control				Yield (q^{ha})
				5th DAS	7th DAS	10th DAS	Mean percent	
T_1- *Paecilomyces*-1 1.5%	10	1×10^7	15.00	22.03 (27.78)	32.14 (34.3)	46.91 (43.2)	**33.69**	40.39
T_2- *Paecilomyces*-1 5%	10	1×10^8	14.44	30.50 (33.36)	44.89 (41.92)	54.97 (47.8)	**43.45**	41.20
T_3- *Paecilomyces-1* 10%	10	1×10^9	14.44	54.80 (47.70)	79.48 (63.46)	87.67 (70.5)	**73.98**	46.72
T_4- *Beauveria bassiana* 50% + *Paecilomyces* 50%	10	1×10^9	12.22	38.94 (38.46)	54.08 (47.3)	71.5 (57.9)	**54.84**	42.03
T_5- *Paecilomyces*-2 1.5%	10	1×10^7	16.11	26.55 (30.94)	34.18 (35.64)	48.34 (44.02)	**36.65**	40.49
T_6- *Paecilomyces* -2 5%	10	1×10^8	13.89	32.20 (34.49)	45.91 (43.08)	59.71 (50.69)	**45.94**	41.50
T_7 - *Paecilomyces* -2 10%	10	1×10^9	15.55	49.15 (54.26)	67.34 (55.20)	84.83 (68.16)	**67.10**	45.39
T_8 - *Paecilomyces* 50% + *BT* 50%	10	1×10^9	15.55	35.02 (34.29)	52.04 (46.14)	67.77 (55.5)	**51.61**	42.12
T_9- Novaluron 5.25% + Indoxacarb 4.5% SC	1.65	-	16.22	82.48 (65.48)	87.2 (70.14)	93.08 (77.47)	**87.58**	49.54
T_{10} - Control(water spray)	10	-	17.77	-	-	-		35.26
MEAN	-	-	**15.12**	**41.29**	**55.25**	**68.30**		-
SEm±				2.05	2.90	3.86		2.683
C.D.			NS	6.17	8.7	11.5		6.434
C.V.				8.75	10.3	11.6		11.129

Data in parentheses shows arcsin percent transformation, BS- Before Spray, NS- Non significant, DAS- days after spray

Table 2: Field efficacy of *Paecilomyces* spp. against rice leaf folder (*Cnaphalocrosis medinalis*) in variety Swarna.

Treatment	Dose	Cfu g^{-1}	% infestation leaf folder $plant^{-1}$	Percent infestation reduction of *Cnaphalocrosis medinalis* over control				Yield (q^{ha})
			BS	5th DAS	7th DAS	10th DAS	MEAN	
T_1- *Paecilomyces*-1 1.5%	10	1×10^7	14.98	18.07 (25.1)	29.28 (32.7)	47.44 (43.46)	**31.59**	38.29
T_2- *Paecilomyces*-1 5%	10	1×10^8	13.50	22.89 (28.3)	40.33 (39.3)	54.41 (47.54)	**39.21**	39.38
T_3- *Paecilomyces-1* 10%	10	1×10^9	12.00	50 (45)	63.53 (52.7)	86.51 (74.39)	**66.68**	45.58
T_4- *Beauveria bassiana* 50% + *Paecilomyces* 50%	10	1×10^9	15.50	30.72 (33.6)	48.61 (44.22)	72.09 (58.39)	**50.47**	41.08
T_5- *Paecilomyces*-2 1.5%	10	1×10^7	14.50	21.08 (27.2)	35.91 (36.85)	50.53 (45.38)	**35.84**	38.55
T_6 - *Paecilomyces*-2 5%	10	1×10^8	15.16	27.71 (31.3)	41.43 (39.98)	58.13 (49.64)	**42.42**	39.20
T_7 - *Paecilomyces*-2 10%	10	1×10^9	13.33	45.78 (42.5)	56.35 (48.83)	84.65 (49.64)	**62.26**	44.82
T_8- *Paecilomyces* 50% + *BT* 50%	10	1×10^9	14.83	28.91 (32.5)	44.75 (41.89)	67.44 (67.14)	**47.03**	40.39
T_9- Novaluron 5.25% + Indoxacarb 4.5% SC	1.65	-	15.16	77.10 (61.4)	88.39 (73.63)	92.55 (77.61)	**86.01**	47.42
T_{10} – Control (water spray)	10	-	16.66	-	-	-		34.26
MEAN	-		**13.36**	**35.80**	**49.84**	**68.194**		-
SEm±			-	2.48	3.6	2.54		2.82
C.D.			NS	7.4	11.0	10.6		6.45
C.V.			-	11.8	14.0	8.6		11.36

Data in parentheses shows arcsin percent transformation; BS- Before Spray; NS- Non significant; DAS- days after spray

Table 3: Field efficacy of entomopathogenic fungi *Paecilomyces* spp. against rice stem borer (*Scirpophaga incertulas*)

Treatments	Dose (ml g^{-1})	cfu ml^{-1}	Var. Rajeshwari		Yield (q^{ha})	Var. Swarna		Yield (q^{ha})
			% stem borer (WE) row^{-m}	% Reduction of stem borer (WE)		% stem borer (WE) Row^{-m}	% reduction of stem borer (WE)	
			BS	7th DAS		BS	7th DAS	
T_1- *Paecilomyces*-1 1.5%	10	1×10^7	14.5	34.28 (35.76)	40.39	10.5	34.95 (35)	38.29
T_2- *Paecilomyces*-1 5%	10	1×10^8	15.3	54.28 (47.51)	41.20	8.3	65.04 (65)	39.38
T_3- *Paecilomyces-1* 10%	10	1×10^9	13.4	81.71 (66.4)	46.72	9.3	82.92 (83)	45.58
T_4 - *Beauveria bassiana* 50% + *Paecilomyces* 50%	10	1×10^7	12.5	73.14 (58.83)	42.03	8.3	69.10 (69)	41.08
T_5- *Paecilomyces*-2 1.5%	10	1×10^9	14.3	31.42 (33.93)	40.49	11.3	39.02 (39)	38.55
T_6 - *Paecilomyces* -2 5%	10	1×10^9	15.5	48 (43.84)	41.50	8.5	55.28 (55)	39.20
T_7 - *Paecilomyces* -2 10%	10	1×10^9	12.3	79.42 (63.51)	45.39	9.3	79.67 (79.66)	44.82
T_8 - *Paecilomyces* 50% + *BT* 50%	10	1×10^9	15.3	70.28 (57.06)	42.12	10.5	74.79 (73.66)	40.39
T_9 - Novaluron 5.25% + Indoxacarb 4.5% SC	1.65	-	11.3	91.42 (75.76)	49.54	9.5	91.05 (91)	47.42
T_{10} - Control(water spray)	10	-	17.5	-	35.26	12.3	----	34.26
Mean	-		**14.19**	**56.39**	-	**9.78**	**66.54**	-
SEm±			-	3.819	2.68	-	5.0	2.82
C.D.			NS	11.15	6.43	NS	15.0	6.45
C.V.			-	12.33	11.13	-	13.2	11.36

Data in parenthesis shows arcsin percentage transformation; BS- before spray; NS – Non significant; DAS – days after spray

CONCLUSIONS

- *Spodoptera* spp. was better insect host for isolation of *Paecilomyces* spp.
- 25°C was ideal temperature for mycelial growth, average growth and sporulation.
- Dextrose, Peptone was ideal media for growth and sporulation of *Paecilomyces.*
- pH 7 was ideal for production of fungus.
- *Paecilomyces* spp. 10^9 spore loads @10 ml^{-1} was better alternative option in safer management of rice stem borer and leaf folder.

FUTURE SCOPE

- Need to enhance field study of entomopathogenic fungi *Paecilomyces* in different crop pests.
- Large scale screening of soil for isolation of *Paecilomyces.*
- Compatibility study with others entomopathogen and agrochemicals.
- Need more indigenous isolate and more strain from local climates.

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