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Entomopathogenic fungi for managing the Rice leaf roller, *Cnaphalocrocis medinalis* Guen

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Abstract
The present experiment was carried out to assess the efficacy of entomopathogenic fungi against rice leaf roller, *C. medinalis*. The treatments include: T1-Talc based formulation of *B. bassiana* (Bb 5) @ 20 g l^{-1}, T2-Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}, T3-Talc based formulation of *M. anisopliae* (Ma 4) @ 20 g l^{-1}, T4-*B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1}, T5-*M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1}, T6-*A. flavus* (Af-m1) @ 10^{10} spores ml^{-1}, T7-Acephate 75 percent SP @ 750 g a.i ha^{-1}, T8-Chlorantraniliprole 18.5 percent SC @ 30 g a.i ha^{-1}, T9-Malathion 50 percent EC @ 575 g a.i ha^{-1}, T10-Thiamethoxam 25 percent WG @ 25 g a.i ha^{-1}, T11-Untreated. From the observations taken at different intervals, the best treatment among the fungal pathogens for reducing the larval, adult population and maximum reduction in damage of *C. medinalis* was given by *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1}.

Keywords: Rice leaf roller, entomopathogenic fungi, larva, adult, leaf damage, benefit cost ratio

Introduction
Insect pests that ravage the rice crop are one of the impediments in maximising its production. The crop is prone to the attack of the leaf roller, *C. medinalis*. The leaf roller that appear in the vegetative phase as well as in the panicle initiation to booting stages cause 63 to 80 percent yield loss in rice (Rajendran *et al*, 1986) [13]. Safer management strategies incorporating biocontrol agents are warranted in rice crop too to ward off the adversities of insecticides. Temperature and relative humidity are the two physical factors having much impact on the development of fungal infections (Benz, 1987 and James *et al.*, 1998) [2, 5]. The microclimate prevailing in waterlogged paddy fields ensure high humidity and favour the use of entomopathogenic fungi for pest management in rice. Today, research converges to biological control by virtue of the effectiveness of the bioagents and their safety to non targets and environment. The naturally existing and disease causing microbes of insects are applauded as important biocontrol agents world over and research is spinning ahead for exploiting their potential. Of the different microbes, the entomopathogenic fungi having the ability to breach insect cuticle and enter insect body to cause infection in both chewing and sucking insects have instilled their role as biocontrol agents. Hence the present experiment was conducted to evaluate the field efficacy of the effective fungal pathogens and newer molecules of pesticides against major pests.

Materials and Methods
The experiments were conducted during puncha season at Cropping System Research Centre (CSRC), Karamana, Kerala Agricultural University. Experimental design was Randomised block design with 11 treatments which were replicated thrice in an experimental area of 5m x2 m each with a spacing of 20 cm x 10 cm. The variety used was Uma (MO 16) obtained from College of Agriculture, Vellayani. Planting, application of fertilizers and other crop husbandry practices such as weeding and irrigation were done as per Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2011) [7] excluding the plant protection measures. The treatments were, T1-Talc based formulation of *B. bassiana* (Bb 5) @ 20 g l^{-1}, T2- Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}, T3-Talc based formulation of *M. anisopliae* (Ma 4) @ 20 g l^{-1}, T4-*B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1}, T5-*M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1}, T6 -*A. flavus* (Af-m1) @ 10^{10} spores ml^{-1}, T7-Acephate 75 percent SP @ 750 g a.i ha^{-1}, T8-Chlorantraniliprole 18.5 percent SC @ 30 g a.i ha^{-1}, T9-Malathion 50 percent EC @ 575 g a.i ha^{-1}, T10-Thiamethoxam 25 percent WG @ 25 g a.i ha^{-1}, T11-Untreated.

The treatments were applied on need basis at 95 and 105 days after sowing (DAS) during first and second field trials, respectively using high volume sprays @ 500 litres of spray fluid/ha. Pre-treatment count and post treatment count at 4,7,14 and 21 days after spraying was taken. Observations on population of *C. medinalis* was recorded by counting the number of adults in 10 sweeps plot^{-1} and number of larvae in 10 randomly selected hills plot^{-1}. Intensity of damage by *C. medinalis* was assessed by computing the percentage of damaged leaves in 10 randomly selected hills plot^{-1}.

Results and Discussion

Effect on larval population

The data on the larval population of *C. medinalis* assessed on the basis of the number of larvae present in ten hills plot^{-1} are presented in Table 1.

The pretreatment population of larvae of *C. medinalis*, in various plots was statistically similar. On the fourth day after spraying, all the treatments showed significant reduction in the population when compared to untreated (22.33). Among the fungal pathogens, the lowest population was observed in plots treated with *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (12.33) which was statistically on par with *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (13.33), talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (13.67), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (14.00), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (15.00) and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (15.00). Chlorantraniliprole @ 30 g a.i ha^{-1} treated plots had the lowest mean population (2.00) and it was significantly superior to all other treatments. Thiamethoxam @ 25 g a.i ha^{-1} (4.00) and acephate @ 750 g a.i ha^{-1} (4.67) was statistically on par. Malathion @ 575 g a.i ha^{-1} treated plots (6.00) was statistically similar with acephate @ 750 g a.i ha^{-1}. In this initial observation, the larval population in plots treated with entomopathogens was significantly higher than that treated with chemical pesticides. At seven DAT also, all the treatments showed significant reduction in the population than untreated (18.67). *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} treated plots had the lowest mean population of 7.67 among the fungal treatments and was statistically on par with talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (9.67), acephate @ 750 g a.i ha^{-1} (5.67), chlorantraniliprole @ 30 g a.i ha^{-1} (6.00), malathion @ 575 g a.i ha^{-1} (7.33) and thiamethoxam @ 25 g a.i ha^{-1} (8.00). *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} treated plots had mean population count of 10.67 and was statistically similar to thiamethoxam, talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (11.67), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (12.00) and *A. flavus* (Af-m1) @ 10^{10}spores ml^{-1} (12.67). Significant reduction in the population of *C. medinalis* larvae in all the treatments was evident at 14 DAT also, when compared to that of the untreated (22.67). *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} treated plots had the lowest mean population of 7.33, among the fungal treatments, which was on par with the insecticides, chlorantraniliprole @ 30 g a.i ha^{-1} (6.00), acephate @ 750 g a.i ha^{-1} (6.33), thiamethoxam @ 25g a.i ha^{-1} (7.67), malathion @ 575 g a.i ha^{-1} (7.67), talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (11.67), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (12.00), *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (13.00), *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (13.00) and talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (13.67) were found to be statistically on par. At 21 DAT, the trend was similar to that of the previous days, with significant difference in the population of *C. medinalis* present in untreated (19.33) and other treated plots. Among the fungal treatments, *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} had the lowest mean population of 8.00 ten^{-1} hills plot^{-1} which was on par with talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (10.33), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (11.00), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (11.00), *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (11.00) and *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (11.33). Among the insecticides, chlorantraniliprole @ 30 g a.i ha^{-1} recorded the lowest population of 5.67 and this was on par with thiamethoxam @ 25 g a.i ha^{-1} (6.00), acephate @ 750 g a.i ha^{-1} (7.00) and malathion @ 575 g a.i ha^{-1} (8.00). The effect of *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} was on par with all the insecticides while that of talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} was on par with acephate @ 750 g a.i ha^{-1} and malathion @ 575 g a.i ha^{-1}.

From the observations taken at different intervals, the best treatment among the fungal pathogens for reducing the larval population of *C. medinalis* was found as *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} which recorded a population reduction of 40.30 and 58.61 percent over untreated on the fourth day and on the twenty first day after treatment, respectively. The corresponding reduction in the larval population was 38.78 to 46.56 in talc based B. bassiana (Bb 5) @ 20g l^{-1}, 37.30 to 43.09 in talc based *B. bassiana* (Bb 21) @ 20 g l^{-1}, 32.83 to 43.09 in talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} respectively. Though the initial percentage reduction was higher (44.78) in *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1}, its performance was inferior, subsequently. There are only very few reports on the field evaluation of fungal pathogens against *C. medinalis*. On evaluation of *M. anisopliae* @ 10^{8} spores ml^{-1} against *C. medinalis*, Padmaja and Kaur (2001) [10] recorded 60 to 70 percent mortality of the pest. Shahid *et al*. (2003) [17] observed significant reduction in rice leaf folder incidence by applying *M. anisopliae* @ 250 g acre^{-1}. Among the insecticides evaluated, maximum reduction in larval population of C. medinalis (91.04 percent) over the untreated was noted in chlorantraniliprole @ 30 g a.i ha^{-1} and it was followed by thiamethoxam @ 25 g a.i ha^{-1} (82.09), acephate @ 750 g a.i ha^{-1} (79.09) and malathion @ 575 g a.i ha^{-1} (73.13), respectively**.** Though, the initial percentage reduction in the larval population of C. medinalis in the treatments with insecticides was significantly higher than that noted in fungal pathogens, over the period of observation it was seen that the effect of the chemical insecticides decreased while that of the fungal treatments increased and on the twenty first day, the effect of *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} was on par with all chemicals. The effect of talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} was on par with acephate @ 750 g a.i ha^{-1} and malathion @ 575 g a.i ha^{-1} on the twenty first day after application of treatments. The present result reflects the beneficial character of the fungal pathogens *i.e.,* extended insect management, which can be accounted to their self-perpetuating nature and sustained effect. Similar observations on the performance of entomopathogenic fungi was recorded by Rombach *et al*. (1986) [16]; Nghiep *et al*. (1999) [9]; Li et al. (2012) [8]; and Reddy *et al*. (2013) [15].

Effect on adult population

The data on the adult population of *C. medinalis* assessed on the basis of the number of adult present in ten sweeps plot^{-1} are presented in Table 2. There was no significant difference in the pretreatment population of *C. medinalis* adults in various plots. No significant difference was observed in the population of adults in untreated (13.00) and entomopathogen treated plots on the fourth day after spraying. The mean number of adults present in *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (11.67), *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (11.67), talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (12.00), *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (12.00), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (13.00), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (13.33) were statistically on par. The lowest population was recorded in chlorantraniliprole @ 30 g a.i ha^{-1} treated plots (3.00) which was on par with acephate @ 750 g a.i ha^{-1} (4.00) and thiamethoxam @ 25 g a.i ha^{-1} (4.00). Malathion @ 575 g a.i ha^{-1} treated plots harboured mean population of 6.00 and was statistically inferior to other insecticides evaluated. At seven DAT, all the treatments showed significant reduction in the population than untreated (16.00). *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} treated plots had mean population of 8.00 and it was significantly lower than that in the other fungal treated plots and was on par with malathion @ 575 g a.i ha^{-1} treated plots (7.00). Talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (10.33), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (11.00), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (11.33) and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (11.00) were statistically on par. *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} treated plots had mean population of 13.00 and it was on par with other fungal treatments except *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} and talc based *B. bassiana* (Bb 5) @ 20 g l^{-1}. Chlorantraniliprole @ 30 g a.i ha^{-1} treated plots recorded mean population count of 5.33 and was on par with acephate @ 750 g a.i ha^{-1} (6.00) and thiamethoxam @ 25 g a.i ha^{-1}(6.00). Malathion @ 575 g a.i ha^{-1} (7.00) was on par with other chemicals except chlorantraniliprole @ 30 g a.i ha^{-1}.There was significant difference in the adult population in treated and untreated (16.33) at 14 DAT. Among the fungal treatments, *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} treated plots had the lowest mean population of 8.00 adults ten^{-1} sweeps plot^{-1}, which was statistically on par with the effect of talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (9.00), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (9.00), acephate @ 750 g a.i ha^{-1} (6.67) and malathion @ 575 g a.i ha^{-1}(7.00). *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (10.00), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (10.67) and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (10.67) were statistically similar. The mean population in thiamethoxam @ 25 g a.i ha^{-1}, chlorantraniliprole @ 30 g a.i ha^{-1}, acephate @ 750 g a.i ha^{-1} and malathion @ 575 g a.i ha^{-1} treated plots was 6.00, 6.00, 6.67 and 7.00, respectively and were on par. The effect of the fungal pathogens as well as insecticides continued to 21 DAT also, with significant difference in adult population in the treated and untreated plots (13.67). The lowest population of 8.00 was recorded in talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} and *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} which was on par with *A. flavus* (Af-m1) @ 10^{10}spores ml^{-1} (8.33), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (8.67), *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (9.33) and talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (9.67). Among the insecticides, the lowest mean population of 6.00 in thiamethoxam @ 25 g a.i ha^{-1} treated plots was statistically on par with chlorantraniliprole @ 30 g a.i ha^{-1} (6.33), acephate @ 750 g a.i ha^{-1} (7.00) and malathion @ 575 g a.i ha^{-1}(7.33). Talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} and *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} were on par with all chemicals tested while *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} was on par with all chemicals except thiamethoxam. Talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} were on par with acephate @ 750 g a.i ha^{-1}and malathion @ 575 g a.i ha^{-1}.

Maximum reduction in adult population of *C. medinalis*, was brought about by B. bassiana (Bb 5) @ 10^{10} spores ml^{-1} and talc based B. bassiana (Bb 5) @ 20 g l^{-1}, each with 41.48 percent reduction over untreated field trial. However, it was noted that there was no statistical difference among the fungal treatments evaluated at 21 DAT.

Significant and quicker effect of the chemical pesticides in reducing the adult population of *C. medinalis*, compared to the fungal pathogens was evident in the observations on the fourth day. All the chemicals, except malathion @ 575 g a.i ha^{-1} were on par in their effectiveness, the percentage reduction in population ranged from 76.92 in chlorantraniliprole @ 30 g a.i ha^{-1} to 53.85 in malathion @ 575 g a.i ha^{-1}. However, in the subsequent observations the effect of these chemicals was seen to decline. At 21 DAT, B. bassiana (Bb 5) @ 10^{10} spores ml^{-1} and talc based B. bassiana (Bb 5) @ 20 g l^{-1} were on par with all insecticides evaluated.

Effect on extent of damage

The data on the effect of treatments on the extent of damage by *C. medinalis*, assessed in terms of the percentage of damaged leaves in ten hills plot^{-1} are presented in Table 3. There was no significant difference in the leaf damage in the pretreatment observations. On the fourth DAT, *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} treated plots had the lowest leaf damage of 3.67 percent and it was on par with *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (3.80) and talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (4.07). These three fungal treatments were significantly superior to untreated plots (5.07 percent). However, there was no significant difference in the percentage of leaves damaged in talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (4.20), *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (4.27) talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (4.53) treated and untreated plots. Malathion @ 575 g a.i ha^{-1} had the lowest leaf damage of 1.13 percent which was statistically on par with acephate @ 750 g a.i ha^{-1} (1.20), thiamethoxam @ 25 g a.i ha^{-1} (1.20) and chlorantraniliprole @ 30 g a.i ha^{-1} (1.40).There was significant difference in the percentage of leaf damaged in treated and untreated plots (8.53) at seven DAT. *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} treated plots showed the lowest leaf damage of 2.60 percent among the different fungal treatments and were on par with acephate @ 750 g a.i ha^{-1} (2.27), chlorantraniliprole @ 30 g a.i ha^{-1} (2.40) and thiamethoxam @ 25 g a.i ha^{-1} (2.67). *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (3.47) was on par with talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (3.53), talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (3.67), talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (3.87), *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (4.47) and thiamethoxam @ 25 g a.i ha^{-1}. All the fungal treatments, except *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} were statistically on par with malathion @ 575 g a.i ha^{-1} (3.60).At 14 DAT, all the treatments recorded significantly lower leaf damage than the untreated (9.00). The lowest leaf damage was recorded in *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (2.13) treated plots and it was on par with acephate @ 750 g a.i ha^{-1} (2.60) and chlorantraniliprole @ 30 g a.i ha^{-1} (2.73) treated plots. Talc based *B. bassiana* (Bb 5 and Bb 21) @ 20 g l^{-1} (3.07) was on par with *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (3.67), thiamethoxam @ 25 g a.i ha^{-1} (3.07) and chlorantraniliprole @ 30 g a.i ha^{-1}. Talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (4.40) and *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (4.53) were statistically similar to that in malathion @ 575 g a.i ha^{-1} (3.87 percent).All the treatments recorded significantly lower leaf damage than that in the untreated plots (7.73) at 21 DAT also. *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (1.87) treated plots that recorded lowest leaf damage was on par with acephate @ 750 g a.i ha^{-1} (2.27). The effect of talc based *B. bassiana* (Bb 5) @ 20 g l^{-1} (2.80), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (2.87) and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (3.07) were statistically similar to thiamethoxam @ 25 g a.i ha^{-1} (2.60) and malathion @ 575 g a.i ha^{-1} (3.13). *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} treated plots recorded 3.60 percent leaf damage and was on par with talc based *M. anisopliae* (Ma 4) @ 20 g l^{-1} (3.73) and malathion @ 575 g a.i ha^{-1}. Chlorantraniliprole @ 30 g a.i ha^{-1} treated plots showed leaf damage to the tune of 2.33 percent and was on par with acephate @ 750 g a.i ha^{-1} and thiamethoxam 25 g a.i ha^{-1}.

Considering the damage caused by *C. medinalis* to rice leaves, it was seen that the maximum reduction in damage was provided by *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} which harboured the lowest larval as well as adult population in the experiment. At 21 DAT, percentage reduction in damage noted in this treatment was to the tune of 75.81 whereas in other treatments with fungal pathogens, the reduction in damage was from 51.75 to 63.78 percentage. Immediate and significant effect of the chemical pesticides was evident in the damage caused by *C. medinalis* too. Acephate @ 750 g a.i ha^{-1} and thiamethoxam @ 25 g a.i ha^{-1} recorded the highest percentage reduction of 76.33 each, over untreated at 4 DAT. The effect of *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} came on par with acephate @ 750 g a.i ha^{-1} at 21 DAT.

Efficacy of entomopathogenic fungi against other rice pests under field conditions was reported by many researchers. The suitability of *M. anisopliae* and *B. bassiana* @ 10^{12} spores ml^{-1} in managing *N. lugens* was observed by Aguda and Rombach (1987) [1] Rao (1989) [14] and Reddy *et al*. (2013) [15]. *B. bassiana* @10^{6} spores ml^{-1} was recommended for the management of *Dicladispa armigera* (Oliver) (Hazarika and Puzari, 1990 [4]; Puzari and Hazarika, 1991 [11] and Puzari *et al*., 1994) [12]. Karthikeyan and Jacob (2010) [6] recorded the efficiency of *B. bassiana* @ 10^{7} spores ml^{-1} in managing *Leptispa pygmaea* Baly under Kerala conditions. Fazeli-Dinan *et al*. (2012) [3] recommended the use of *B. bassiana* @ 10^{7} spores ml^{-1} as a cost effective method for the management of the green semi looper, *Naranga aenescens* Moore.

Effect on yield

The effect of the different fungal treatments was reflected correspondingly in the yield obtained also. The treatments *viz.,B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} which recorded the lowest population and damage of *C. medinalis* produced the maximum yield among the fungal treatments. During the field trial *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} and *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} treatments caused 74.19 percent and 64.52 percent increase in grain yield over untreated

Only economically viable technologies will be conceived by farmers, hence, computation of benefit cost ratio (BCR) for the different treatments is also inevitable. The perspective of the Keralites to chemical free agriculture produce favours its market in spite of the higher price. 25 percent hike in price for chemical free unhusked paddy grains are offered currently in the market. Considering this, the BCR worked out in the trial, ranked in the following order *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} (1.65), chlorantraniliprole @ 30 g a.i ha^{-1} (1.58), *M. anisopliae* (Ma 4) @ 10^{10} spores ml^{-1} (1.55), acephate @ 750 g a.i ha^{-1} (1.48), malathion @ 575 g a.i ha^{-1} (1.46), talc based *B. bassiana* (Bb 5) @ 20g l^{-1} (1.44), thiamethoxam @ 25 g a.i ha^{-1} (1.39), talc based *M. anisopliae* (Ma 4) @ 20g l^{-1} (1.38), talc based *B. bassiana* (Bb 21) @ 20 g l^{-1} (1.20) and *A. flavus* (Af-m1) @ 10^{10} spores ml^{-1} (1.12).Reddy *et al*. (2013) [15] recorded BCR of 1.9 and 1.7 for the treatments with *B. bassiana* 0.5 percent and *M. anisopliae* 0.5 percent, respectively in rice plots.

Table 1: Effect of treatments on the population of *C. medinalis* larvae

Treatments	Mean number of larva 10^{-1} hills plot^{-1}				
	Precount	**4 DAT**	**7 DAT**	**14 DAT**	**21 DAT**
Talc based formulation of *B. bassiana* (Bb 5) @ 20 g l^{-1}	19.00 (4.36)	13.67 (3.69)	9.67 (3.09)	11.67 (3.41)	10.33 (3.21)
Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}	16.67 (4.08)	14.00 (3.73)	12.00 (3.46)	12.00 (3.46)	11.00 (3.31)
Talc based formulation of *M. anisopliae* (Ma 4) @ 20 g l^{-1}	17.00 (4.12)	15.00 (3.87)	11.67 (3.41)	13.67 (3.68)	11.00 (3.29)
B. bassiana (Bb 5) @ 10^{10} spores ml^{-1}	17.33 (4.16)	13.33 (3.65)	7.67 (2.76)	7.33 (2.69)	8.00 (2.83)
M. anisopliae (Ma 4) @ 10^{10} spores ml^{-1}	16.00 (3.99)	15.00 (3.87)	10.67 (3.26)	13.00 (3.60)	11.00 (3.31)
A. flavus (Af-m1) @ 10^{10} spores ml^{-1}	18.00 (4.24)	12.33 (3.51)	12.67 (3.56)	13.00 (3.58)	11.33 (3.36)
Acephate @ 750 g a.i ha^{-1}	17.00 (4.12)	4.67 (2.14)	5.67 (2.37)	6.33 (2.51)	7.00 (2.62)
Chlorantraniliprole @ 30 g a.i ha^{-1}	16.67 (4.08)	2.00 (1.38)	6.00 (2.44)	6.00 (2.44)	5.67 (2.38)
Malathion @ 575 g a.i ha^{-1}	18.00 (4.24)	6.00 (2.44)	7.33 (2.69)	7.67 (2.76)	8.00 (2.83)
Thiamethoxam @ 25 g a.i ha^{-1}	16.33 (4.04)	4.00 (1.99)	8.00 (2.81)	7.67 (2.76)	6.00 (2.43)
Untreated	19.33 (4.39)	22.33 (4.73)	18.67 (4.32)	22.67 (4.76)	19.33 (4.36)
CD (0.05)	NS	(0.411)	(0.447)	(0.508)	(0.617)

Mean of three replications
Figures in parentheses are $\sqrt{x}$ transformed values.
DAT- Days after treatment
NS- Non significant

Table 2. Effect of treatments on the population of *C. medinalis* adult

Treatments	Mean number of adult 10^{-1} sweeps plot^{-1}				
	Precount	4 DAT	7 DAT	14 DAT	21 DAT
Talc based formulation of *B. bassiana* (Bb 5) @ 20 g l^{-1}	13.67 (3.69)	12.00 (3.46)	10.33 (3.21)	9.00 (2.99)	8.00 (2.82)
Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}	13.67 (3.69)	13.33 (3.65)	11.33 (3.37)	10.67 (3.26)	9.67 (3.11)
Talc based formulation of *M. anisopliae* (Ma 4) @ 20 g l^{-1}	13.33 (3.64)	13.00 (3.60)	11.00 (3.31)	9.00 (2.99)	8.67 (2.94)
B. bassiana (Bb 5) @ 10^{10} spores ml^{-1}	14.00 (3.74)	11.67 (3.41)	8.00 (2.83)	8.00 (2.83)	8.00 (2.82)
M. anisopliae (Ma 4) @ 10^{10} spores ml^{-1}	13.67 (3.69)	11.67 (3.42)	11.00 (3.31)	10.67 (3.27)	9.33 (3.05)
A. flavus (Af-m1) @ 10^{10} spores ml^{-1}	12.67 (3.55)	12.00 (3.46)	13.00 (3.60)	10.00 (3.16)	8.33 (2.87)
Acephate @ 750 g a.i ha^{-1}	14.67 (3.83)	4.00 (1.99)	6.00 (2.44)	6.67 (2.58)	7.00 (2.63)
Chlorantraniliprole @ 30 g a.i ha^{-1}	16.00 (3.99)	3.00 (1.72)	5.33 (2.29)	6.00 (2.44)	6.33 (2.52)

Malathion @ 575 g a.i ha^{-1}	12.67 (3.55)	6.00 (2.44)	7.00 (2.64)	7.00 (2.64)	7.33 (2.69)
Thiamethoxam @ 25 g a.i ha^{-1}	13.33 (3.65)	4.00 (1.99)	6.00 (2.44)	6.00 (2.44)	6.00 (2.44)
Untreated	14.67 (3.83)	13.00 (3.60)	16.00 (3.99)	16.33 (4.04)	13.67 (3.69)
CD (0.05)	NS	(0.372)	(0.338)	(0.276)	(0.425)

Mean of three replications
Figures in parentheses are $\sqrt{x}$ transformed values.
DAT- Days after treatment
NS- Non significant

Table 3: Effect of treatments on the extent of damage by *C. medinalis*

Treatments	Mean damaged leaves 10^{-1} hills $plot^{-1}$ (%)				
	Precount	4 DAT	7 DAT	14 DAT	21 DAT
Talc based formulation of *B. bassiana* (Bb 5) @ 20 g l^{-1}	4.33 (2.15)	4.07 (2.02)	3.67 (1.92)	3.07 (1.75)	2.80 (1.67)
Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}	4.60 (2.14)	4.53 (2.12)	3.53 (1.87)	3.07 (1.74)	2.87 (1.69)
Talc based formulation of *M. anisopliae* (Ma 4) @ 20 g l^{-1}	4.27 (2.02)	4.20 (2.04)	3.87 (1.97)	4.40 (2.09)	3.73 (1.93)
B. bassiana (Bb 5) @10^{10} spores ml^{-1}	4.60 (2.14)	3.80 (1.95)	2.60 (1.61)	2.13 (1.46)	1.87 (1.37)
M. anisopliae (Ma 4) @ 10^{10} spores ml^{-1}	4.27 (2.07)	3.67 (1.91)	3.47 (1.86)	3.67 (1.91)	3.07 (1.75)
A. flavus (Af-m1) @ 10^{10} spores ml^{-1}	4.93 (2.21)	4.27 (2.07)	4.47 (2.10)	4.53 (2.13)	3.60 (1.89)
Acephate @ 750 g a.i ha^{-1}	5.13 (2.26)	1.20 (1.09)	2.27 (1.50)	2.60 (1.61)	2.27 (1.51)
Chlorantraniliprole @ 30 g a.i ha^{-1}	4.07 (2.01)	1.40 (1.18)	2.40 (1.54)	2.73 (1.65)	2.33 (1.53)
Malathion @ 575 g a.i ha^{-1}	4.53 (2.13)	1.13 (1.06)	3.60 (1.88)	3.87 (1.96)	3.13 (1.77)
Thiamethoxam @ 25 g a.i ha^{-1}	4.40 (2.09)	1.20 (1.09)	2.67 (1.63)	3.07 (1.75)	2.60 (1.61)
Untreated	5.13 (2.26)	5.07 (2.25)	8.53 (2.92)	9.00 (3.00)	7.73 (2.78)
CD (0.05)	NS	(0.215)	(0.241)	(0.189)	(0.14)

Mean of three replications
Figures in parentheses are $\sqrt{x}$ transformed values.
DAT- Days after treatment
NS- Non significant

Table 4. Grain and straw yield from the different treatments and benefit-cost ratio (BCR)

Treatments	Grain yield (kg $plot^{-1}$)	Straw yield (kg $plot^{-1}$)	BCR
Talc based formulation of *B. bassiana* (Bb 5) @ 20g l^{-1}	3.13	5.10	1.44
Talc based formulation of *B. bassiana* (Bb 21) @ 20 g l^{-1}	2.63	4.10	1.20
Talc based formulation of *M. anisopliae* (Ma 4) @ 20g l^{-1}	3.00	4.97	1.38
B. bassiana (Bb 5) @ 10^{10} spores ml^{-1}	3.60	5.27	1.65
M. anisopliae (Ma 4) @ 10^{10} spores ml^{-1}	3.40	5.16	1.55
A. flavus (Af-m1) @ 10^{10} spores ml^{-1}	2.50	4.10	1.12
Acephate @ 750 g a.i ha^{-1}	3.77	6.00	1.48
Chlorantraniliprole @ 30 g a.i ha^{-1}	4.07	5.94	1.58
Malathion @ 575 g a.i ha^{-1}	3.70	5.00	1.46
Thiamethoxam @ 25 g a.i ha^{-1}	3.53	5.75	1.39
Untreated	2.07	3.15	-
CD (0.05)	(0.266)	(0.378)	-

Conclusion

The present study assessed the efficacy of entomopathogenic fungi in managing the rice leaf roller attacking rice. The study revealed that *B. bassiana* (Bb 5) @ 10^{10} spores ml^{-1} was the best treatment, on the basis of pest population, reduction in damage by pests and benefit-cost ratio. Significant and quicker effect of the chemical pesticides in reducing the population of *C. medinalis*, compared to the fungal pathogens was evident in the observations on the initial days. However, by third week, the efficiency of entomopathogens were on par with the chemicals. Thus it can be very well concluded that entomopathogenic fungi are potent candidates for pest management in rice ecosystem.

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