J.Mycopathol.Res. 64(1) : 131-145, 2026, ISSN : 0971-3719 (Print), 2583-6315 (Online) 10.57023/JMycR.64.1.2026.131

Determination of potential UV protectants and its effect on survivability and pathogenicity of *Beauveria bassiana* (Bals.) Vuill. against *Nodostoma subcostatum* (Jacoby)

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Received : 04.01.2026 Accepted : 24.02.2026 Published : 30.03.2026

Ten UV protectants *viz*., Codacide, Ashlade, Peanut Oil, Natur'l oil, Sunflower oil, Mineral oil, Shellsol, Cutinol, Tinopal LPW, and Congo red at four (4) concentrations (2.5%, 5%, 7.5% and 9.5%) were tested for its efficacy on the conidial germination of *Beauveria bassiana* under different exposure time both on banana leaves and glass slides. When exposed to UV source in the laboratory, significant interactions were observed between concentration of UV protectants, conidial formulation and duration of exposure. Conidial germination of *B. bassiana* was found to be highest at 9.5 per cent concentration of UV protectants when compared with the other concentrations 2.5, 5.0 and 7.5 per cent. It was found that Peanut oil, Shellsol, Codacide, Congo red and Tinopal tested in laboratory, provided a higher degree of protection from UV radiation.Spraying of *B. bassiana*in combination with Congo red and Tinopal at 9.5% and 0.3% APSA-80 were most effective in minimizing the population of *Nodostoma subcostatum*and gave positive effect in the persistence of *B. bassiana* in the field.

Keywords : Codacide, Congo red, Stilbene brightener, Shellsol, Tinopol, UV Protectant

INTRODUCTION

The entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuill. has shown considerable potential as mycoinsecticide for the management of insect pests. Conidia of *Beauveria* come in contact with the host cuticle, they develop germ tubes and penetrate the host cuticle and invade the haemocoel. On invading the haemocoel, the fungus proliferates and host insects are killed due to depletion of their haemolymph nutrients and/ or due to toxaemia caused by fungal toxic metabolites. Under moist conditions, the fungus emerges and produces a layer of aerial conidia on the surface of host cadavers.

A major obstacle in using entomopathogenic fungi under field conditions is the rapid inactivation of the conidia caused by ultra-violet (UV) radiation, humidity and extreme temperatures.

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Fungal conidia are very susceptible to solar radiation and investigators have for many years tried to find ways of protecting conidia against damage caused by UV radiation. Exposure of conidia to UV radiation can have two effects- direct damage to DNA, creating strand breaks or cross-linkages between bases, which can block the synthesis of normal DNA and create high levels of mutations; the production of highly reactive and deleterious radicals such as peroxides. The result of both is rapid loss of conidial viability and a limit to its insecticidal activity (Braga *et al*. 2015). In addition to inactivating conidia, UV radiation has been shown to cause delay in the germination process of the surviving conidia. However, conidiation under illumination enhances conidial tolerance of insect-pathogenic fungi to environmental stresses (Dias *et al*. 2021). All these reduce the efficiency of fungi as biocontrol agents under field conditions where there is a strong solar irradiation. However, through selection of the most UV-B resistant isolates and incorporation of UV protectants in formulations, it may be possible to significantly prolong the persistence of these fungi in highly isolated habitats and thereby significantly increasing efficacy of fungi against target pests. Therefore,banana leaf and fruit scaring beetle, *Nodostoma subcostatum* (Jacoby) is taken as target insect for *B. bassiana* considering its importance in banana cultivation throughout the world.We hypothesized that, application of *B. bassiana* with UV protectants can prolong the survivability of conidia in field conditions and can be encouraged in IPM strategies.

Therefore, efforts had been made to study the efficacy of *B. bassiana* incorporated with UV protectants applied through foliar and whorl application against banana leaf and fruit scarring beetle.

MATERIALS AND METHODS

Isolation and identification of fungus

The leaf and fruit scarring beetles infected by fungus were collected during survey and brought to the laboratory and pathogens were isolated on Potato Dextrose Agar (PDA). Morphological characterisation based on microscopic observation has been documented for the identification of the fungus. The macroscopic characteristics of each colony were described through the observation of the parameters like growth rate considering the colony diameter, aspect and colour of conidial and reverse masses and exudates production.The fungus was identified following relevant literatures as available and confirmed by International Mycological Institute, CABI, U.K as *Beuaveria bassiana* (IMI335352). Details of molecular characterization has been documented (Temjenmenla *et al.,* 2022)

Laboratory tests on protectant materials

Ten UV protectants *viz.*, adjuvant oils (Codacide), Ashlade, 3 vegetable oils (Peanut Oil, Natur'l oil, Sunflower oil), Mineral oil, Congo red and Stilbene brightener (Cutinol, Shellsol), Tinopal LPW were tested for its efficacy on the conidial germination of *B. bassiana* under different exposure time both on banana leaves and glass slides. The survival of conidia exposed to UV source on glass slides and banana leaves were compared following the procedure of Edgington *et al.* (2000). For testing, conidia were scraped by using camel hair brush (No. 1) from the surface of 12 days old fungal mass of PDA plates and then suspended to a concentration of $1x10^7$ spores/ml in 0.1% Tween 80 plus a range of UV protectant materials at different concentrations as per the treatment combinations, T1: Conidial suspension of *B. bassiana* + Water, T2: Conidial suspension of *B. bassiana* + 0.05%. Tween-80, T3: Conidial suspension of *B. bassiana* + Codacide (2.5%, 5 %,7.5% and 9.5%), T4: Conidial suspension of *B. bassiana* + Ashlade (2.5%, 5 %,7.5% and 9.5%), T5: Conidial suspension of *B. bassiana* + Peanut oil (2.5%, 5 %,7.5% and 9.5%), T6: Conidial suspension of *B. bassiana* + Natur'l oil (2.5%, 5 %,7.5% and 9.5%), T7: Conidial suspension of *B. bassiana* + Sunflower oil (2.5%, 5 %,7.5% and 9.5%), T8: Conidial suspension of *B. bassiana* + Mineral oil (2.5%, 5 %,7.5% and 9.5%), T9: Conidial suspension of *B. bassiana* + Shellsol (2.5%, 5 %,7.5% and 9.5%), T10: Conidial suspension of *B. bassiana* + Cutinol (2.5%, 5 %,7.5% and 9.5%), T10: Conidial suspension of *B. bassiana* + Tinopal (2.5%, 5 %,7.5% and 9.5%), T11: Conidial suspension of *B. bassiana* + Congo Red (2.5%, 5 %,7.5% and 9.5%). Data on *in vitro* study was analysed by completely randomized block design with five replicates.

A 3 μl droplet of the suspension was smeared evenly across the length of a clean glass slide using the edge of another slide and onto the surface of the fresh banana leaves.The source of ultraviolet light rays was a UV-B fluorescent bulb of 30 W with a wavelength 260 to 400 nm.Test slides and leaf pieces were located at a distance of 50 cm from the UV source and exposed for different periods *viz.*, 0, 30, 60, 90, 120, 150 and 180 min. Following exposure, a thin layer of 3% PDA was added onto each slide and all were then placed in a dark humid box for 24 hours at ambient laboratory temperatures (25ºC).

Conidia exposed on the leaf surface were washed with 10 ml of sterile distilled water onto a glass beaker. An aliquot 200 μl of this wash off was inoculated into Eppendorf tubes containing

1 ml of PD medium and incubated at 25ºC. For observation of conidial germination, 60 µl of conidial suspension from the tube was dispensed onto a glass slide (Reddy *et al*. 2008).

Conidial germination for both tests carried out on glass slides and banana leaves was recorded after 48 hours of incubation. Conidia were examined at 40x magnification and germination was recorded when the germ tube was visible. All the conidia in each field of view were counted to obtain at least a total of 300 conidia ranging from 300 to 400 conidia, for each replicate (Moore *et al*. 1993). The mean per cent spore germination was calculated for each slide by counting the number of germinated and ungerminated spores in each field of view. Five replicates were maintained for each treatment.

***Field efficacy of UV protectants incorporated Beauveria bassiana against banana leaf and fruit scarring beetle (Nodostoma subcostatum*)**

Field experiments were conducted consecutively for two seasons to evaluate the performance of UV protectants incorporated *B. bassiana* against scarring beetle (*Nodostoma subcostatum*). Spores of *Beauveria bassiana* were harvested from Rice Husk (RH): Saw Dust (SD): Rice Bran (RB) medium after 30 days of inoculation and thoroughly mixed with the UV protectant materials with 0.1 per cent Tween-80. The best result concentration of the different UV protectants interm of conidial germinability were tested in the protection ability of conidia of *B. bassiana* in the field condition on live banana plants as per the different treatments, T1: Conidial suspension of *B. bassiana* + 0.05% Tween-80, T2: Conidial suspension of *B. bassiana* + Crabaryl (0.3%) + APSA-80 (0.03%), T3: Conidial suspension of *B. bassiana* + Congo Red (9.5% w/v) + APSA-80 (0.03%), T4: Conidial suspension of *B. bassiana* + Shellsol (9.5%) + APSA-80 (0.03%), T5: Conidial suspension of *B. bassiana* + Codacide (9.5%) + APSA-80 (0.03%), T6: Conidial suspension of *B. bassiana* + Peanut oil (9.5%) + APSA-80 (0.03%), T7: Conidial suspension of *B. bassiana* + Tinopal (9.5% w/v) + APSA-80 (0.03%). The experiment was conducted at the Horticultural Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat with 4 replications and arranged in randomized block design with a individual plot size of 3.0 m X 3.0 m and following observations were recorded:

Number of scars on leaves

Scarring beetle of banana produce scars on leaves by scrapping the chlorophyll. The numbers of scars on leaves from 5 sq. cm. of leaf surface were recorded on first two tender leaves at three different locations after two (2) days of each application.

Number of scarring beetle

Number of scarring beetle was recorded two days after spraying by counting them on leaves including those hidden inside whorl of crown leaves from the randomly selected plants during morning hours.

Number of infected beetle

Number of scarring beetle infected with *Beauveria bassiana* was recorded both on the leaves and fruit.

Mean fruit infestation and yield

Observations pertaining to the number of healthy and infested fingers/bunch data were used for computing the mean (%) finger infestation. It was recorded after harvesting the crop. Yield data from each treatment was recorded after harvest.

RESULTS AND DISCUSSION

Effect of concentration of UV protectants and exposure time on conidial germination of B. bassiana on leaves

The mean per cent germination of *Beauveria bassiana* conidia following treatment with ten UV-protective adjuvants at concentrations ranging from 2.5% to 9.5% is presented in Table1. Under baseline conditions (0 min UV exposure), the highest germination rate of 70.02% was observed at the 9.5% concentration, which was statistically comparable (P > 0.05) to the germination rates at 7.5% (69.89%) and 5.0% (69.62%), as illustrated in (Fig. 1). The lowest germination at this exposure time was recorded at 2.5% concentration (68.71%).Following UV exposure durations of 30, 60, and 90 minutes, the 9.5% concentration maintained germination rates of 63.26%, 56.85%, and 51.54%, respectively. These values were statistically at par with those observed at 7.5% (63.34%, 56.89%, and 51.50%) and 5.0% (62.87%, 56.49%, and 51.10%), indicating concentration-dependent equivalence among these treatments. Conversely, the 2.5% concentration consistently yielded the lowest germination across these time points, with rates of 61.68%, 55.64%, and 50.33%, respectively.At 120 minutes of exposure, maximum germination was again recorded at 9.5% (47.46%), which was statistically similar to the 7.5% treatment (47.33%). This trend persisted through the 150-minute exposure interval. Minimal germination was observed at the lowest concentrations, with 2.5% and 5.0% yielding 40.93% and 41.41%, respectively. Following the maximum exposure duration of 180 minutes, the 9.5% concentration continued to support the highest germination rate (36.08%), though this did not differ significantly from the rates at 5.0% (35.35%) and 7.5% (35.30%).

Effect of different UV protectants and exposure time on conidial germination of B. bassiana on leaves

The data on mean conidial germination of *B. bassiana* with different UV protectants under different exposure time showed that at 0 and 30 minutes exposure Tinopal (T11) gave the best performance recording 77.74 and 72.70 per cent, respectively and was followed by Congo red (T12) 75.86 and 72.29 per cent at both the exposure time (Table 2). But when the exposure time was increased to 60, 90, 120 and 150 minutes performance of Peanut oil (T5) was best with 68.39, 64.21, 59.09 and 55.84 per cent, respectively. This was followed by Tinopal (T11) showing germination percentage of 66.62, 62.30, 58.82 and 53.56 per cent at 60, 90, 120 and 150 minutes. At 180 minutes, Shellsol (T9) gave maximum conidial germination of 50.34 per cent, which is followed by Peanut oil (T5) 50.07 per cent and Tinopal (T11) 48.75 per cent without having any significant difference between them. Of all the UV protectants tested, Cutinol (T10) showed the lowest conidial germination ranging from 39.48 per cent at 0 minute to 13.28 per cent at 180 minutes exposure.Control 1(T1) showed good performance of germination 75.53 per cent at 0 minute exposure but with the increasing 30, 60, 90, 120, 150 and 180 minutes exposure time the germination reduced to 43.99, 26.56, 0.00, 0.00, 0.00 and 0.00 per cent, respectively. In contrast to Control 1 (T1), Control 2 (T2) gave better conidial germination at all exposure time ranging from 65.59 per cent to 28.47 per cent (Fig.1).

Interaction effect of concentration and UV protectants under different exposure time on conidial germination of B. bassiana on leaves

Analysis of the interaction between UV protectant formulation and concentration on *Beauveria bassiana* conidial viability on phylloplane surfaces is presented in (Table3). Under baseline conditions (0 min), mean germination ranged from 38.2% (Cutinol, T10, 2.5%) to 77.92% (Tinopal LPW, T11, 9.5%). Tinopal exhibited superior germination across all concentrations at 0 and 30 min exposures, followed by Peanut oil (T5). However, from 60 to 180 min exposure, Peanut oil demonstrated maximum germination. Congo red (T12) showed secondary efficacy at 60, 90, and 150 min, while Shellsol (T9) outperformed others at 120 and 180 min, followed by Peanut oil. Untreated controls (T1) showed 75.53% germination at 0 min, which declined precipitously to 43.99% and 26.56% at 30 and 60 min respectively, with complete germination inhibition beyond 90 min exposure. Cutinol consistently yielded minimal germination across all concentrations and exposure durations, ranging from 39.95% (9.5%, 0 min) to 12.35% (2.5%, 180 min). Statistical analysis revealed parity among Tinopal, Peanut oil, and Congo red at 0 min across all concentrations ($P > 0.05$). At 30 min, no significant differences emerged among Tinopal, Peanut oil, Congo red, Shellsol, and Codacide (T3). By 60 min, Peanut oil demonstrated statistically superior germination (67.47-68.70%) across all concentrations. At 90 min, Peanut oil showed concentration-dependent parity with Congo red and Tinopal at lower concentrations (2.5-5.0%), while exhibiting significant differentiation at higher concentrations (7.5-9.5%). At 120 min, Peanut oil maintained statistical significance versus Shellsol, Codacide, and Tinopal. At 180 min, Peanut oil and Shellsol demonstrated statistical equivalence across all concentrations.

Effect of concentration of UV protectants and exposure time on conidial germination of B. bassiana on glass slides

The mean conidial germination of *B. bassiana* treated with different UV protectants at concentrations 2.5, 5.0, 7.5 and 9.5 per cent depicted in Table 4 showed that irrespective of exposure time, all UV protectants at 9.5 per cent concentration gave best performance with maximum per cent of conidial germination. As and when the concentration is reduced, germination percentage is also reduced showing positive correlation with each other *i.e.,* concentration of UV protectants and conidial germination.The highest germination (73.27%) was observed at 9.5 per cent concentration when there was no exposure (0 minute) followed by 7.5 and 5.0 per cent concentration showing germination of 73.22 and 73.07 per cent, respectively. Minimum germination (37.46%) occurred at 2.5% concentration following 180 min UV exposure. Germination rates across concentrations were statistically equivalent ($P > 0.05$) at all exposure intervals except 120 and 180 min. At 0 min exposure, maximum germination (73.27%) was observed at 9.5% concentration. However, at 30 and 60 min, the highest germination rates (67.06% and 60.07%, respectively) were recorded at 7.5% concentration. At 90 and 150 min intervals, both 9.5% and 7.5% concentrations yielded equivalent maximum germination (52.66% and 43.79%, respectively). Following 120 and 180 min exposure, 9.5% concentration demonstrated superior germination (48.56% and 38.38%, respectively), statistically comparable to 7.5% (48.46% and 38.06%) but significantly different from lower concentrations (5.0% and 2.5%).

Effect of different UV protectants and exposure time on conidial germination of B. bassiana on glass slides

Results on the effect of different UV protectants on germination of *B.bassiana* at different exposure time showed that when there was no exposure (0 minute), significant difference among all treatments was observed with highest germination of 81.85 percent in Tinopal (T11) followed by control 1 (T1) 80.98 per cent and 80.07 per cent in Congo red (T12). Similarly, at 30 minute exposure Tinopal (T11) recorded the maximum germination of 77.85 per cent followed by Peanut oil (T5) 76.35 per cent and Congo red 75.64 per cent. At 60 minute exposure Peanut oil (T5) showed the highest germination of 69.62 per cent followed by Tinopal 68.39 per cent without any significant difference. Cutinol (T10) exhibits the lowest germination of 34.16 per cent (Table 5).Conidial germination in control 1 (T1) at 0 minute recorded 80.98 which was greatly reduced on exposure to 30 and 60 minute 53.49 and 37.53 per cent, respectively. However, on exposure from 90 minute to 180 minute germination was 0.00 per cent. At 90, 120, 150 and 180 minutes, the highest germination was exhibited by Peanut oil (T5) 64.88, 60.46, 57.30 and 53.27 and was significantly superior when compared with control 1 (T1) 0.00 per cent.

Interaction effect of concentration and UV protectants under different exposure time on conidial germination of B. bassiana on glass slides

The data on the effect of concentration and different UV protectants on germination of *B. bassiana* on glass slides showed that conidial germination in control 1 was gradually decreased with the increase in exposure time from 0, 30, 60, 90, 120, 150 and 180 minute recording (80.98, 53.49, 37.53, 0.00, 0.00, 0.00 and 0.00%), respectively(Table6). Tinopal (T11) exhibited maximum conidial germination at 0 and 30 minutes exposure time but with the increase in exposure time 60, 90, 120, 150 and 180 minutes Peanut oil (T5) showed the highest germination at all concentrations. At 0 minute exposure the maximum germination percentage of Tinopal (T11) at 2.5, 5, 7.5 and 9.5 per cent concentration was 81.96, 80.60, 81.95 and 82.90 per cent, respectively was followed by Congo red (T12) 80.41, 79.34, 80.33 and 80.20 per cent with no significant difference between them. However, at 30 minutes exposure germination percentage with Tinopal (T11) at 2.5, 5.0, 7.5 and 9.5 per cent concentration was 78.86, 77.27, 77.47 and 77.79 per cent, respectively and was followed by Peanut oil (T5) 76.58, 78.45, 76.51 and 76.81 per cent

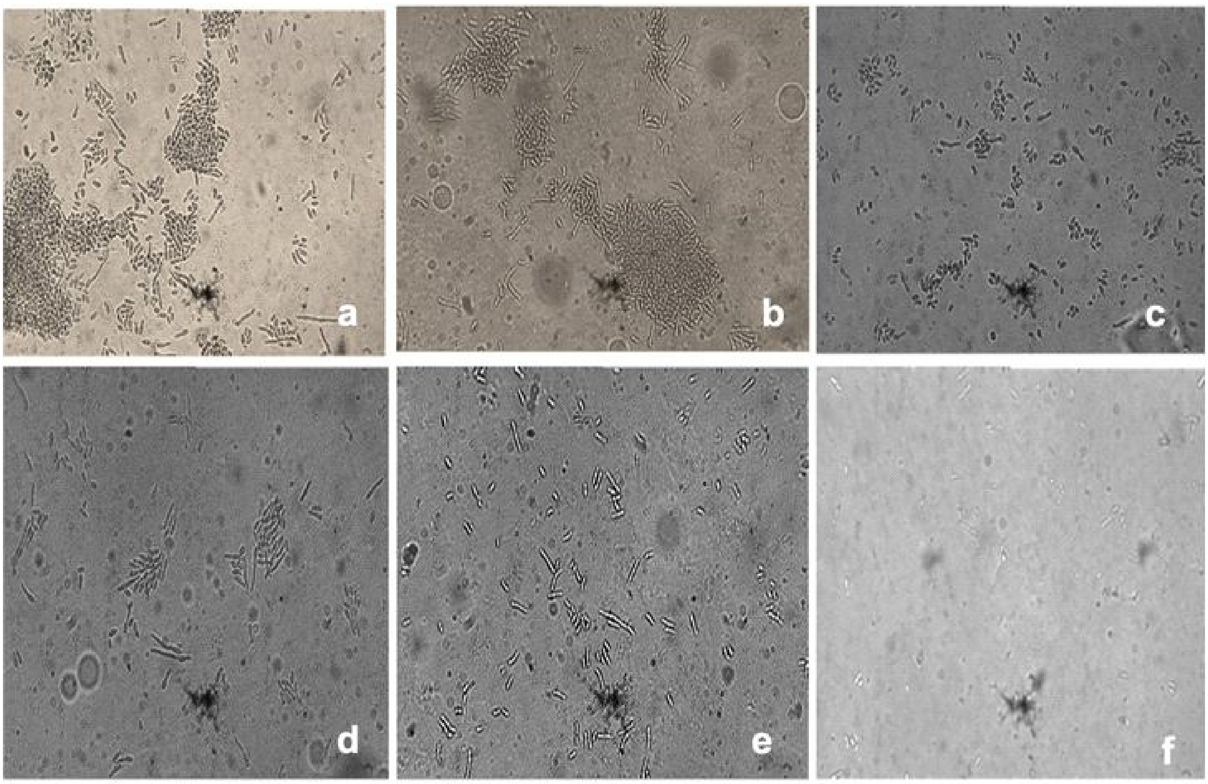

Fig. 1: (a-d). Interaction effect of conidial germination of *Beauveria bassiana* with peanut oil (9.5% w/v) under different exposure time on leaves to sunlight a. conidial germination of *Beauveria bassiana* with peanut oil at 0 min. exposure time on leaves to sunlight , b. conidial germination of *Beauveria bassiana* with peanut oil at 30 min. exposure time on leaves to sunlight c.conidial germination of *Beauveria bassiana* with peanut oil at 60 min exposure time on leaves to sunlight, d. conidial germination of *Beauveria bassiana* with peanut oil at 120 min. exposure time on leaves to sunlight e. conidial germination of *Beauveria bassiana* with peanut oil at 150 min. exposure time on leaves to sunlight., f. conidial germination of *Beauveria bassiana* with peanut oil at 180 min. exposure time to on leaves to sunlight.

and was statistically at par with each other. Tinopal (T11) recorded the second highest germination next to Peanut oil (T5) at 60 and 90 minutes exposure time without having any significant difference. When the exposure time was increased to 120, 150 and 180 minutes, Peanut oil (T5) at all concentrations gave the best performance which was followed by Shellsol (T9). There was no significant difference between germination percentage of Peanut oil (T5) 62.39, 61.64, 60.45 and 62.24 and Shellsol (T9) 60.03, 59.70, 58.99 and 60.47 per cent at different concentrations. Peanut oil (T5) exhibited significantly superior among all other formulations at 150 and 180 minutes. The lowest conidial germination was recorded in Cutinol (T10) when there was no exposure (0 minute) the germination percentage was 42.09 at 9.5 per cent concentration under 0 minute exposure which drastically reduced to 13.45 at 5.0 per cent concentration and 180 minutes exposure. Ten UV protectants *viz.*, adjuvant oils, vegetable oils, Congo red and stilbene brightener, Tinopal LPW were tested for its efficacy on the germination of *B. bassiana* under different exposure time. Among those, Tinopal (T11), Congo red (T12), Peanut oil (T5), Shellsol (T9) and Codacide (T3) showed better results, which were further tested in the field environment.

Efficacy of different UV protectants under field conditions

Number of scars on banana leaves per unit area of leaf surface

Over two seasons, banana leaf scarring by *Nodostoma* beetles increased from 7.51 to 14.65 lesions/5 cm² in untreated controls across five applications(Table7). Tinopal (T7) at 9.5% combined with *B. bassiana* (1×10w conidia / mL to 1X107 conidia / mL) plus Tween 80 consistently demonstrated superior efficacy, achieving the lowest scarring after first (3.37–4.09

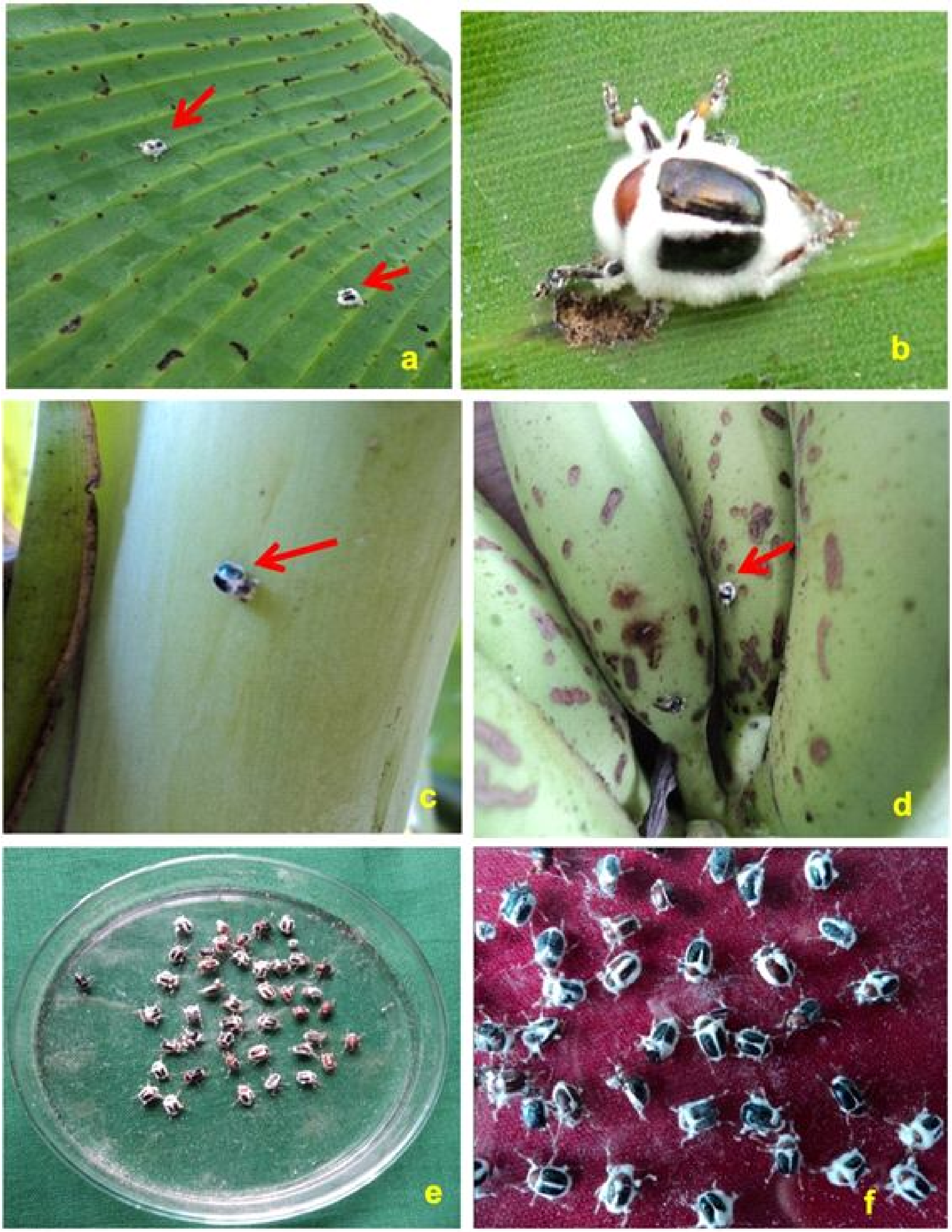

Fig 2 : (a-f). Post application infection of *Beauveria bassiana* on banana fruit and leaf scaring beetle in field condition, a. infected beetle on banana leaves (marked with arrow), b. growth of *Beauveria bassiana* on infected beetle, c. infected beetle on banana central whorl of leaf, d. infected beetles on banana hands (marked with arrow), e & f. *Beauveria bassiana* infected cadavars of beetle collected during field experimentation.

Fig 3: (a-d). Banana bunches sprayed with different treatment combination a. T1: spraying of conidial suspension of *B. bassiana* + 0.05% Tween-80, b. spraying of conidial suspension of *B. bassiana*+ Congo Red (9.5% w/v) +APSA-80 (0.03%), c. spraying of conidial suspension of *B. bassiana*+ Tinopal (9.5% w/v) +APSA-80 (0.03%), d. spraying of conidial suspension of *B. bassiana*+ Peanut oil (9.5%) +APSA-80 (0.03%).

lesions), second (8.30–8.47 lesions), third (9.88–11.12 lesions), and fifth applications (8.46–9.04 lesions), statistically at par with Congo red (T3) throughout. Most significantly, following the fifth application, Tinopal reduced scarring by 39.8% compared to controls, confirming that optical brighteners significantly enhance entomopathogenic fungal efficacy against foliar-feeding Coleoptera.

Number of leaf and fruit scarring beetle per plant

Congo red (T3) and Tinopal (T7) demonstrated superior efficacy in reducing *Nodostoma* scarring beetle populations across five consecutive applications during two seasons, with Congo red recording the lowest beetle counts after the 1st, 2nd and 5th applications (Table 8), while Tinopal excelled after the 3rd and 4th applications both treatments statistically at par with the chemical standard Carbaryl (T2). Beetle populations increased progressively until the third application, followed by a gradual decline in all treatments from the fourth application onward. After the fifth application, Congo red, Tinopal and Carbaryl showed statistically equivalent beetle counts (11.17–11.83/plant in Season I; 12.25–12.83/plant in Season II), confirming the biological efficacy of optical brighteners as UV protectants for entomopathogenic fungi. Regarding mycosis incidence, Congo red and Tinopal induced maximum *Beauveria bassiana* infection in beetles throughout the cropping period. Post-fifth application, Congo red recorded the highest number of infected beetles (11.00–12.33/plant), followed closely by Tinopal (10.00–11.67/plant). Codacide (T5) consistently yielded the minimum infection across all applications (2.33–7.67/plant). Critically, control plots where conidial suspension was sprayed without UV protectants showed zero infection until the second application, and complete absence of mycosis thereafter, definitively confirming that UV protectants are essential for fungal efficacy under field conditions. Two-season averages conclusively established Congo red and Tinopal (Fig. 2)as the best-performing treatments for maximizing beetle infection and population suppression. These findings demonstrate that optical brighteners functioning as UV protectants significantly enhance *B. bassiana* efficacy against scarring beetles, achieving superior pest suppression through prolonged conidial viability and increased mycosis incidence compared to vegetable oils and other adjuvants.

Effect of different treatments on banana fruit infestation

During the season I the per cent fruit infestation was minimum in treatment with Tinopal (T7) 18.21 per cent infestation followed by Congo red (T3) 22.33 per cent and peanut oil 29.25 (Fig.3). Treatment with Carbaryl (T2), Shellsol (T4) and Codacide (T5) 31.65, 35.93 and 36.14 per cent, respectively were found to be statistically at par with each other. All the treatment proved to be statistically superior over control (T1) 66.42 per cent (Table 10).The lowest per cent fruit infestation during the season II was recorded in Congo red (T3) 21.15 per cent which was statistically at par with Tinopal (T7) 23.58 per cent. The remaining treatments Peanut oil (T6), Carbaryl (T2), Codacide (T5) and Shellsol (T4) were found equally effective in minimizing the fruit infestation recording 35.15, 37.70, 39.37 and 40.78 per cent, respectively as compared to control (T1) 63.53 per cent. The average of two seasons exhibited Congo red (T3) with the minimum fruit infestation 21.74 per cent followed by Tinopal (T7) 20.89 per cent without having any significant difference.

Effect of different treatments on yield of banana

Among different treatments, during the season I, Tinopal (T7) gave highest yield (49.80 kg/plant) which was at par with Congo red (T3) 49.63 kg/plant. The remaining treatments Peanut oil (T6), Carbaryl (T2), Shellsol (T4) and Codacide (T5) 44.23, 43.30, 43.20 and 42.37 kg/plant, respectively were found to be statistically at par with each other (Table 11).Similarly, during the second year Tinopal (T7) recorded the highest yield followed by Congo red (T3) 48.40 and 47.53, respectively with no significant difference.In the average of seasons control (T1) gave the lowest banana yield 31.42 kg/plant. While treatment with Tinopal (T7) and Congo red (T3) recorded the highest yield of 49.1 and 48.58 kg/plant respectively and was statistically at par with each other.

The incorporation of UV protectants at a concentration of 9.5% significantly enhanced the ultraviolet tolerance of *Beauveria bassiana* conidia formulated in emulsifiable oils, Congo red, and Tinopal LPW (stilbene brightener). This formulation sustained conidial viability for up to 180 minutes of UV exposure on both banana leaves and glass slides, outperforming conventional aqueous suspensions containing

Table 1: Effect of concentration of UV protectants and exposure time on conidial germination of *B. bassiana* on leaves

Concentration of UV protectants	Exposure time (min)						
	0 min	30 min	60 min	90 min	120 min	150 min	180 min
2.5 %	68.71[b]	61.68[b]	55.64[b]	50.33[b]	45.75[c]	40.93[b]	34.90[b]
5.0 %	69.62[a]	62.87[a]	56.49[a]	51.10[a]	46.71[b]	41.41[b]	35.35[ab]
7.5 %	69.89[a]	63.34[a]	56.89[a]	51.50[a]	47.33[a]	42.33[a]	35.30[ab]
9.5 %	70.02[a]	63.26[a]	56.85[a]	51.54[a]	47.46[a]	42.40[a]	36.08[a]
S.Ed(±)	0.38	0.34	0.25	0.29	0.25	0.36	0.47
C.D. (P=0.05)	0.75	0.68	0.49	0.57	0.50	0.71	0.93

Table 2: Effect of different UV protectants and exposure time on conidial germination of *B. bassiana* on leaves

UV protectants	Conidial germination (%) at different exposure time (min)						
	0 min	30 min	60 min	90 min	120 min	150 min	180 min
T1 : Conidial suspension of *B.bassiana* (Control 1)	75.53[b]	43.99[g]	26.56[j]	0.00[h]	0.00[h]	0.00[h]	0.00[h]
T2 : Conidial suspension of *B.bassiana* + 0.05% Tween 80 (Control 2)	65.89[g]	56.90[f]	53.33[h]	49.74[f]	45.99[f]	36.60[f]	28.47[f]
T3 : T1+ Codacide	73.97[c]	70.98[b]	64.68[c]	61.59[b]	57.90[bc]	51.45[c]	46.69[c]
T4 : T1 + Ashlade	71.60[d]	68.04[cd]	59.73[e]	57.75[d]	51.16[d]	45.44[d]	33.73[e]
T5 : T1 + Peanut oil	75.73[b]	72.09[ab]	68.39[a]	64.21[a]	59.09[a]	55.84[a]	50.07[ab]
T6 : T1 + Natur'l oil	72.27[d]	67.64[d]	61.94[d]	58.78[c]	51.73[d]	46.37[d]	33.76[e]
T7 : T1 + Sunflower oil	67.81[f]	60.90[e]	56.89[f]	53.23[e]	49.00[e]	45.15[d]	37.85[d]
T8 : T1 + Mineral oil	68.59[f]	61.32[e]	55.72[g]	53.68[e]	48.57[e]	43.40[e]	33.40[e]
T9 : T1 + Shellsol	70.26[e]	69.12[c]	64.09[c]	61.40[b]	58.70[ab]	52.40[bc]	50.34[a]
T10 : T1 + Cutinol	39.48[h]	37.49[h]	33.24[i]	28.75[g]	23.82[g]	18.60[g]	13.28[g]
T11 : T1 + Tinopal	77.74[a]	72.70[a]	66.62[b]	62.30[b]	58.82[ab]	53.56[b]	48.75[ab]
T12 : T1 + Congo Red	75.86[b]	72.29[a]	66.44[b]	61.96[b]	56.96[c]	52.35[bc]	48.56[b]
S.Ed(±)	0.66	0.59	0.43	0.44	0.50	0.62	0.81
C.D. (P=0.05)	1.30	1.17	0.85	0.86	0.99	1.24	1.61

*C.S : Conidial suspension

0.05% Tween 80. Across all exposure intervals (0, 30, 60, 90, 120, 150, and 180 minutes), the 9.5% concentration of UV protectants consistently supported the highest germination rates relative to lower concentrations (2.5, 5.0, and 7.5%).
These observations align with those of Roberto et al. (1998), who reported that the addition of various oils (Peanut oil, Shellsol, Ondina, Emoleo®, Codacide®, Natur'l oil®, Ashlade®) at a 10% concentration conferred UV tolerance to *Metarhizium anisopliae* for up to six hours, exceeding the protection offered by conventional water–Tween 80 formulations.Kaiser *et al.* (2019) have reported that it is possible to increase the persistence of *B. bassiana* spores under exposure to UV radiation by formulation with natural UV-protective additives. UV protectants might, therefore, increase the efficacy of entomopathogenic fungi as biocontrol agents in open field applications Additionally, Inglis *etal.* (1995) demonstrated that Congo red, clay, and stilbene brighteners offered partial protection against artificial UV-B radiation.Tinopal was found to be a suitable adjuvant for *B. bassiana*-based biopesticide formulations by Reddy *et al.* (2008). It conferred tolerance to sunlight and caused stress in the insect, leading to a synergistic effect with *B. bassiana.*

Notably, conidial germination across all treatments was higher on glass slides than on banana leaves. This differential survival may be attributed to the physical and chemical properties of the carrier. It has been observed earlier that oil-formulated conidia of *M. flavoviride* were less susceptible to UV radiation (below 305 nm) compared to aqueous suspensions, presumably due to UV absorption by the oil matrix. Inglis *et al.*

Table 3: Interaction effect of concentration and UV protectants under different exposure time on germination of *B. bassiana* on leaves

UV protectants	Exposure time (0 min) Concentration (%)				Exposure time (30 min) Concentration (%)				Exposure time (60 min) Concentration (%)				Exposure time (90 min) Concentration (%)				Exposure time (120 min) Concentration (%)				Exposure time (150 min) Concentration (%)				Exposure time (180 min) Concentration (%)			
	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	**7.5**	**9.5**
T1	75.53	75.53	75.53	75.53	43.99	43.99	43.99	43.99	26.56	26.56	26.56	26.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	65.89	65.89	65.89	65.89	56.90	56.90	56.90	56.90	53.33	53.33	53.33	53.33	49.74	49.74	49.74	49.74	45.99	45.99	45.99	45.99	36.60	36.60	36.60	36.60	28.47	28.47	28.47	28.47
T3	71.87	73.69	74.76	75.59	69.44	70.75	71.69	72.03	63.48	64.87	65.08	65.31	60.78	61.57	61.89	61.59	57.32	58.79	59.71	58.44	49.87	51.58	52.09	52.27	46.35	46.62	46.80	47.01
T4	70.15	71.86	72.10	72.29	66.99	68.19	68.43	68.53	58.76	59.51	60.22	60.44	56.53	57.70	58.15	58.63	49.68	51.06	51.70	52.21	44.80	45.24	45.84	45.89	33.22	33.56	33.85	34.31
T5	74.71	75.91	76.58	76.66	70.14	72.34	72.92	73.52	67.47	68.44	68.98	68.70	62.49	63.94	64.98	65.44	58.78	59.08	59.74	60.20	53.99	56.04	56.46	56.88	50.90	51.56	50.33	52.44
T6	70.98	72.81	73.04	72.27	66.58	67.92	68.31	67.74	60.96	62.16	62.52	62.11	56.95	59.03	59.66	59.47	49.99	51.57	52.77	52.59	44.62	46.88	47.13	46.87	32.42	33.40	34.52	34.71
T7	66.71	67.96	68.15	68.41	58.45	60.96	61.82	62.39	55.38	56.76	57.57	57.85	50.94	53.33	54.05	54.60	47.52	48.71	49.69	50.10	43.59	44.56	45.93	46.51	36.06	37.73	38.31	39.32
T8	68.27	68.44	68.58	69.09	60.28	61.82	61.79	61.38	54.62	55.86	56.07	56.33	52.17	53.88	54.09	54.57	47.05	48.49	49.23	49.53	42.00	43.38	43.98	44.23	32.22	33.01	33.55	34.84
T9	70.86	69.73	70.14	70.30	69.81	68.98	69.45	68.23	65.23	63.60	64.01	63.51	61.65	60.98	61.51	60.86	56.97	58.60	58.99	59.82	52.94	51.69	52.30	52.15	50.40	49.86	49.19	50.25
T10	38.92	39.40	39.65	39.95	37.02	37.71	38.14	37.11	32.15	33.29	34.16	33.38	28.93	28.33	29.06	28.70	22.37	23.74	24.69	24.49	17.12	18.52	19.56	19.21	12.35	13.25	13.97	13.54
T11	76.30	78.92	77.81	77.92	70.87	73.12	73.78	74.25	64.40	67.01	67.28	67.80	61.47	62.46	62.44	61.51	56.96	57.90	58.33	58.40	52.11	49.13	54.06	54.11	47.93	48.58	45.90	49.30
T12	74.42	75.33	76.46	76.29	69.64	71.81	72.90	73.05	65.35	66.55	66.99	66.86	62.27	62.21	62.49	62.82	56.34	56.57	57.14	57.79	53.48	53.34	53.96	54.02	48.53	48.19	48.68	48.83
S.Ed (±)	1.31				1.18				0.85				0.87				1.00				1.25				1.62			
C.D. (P=0.05)	2.61				2.35				1.69				1.73				1.99				2.47				3.22			

(** T1 : Conidial suspension of *B. bassiana*(Control 1), T2 : T1+ 0.05% Tween 80 (Control 2), T3 : T1 + Codacide, T4 : T1 + Ashlade, T5 : T1+ Peanut oil, T6 : T1 + Natur'l oil, T7 : T1 + Sunflower oil, T8 : T1+ Mineral oil, T9 : T1 + Shellsol, T10 : T1 + Cutinol, T11 : T1 + Tinopal, T12 : T1 + Congo Red)

Table 4: Effect of concentration of UV protectants and exposure time on conidial germination of *B. bassiana* on glass slides

Concentration of UV protectants	Exposure time (min)						
	0 min	30 min	60 min	90 min	120 min	150 min	180 min
2.5 %	72.92[a]	66.98[a]	59.39[a]	52.24[a]	47.57[b]	43.36[a]	37.46[c]
5.0 %	73.07[a]	67.04[a]	59.35[a]	52.15[a]	47.83[ab]	43.45[a]	37.61[bc]
7.5 %	73.22[a]	67.06[a]	60.07[a]	52.66[a]	48.46[a]	43.79[a]	38.06[ab]
9.5 %	73.27[a]	66.97[a]	59.76[a]	52.66[a]	48.56[a]	43.79[a]	38.38[a]
S.Ed(±)	0.36	0.39	0.43	0.42	0.42	0.32	0.27
C.D. (P=0.05)	0.73	0.77	0.86	0.83	0.84	0.63	0.55

(1995) corroborated these findings, reporting enhanced conidial survival on leaves when applied in oil; however, persistence was diminished relative to glass surfaces, possibly due to oil absorption into leaf mesophyll tissues. Hedimbi *et al.* (2008) similarly reported that oil-based formulations (without additional sunscreens) improved post-UV viability across exposure durations compared to aqueous suspensions. The higher metabolic activity and moisture content of aqueous-suspended conidia may render them more vulnerable to UV-induced DNA damage (Moore *et al.*, 1996). Bateman *et al.* (1993) further demonstrated that at relative humidity as low as 35%, oil formulations of *M. flavoviride* achieved 76% greater infectivity against the desert locust (*Schistocerca gregaria*) compared to water, citing slower evaporation

Table 5: Effect of different UV protectants and exposure time on conidial germination of *B. bassiana* on glass slides

UV protectants	Exposure time (min)						
	0 min	30 min	60 min	90 min	120 min	150 min	180 min
T1 : Conidial suspension of *B. bassiana* (Control 1)	80.98^{ab}	53.49^{g}	37.53^{h}	0.00^{f}	0.00^{h}	0.00^{h}	0.00^{j}
T2 : Conidial suspension of *B. bassiana* + 0.05% Tween 80 (Control 2)	77.37^{c}	73.03^{d}	67.54^{bc}	58.99^{c}	52.28^{e}	49.08^{c}	38.42^{f}
T3 : T1+ Codacide	77.31^{c}	74.71^{c}	66.20^{cd}	63.24^{b}	59.08^{ab}	52.73^{b}	48.80^{d}
T4 : T1 + Ashlade	72.58^{e}	69.74^{e}	61.25^{f}	58.19^{c}	51.76^{e}	46.77^{d}	38.22^{f}
T5 : T1 + Peanut oil	78.17^{c}	76.35^{b}	69.62^{a}	64.88^{a}	60.46^{a}	57.30^{a}	53.27^{a}
T6 : T1 + Natur'l oil	74.54^{d}	70.16^{e}	63.72^{e}	59.02^{c}	55.39^{d}	47.05^{d}	36.61^{g}
T7 : T1 + Sunflower oil	70.09^{f}	61.12^{f}	58.38^{g}	54.00^{d}	49.26^{f}	45.46^{e}	39.52^{e}
T8 : T1 + Mineral oil	70.64^{f}	61.67^{f}	57.20^{g}	53.60^{d}	48.97^{f}	44.21^{f}	35.15^{h}
T9 : T1 + Shellsol	72.17^{e}	70.76^{e}	64.80^{de}	62.65^{b}	60.16^{a}	53.82^{b}	50.75^{b}
T10 : T1 + Cutinol	41.66^{g}	39.64^{h}	34.16^{i}	29.40^{e}	24.67^{g}	19.47^{g}	14.23^{i}
T11 : T1 + Tinopal	81.85^{a}	77.85^{a}	68.39^{ab}	63.03^{b}	58.27^{bc}	53.84^{b}	49.93^{bc}
T12 : T1 + Congo Red	80.07^{b}	75.64^{bc}	66.88^{bc}	62.10^{b}	56.95^{c}	53.43^{b}	49.62^{cd}
S.Ed(±)	0.63	0.67	0.75	0.73	0.73	0.55	0.48
C.D. (P=0.05)	1.26	1.34	1.49	1.44	1.45	1.09	0.95

*C.S : Conidial suspension

Table 6 : Interaction effect of concentration and UV protectants under different exposure time on germination of *B. bassiana* on glass slides

UV protect-tants	Exposure time (0 min) Concentration (%)				Exposure time (30 min) Concentration (%)				Exposure time (60 min) Concentration (%)				Exposure time (90 min) Concentration (%)				Exposure time (120 min) Concentration (%)				Exposure time (150 min) Concentration (%)				Exposure time (180 min) Concentration (%)			
	2.5	5.0	7.5	2.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5	2.5	5.0	7.5	9.5
T1	80.98	80.98	80.98	80.98	53.49	53.49	53.49	53.49	37.53	37.53	37.53	37.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	77.37	77.37	77.37	77.37	73.03	73.03	73.03	73.03	67.54	67.54	67.54	67.54	58.99	58.99	58.99	58.99	52.28	52.28	52.28	52.28	49.08	49.08	49.08	49.08	38.42	38.42	38.42	38.42
T3	75.38	77.54	78.33	78.00	74.35	75.47	74.97	74.06	65.20	65.97	66.95	66.70	62.89	63.01	63.31	63.48	56.99	59.04	60.08	60.20	51.69	52.98	53.42	52.85	47.43	48.87	49.73	49.18
T4	72.78	72.89	72.10	72.56	68.58	70.28	69.98	70.13	61.06	61.35	61.13	61.46	57.58	58.23	58.46	58.51	51.07	51.57	52.08	52.33	46.87	46.41	46.81	47.00	37.57	38.18	38.46	38.66
T5	78.87	78.39	77.64	77.81	76.58	75.45	76.51	76.86	69.90	69.14	69.56	69.89	64.50	64.74	64.98	65.30	62.39	61.64	60.45	62.24	57.85	56.86	57.15	57.34	53.48	52.82	53.27	53.53
T6	73.43	75.39	74.94	74.40	70.19	71.13	70.18	69.14	63.56	63.75	64.00	63.60	58.43	59.22	59.38	59.04	52.55	52.44	61.77	54.82	46.48	47.10	47.47	47.15	35.18	36.10	36.40	38.76
T7	69.26	70.51	70.36	70.23	60.92	61.51	61.11	60.94	56.87	57.08	61.87	57.70	53.30	54.25	53.98	54.50	48.83	49.08	49.37	49.79	44.81	45.27	45.76	46.00	39.16	39.34	39.58	40.01
T8	72.11	71.22	69.97	69.27	61.90	62.25	61.52	61.01	56.32	57.13	57.58	57.79	54.02	50.55	55.22	54.63	48.09	48.89	49.16	49.76	43.91	44.18	44.24	44.50	34.79	34.79	35.28	35.75
T9	70.88	71.70	72.80	73.31	70.22	70.60	71.03	71.19	65.11	64.55	64.75	64.80	62.18	62.31	62.51	62.67	60.03	59.70	58.97	60.47	53.88	53.84	54.20	54.44	50.84	50.35	50.81	51.02
T10	41.64	40.94	41.88	42.19	39.42	39.07	40.13	39.93	34.46	33.32	34.73	34.13	29.42	28.92	29.70	29.57	24.19	23.92	25.24	25.33	19.60	18.95	19.60	19.75	13.72	13.45	14.79	14.96
T11	81.96	80.60	81.95	82.90	78.86	77.27	77.47	77.79	68.54	67.77	69.40	69.83	63.12	63.05	63.57	63.57	56.91	58.08	55.58	59.14	52.88	53.66	53.80	53.95	49.28	49.73	50.25	50.45
T12	80.41	79.34	80.33	80.20	76.18	74.97	75.35	76.04	66.58	67.04	65.78	66.17	62.48	62.52	61.79	61.63	57.52	57.32	56.54	56.43	53.22	53.10	53.92	53.47	49.64	49.31	49.74	49.81
S.Ed(±)	1.27				1.35				1.50				1.45				1.47				1.10				0.95			
C.D. (P=0.05)	2.52				2.67				2.97				2.89				2.91				2.18				1.89			

(** T1 : Conidial suspension of *B. bassiana*(Control 1), T2 : T1+ 0.05% Tween 80 (Control 2), T3 : T1 + Codacide, T4 : T1 + Ashlade,T5 : T1+ Peanut oil, T6 : T1 + Natur'l oil, T7 : T1 + Sunflower oil, T8 : T1+ Mineral oil, T9 : T1 + Shellsol, T10 : T1 + Cutinol, T11 : T1 + Tinopal, T12 : T1 + Congo Red)

rates and enhanced cuticular adhesion. Additional advantages of oil-based formulations include superior suspension of lipophilic *B. bassiana* conidia and compatibility with ultra-low volume controlled droplet application (CDA), facilitating field deployment.

Across all treatments, increasing UV exposure from 0 to 180 minutes resulted in a progressive decline in conidial germination. Carrier liquids in spray formulations have been shown to confer partial UV protection (Inglis et al., 1995). Nevertheless, conidial survival on foliage remains

Table 7: Number of scars on banana leaves per unit area of leaf surface recorded in different treatments

	No.of leaf scars/5cm^{2} leaf surface														
Treatments	After 1st application			After 2nd application			After 3rd application			After 4th application			After 5th application		
	I	II	Average	I	II	Average	I	II	Average	I	II	Average	I	II	Average
T1 (Control)	5.96^{c}	9.35^{f}	7.51^{d}	13.67^{cd}	15.08^{d}	14.07^{d}	14.27	15.27^{c}	15.07^{d}	14.86^{d}	16.98^{c}	15.92^{e}	13.96^{c}	15.34^{e}	14.65^{d}
T2 (Carbaryl)	5.05^{bc}	6.32^{cd}	5.58^{b}	11.34^{c}	11.57^{abc}	11.45^{c}	12.46^{bc}	14.18^{bc}	13.28^{c}	12.38^{c}	12.40^{b}	12.39^{d}	11.67^{bc}	11.73^{cd}	11.75^{c}
T3(Congo Red)	3.99^{ab}	4.27^{ab}	4.13^{a}	8.80^{ab}	9.68^{ab}	9.24^{a}	10.59^{a}	11.35^{ab}	10.97^{a}	9.99^{ab}	9.50^{a}	9.74^{ab}	9.70^{ab}	9.26^{ab}	9.48^{ab}
T4 (Shellsol)	5.43^{bc}	8.50^{ef}	6.63^{cd}	10.91^{bc}	10.47^{abc}	10.69^{a}	11.10^{ab}	11.38^{ab}	11.24^{ab}	9.59^{a}	12.28^{b}	10.93^{bc}	9.87^{ab}	12.83^{d}	11.35^{c}
T5 (Codacide)	4.83^{abc}	7.27^{de}	5.97^{bc}	11.35^{c}	13.20^{cd}	12.27^{cd}	12.50^{bc}	14.12^{bc}	13.31^{c}	11.78^{bc}	12.32^{b}	12.05^{cd}	11.33^{abc}	12.23^{d}	11.78^{c}
T6 (Peanut oil)	5.87^{c}	5.55^{bc}	5.66^{b}	12.55^{cd}	12.02^{bcd}	12.28^{cd}	12.92^{c}	12.52^{abc}	12.72^{bc}	12.50^{c}	11.70^{b}	12.10^{cd}	11.77^{bc}	10.65^{bc}	11.16^{bc}
T7 (Tinopal)	3.37^{a}	4.09^{a}	3.66^{a}	8.30^{a}	8.47^{a}	8.38^{a}	9.88^{a}	11.12^{a}	10.55^{a}	9.14^{a}	9.43^{a}	9.29^{a}	8.46^{a}	9.04^{a}	8.75^{a}
S.Ed(±)	0.76	0.61	0.42	1.13	1.56	0.96	0.77	1.36	0.75	0.85	0.86	0.78	0.96	0.97	0.82
C.D.(P=0.05)	1.67	1.33	0.91	2.46	3.39	2.10	1.67	2.96	1.63	1.84	1.88	1.71	2.08	2.11	1.80

Table 8: Number of leaf and fruit scarring beetle recorded in different treatments

	No. of leaf and fruit scarring beetle/plant														
Treatments	After 1st application			After 2nd application			After 3rd application			After 4th application			After 5th application		
	I	II	Average	I	II	Average	I	II	Average	I	II	Average	I	II	Average
T1 (Control)	10.42^{e}	12.67^{d}	11.54^{d}	13.33^{c}	15.08^{c}	14.21^{c}	19.25^{d}	19.67^{c}	19.46^{d}	18.25^{b}	18.33^{b}	18.29^{d}	17.00^{c}	18.25^{c}	17.62^{c}
T2 (Carbaryl)	7.08^{bc}	8.83^{bc}	7.96^{bc}	8.67^{ab}	11.00^{ab}	9.83^{a}	13.42^{b}	14.33^{ab}	13.87^{ab}	11.00^{a}	13.08^{a}	12.04^{abc}	11.83^{ab}	12.83^{ab}	12.00^{a}
T3 (Congo Red)	5.33^{a}	6.17^{a}	5.75^{a}	7.33^{a}	8.75^{a}	8.04^{a}	12.33^{a}	13.50^{ab}	12.92^{a}	10.67^{a}	12.42^{a}	11.54^{ab}	11.17^{a}	12.25^{a}	11.75^{a}
T4 (Shellsol)	7.75^{cd}	7.83^{ab}	7.79^{bc}	11.25^{bc}	11.17^{ab}	11.21^{ab}	15.92^{c}	15.25^{b}	15.58^{c}	12.58^{a}	14.75^{a}	13.67^{abc}	14.92^{bc}	15.00^{b}	14.96^{b}
T5 (Codacide)	8.58^{d}	9.25^{bc}	8.92^{c}	12.08^{c}	13.25^{bc}	12.67^{bc}	15.42^{c}	15.00^{b}	15.21^{bc}	12.00^{a}	15.58^{a}	13.79^{bc}	14.67^{abc}	14.83^{ab}	14.75^{b}
T6 (Peanut oil)	7.00^{bc}	10.50^{cd}	8.75^{c}	12.67^{c}	13.75^{bc}	13.21^{bc}	13.58^{b}	15.17^{b}	14.37^{bc}	12.75^{a}	15.08^{a}	13.92^{c}	12.42^{ab}	14.00^{ab}	13.21^{ab}
T7 (Tinopal)	6.08^{ab}	8.67^{bc}	7.37^{b}	8.42^{ab}	10.83^{ab}	9.62^{a}	12.83^{ab}	12.58^{a}	12.71^{a}	10.50^{a}	12.33^{a}	11.42^{a}	11.25^{b}	12.42^{ab}	12.12^{a}
S.Ed(±)	0.54	1.03	0.59	1.34	1.73	1.14	0.49	1.06	0.61	1.30	1.68	1.07	1.65	1.22	1.06
C.D.(P=0.05)	1.18	2.24	1.28	2.91	3.76	2.49	1.06	2.30	1.34	2.84	3.67	2.32	3.59	2.65	2.32

Table 9: Number of leaf and fruit scarring beetle infected with *Beauveria bassiana* recorded in different treatments

	No. of infected beetle														
Treatments	After 1st application			After 2nd application			After 3rd application			After 4th application			After 5th application		
	I	II	Average	I	II	Average	I	II	Average	I	II	Average	I	II	Average
T1 (Control)	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	2.33^{a}	3.00^{a}	2.67^{a}	4.67^{a}	5.00^{a}	4.83^{a}	5.33^{a}	5.67^{a}	5.50^{a}
T2 (Carbaryl)	3.00^{b}	4.00^{b}	3.50^{bcd}	4.33^{bc}	4.67^{cde}	4.50^{cde}	5.67^{bc}	5.67^{bcd}	5.67^{c}	8.33^{b}	8.00^{b}	8.17^{cd}	9.33^{bcd}	9.33^{b}	9.33^{cd}
T3 (Congo Red)	3.67^{b}	4.33^{c}	4.00^{d}	5.33^{bc}	5.00^{de}	5.17^{de}	5.67^{bc}	6.67^{d}	6.17^{c}	9.33^{b}	10.33^{d}	9.83^{e}	11.00^{d}	12.33^{c}	11.67^{e}
T4 (Shellsol)	2.67^{b}	3.33^{b}	3.00^{bc}	4.00^{bc}	3.67^{bc}	3.83^{bc}	5.33^{bc}	5.33^{bcd}	5.33^{bc}	7.67^{b}	6.00^{a}	6.83^{bc}	8.33^{bc}	7.33^{ab}	7.83^{bc}
T5 (Codacide)	2.33^{ab}	2.67^{b}	2.50^{b}	3.00^{b}	3.33^{b}	3.17^{b}	3.33^{ab}	4.33^{ab}	3.83^{ab}	6.67^{ab}	5.67^{a}	6.17^{b}	7.33^{ab}	7.67^{ab}	7.50^{b}
T6 (Peanut oil)	2.67^{b}	3.00^{b}	2.83^{bc}	4.67^{bc}	4.00^{bcd}	4.33^{cd}	5.00^{bc}	4.67^{abc}	4.83^{bc}	6.67^{ab}	7.33^{b}	7.00^{bc}	8.67^{bcd}	9.33^{b}	9.00^{bc}
T7 (Tinopal)	3.33^{b}	4.00^{b}	3.67^{cd}	5.67^{c}	5.33^{e}	5.50^{e}	6.67^{c}	6.33^{cd}	6.50^{c}	9.00^{b}	9.00^{c}	9.00^{de}	10.00^{cd}	11.67^{c}	10.83^{de}
S.Ed(±)	1.20	0.61	0.46	1.20	0.59	0.52	1.20	0.88	0.81	1.29	0.46	0.68	1.19	0.97	0.79
C.D.(P=0.05)	2.62	1.33	1.01	2.62	1.30	1.14	2.62	1.92	1.76	2.81	1.01	1.48	2.58	2.11	1.72

generally poor, with solar radiation identified as the primary limiting factor in epigeal environments.. UV protectants function both as photoprotective agents and surfactants, thereby improving conidial viability under field conditions (Divi and Reddy, 2009).

In the present investigation, Tinopal LPW demonstrated superior field performance, consistent with findings by Inglis et al. (1995), who reported enhanced persistence of *B. bassiana* conidia on wheatgrass leaves when formulated with this stilbene-derived optical brightener. Tinopal LPW is water-soluble, non-toxic, and absorbs UV radiation while re-emitting visible blue wavelengths, thereby conferring photoprotection to microbial agents (Martinez *et al.*, 2004). Its stability and prolonged field persistence have been documented, and synergistic effects with *B. bassiana* have also been reported (Reddy *et al.*, 2008). Furthermore, Tinopal LPW has been shown to enhance the virulence of nucleopolyhedrovirus (NPV).

Table 10: Effect of different treatments on banana fruit infestation

Treatments	Mean Fruit infestation (%)		
	2011-12	2012-13	Average
T1 (Control)	66.42^{d}	63.53^{c}	64.97^{d}
T2 (Carbaryl)	31.65^{c}	37.70^{b}	34.67^{bc}
T3 (Congo Red)	22.33^{ab}	21.15^{a}	21.74^{a}
T4 (Shellsol)	36.14^{c}	40.78^{b}	38.46^{c}
T5 (Codacide)	35.93^{c}	39.37^{b}	37.65^{bc}
T6 (Peanut oil)	29.25^{bc}	35.15^{b}	32.19^{b}
T7 (Tinopal)	18.21^{a}	23.58^{a}	20.89^{a}
S.Ed(±)	3.28	4.67	2.56
C.D.(P=0.05)	7.15	10.17	5.58

Table 11: Effect of different treatments on yield of banana

Treatments	Yield (kg)		
	2011-12	2012-13	Average
T1 (Control)	32.50^{a}	30.33^{a}	31.42^{a}
T2 (Carbaryl)	43.20^{b}	42.70^{bc}	42.80^{b}
T3 (Congo Red)	49.63^{c}	47.53^{d}	48.58^{c}
T4 (Shellsol)	43.30^{b}	42.17^{bc}	42.73^{b}
T5 (Codacide)	42.37^{b}	40.20^{b}	41.28^{b}
T6 (Peanut oil)	44.23^{b}	43.47^{c}	43.85^{b}
T7 (Tinopal)	49.80^{c}	48.40^{d}	49.1^{c}
S.Ed(±)	2.33	1.18	1.49
C.D.(P=0.05)	5.07	2.56	3.25

In addition to Tinopal, Congo red (T3) contributed positively to conidial persistence under field conditions. This outcome diverges from the findings of Inglis et al. (1995), who observed that Congo red and the stilbene brightener BSU were ineffective in field environments despite providing protection against artificial UV-B radiation. Discrepancies may be attributable to variations in climatic conditions, host plant species, and fungal dosage.

ACKNOWLEDGEMENT

The author acknowledges the support received from the Vice Chancellor, Director of Post Graduate Studies, Assam Agricultural University, Jorhat, Assam for the facilities provided for completion of the study.

DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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