UPGRADING THE FORMULATION OF *Bacillus cereus* HSTUB 17 FOR THE MANAGEMENT OF PHOMOPSIS BLIGHT OF BRINJAL

A THESIS

BY

FAHAMIDA AKTER

Student No. 1701407

Session: 2023-2024

MASTER OF SCIENCE (MS)

IN

PLANT PATHOLOGY

DEPERTMENT OF PLANT PTHOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2024

UPGRADING THE FORMULATION OF *Bacillus cereus* HSTUB 17 FOR THE MANAGEMENT OF PHOMOPSIS BLIGHT OF BRINJAL

A THESIS

BY

FAHAMIDA AKTER

Student No. 1701407

Session: 2023-2024

SUBMITTED T0

Department of Plant pathology

Hajee Mohammad Danesh Science and Technology University, Dinajpur

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN

PLANT PATHOLOGY

DEPERTMENT OF PLANT PTHOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2024

UPGRADING THE FORMULATION OF *Bacillus cereus* HSTUB 17 FOR THE MANAGEMENT OF PHOMOPSIS BLIGHT OF BRINJAL

A THESIS

BY

FAHAMIDA AKTER

Student No. 1701407

Session: 2023-2024

Approved as to the style and content by:

_____

Professor Dr. Md. Mohidul Hasan

Supervisor

_____

Professor Dr. SK. Md. Modarak Hossain

Co-supervisor

_____

Professor Dr. Md. Mohidul Hasan

Chairman, Examination Committee

and

Chairman, Department of Plant Pathology

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2024

Dedicated

To My

Beloved

PARENTS

ACKNILOWLEDGEMENTS

All praises are due to the Almighty Allah, the great gracious, merciful, and supreme ruler of the university to complete the research work and thesis successfully for the degree of Master of Science (MS) in plant pathology.

The author express the deepest sense of gratitude, sincere appreciation and heartful indebtedness to his reverend research Supervisor, ***Professor Dr. Md. Mohidul Hasan,*** *Chairman, Department of Plant Pathology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his guidance, innovation suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.*

The author deems it a proud privilege to acknowledge her gratefulness, boundless gratitude, and best regards to her respectable Co- supervisor, ***Professor Dr. SK. Md. Mobarak Hossain,***

Department of Plant Pathology, HSTU, for his valuable advice, constructive criticism and factual comments in upgrading the research work and the documents.

The author expresses his gratefulness to his honorable teachers ***Professor Dr. A.T.M. Shafiqul Islam, Professor Dr. S. M. Emdadual Hassan, Md. Mobinul Islam and Md. Ahsan Habib,*** *lecturer of the Department for their valuable teaching, sympathetic co-operation, and inspiration throughout this study and research work. The author is deeply indebted to his respectful father, mother, sisters and brother for their moral support, encouragement, unquantifiable love with cordial understanding and financial support.*

The author remembers from the deep of her soul, for the instruction and proper consultations of her dearest senior Md. Shariful Islam and Mirza Galiba Naushin, dearest friend Sidratul Muntaha Otithi, Antarin Zulfikar Taree, Chamak sharker, Paris Uddin, Afroza Nishi, Suchona Pandey, Zakia Islam. Nusrat Nizhu, Sohel Rana.

Finally, the authorappreciate the assistance rendered all the staffs and officials of the Department of Plant Pathology, HSTU, Dinajpur for their continuous help.

The author

ABSTRACT

Phomopsis blight/fruit rot of brinjal caused by *Phomopsis vexans* responsible for huge yield loss in Bangladesh. For the sustainable and eco-friendly management of phomosis blight/fruit rot, an upgraded formulation aimed to develop using *Bacillus cereus* HSTUB 17 with pea bran and different combination of potato starch, tryptone, and yeast extract. In dual culture method, *B. cereus* HSTUB 17 showed a clear zone of inhibition (54.55 %) against *P. vexans*. In net house, pea bran with potato starch-based biofungicide followed by spraying of that formulation showed the maximum reduction of phomopsis blight incidence and severity in BARI begun 8 (75.74 % and 78.84 % respectively) and BARI begun 12 (76.733 % and 78.84 % respectively). In both varieties, the same formulated bio-fungicide also revealed the highest plant height (90.33 cm and 90.66 cm, respectively), the highest shoot weight (350 g and 376 g, respectively), the highest root length (28.33 cm and 41 cm, respectively), highest root weight (74 g and 399.67 g, respectively), highest number of leaves/plant (60 and 58.330, respectively) highest number of branch/plants (17 and 13.66, respectively), highest number of flower/plants (5.33 and 4.66, respectively), highest number fruit/plants (12 and 11, respectively), highest yield/plant (2.02 and 3.12 Kg, respectively), highest fruit weight (73 g and 304 g, respectively), highest fruit length (24 cm and 20 cm, respectively), highest fruit diameter (9.33 cm and 24 cm, respectively), highest amount of chlorophyll-a content (715.3 mg m^{-2} and 778.7 mg m^{-2}, respectively), highest amount of chlorophyll-b content (164.47 mg m^{-2} and 141.4 mg m^{-2}, respectively), highest amount of total chlorophyll content (880 mg m^{-2} and 920.27 mg m^{-2}, respectively), higher amount of total phenol content (8.894 mg/100 g and 8.0467 mg/100 g, respectively), higher content of total soluble solid (6.433 ^{0}Brix and 6.4 ^{0}Brix, respectively), higher grade of firmness (2.81 Kg/min and 2.416 Kg/min, respectively), and maximum pH (6.546 and 6.28, respectively). The survival rate of the formulated bio-fungicide was also studied in different storage conditions for 8 months *viz.* A: Wooden shelve B: Refrigerated (4 ℃). The shelfs life study for revealed higher amount bacterial population (from 150 to 745 CFU/mL) in pea bran with potato starch-based biofungicide, in wooden shelves condition with pea bran with yeast based biofungicide (from 150 to 1260 CFU/mL). The finding of the research concluded that the possibility of using of formulated *B. cereus* HSTUB 17 with pea bran combination of potato starch for the sustainable and eco-friendly management of Phomopsis blight of brinjal.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Eggplant (*Solanam melongena*) also known as brinjal is one of the most popular and important vegetable crops worldwide and also in Bangladesh. Eggplant has originated in the Indian sub-continent and China belongs to Solanaceae family (Thompson and Kelly, 1957; Purewal, 1957; Martin and Rhodes, 1979). Asia possesses the largest eggplant production which comprises 87 % of word production and more than 90 % world production area (Chowdhary and Gaur, 2009). Eggplant is the 4th ranked as vegetable in the world having global production 60 million tons in about 1.85million hectares in 2022. (FAO 2023). The eggplant is extensively grown in Bangladesh round the year. Its position in terms of production is 1st in winter and summer vegetable crops in Bangladesh. (BBS, 2023). Due to its taste and year-round availability, it is one of the widely consumed vegetables in the world.

The production of brinjal was 681196.58 metric tons in Bangladesh which is much low than the Global production (575730732.3) (FAO 2023; BBS, 2022-2023). The reduced yield of brinjal is influenced by a number of factors, including soil nutrients, ambient conditions, insect pests, diseases and edaphic environments. Among the factors, diseases like Phomopsis blight caused by *Phomopsis vexans* is considered as the main disease (Meah *et al.* 1998). It results in yield loss of around 80-90% (Quamruzzaman *et al.* 2019). *Phomopsis vexans* attacks stems, causing wilting; it also creating soft rots into the fruit (Meah *et al.* 2003).

Sulphur containing fungicide would be the last resort for managing the disease. Without considering how their use may affect others, farmers heavily utilize chemicals to manage the diseases. Chemical use has detrimental effects on the ecosystem, soil, water, and human health (Ahmed *et al.* 2022). Biodiversity is

destroyed when fungicides are used excessively. Therefore, as part of Integrated Disease Management (IDM), it is imperative to search for alternate, environmentally friendly approaches. Using resistant cultivars, grafting seedlings onto wild rootstock, crop rotation, soil fumigation, and biological controls are some of these methods. Both organic farming and IDM are productive agricultural practices that depend on biological control as a tool for farmers. For the successful management of plant diseases, biological control agents, such as various beneficial fungi and bacteria, have been seen as a consumer-friendly, environmentally acceptable, instrument substitute for chemicals (O'Brien, 2017; Shahzad *et al.* 2018). Because of their antimicrobial efficacy against *P. vexans*, a variety of beneficial microbes, such as *R. solanacearum, Pseudomonas putida, P. fluorescence, Trichoderma spp., Metarhizium anisopiae, Paecilomyces lilacinus, Gliocladium spp., Bacteriophages Steptomyces spp., Acinetobacter spp., Enterobactor spp., Bacillus spp., and Paenibacillus macerans*, etc. have been used as bio-control agents (Kamla and Indria 2014). Bacteria (bio-control agents) *Bacillus cereus* HSTUB 17, have successfully manage of bacterial wilts of brinjal caused by *Rastonia solanacearum* for the first time in Bangladesh (Qulsam *et al.* 2023). Pea bran based *Entrobacter ludwiggi* HSTUB 16 and *Serratia macescens* HSTUB 8 have successfully manage *Phomopsis vexans* in both *in vitro* and *in vivo* condition (Surovi 2022). Pea barn based *Serratia marcescens* HSTUB 8 have successfully manage *Phomopsis vexans* both *in vitro* and *in vivo* condition (Dewan 2023).

Bacillus species are engaged in the biocontrol of plant diseases and the stimulation of plant development, making them suitable for use in the majority of agricultural and biotechnological applications. *Bacillus* excrete extracellular compounds like siderophores, cell hydrolases, and antibiotics, demonstrating antagonistic action. By inducing induced systemic resistance, *Bacillus* species

enhance plant defense against pathogen invasion (ISR). *Bacillus cereus* is nitrogen fixing bacteria. By fixing nitrogen, soluble phosphate, and producing phytohormones, *Bacillus* species stimulate plant growth. Strains of *Bacillus spp.* that are antagonistic and promote plant growth may be helpful in creating novel preparations (Miljakovic *et al.* 2020).

The bio-control agents made of *Bacillus cereus* formed on pea bran have shown to be a major substitute for plant nourishment and protection against brinjal blight caused by Phomopsis. Pea bran base *Bacillus cereus* HSTUB 17 showed best performance in manage anthracnose disease of chili with high amount of bacterial colony both *in vivo* and *in vitro* (Shimu 2023). The inconsistent performance of the formulated biofungicides is the major limitation for their commercialization or sustainability. Hence, it is urgent to upgrade the current formulation to overcome the limitations. Therefore, the present investigation deals with the upgrading of the previously developed pea-bran based formulation for its better delivery system and sustainably.

The specific objective of the present investigation are as follows:

1. To upgrade pea bran- based formulation of *B. cereus* HSTUB 17
2. To evaluate the upgraded formulated *B. cereus* HSTUB 17 for the management of phomopsis blight in pot conditions
3. To determine the efficacy of the upgrade formulation in plant growth promotion of brinjal.

CHAPTER II

REVIEW OF LITERATRE

The disease Phomopsis blight, which affects brinjal and many other solanaceous agricultural plants, is brought on by the pathogen *P. vexans*. The use of formulated beneficial bacteria, such as *Bacillus cereus* under pot conditions, was attempted to manage the infections. The following list of pertinent literatures is reviewed:

2.1 Causes of phomopsis blight

Mahadevakumar S and Janardhana GR (2016) concluded that six agro-ecological zones in Karnataka, India, were evaluated for the severity of fruit rot and leaf blight diseases. The frequency of *P. vexans* isolation from each location was also determined. On potato dextrose agar medium, *P. vexans* isolates were cultivated and subsequently identified through morphological and cultural traits.

Bhat *et al.* (2019) found that the diversity of thirty *Phomopsis vexans* isolates was gathered and examined. It was discovered that the cultural behavior of the isolates ranged from fluffy to embedded with regular to irregular boundaries. Colonies ranged in color from pinkish white to greyish, black to brown. On PDA, sporulating pycnidia were produced in 10–20 days by 50 % of the isolates. Based on the disease response displayed by various brinjal lines, it was discovered that SK-BL-01 was the least sensitive to *P. vexans* isolates, while Pusa Purple Long (PPL) was the most vulnerable.

Udayashankar *et al.* (2019) proved that brinjals are severely affected by *Phomopsis vexans*, which causes fruit rot and leaf blight. It can be challenging to find *P. vexans* in brinjal plant parts and seeds, especially if the inoculum is low in the plant or covered up by other seed-borne pathogens or saprophytic fungi that proliferate quickly.

Manda *et al*. (2020) concluded that one of the most significant biotic factors limiting brinjal output is phomopsis blight. Because it renders brinjal fruit unmarketable and inedible, it is considered a significant disease that limits the benefits of brinjal for nutrition, health, and money creation. This illness causes a 40–70% reduction in production. *Phomopsis vexans* attacks stems, causing wilting, and pierces fruit, causing soft rot. At any point in the plant's development, this pathogen can infect every part of the plant.

Xie *et al.* (2022) concluded that it has been documented all around the world that *Phomopsis vexans* is the cause of Phomopsis blight against eggplant. In Hunan, Hubei, Jiangxi, Sichuan, Zhejiang, Fujian, Guangdong, and Anhui Provinces, 162 phomopsis blight infected brinjal leaf and fruit samples were collected between 2017 and 2019 in order to investigate the biocontrol of this disease. Findings indicated that the best medium for quick sporulation was brinjal tissue medium, and mycoviruses with mostly mixed infections were present in all isolates.

Heng *et al*. (2023) proved that the primary factor restricting eggplant production is Phomopsis blight, which is caused by the phytopathogenic fungus *Phomopsis vexans*. Phylogenetic study and homology searching revealed that *P. vexans* differs in synteny from *Diaporthe ampelina* and *Diaporthe helianthi*, but is closest to the latter in terms of evolution. Overall, they think this genome will be a valuable resource for research on *P. vexans* pathogenesis.

2.2 Biological control of *Phomopsis vexans*

Joy *et al.* (2004) found that the impact of cashew leaf, fruit, and shell extracts on the growth of a few polypathogenic fungi that infect crops in Kerala (*Phytophthora palmiovora, Alternaria solani, Fusarium solani, Rhizoctonia bataticola, Sclerotium rolfsii, Pellicularia filamentosa, Macrophomina phaseolina,*

and Phomopsis vexans) was evaluated in a preliminary-investigations. All fungus were inhibited in growth by cashew shell extract, which makes it a potential botanical antifungal treatment for sustainable and environmentally friendly diseases.

Islam M & Meah M. (2012) found that compared to seed infection and seed germination observed in farmer's seed, the least amount of *P. vexans* and greatest germination (86.75 %) were found in seed that appeared to be in good health. Seeds treated with hot water (56 °C for 15 minutes), garlic (*Allium cepa L) bulb extract, allamanda (Allamanda cathertica L*) leaf extract, *Trichoderma harzianum CP, Trichoderma harzianum T22, and bavistin*. It found that damping off and tip-over were achieved by combining seemingly healthy seed (T2), treating the soil with *T. harzianum CP (T11)*, and treating it with garlic bulb extract (T3).

Hossain *et al.* (2013) found that in order to combat *Phomopsis vexans*, which causes Phomopsis blight and fruit rot of eggplant, four fungicides Bavistin 50 WP (Carbendazim), Tilt 250 EC (Propiconazole), Cupravit 50 WP (Copperoxychloride), and Dithane M-45 (Mancozeb) as well as micronutrients Gypsum, ZnO, and Boric acid as well as four micronutrients Gypsum, ZnO, and Boric acid were evaluated against *Phomopsis vexans*, which cause Phomopsis blight and fruit rot of eggplant. The fungicides, whether applied alone or in combination.

Reddy PYN, Janker SS and Dahiya OS. (2018) found that the *Phombopsis vexans*, infection reduce by plant extracts such as neem oil, cake, leaf extracts, plant-derived substances like nimbidine, or bio-fungicides like *Trichoderma* species.

Bhanushree *et al*. (2023) found that using resistance sources and cutting-edge breeding techniques, high-yielding resistant cultivars can be developed in the most sustainable way. The utilization of wild species demonstrated their promise

as prospective root stocks for grafting techniques. In order to give current knowledge on the disease and its management techniques through breeding, including source identification of resistance, resistance inheritance, and use of modern breeding tools for use in breeding programmes, this review was put together.

Kumar *et al.* (2023) concluded that investigated plant extracts and biocontrol agents as viable management techniques for Phomopsis blight in eggplants. Neem leaf extract's potential for integrated disease management is further highlighted by its antibacterial activities against the pathogen.

2.3 Beneficial bacteria to control phomopsis blight

Chakravarty G and Kalita MC. (2011) found that *P. fluorescens* has demonstrated potential and scope as a plant growth promoting rhizobacteria (PGPR) when it is employed in conjunction with an appropriate substrate carrier and adhesive to effectively manage the bacterial wilt of brinjal under local conditions.

Sivakumar G, Rangeshwaran R, and Sriram S. (2011) found that out of 100 isolates of *Bacillus spp*. that were tested against *Ralstonia solanacearum*, the culprit behind bacterial wilt in brinjal, ten were shown to be inhibitory. *B. megaterium* successfully controlled the bacterial wilt by utilizing a range of application methods. Combining four techniques seed treatment, soil application, seedling root plunge, and foliar spray proved to be the most effective method.

Rohini *et al.* (2016) found that in order to manage Phomopsis leaf blight on brinjal (*Solanum melongena L.*), beneficial rhizosphere colonizing bacteria (RCB) and phylloplane colonizing bacteria (PCB) were evaluated separately and in combination. This finding showed that the best way to manage the illness and

promote plant development is to apply biocontrol agents in combination rather than singly.

Tumpa *et al*. (2017) found that the effectiveness of *Bacillus subtilis*, an exotic strain, was assessed by using the dual culture method to limit growth and reduce seed-borne fungus in seeds treated with the bioagent. The results of this study indicate that *B. subtilis* may be utilized as a seed treatment agent instead of chemical fungicides to control vegetable diseases that are spread by seeds.

de Almeida *et al*. (2018) found that peptides play a major role in the action of *Bacillus* and *Burkholderia* species, which were the most effective isolates in eliminating fungal infections *in vitro*. Still, most of the tested microorganisms had antimicrobial compounds—peptides, bacteriocins, or secondary metabolites—found in the culture supernatant.

Hazarika *et al*. (2019) found that a variety of fungal infections, including those from the *Saccharicola, Cochliobolus, Alternaria*, and *Fusarium genera*, were shown to be inhibited by the *Bacillus subtilis* SCB-1 isolate. The potent antifungal compound surfactin and the volatiles produced by the bacterial isolate may be responsible for its capacity to biocontrol fungal infections.

Surovi (2022) found that pea bran based *Serratia marcescens* HSTUB 8 and *Enterobacter ludwiggi* HSTUB 16 successfully manage Phomopsis blight in pot condition. Here, the bacterial treatment plant showed higher plant height, branch, fruit number, root number, fruit weight.

Dewan (2023) found that pea bran based *Serratia marcescens* HSTUB 8 biofungicide showed the lowest Phomopsis blight severity (%) with higher plant height and branch number, fruit number, shoot weight, root weight, and biochemical data with higher shelf life.

Sumoni (2023) found that pea bran-based *Enterobacter cloacae* HSTUB 12 successfully manage antracnose disease of chilli. Here, plant that was treated by

bacteria show higher agronomic character and biochemical character with higher shelf life.

2.4 Control of *Phomopsis vexans* by beneficial fungi

Harman *et al.* (2004) found that numerous *Trichoderma strains* have the ability to colonize the roots of dicot and monocot plants, causing inducible suppression of root rot (ISR), which is a powerful defence against a variety of diseases. *Trichoderma spp*. Are regarded as opportunistic plant symbionts since they may live freely in soil.

Vos *et al.* (2015) found that a promising group of organisms with the potential to manage *B. cinerea* is the genus *Trichoderma*. When *Trichoderma* and the pathogen are physically separated, biocontrol has also been seen, suggesting an indirect systemic plant defensive response.

Zheng *et al.* (2017) found that the endophytic fungal diversity of healthy *Panax notoginseng* and assessed its possible antibacterial efficacy against five main phytopathogens that cause *P. notoginseng* root rot. The findings indicated that *P. notoginseng* contains a variety of endophytic fungi, which could serve as a foundation for the discovery of novel bioactive substances and the efficient biocontrol of notoginseng root rot.

Silva *et al.* (2019) found that a few species of *Trichoderma* are thought to be possible agents in the management of fungal plant diseases. They have the ability to directly interact with roots, promoting plant growth, disease resistance, and abiotic stress tolerance. Moreover, *Trichoderma* employs mycoparasitism and antibiosis to directly destroy fungal plant diseases.

Guzmán-Guzmán *et al*. (2023) concluded that *Trichoderma* fungi are among the most widely utilized and researched microorganisms as biocontrol agents (BCAs) because of their diverse range of biocontrol attributes, including

antibiosis, parasitism, the production of secondary metabolites (SM), and activation of the plant defense system. Numerous *Trichoderma species* are commonly recognized as mycoparasites. But some of those species are also capable of attacking other living things, like nematodes and plant pests, which makes this fungus an extremely adaptable BCA. Whether alone or in combination with other plant-beneficial microbes like plant growth-promoting bacteria (PGPB), *Trichoderma* has been employed in agriculture as part of creative bioformulations.

2.5 Biocontrol activity of *Bacillus cereus*

Huang *et al.* (2004) found that Taiwan lily plant samples were used to isolate the chitinolytic bacterium *Bacillus cereus 28-9*. Based on detached leaf assay and dual culture assay results, this bacterium showed potential for biocontrol of Botrytis leaf blight of lilies. According to an in vitro experiment, *Botrytis elliptica*, a common fungal pathogen that causes lily leaf blight, demonstrated inhibition of conidial germination when the pure ChiCW was added.

Romeiro *et al*. (2010) found that *Bacillus cereus* isolate UFV-101 was chosen to encourage the development of growth-inducing resistance in plants. It was discovered that the microorganism cultures in liquid media produced a supernatant that might cause tomato foliage to become resistant to the pathogen *Pseudomonas syringae pv. Alternaria solani*, *Corynespora cassiicola*, tomato, and *Xanthomonas vesicatoria*.

Xu *et al.* (2014) found that *Bacillus cereus strain 0–9*, an endophytic bacterium isolated from the root systems of healthy wheat cultivars, has biocontrol capabilities. One important regulator of the metabolism of carbohydrates in bacteria is the phosphotransferase system. One of the system's protein constituents is enzyme I. Through homologous recombination, the *B. cereus* enzyme I-coding gene ptsI was specifically disrupted and complemented. When ptsI was disrupted

in *B. cereus,* biofilm production was reduced by 70 %, biocontrol efficiency was decreased by 30.4 %, and colonization was reduced by 1000 times.

Meng *et al.* (2019) found that full genome sequencing, *Bacillus cereus* AR156 is a rod-shaped, gram-positive bacterium that can be employed as a biocontrol agent to manage *M. incognita.* A gene linked to biocontrol in AR156 was found. In contrast to the wild-type AR156, BC41 exhibited decreased protease synthesis, rhizosphere colonization, biofilm formation, and swarming motility. Its insertion site is the peptidase of the M60 family, which reduced the capacity to biocontrol *M. incognita*. Based on the examination of biocontrol-related functional data, M60 family peptidase is critical to *B. cereus* AR156's biocontrol activity.

Zhou *et al* (2021) found that the *Bacillus cereus YN917* strain was isolated from a rice leaf and showed remarkable antifungal activity against *Magnaporthe oryzae*. The *YN917* was utilized as an inoculant, the rice plants' growth condition was assessed based on several factors, including rice plumule, radicle lengths, plant height, stem width, root lengths, fresh weights, dry weights, and root activity. Under detached leaf and greenhouse settings, *YN917* considerably decreased the severity of rice blasts.

Jasca *et al.* (2021) found that an investigation on the antifungal potential of four possible probiotics against marine oomycetes, specifically *L. thermophilum* IPMB 1401, was carried out. *Lactobacillus plantarum GS12* and *Bacillus cereus GS15* postbiotics were found to have positive antifungal activity against *L. thermophilum* IPMB 1401 in the screening test. According to this, *B. cereus GS15* has a great deal of potential as a substitute technique of controlling fungal diseases in the crab culture sector.

Khadiri *et al*. (2023) found that *in vitro* dual cultures of *Bacillus cereus (B8W8*) and fungal pathogens demonstrated the antifungal activity of *B8W8* at high rates of inhibition of the mycelial growth of *Monilinia laxa* and *Penicillium*

digitatum. The *in vivo* bioassays showed that *B8W8* significantly reduced the severity of the causative agents' diseases or prevented them altogether, especially green mould of fruits and brown rot of apples produced by *M. laxa*.

Qulsum *et al.* (2023) found that *Bacillus cereus* HSTUB 17 showed maximum zone of inhibition against *R. solanacearum* in dual culture method. Here the combined application of *B. cereus*, *T. harzianum* and akanda leaf extracts exhibited maximum reduction of wilt disease.

Shimu (2023) found that *Bacillus cereus* HSTUB 17 showed maximum zone of inhibition against *Colletotrichum capsica* in dual culture method. Here, the pea bran based biofungicide showed the lowest anthracnose of chilli disease severity (%).

CHAPTER III

MATERIALS AND METHODS

The study was aimed for the eco-friendly management of phomopsis blight caused by *Phomopsis vexans* through the upgraded formulated *Bacillus cereus* HSTUB 17. The detailed methology used to carry the experiments are as follows:

3.1 Collection of phomopsis blight infected fruit of brinjal

Infected brinjal fruits were collected in November 2023 from the agriculture research field, HSTU, Dinajpur-5200.Infected specimens were brought to the lab and inspected under a microscope to isolate and identify the pathogen in advance.

Figure 1: Infected brinjal fruit showing phomopsis blight symptom.

3.1.1 Isolation of *Phomopsis vexans*

The infected tissues were taken and cut into small bits with help of sterilized blade. Bits of diseased tissues were surface sterilized with 70 percent ethanol solution for 3 minutes followed by three times washing with sterilized distilled water in sterilized perti plates. The surface sterilized tissue was then placed directly on the surface of potato dextrose agar (PDA) in Petri plates under aseptic conditions and incubated at 27±1 ℃ temperature. Typical fungal growth

development around the bits. Microscopic observations of fungal culture revealed septate hyphae. The pure culture was received by hyphal tip method.

3.1.2 Culture media preparation

Potato dextrose agar (PDA) (Dhingra & Sinclair, 1995) medium was used for pure cultures of fungi used in experiments. The ingredient of semi-synthetic media used was as follows. Potatoes (Peeled and Sliced):200 g, Dextrose (Anhydrous):20 g, Agar-agar: 20 g, Distilled water: 1000 mL.

3.1.3 Morphological identification of *Phomopsis vexans*

Through microscopic examination of pure culture using cultural and physical traits, the pathogens were tentatively identified. Under a compound microscope, the morphological traits of the fungal structures were examined. At magnifications of 10X and 40X, microscopic observations of pycnidia and conidia were made. By comparing the cultures to prior literature, the cultures were further validated and identified. Additionally, a microphotograph was captured. Sub – culturing was used to sustain cultures on PDA slants, and they were kept at 4 ℃ for future research.

3.1.4 Molecular identification of *Phomopsis vexans*

The fungal isolates were grown on PDA medium for 8–10 days. Fungal mycelia were harvested (500 mg), freeze dried and ground to a fine powder with liquid nitrogen in a mortar and pestle. Genomic DNA was extracted following the protocol of Zhang *et al.* (1998) and used for PCR. The internal transcribed spacer (ITS) region of ribosomal DNA containing 18S-ITS1-5.8SITS2-28S were amplified by using ITS1 (5’-CGGATCTCTTGGTTCTGGCA-3’) and ITS4 (5’-GACGCTCGAACAGGCATGCC-3’) primer pair (White *et al.* 1990). The PCR

amplification was carried out in 25 µl reaction mixture containing 1 µl of DNA sample with 2.5 µl of 10 × PCR buffer, 2.5 µl of 2.5 mM MgCl2, 2.0 µl of 2 mM dNTPs, 1.0 µl of each forward and reverse primer (20pM) and 0.2 µl of Taq DNA Polymerase (Sigma Aldrich, USA) and made up to 25 µl with nuclease free water (14.8 µl). The amplification was performed using the cycling program of initial denaturation at 95º C for 3 min; followed by 35 cycles of denaturation at 94º C for 30 s; annealing at 55º C for 30s, and extension at 72º C for 1 min; and a final extension for 10 min at 72º C. The PCR was performed using Advanced Thermus25 Thermo cycler (Peqlab, Germany). The amplified PCR product was run on 1.5% agarose gel along with 1 kb DNA marker. Amplified PCR products were sequencing using Sanger Sequencing by Apical Scientific-Malaysia. The sequence results were subjected to deposit in GenBank of the National Centre for Biotechnology Information (NCBI) to get an accession number.

3.1.5 Maintenance the culture of *P. vexans*

The *P. vexans* fungus was put onto agar slants containing potato dextrose agar. After cultivating the *P. vexans* culture, the slants were refrigerated at -20 ℃. The pathogen was moved to new slants after every 2-3 months to maintain the culture.

3.2 Collection of *Bacillus cereus* HSTUB 17

On the basis of molecular analysis, *B. cereus* HSTUB 17 have already been isolated, identified previously and used in this work.

3.3 *In vitro* efficacy of the collected *B. cereus* HSTUB 17 against *P. vexans*

By adopting a dual culture approach, the antibacterial effectiveness of *B. cereus* HSTUB 17 was evaluated against *P. vexans* (Lemessa and Zeller 2006). In

brief, isolated bacteria was collected from pure culture using a sterilized toothpick and inoculated in nutrient broth (5 mL) and incubated overnight at 28 ℃ in a shaking incubator for 24 h. Ten (10) µL overnight-cultured bacteria were inoculated in NA petri plates and incubated for 24 h at 28 ℃. Next day, the petri plates were filled with 5 mL of chloroform after colony formation, and the lids were then fastened for 10 min. To make sure that no chloroform was present in the petri plates after that, the lid was kept open in the laminar flow for 15 min. Later, the colony of beneficial bacteria had been treated with chloroform followed by pouring one mL of *P. vexans* suspension to the entire petri plate. The dual cultured were kept in an incubator for 24 h at 28 ℃. A measuring scale was used to quantify the formation of a clear zone or zone of inhibition surrounding the beneficial colony. Growth inhibition (%) was calculated using the following formula:

I=(C-T) *100/C

Where, I= % inhibition in mycelia growth; C=growth of pathogen in control plates; T=growth of pathogen in dual culture plates.

3.4 Preparation of upgrade biofungicides using *B. cereus* HSTUB 17

For 48 h, *B. cereus* HSTUB 17 was cultured in nutrient broth media. For the development of formulated *B. cereus* HSTUB 17, pea bran with potato starch, tryptone, yeast extract was selected as an additional substrate. The collected pea bran was dried and blended followed by added adhesive (white flour gram) in a 10:1 ratio.

A table for upgraded formulation

100 g pea bran with 0.4 g potato starch powder
100 g pea bran with 0.5 g tryptone
100 g pea bran with 0.3 g yeast extract
100 g pea bran with 50% (0.2 g) potato starch powder and 50 % (0.15 g) yeast extract
100 g pea bran with 50% (0.2 g) potato starch powder and 50 % (0.25 g) tryptone
100 g pea bran with of potato starch 50 % (0.2 g) and yeast extract 25 % (0.075 g) and tryptone 25 % (0.125 g)

While keeping the pH at 7.4, autoclaved under pressure of roughly 15 pounds per square inch to reach a chamber temperature of 121 ℃ for 15 min. Following autoclaving, the mixture was spread on aluminum foil and shed dried. Mannitol (8.5 mL of 3 %) was added to the 100g mixture in 10:1 ratio, dried at room temperature for three days in a sterile atmosphere. The created bacterial upgraded formulation was stored in a sterile atmosphere. The created bacterial formulation was stored in an airtight bag to be used later in a 4 ℃ refrigerator.

3.5 Shelf-lives of formulated biofungicide

The viable cell of upgrade formulated products were counted by the method of serial dilatation at 15 days interval up to the last viable cell found. In this method, serial dilatation was done on nutrient agar (NA) media. The media were sterilized for 10 min 120 ℃. Serial dilution was done by dissolving a 1g prepared sample in 9 mL of sterile water. The same process is then carried out, adding 1 mL from test tube to 9 mL of test 2, 1 mL from test tube 2 to 9 mL of test tube 3, and so on, until the required concentration is obtained. Using the pour plate approach, 1 mL of the diluted solution was poured on nutrient agar (NA) plates, and plates were then incubated at 28 ℃ for 24 h.

$$\text{Viable cell count (CFU/g formulation)} = \frac{\text{Number of colonies}}{\text{Volume of inoculum}} \times \text{Dilution factor}$$

3.6 Management of Phomopsis blight of brinjal by application of upgrade formulated biofungicide.

The experiment was carried out during November 2023 to May 2024 on the net house under the Department of Plant Pathology, HSTU, Dinajpur.

3.6.1 Location

Geographically the experimental field was located at 25.6980198 N latitude and 88.65336 E longitude, with a height of 38 m above the sea level belonging to Agro-ecological Zone-I (AEZ-I) named old Himalayan piedmont plain.

3.6.2. Soil preparation

At first sandy loam soil, sand and well decomposed cow-dung were collected and mixed properly at ratio of 2:2:1. Sandy loam soil, sand soil and well decomposed cow-dung were collected from the field of HSTU. Then the mixed soil was sterilized with formaldehyde at the rate of 4 % per cubic feet soil. The treated soil was covered by brown paper for 72 h without disturbance. After 72 h, the brown paper was removed and the sterilized soil was exposed to air drying for 48 h in order to remove excess vapor of formaldehyde. Total 48 plastic pot were washed with water and sterilized with formaldehyde. After the sterilization each pot was felled with 10 Kg dried soil.

3.6.3 Collection of seeds and raising of seedling

The seeds were collected from Bangladesh Agricultural Development Corporation (BADC), Dinajpur, two varieties of brinjal seeds (BARI Begun 8 and BARI Begun 12) were procured. Manure and sterilized soil were used for the bed preparation. Then the seed was treated with *B. cereus* suspension where seed were soaked for 3 h and another one was controlled condition.

Figure 2: Controlled seedbed BARI begun 8

Figure 3: Treated seedbed BARI begun 8

Figure 4: Controlled seedbed BARI begun 12

Figure 5: Treated seedbed BARI begun 12

3.6.4 Application of fertilizer

According to the fertilizer recommendation guide, fertilizer dosage was utilized for the production of brinjal (BARI Fertilizer dose-2018). All fertilizer

were used during the land preparation of soil, with the exception of urea and MOP. Urea and MOP were administered three times during land preparation process, 20-28 DAT, and mid-harvest (Table 1).

Table 1. Recommended fertilizer dose (Fertilizer recommendation guide, BARI).

Fertilizer and Manure	Kg/ha
Cow dung	10000
Urea	300
Tsp	200
Mop	200
Gypsum	100
Zinc	12
Boron	10

3.6.5 Application of formulated biofunngicide

Upgrade formulated biofungicide of with pea bran with various substrate were applied for the management of Phomopsis blight of brinjal in net house conditions. The experiment comprised with eight treatments with three replications are as follows:

T_0: Control (only *P. vexans*)

T_1: Pea bran with of potato starch based biofungicide followed by spraying that formulation suspension.

T_2: Pea bran with tryptone based biofungicide followed by spraying that formulation suspension.

T_3: Pea bran with yeast extract based biofungicide followed by spraying that formulation suspension.

T_4: Pea bran with potato starch and yeast extract based biofungicide followed by spraying that formulation suspension.

T_5: Pea bran with potato starch and tryptone based biofungicide followed by spraying that formulation suspension.

T_6: Pea bran with potato starch and tryptone and yeast extract based biofungicide followed by that formulation suspension.

T_7: Mancozeb.

3.6.6 Experimental design and layout

The experiment was laid out in Completely Randomize Design (CRD) with three replications. The pot size was (25×25) $cm^{2.}$ There were 48 pots altogether in the experiment. Pot to pot distance was 10 cm.

3.6.7 Application of formulated biofungicide

After preparation of pot soil, formulated biofungicide @ 5 g/pot were applied before three days of transplantation and maintain proper moisture. After 15 days of transplantation formulated biofungicide was applied in pot soil.

3.6.8 Transplantation of seedlings

35 days old seedlings were transplanted in the pot on 10 January, 2024. After transplantation, seedlings were watered regularly to make a firm relation with roots and soil to strand alone.

3.6.9 Application of formulated biofungicide suspensions

Ten (10 g) of formulated biofungicide was taken into 1 L sterile water for making suspension. Then the mixture was shaken properly and filtered it. Then the suspension was ready for spraying. 5 mL suspension was sprayed on the plant at 15 days interval up to 90 (DAT). Mancozeb was prepared @ 2 g/L and sprayed at the same day of the application of formulated *B. cereus* HSTUB 17 suspensions.

3.6.10 Inoculation of *P. vexans*

Spore suspension of *Phomopsis* containing 5×10^6 spore was sprayed 30 (DAT). After inoculation, the plants were covered with polytene bags for 24 h to ensure favorable microclimate for the successful infection by the pathogen.

Figure 6: Plant covered with polythene bag for successful inoculation.

3.6.11 Irrigation

After the transplantation, the pot was irrigated as per necessary.

3.6.12 Application of pesticides

In avoid to insect infestation, Setara (550 EC Cypermethrin +Chloropyriphos) and Surat (20EC Fenpropathrin+ pyriproxyfen) was applied 4 times at an interval of 7 days.

3.6.13 Weeding, thinning and gap filling

There are different types of weeds which were controlled effectively by hand weeding. Thinning and gap filling was also done after 10 DAT.

3.7 Recording of data on disease

3.7.1 Counting healthy and infected plants

The experiment field was taken a look at every day to observe whether the plant became infected with *P. vexans* or not. However, the infected and healthy plant data were recorded at 40 DAT up to 120 DAT at 20 days interval. The percentage of plant infection and plan recovery were recorded.

3.7.2 Recording of disease

After 10 days of pathogen inoculation (40 DAT) percent of leaf infection, percent of leaf area infection and percent of fruit infection data were recorded. All the leaves and fruit of a plant, including healthy and disease ones, were recorded to determine the percentage of infection of leaves and fruit. (Islam and Pan 1990):

$$\text{Leaf/fruit infection } (\%) = \frac{\text{Number of affected leaves/fruit}}{\text{Total number of leaves/fruit}} \times 100$$

$$\text{Phomopsis blight severity}(\%) = \frac{\text{Total rating}}{\text{Total observation} \times \text{Maximun grade}} \times 100$$

Leaf area disease (%) was estimated through eye estimation. The whole area leaf was considered as 100 % and disease area was estimated of five leaves of one plant, discarding the younger and older ones (Islam and Pan, 1990). For estimation of leaf and fruit area disease (%), the whole leaf surface and fruit area was estimated through eye estimation. The disease index (%) severity was estimated following measuring scales (Islam and Pan 1990). The data on affected ad healthy plants were recorded in every 20 days interval starting from 40 DAT up to 120 DAT.

Table 2. Grading scale of Phomopsis blight severity (%) (Kalda *et al.* 1976)

Infection grade	Phomopsis blight severity (%) grading scale leaf and fruit
0	No infection
1	1-5
2	5-10
3	11-25
4	26-50
5	>50

3.7.3 Reduction of phomopsis blight incidence (%)

Reduction of Phomopsis blight incidence (%) was calculating using following formula:

$$\text{Reduction of phomopsis blight incidence (\%) over control} = \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \times 100$$

3.7.4 Reduction of Phomopsis blight severity (%)

$$\text{Reduction of phomopsis blight severity (\%) over control} = \frac{\text{PDS in control} - \text{PDS in treatment}}{\text{PDS in control}} \times 100$$

3.8 Recording of agronomic data

3.8.1 Plant height (cm)

The height of plant (cm) was measured at 20 DAT up to 120 DAT at 20 days interval. The height of the plant was measured from the soil to the tips of the leaves.

3.8.2 Number of leaves per plant

Leaves number counting started at 20 DAT up to 120 DAT with 20 days interval.

3.8.3 Number of branches per plant

Branch number was counted at 20 days interval 20 DAT up to 120 DAT. The number of branches emerging from the main stem above the ground.

3.8.4 Number of flowers per plant

First flowering started 55 DAT. Flower data was counted 60 DAT up to 120 DAT with 20 days interval.

3.8.5 Number of fruits per plant

First fruits were harvested at 96 DAT up to 120 DAT. Total number of fruits was counted and average number of fruits per plant was calculated. Fruits were picked on the basis of horticultural maturity, size, color and age being for determined for the purpose of composition as the fruit grew rapidly and soon get beyond the marketable stage.

3.8.6 Yield (Kg/plant)

Yield was recorded from every plant and total yield was calculated through average yield by multiplying plant population during harvest time up to 120 DAT.

3.9 Biochemical analysis

3.9.1 Estimation of total chlorophyll content of leaf (mg m^{-2})

According to Gogoi and Basumatary (2018), 1 g leaf was taken, chopped into tiny pieces, and then ground with a mortar and pestle. After that, 0.5 g of ($MgCO_3$) powder and 20 mL of 80 % acetone were added, and the mixture was carefully ground again using. After that, the mixture was incubated for three hours at 4 ℃. The combination was centrifuged for five minutes at 2500 rpm, and the supernatant was then moved to a 100 mL volumetric flask. The volume was then increased to 100 mL by adding 80 % acetone, and the solution was used to estimate the amount of chlorophyll solutions were measured on a SPECTROPHOTOMETER model-T 60 at 645 and 663 nm, using an 80 % acetone solution as a blank (Sadasivam & Manickam 1996). The chlorophyll content was calculated by taking the average of three readings from the sample. The following (Arnon 1949) formulas were used to compute the chlorophyll a, b, and a + b (total chlorophyll contents:-

$$\textbf{mg chlorophyll a/g tissue} = \frac{(12.7 \times A663 - 2.29 \times A645)V}{1000 \times W}$$

$$\textbf{mg chlorophyll b/g tissue} = \frac{(22.9 \times A645 - 4.68 \times A663) \times V}{1000 \times W}$$

$$\textbf{Total chlorophyll} = \textbf{Chlorophyll a} + \textbf{chlorophyll b}$$

Where,

A = absorbance at specific wavelength

V = final volume of chlorophyll extract in 80 % acetone

W = fresh weight of tissue extracted

3.9.2 Estimation of total phenol content of fruit (mg/100g)

According to Saikia *et al.* (2012), the total phenol was estimated. In brief, 25mL falcon tube was used, and 0.5 mL of the sample and 0.5 mL of Folin Ciocalteu's reagent were added and thoroughly mixed. One milliliter (7.5 % saturated) of sodium carbonate (Na_2CO_3) was added to the solution to neutralize it, and mixture was then allowed to react before being vortexed for 30 seconds. The mixture was centrifuged at 4000 g for 10 min. after being allowed to sit for 35 min. in a dark area at room temperature. A SPECTROPHOTOMETER model-T 60 reading the sample's absorbance at 725 nm was used to determine the absorption. Gallic acid was used to execute a standard (calibration) curve. The findings have been shown to be equal mg/100 g of Gallic acid per 100 g of juice.

$$\textbf{Total phenol content (\%)(mg/100 g)sample} = \frac{\textbf{Amount of phenol obtain}}{\textbf{Weight of sample}} \times \textbf{100}$$

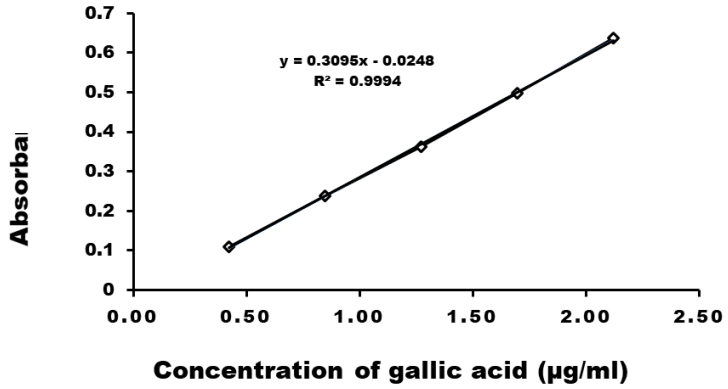

Figure 7: Standard curve of gallic acid for estimation of total Phenol

3.9.3 Estimation of total soluble solids (°Brix)

By using refract meter the amount of total soluble solid (TSS), which are given as °Brix was measured.

3.9.4 Estimation of firmness (Kg/min)

With a digital penetrometer (Kg/min) firmness was measured.

3.9.5 pH

pH was measured by a digital pH meter.

3.10 Statistical analysis

Data from several parameters were statistically analyzed to determine the degree of efficacy of various treatments for brinjal phomopsis blight management. Statistical 10 software was used to carry out the analysis of variance. Duncan's Multiple Range Test (DMRT) was used to assess the mean difference between the treatments at a 5 % probability level (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS

An effort was taken to upgrade a formulation of biofungicide using *B. cereus* HSTUB 17. The upgrade formulated biofugnicide was further used for the environment friendly management of Phomopsis blight of the brinjal in field in pot conditions. The potentiality of the upgrade formulated *B. cereus* HSTU 17 to control the devastating disease are described below:

4.1 Characteristics of *P. vexans*

The morphological characteristics of *P. vexans* showed a septate, hyaline mycelium with a diameter ranging from 2.9 to 3.6 µm. (Thesiya *et al*.2020) (Fig. 8 A& B).

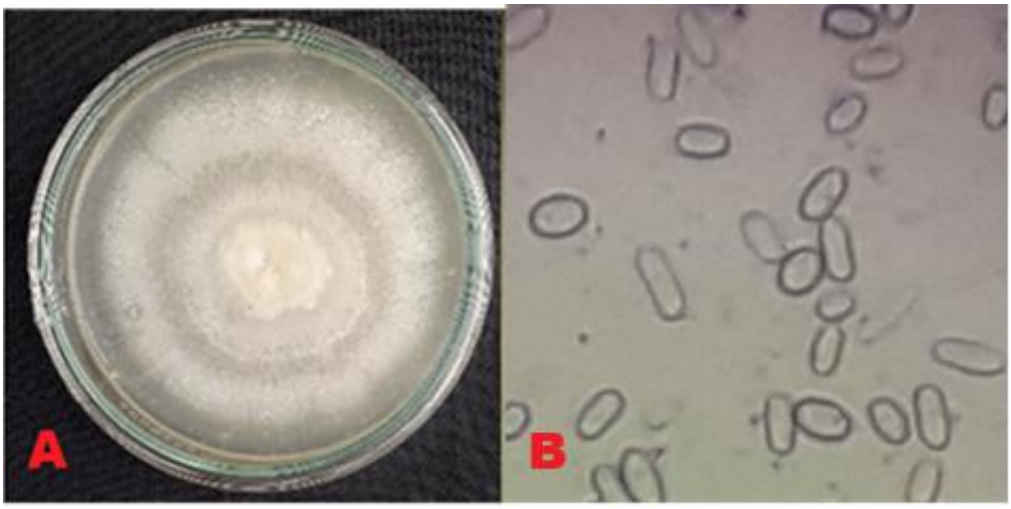

Figure 8: A Pure culture of *P. vexans* B. Microscopic view of *P. vexans*

4.2 Molecular characterization of the potential

4.2.1 Gel Electrophoresis

The isolate pathogen showed antagonistic effect was characterized using ITS gene sequencing. PCR products were sequenced and compared with ITS gene sequences deposited in the Gene Bank Database by using Neighbor joining methods. The ITS sequences of pathogen showed 92 % similarity with sequences of *Phomopsis vexans* (Fig. 9). 1465 base of in gel electrophoresis, the DNA was found as 375 bp length.

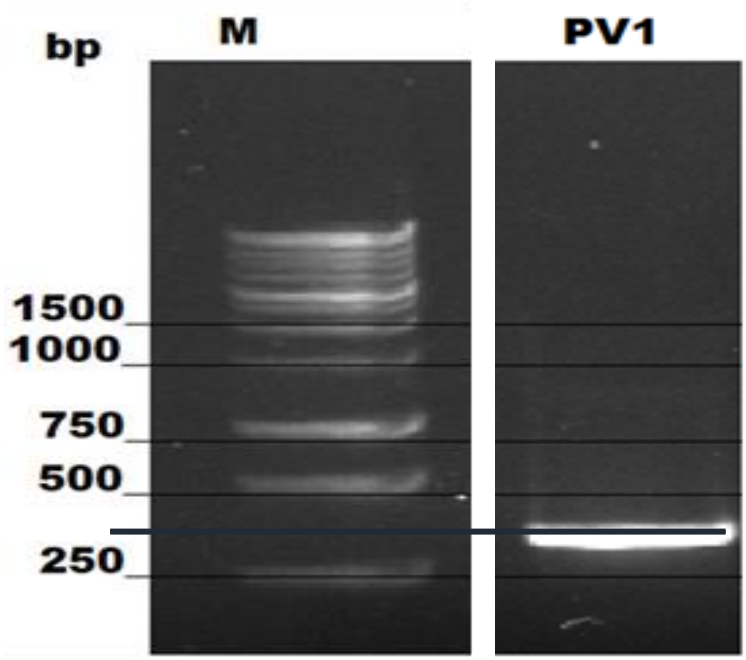

Figure 9: Gel electrophoresis of the PCR amplified DNA of *P. vexans*

4.3 Antifungal efficacy of *B. cereus* HSTUB 17 against *P. vexans*

B. cereus HSTUB 17 were showed antifungal efficacy against *P. vevans* in dual culture. However, the bacterium showed 54.55 % zone of inhibition against *P. vexans* fungus (Fig. 10)

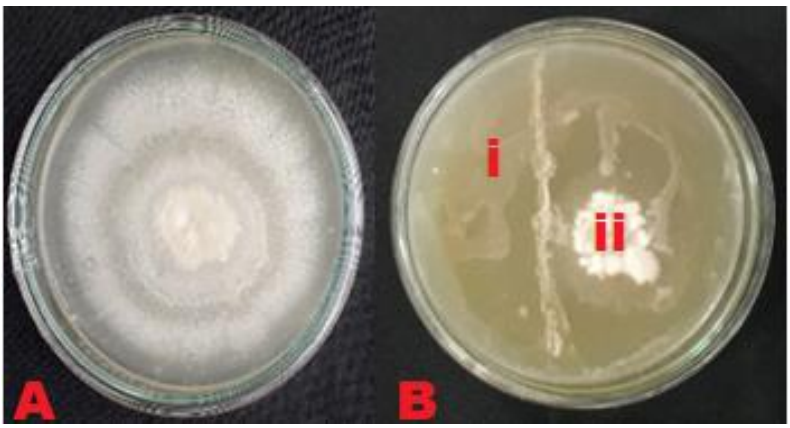

Figure 10: A Full growth *P. vexans* B. Dual culture of *P. vexans* with *B. cereus* HSTUB 17 (i Bacteria & ii pathogen).

4.4 Efficacy of formulated biofungicide to control Phomopsis blight of brinjal at pot condition

A pot experiment was conducted during mid Rabi to Kharif season (2024) on the management of Phomopsis blight of brinjal caused by *P. vexans* with upgrade *B. cereus*. HSTUB 17 formulation. The results of the experiment were presented below:

4.5 Efficacy of formulated biofungicie against Phomopsis blight incidence (%) at 120 DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied plant showed the lowest phomopsis blight incidence (16.55 %) followed by T_4 (20.33 %), T_2 (21.33 %), T_3 (22.33 %), T_6 (22.33 %), T_5 (26.33 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight incidence (66.66 %) (Table 3).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied plant showed lowest disease incidence (15.333 %) followed by T_4 (15.467 %), T_5

(16.333 %), T_3 (17.667 %), T_6 (18.667 %), T_2 (21.33 %). Plants inoculated with *P. vexans* only (control) showed the highest incidence (65.33 %) (Table 3).

Table 3. Efficacy of formulated biofungicide against Phomopsis blight incidence (%) of brinjal at 120 DAT.

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight incidence (%)	Reduction over control	Phomopsis blight incidence (%)	Reduction over control
T_0	67.67a±0.763	0.00	65.33a±0.517	00
T_1	16.33f±0.577	75.74	15.33f±0.190	76.73
T_2	21.33d±0.529	68.48	21.33b±0.928	67.35
T_3	22.33c±0.513	66.98	17.67b±0.577	72.85
T_4	20.33e±0.551	70.09	16.67d±0.642	75.53
T_5	26.33b±0.577	61.98	15.47ef±0.519	75.53
T_6	22.33c±0.950	66.98	18.67c±0.577	71.32
T_7	13.67g±0.577	79.86	12.33g±0.577	81.11
LSD($p \leq 0.05$)	1.599		1.5761	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.6 Efficacy of formulated biofungicide against Phomopsis blight incidence (%) at 80 DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied plant showed the lowest disease incidence (25.00 %) followed by T_4 (30.333 %), T_2 (31.333 %), T_3 (34.667 %), T_6 (34.833 %), T_5 (37.833 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight incidence (73.33 %) (Table 4).

In BARI begun 12, among all the upgrade biofungicide, T_1 biofungicide applied plant showed the lowest disease incidence (22.5 %) followed by T_4 (24.33

%), T_5 (25 %), T_3 (25.33 %), T_6 (26.333 %), T_2 (30.933 %). Plants inoculated with *P. vexans* only (control) showed the highest incidence (70 %) (Table 4).

Table 4. Efficacy of formulated biofungicide against Phomopsis blight incidence (%) of brinjal at 80 DAT.

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight incidence (%)	Reduction over control	Phomopsis blight incidence (%)	Reduction over control
T_0	73.33a±0.577	00	70.00a±0.57	00
T_1	25.00e±1.0	65.863	22.50f±0.168	67.83
T_2	31.33d±0.577	52.70	30.93d±0.89	56.35
T_3	34.00c±0.548	48.12	25.67cd±0.577	63.32
T_4	30.33d±0.94	58.63	24.33e±0.64	63.61
T_5	37.67b±0.61	51.75	24.33e±1.47	64.60
T_6	34.83c±0.61	51.83	26.33c±0.577	62.32
T_7	23.67f±0.587	67.72	20.33g±0.32	71.07
LSD($p \leq 0.05$)	1.78		1.93	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.7 Efficacy of formulated biofungicide against Phomopsis blight incidence (%) at 40 DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight incidence (34.823 %) followed by T_4 (39.823 %), T_2 (40.6 %), T_3 (44.987 %), T_6 (46.007 %), T_5 (48.533 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight incidence (73.33 %).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight incidence (30.733 %) followed by T_4 (33.367 %),

T_5 (35.367 %), T_3 (35.4 %), T_6 (36.8 %), T_2 (40 %). Plants inoculated with *P. vexans* only (control) the highest incidence (74.933 %).

Table 5. Efficacy of formulated biofungicide against Phomopsis blight incidence (%) of brinjal at 40 DAT.

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight incidence (%)	Reduction over control	Phomopsis blight incidence (%)	Reduction over control
T_0	77.7a±1.53	00	74.93a±0.81	00
T_1	34.85e±1	55.144	30.73f±0.57	57.52
T_2	40.82d±1	47.743	40.4b±0.68	47.95
T_3	44.99c±0.50	42.063	35.4d±1	52.95
T_4	39.82d±0.51	48.747	33.37e±0.7	55.65
T_5	48.53b±0.65	36.53	35.37d±0.49	52.82
T_6	46.07c±0.66	41.21	36.8c±0.74	50.72
T_7	33.68e±0.61	56.65	30.73g±0.55	58.61
LSD ($p \leq 0.05$)_	2.31		1.3	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.8 Efficacy of formulated biofungicde against Phomopsis blight severity (%) at 120 DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight severity (14.960 %) followed by T_4 (19.960 %), T_6 (22.7 %), T_3 (22.703 %), T_5 (23.533 %), T_2 (31.333 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight severity (Table 6).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight severity (15.333 %) followed T_5 (15.467 %), T_4

(16.333 %), T_3 (17.667 %), T_6 (18.667 %), T_2 (21.333 %). Plants inoculated with *P. vexans* only (control) showed the highest disease severity (Table 6)

Table 6. Efficacy of formulated biofungicide against Phomopsis blight severity (%) of brinjal at 120 DAT.

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight severity (%)	Reduction over control (%)	Phomopsis blight severity (%)	Reduction over control (%)
T_0	68.33a±0.57	00	65.33a±0.57	00
T_1	14.96e±0.64	78.84	15.33f±0.19	78.84
T_2	31.33b±0.57	55.65	21.33b±0.92	55.67
T_3	22.70c±0.51	61.49	17.67d±0.57	61.49
T_4	19.96d±0.94	67.12	16.33e±0.64	67.11
T_5	23.55c±0.69	64.5	15.57ef±0.51	64.5
T_6	22.7c±0.61	68.91	18.67c±0.57	68.92
T_7	12.63 f±0.51	80.95	12.33g±0.57	80.95
LSD($p \leq 0.05$)	1.46		1.288	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.9 Efficacy of formulated biofungicide against Phomopsis blight severity (%) at 80 DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight severity (25.295 %), T_4 (30.96 %), T_6 (33.370 %), T_3 (33.407 %), T_5 (34.627 %), T_2 (42.333 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight severity (70.333%) (Table 7).

In BARI begun 12, among all the upgrade formulated products, T_1 applied plant showed lowest Phomopsis blight severity (24.14 %), T_6 (30.33 %), T_5 (33.77 %), T_4 (36.33 %), T_3 (36.33 %), T_2 (38.627 %). Therefore, only inoculated with *P. vexans* (T_0) showed the highest disease severity (Table 7)

Table 7. Efficacy of formulated biofungicide against Phomopsis blight severity (%) of brinjal at 80 DAT

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight severity (%)	Reduction over control (%)	Phomopsis blight severity (%)	Reduction over control (%)
T_0	70.333a±0.577	00	67.443a±0.577	00
T_1	25.295f±1.002	64.023	24.147f±0.168	64.023
T_2	42.333b±0.577	63.49	38.627b±0.89	63.49
T_3	33.407d±0.548	46.5	36.333c±0.577	46.6
T_4	30.96e±0.940	51.5	31.467e±0.642	51.5
T_5	34.627c±0.611	49.933	33.7d±1.47	49.933
T_6	33.370d±0.611	53.747	30.333e±0.577	53.747
T_7	23.553g±0.58	67.133	21.867g±0.32	67.133
LSD($p \leq 0.05$)	1.148		1.233	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.10 Efficacy of formulated biofungicide against Phomopsis blight severity (%) at 40 DAT

In BARI begun 8 among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight severity (32.33 %), T_4 (37.84 %), T_6 (40.62 %), T_3 (41.18 %), T_5 (42.59 %), T_2 (49.00 %). Plants inoculated with *P. vexans* only (control) showed the highest Phomopsis blight severity (73.77 %) (Table 8).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied plant showed lowest Phomopsis blight severity (31.327 %), T_6 (37.733 %), T_4 (37.733 %), T_5 (41.877 %), T_3 (42.330 %), T_2 (46.067 %). Plants inoculated with *P. vexans* only (control) showed the highest disease severity (71.033 %). (Table 8)

Table 8. Efficacy of formulated biofungicide against Phomopsis blight severity (%) of brinjal at 40 DAT

Treatments	BARI begun 8		BARI begun 12	
	Phomopsis blight severity (%)	Reduction over control (%)	Phomopsis blight severity (%)	Reduction over control (%)
T_0	73.777a±1.52	00	71.03a±0.81	00
T_1	32.330f±1	56.953	31.327e±0.57	56.53
T_2	49.0b±1	35.387	46.067b±0.68	35.387
T_3	41.18cd±0.50	40.494	42.33c±1	40.494
T_4	37.840e±0.511	46.156	37.8d±0.7	46.337
T_5	42.49c±0.65	41.057	41.877c±0.49	41.057
T_6	40.627d±0.66	46.337	37.733d±0.64	46.337
T_7	30.813g±0.61	59.53	28.737f±0.55	59.53
LSD($p \leq 0.05$)	1.89		1.47	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension.); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.10.1 Interaction effects of biofungicide and variety of brinjal against Phomopsis blight severity (%) of brinjal at 120 DAT

Interaction of treatments and variety revealed that, statistically similar and significance Phomopsis blight severity reduction (78.843 and 78.843 %) was obtained in both variety with the application of upgrade biofungicide over control (Table 9).

Table 9. Interaction effects of formulated biofungicide on Phomopsis blight severity (%) in two varieties at 120 DAT

Treatments× Variety	Disease severity (%)	
	At 120 DAT	Reduction over control (%)
T_0×V_1	68.33a±0.57	00
T_1×V_1	14.96i±0.64	78.84
T_2×V_1	31.33c±0.57	55.65
T_3×V_1	22.70f±0.51	61.49
T_4×V_1	19.96gh±0.94	67.11
T_5×V_1	23.55f±0.69	64.5
T_6×V_1	22.7f±0.61	68.91
T_7×V_1	12.63jk±0.51	80.95
T_0×V_2	65.33b±0.57	00
T_1×V_2	15.33j±0.19	78.84
T_2×V_2	21.33d±0.92	55.65
T_3×V_2	17.67e±0.57	61.49
T_4×V_2	16.33g±0.64	67.11
T_5×V_2	15.47f±0.51	64.5
T_6×V_2	18.67h±0.57	68.91
T_7×V_2	12.33k±0.57	80.95
LSD($p \leq 0.05$)	1.1741	

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11 Efficacy of formulated biofungicide on growth attribute of brinjal plant

The result of all the treatments imposed for the management of Phomopsis blight caused by *P. vexans* and their impact on growth parameters viz, plant height, number of leaves, number of branches, number of flowers, number of fruits, fruit length, fruit diameter, fruit weight, shoot weight, root length, root weight, and Yield (kg/plant) in the brinjal variety BARI begun 8 and BARI begun 12 was recorded as follows:

4.11.1 Efficacy of formulated biofungicide on plant height (cm) of BARI begun 8 at different DAT

At 20 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest plant height (10 cm) followed by T_2 (8.66 cm), T_6 (8.33 cm), T_4 (8.266 cm), T_5 (8.1 cm), T_3 (8 cm), T_0 (7.33 cm) (Table 10). At 40 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest plant height (17.833 cm), T_3 (16.5 cm), T_6 (15.667 cm), T_5 (14.5 cm), T_4 (12.967 cm), T_2 (12.167 cm). Plants inoculated with *P. vexans* only (control) showed the lowest plant height (11.8 cm) (Table 10). At 60 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest plant height (32 cm) followed by T_6 (28.533 cm), T_3 (27.667 cm), T_5 (25 cm), T_4 (24.667 cm), T_2 (23.667 cm). Plants inoculated with *P. vexans* only (control) showed the lowest plant height (18.33 cm) (Table 10). At 80 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest plant height (49.667 cm), T_2 (46.33 cm), T_6 (45 cm), T_4 (42. 667 cm), T_3 (41.33 cm), T_5 (40.33 cm). Plants inoculated with *P. vexans* only (control) showed the lowest plant height (34.3 cm) (Table 10). At 100 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest plant height (74.33 cm), T_4 (73 cm), T_5 (72.333 cm), T_3 (72 cm), T_6 (70.33 cm). Here, Plants inoculated with *P. vexans* only (control) showed the lowest plant height (52.667 cm) (Table 10). At 120 DAT in BARI begun 8, among all the upgrade biofungicide, T_1 biofungicide applied showed the highest plant height (90.33 cm), T_4 (88.667 cm), T_3 (87.33 cm), T_5 (86.33 cm), T_6 (82.33 cm), T_2 (82.0 cm). Plants inoculated with *P. vexans* only (control) showed the lowest plant height (70.667 cm) (Table 10).

Table 10. Efficacy of formulated biofungicide on plant height (cm) of BARI begun 8 at different DAT

Treatments	Plant height (cm) at different DAT					
	20DAT	**40DAT**	**60DAT**	**80DAT**	**100DAT**	**120DAT**
T_0	7.33f±0.57	11.8h±0.76	18.33h±1.5	34.3fg±1	52.67e±0.57	70.67g±0.57
T_1	10a±1	17.83a±1.44	32a±1	49.67a±1.52	74.33a±1	90.33a±0.57
T_2	8.66cd±1.15	12.17g±1.75	23.67f±1.15	46.33b±1.52	71.33bc±1.15	82e±1
T_3	8.00de±1	16.5bcd±1.41	27.67cd±1.52	41.33cd±1.54	72abc±2	87.33cd±1.52
T_4	8.26cde±0.64	12.97fg±1.5	24.67ef±1.15	42.67c±1.154	73ab±1.52	88.67bc±1.15
T_5	8.1cde±0.82	14.5defg±1.3	25ef±1.73	40.33de±1.154	72.33abc±1.52	86.33d±0.57
T_6	8.33cde±0.95	15.67cd±2.08	28.53b±0.8	45b±1	70.33c±1.52	82.33e±1.52
T_7	9b±1	12.7g±1.1	19.93g±1.1	35.3f±1.54	67.33d±1.89	75.33f±0.57
LSD($p \leq 0.05$)	1.6	2.5	2.5	2.21	2.51	1.68

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 11: Showing plant height in different treatment of BARI begun 8

4.11.2 Efficacy of formulated biofungicide on plant height (cm) of BARI begun 12 at different DAT

At 20 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest plant height (11cm) followed by T_2 (9.2 cm), T_4 (9 cm), T_3 (8.533 cm), T_6 (8.227 cm), T_5 (7.66 cm). Only T_0 showed the lowest plant height (7.00 cm) (Table 11). At 40 DAT BARI begun 12, among all the upgrade formulated products, T_1 applied showed the highest plant height (18.66cm) followed by T_4 (18.33 cm), T_5 (18.0cm), T_6 (15.4 cm), T_3 (13.667 cm), T_2 (13.167 cm). Plant inoculated with *P. vexans* only (control) showed the lowest plant height (13.067 cm) (Table 11). At 60 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest plant height (30.33 cm) followed by T_4 (28.0 cm), T_5 (26 cm), T_6 (24.0cm), T_3 (21.33 cm), T_2 (21.11 cm). Plant inoculated with *P. vexans* only (control) showed the lowest plant height (21 cm) (Table 11). At 80 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest plant height (45.33 cm) followed by T_5 (45.0 cm), T_4 (41.33 cm), T_6 (40.33 cm), T_3 (37.00 cm), T_2 (36.33 cm). Plant inoculated with *P. vexans* only (control) showed the lowest plant height (35 cm) (Table 11). At 100 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the

highest plant height (70.66 cm) followed by T_5 (70.33 cm), T_6 (67.66 cm), T_4 (58.66 cm), T_3 (58.00 cm), T_2 (56.66 cm). Plant inoculated with *P. vaxans* only control showed the lowest plant height (50 cm) (Table 11). At 120 DAT BARI begun 12, among all the upgrade biofungicide, T_1 biofungicide applied showed the highest plant height (90.667 cm) followed by T_5 (87.0 cm), T_6 (86 cm), T_3 (80 cm), T_4 (79 cm), T_2 (77 cm). Plant inoculated with *P. vexans* only (control) showed the lowest plant height (77) (Table 11).

Table 11. Efficacy of formulated biofungicide on plant height (cm) of BARI begun 12 at different DAT

Treatments	Plant height (cm) at different DAT					
	20DAT	**40DAT**	**60DAT**	**80DAT**	**100DAT**	**120DAT**
T_0	7d±1	13.07fg±2	21e±1.73	35d±2.081	50f±0.577	77d±1
T_1	11a±1	18.67a±2.08	30.33a±1.73	45.33a±1.52	70.663a±1	90.67a±1
T_2	9.2±1.31	13.17efg±1.1	21.1e±1	36.33a±0.57	56.66ef±1.52	77c±0.5
T_3	8.5bc±0.5	18.33a±1.5	21.33e±2.08	37c±1	58d±1.52	80c±1
T_4	9b±1	18.0ab±2.08	28.0b±1.52	41.33b±1.04	58.6d±1.52	79c±1
T_5	7.6c±0.57	15.4cd±1.04	26.0c±1.7	45a±2	70.33a±0.57	87b±1
T_6	8.22bc±1.14	15.4cd±1.04	24d±2	40.33b±1.52	67.66±0.57	78.66c±1.15
T_7	9.93b±0.9	13.9ef±1.04	23.33de±1.5	39b±1	62.66c±0.57	86b±1
LSD($p \leq 0.05$)	1.5	2.4	2.5	2.21	2.5	1.7

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 12: Showing plant height in different treatment of BARI begun 12

4.11.3 Relation between phomopsis blight incidence (%) and plant height (cm) 0f brinjal

In the regression equation, Phomopsis blight incidence (%) was considered as independent and plant height (cm) as dependent variable. A negative relation was existing between the Phomopsis blight incidence (%) and plant height (cm). Due to Phomopsis blight (%) maximum plant height (cm) loss occurred in BARI begun 8 (89.195 %) and BARI begun 12 (86.103 %) was observed. The regression also showed that, for the unit increase in Phomopsis blight incidence (%), a plant height reduction of BARI begun 8 (0.4149 %) and BARI begun 12 (0.3895 %) will be occurred (Fig. 13)

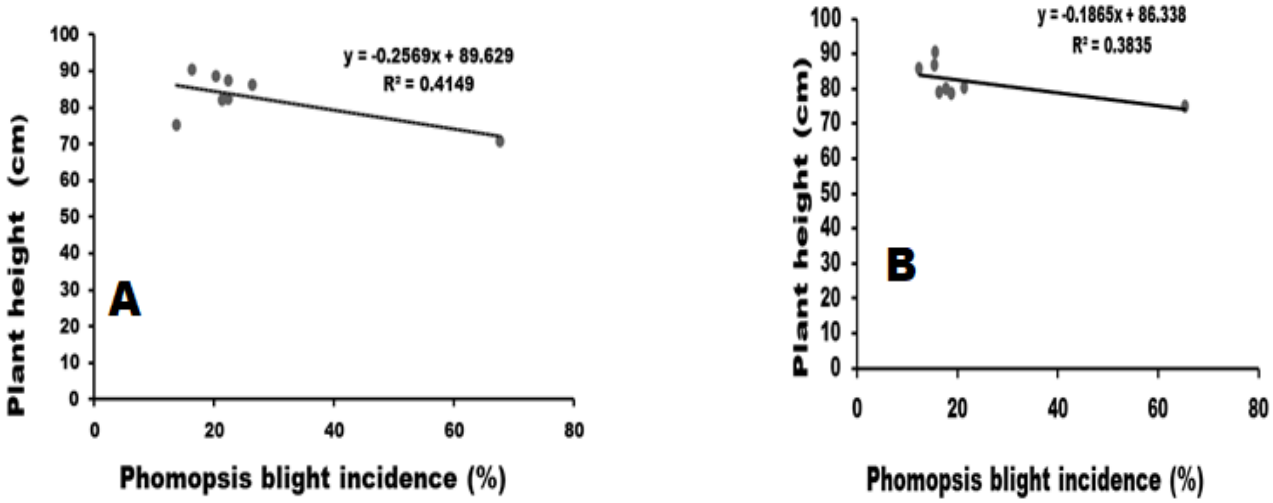

Figure 13: Relation between Phomopsis blight incidence (%) and Plant height (cm) of A. BARI begun 8 and BARI begun 12

4.11.4 Efficacy of formulated biofungicide on the leaf of BARI begun 8

At 20 DAT BARI begun 8, among all the upgrade biofungicide, T_4 applied showed the highest leaf number (7.33) followed by T_1 (7), T_2 (5.66), T_0 (5.33), T_3 (5.33), T_6 (5.33), T_5 (4.66) (Table 12). At 40 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (12) followed by T_4 (11.66), T_2 (11.33), T_6 (10), T_5 (9.66), T_3 (8.33). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (8.33) (Table 12). At 60 DAT BARI begun 8 among all the upgrade biofungicide, T_1 applied showed the highest leaf number (37) followed by T_4 (25.33), T_5 (25.33), T_3 (22.667), T_6 (22), T_2 (21). Plant inoculated with *P. vexans* (control) showed the lowest leaf number (17.667) (Table 12). At 80 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (40.33) followed by T_3 (37.33), T_6 (36), T_5 (35.667), T_4 (34.33), T_2 (33). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (31.31) (Table 12). At 80 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (40.33) followed by T_3 (37.33), T_6 (36), T_5 (35.667), T_4 (34.33), T_2 (33). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (31.31) (Table 12). At 100 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (51.33) followed by T_4 (51), T_6 (49.667), T_3 (46), T_5 (43.66), T_2 (41). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (36.33) (Table. 12). At 120 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (60) followed by T_6 (53.667), T_3 (50.667), T_5 (50.667), T_4 (49.33), T_2 (48). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (46.33) (Table 12).

Table.12 Efficacy of formulated biofungicide on plant leaf number of BARI begun 8

Treatments	Plant leaf number at different DAT					
	20DAT	40DAT	60DAT	80DAT	100DAT	120DAT
T_0	4.66c±0.57	9.33c±0.57	20.33e±1.52	31.33e±0.57	36.33e±1.52	46.33±0.57
T_1	7a±1	14a±1	31a±1.73	40.33a±1.52	51.33a±1.52	60a±1.15
T_2	5.66b±1.54	10.33bc±1.52	22e±1.52	33de±1.52	41d±1	48de±0.57
T_3	5.66b±0.57	11bc±1.72	21.33b±2.08	37.33cd±1.52	46a±1.15	50.667c±1
T_4	5.66b±0.57	9.33±1.52	24cd±2	34.33cd±1.52	51a±1.52	49.33cd±1.73
T_5	6.33b±1.52	13ab±2	25bc±1.73	35.66cd±1	43.33c±1.15	50.667c±1.52
T_6	6b±1	12abc±1.52	29.33bc±2.3	36bc±2	49.67±0.57	53.667b±1
T_7	5.3b±0.57	11.66abc±1.15	26.66b±2	37.33bc±2	42.33c±2.64	58.33a±1
LSD(≤0.05)	1.54	2.83	3.194	2.523	2.09	2.963

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.5 Efficacy of formulated bifungicide on the leaf of BARI begun 12

At 20 DAT BARI begun 12, among all the upgrade biofungicide, T_4 applied showed the highest leaf number (7.33) followed by T_1 (7), T_2 (5.66), T_3 (5.66), T_4 (5.33), T_0 (5.33), T_5 (4.66) (Table 13). At 40 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (12) followed by T_2 (11.3), T_6 (10), T_5 (9.66), T_7 (8.66), T_3 (8.33). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (8.33) (Table 13). At 60 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (37) followed by T_4 (25.33), T_5 (23.33), T_3 (22.66), T_6 (22), T_2 (21). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (17.667) (Table 13). At 80 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (38.33) followed by T_6 (34), T_5 (32), T_4 (31), T_3 (31), T_2 (31). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (30.33) (Table 13). At 100 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (56.33) followed by T_3 (52.33), T_4 (51.33), T_2 (50.66), T_6 (50.33), T_5 (45). Plant inoculated with *P. vevans* only (control) showed the lowest leaf number (41) (Table 13). At 120 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest leaf number (58.33) followed by T_3 (48.33), T_4 (51.0), T_2 (47.66), T_6 (51.667), T_5 (50.66). Plant inoculated with *P. vexans* only (control) showed the lowest leaf number (44.667) (Table 13).

Table.13 Efficacy of formulated biofungicide on plant leaf number of BARI begun 12

Treatments	Plant leaf number at different DAT					
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT
T_0	5.33c±0.57	8.33c±0.57	17.66d±1.15	30.33d±0.57	41d±1.73	44.67e±.05
T_1	7ab±1	12a±1	37a±1.5	38.33a±1	56.33a±2.01	58.33a±1.52
T_2	5.66bc0.57±	11.33ab±0.57	21c±1.7	31d±1.15	50.66b±1.52	47.67d±1
T_3	5.33c±1.15	8.33c±0.57	22.66c±1.53	31d±1	52.33b±1.52	48.33d±0.57
T_4	7.33±1.52	11.66ab±1.52	25.32b±1	31d±2.08	51.33b±2.3	51c±1
T_5	4.66d±0.57	9.66bc±1.52	25.33b±1.52	31cd±2.0	45c±1	50.66c±0.57
T_6	5.33c±1.15	10abc±1.73	22c±1	34bc±1	56.33b±1.52	51.67c±0.57
T_7	5.33c±0.57	8.77c±1.15	22.66c±2.08	35.33b±1	42.66cd±2.1	54b±0.57
LSD($p \leq 0.05$)	1.657	2.027	2.57	2.2898	3.059	1.7476

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.) ; T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.10.6 Relation between Phomopsis blight incidence (%) and number of brinjal

In the regression equation, Phomopsis blight incidence (%) was considered as independent and plant leaf number as dependent variable. A negative relation was existing between the Phomopsis blight incidence (%) and plant leaf. Due to Phomopsis blight (%) maximum plant leaf number loss occurred in BARI begun 8 (48.984 %) and BARI begun 12 (48.80 %) was observed. The regression also showed that, for the unit increase in Phomopsis blight incidence (%), a plant leaf number reduction of BARI begun 8 (0.2323 %) and BARI begun 12 (0.3038 %) will be showed fig. 14.

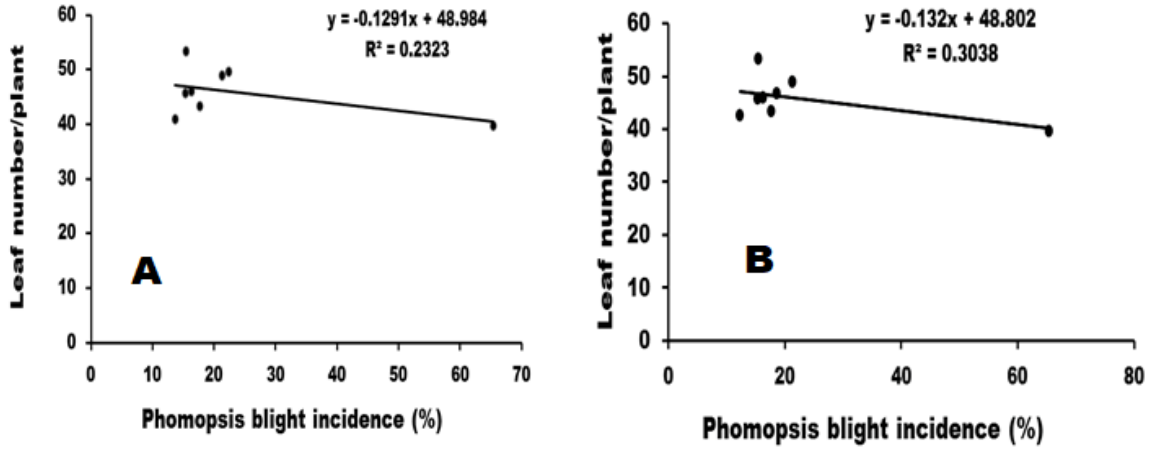

Figure 14: Relation between Phomopsis blight incidence (%) and Plant leaf number of A. BARI begun 8 and BARI begun 12

4.11.7 Efficacy of formulated biofungicide on the branch of BARI begun 8 at different DAT

At 60 DAT BARI begun 8, among all the upgrade biofugicide, T_1 applied showed the highest branch number (6) followed by T_6 (4), T_2 (3), T_5 (3), T_3 (2.33), T_4 (1.66). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (1.33) (Table 14). At 80 DAT BARI begun 8, among all the upgrade

biofungicide, T_1 applied showed the highest branch number (10.33) followed by T_6 (10), T_3 (9), T_4 (8.66), T_5 (8.66), T_2 (7). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (4.667) (Table 14). At 100 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest branch number (13.33) followed by T_3 (13.33), T_6 (11.33), T_5 (10.77), T_4 (10), T_2 (10). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (8.33) (Table 14). At 120 DAT BARI begun 8, among all the upgrade biofungicide, T_1 biofungicide applied showed the highest branch number (17.6) followed by T_3 (13.66), T_6 (13.66), T_5 (12), T_4 (11), T_2 (10.33). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (8.33) (Table 14).

Table 14. Efficacy of formulated biofungicide on plant branch number of BARI begun 8 at different DAT

Treatments	**Plant branch number at different DAT**			
	60 DAT	**80 DAT**	**100 DAT**	**120 DAT**
T_0	1.33d±1.53	4.67d±1.15	8.33d±1.52	8.33d±0.57
T_1	6a±2	10.33a±1	13.3a±0.57	17.6a±0.57
T_2	3bc±1	7bc±1.52	10bc±1.73	10.33c±1
T_3	2.33bc0.57±	9ab±1.73	13.33a±1.54	13.66b±0.57
T_4	1.66cd±1.15	8.66bc±1.73	10bc±1.73	11c±1
T_5	3bc±1.73	8.66bc±1.15	10.67abc±1.52	12bc±1.73
T_6	4b±1.73	10a±1.52	11.33ab±2.08	13.66b±1.54
T_7	1.66cd±1.52	8bc±1	11abc±2	12bc±0.57
LSD($p \leq 0.05$)	2.5478	2.3963	2.782	1.69

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.8 Efficacy of formulated biofungicide on the branch of BARI begun 12 at different DAT

At 60 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest branch number (4.66) followed by T_2 (4.66), T_4 (4.66), T_5 (3), T_3 (1.33), T_6 (1.33). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (1.11) (Table 15). At 80 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest branch number (10.33) followed by T_4 (10), T_3 (9.33), T_6 (9), T_2 (9), T_5 (6). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (5) (Table 15). At 100 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest branch number (12) followed by T_6 (10.33), T_4 (10), T_3 (9.66), T_5 (8.66), T_2 (8.66). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (8) (Table 15). At 120 DAT BARI begun 12, among all the upgrade biofungicide, T_1 upgrade biofungicide showed the highest branch number (13.6) followed by T_3 (11.66), T_4 (11.33), T_6 (11.33), T_5 (10.66), T_2 (10.33). Plant inoculated with *P. vexans* only (control) showed the lowest branch number (9) (Table 15).

Table 15. Efficacy of formulated biofungicide on the branch of BARI begun 12 at different DAT

Treatments	Plant branch number at different DAT			
	60 DAT	80 DAT	100 DAT	120 DAT
T_0	1.11d±1.154	5d±1.52	8c±1	9d±0.57
T_1	4.66a±o.57	10.33a±1	12a±1	13.66a±1.15
T_2	4.66ab±0.57	9abc±2.08	8.66bc±1	10.33c±1.54
T_3	1.66c±1.52	9.33abc±0.57	9.66bc±2	11.66b±1.52
T_4	4.66ab±1	10ab±1.52	10b±0.77	11.33b±1.52
T_5	3b±1.73	6cd±1	8.66bc±1.54	10.66c±0.57
T_6	1.33cd±1.15	9abc±0.57	10.33b±1.54	11.33b±1.15
T_7	1.33cd±1.15	7c±0.57	8.66bc±1.52	10.33c±1.15
LSD($p \leq 0.05$)	2.36	2.32	2.45	1.78

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.9 Relation between phomopsis blight incidence (%) and plant branch number of brinjal

In the regression equation, Phomopsis blight incidence (%) was considered as independent and plant leaf number as dependent variable. A negative relation was existing between the Phomopsis blight incidence (%) and plant branch number. Due to Phomopsis blight (%) maximum plant branch number loss occurred in BARI begun 8 (14.811 %) and BARI begun 12 (11.815 %) was observed. The regression also showed that, for the unit increase in Phomopsis blight incidence (%), a plant branch number reduction of BARI begun 8 (0.3392 %) and BARI begun 12 (0.118 %) will be showed fig. 15.

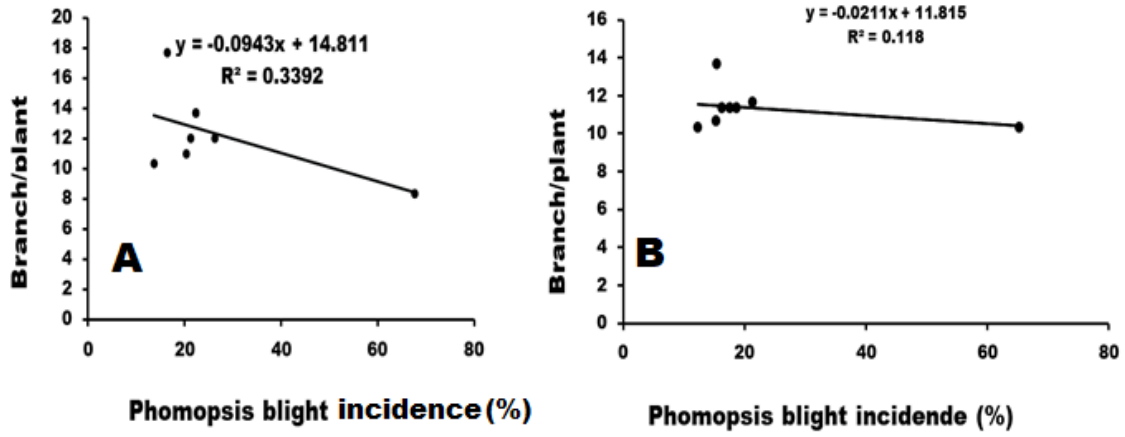

Figure 15: Relation between Phomopsis blight incidence (%) and Plant branch number of A. BARI begun 8 and BARI begun 12

4.11.10 Efficacy of formulated biofungicide on the flower number of BARI begun 8 at different DAT

At 60 DAT BARI begun 8, among all the upgrade biofungicide, T_1 the highest flower number (2.33) followed by T_5 (2), T_6 (2), T_4 (1.33), T_3 (1), T_2 (1). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (0.33) (Table 16). At 80 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest flower number (4.66) followed by T_2 (3), T_6 (1.66), T_3 (1.66), T_4 (1.33), T_5 (1.33). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (0.667) (Table 16). At 100 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest flower number (5) followed by T_3 (5), T_4 (5), T_5 (5), T_2 (4.0), T_3 (3). Plant inoculated with *P. vexans* only (control) showed the flower number (3) (Table 16). At 120 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest flower number (5.33) followed by T_6 (5.33), T_3 (4.66), T_4 (4), T_5 (3.33), T_2 (3). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (2.66) (Table 16).

Table 16. Efficacy of formulated biofungicide17 on plant flower number of BARI begun 8 at different DAT

Treatments	Plant flower number at different DAT			
	60 DAT	80 DAT	100 DAT	120 DAT
T_0	0.333±1	0.66d±0.577	3c±1.73	2.66d±0.57
T_1	2.33a±2.33	4.667a±1.73	5a±1	5.33a±0.57
T_2	1b±2	3b±1.73	4a±1.73	3cd±1
T_3	1b±1	1.66cd±0.57	5a±1	4.66ab±0.57
T_4	1.33b±1.33	1.33cd±0.57	5a±2	4bc±1
T_5	2a±0.66	1.33cd±0.57	5a±1	3.33cd±0.57
T_6	2a±2	1.66cd±0.57	3c±1	5.33a±0.57
T_7	1b±2	2c±1.154	3c±2.08	3.33cd±0.57
LSD($p \leq 0.05$)	2.06	1.836	2.62	1.22

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.11 Efficacy of formulated biofungicide on the flower number of BARI begun 12 at different DAT

At 60 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed highest flower number (3) followed by T_4 (1.66), T_2 (1.33), T_5 (1.33), T_6 (1), T_3 (0.667). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (0.33) (Table 17). At 80 DAT BARI begun 12, among all the upgrade biofungicide, T_1 biofngicide applied showed highest flower number (5.66) followed by T_4 (5), T_5 (3.33), T_2 (3), T_6 (2.33), T_3 (2). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (1) (Table 17). At 100 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest flower number (5.33) followed by T_7 (5), T_4 (4.667), T_3 (4.33), T_5 (3), T_6 (2.66). Plant inoculated with *P. vexans* only (control) showed the flower number

(2.11) (Table 17). At 120 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest flower number (4.66) followed by T_5 (4.33), T_6 (4.33), T_3 (4), T_4 (3.33), T_2 (3). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (2.33) (Table 17).

Table 17. Efficacy of formulated biofungicide on plant flower number of BARI begun 12 at different DAT

Treatments	Plant flower number at different DAT			
	60 DAT	**80 DAT**	**100 DAT**	**120 DAT**
T_0	0.33c±0.57	1d±0.570.57	2.11cd±1	2.33d±0.57
T_1	3a±0.57	5.66a±1.73	5.33a±1.52	4.66a±1
T_2	1.33b±0.57	3b±0.57	2.33cd±2.64	3cd±0.57
T_3	0.667c±0.57	2c±1.73	4.33b±0.57	4ab±1
T_4	1.667b±1.73	5a±0.57	4.66b±2.08	3.33cd±0.57
T_5	1.33b±1.52	3.33b±0.57	3bc±1	4.33cd±0.57
T_6	1b±0.57	2.33c±0.57	2.66cd1.52±	4.33ab±0.57
T_7	1.33b±0.57	2.66c±0.57	2.33cd±0.57	3cd±0.57
LSD($p \leq 0.05$)	1.6	1.65	2.57	1.71

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.12 Efficacy of formulated biofungicide on the fruit number of BARI begun 8 at different DAT

At 80 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (3.33) followed by T_3 (2.33), T_4 (1), T_6 (1), T_2 (0.66), T_5 (0.66). Plant inoculated with *P. vexans* only (control) showed the lowest fruit number (0.33) (Table 18). At 100 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (2.66) followed by T_3 (1.66), T_6 (1.66), T_4 (1.33), T_2 (1.33), T_5 (1.33). Plant inoculated with *P. vexans*

only (control) showed the lowest fruit number (0.66) (Table 18). At 120 DAT BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (3.33) followed by T_4 (1.66), T_6 (1.66), T_5 (1.33), T_3 (1.33), T_2 (1.33). Plant inoculated with *P. vexans* only (control) showed the lowest flower number (0.66) (Table 18).

Table 18. Efficacy of formulated biofungicide on plant fruit number of BARI begun 8 at different DAT

Treatments	Plant fruit number at different DAT		
	80 DAT	100 DAT	120 DAT
T_0	0.33d±0.57	1c±0.57	0.66c±0.57
T_1	3.33a±1.73	2.66a±1.15	3.36a±1
T_2	0.67cd±1.15	1.33bc±0.57	1.33bc±1.15
T_3	2.33b±0.57	1.67b±0.57	1.33bc±0.57
T_4	1c±0.57	1.33bc±1.15	1.67b±0.57
T_5	0.66cd±0.57	1.33bc±0.57	1.33bc±0.57
T_6	1c±0.67	1.67b±0.57	1.66b±0.57
T_7	1c±0.57	1.33bc±1.15	1.33bc±0.57
LSD($p \leq 0.05$)	1.17	1.17	1.17

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11.13 Efficacy of formulated biofungicide on the fruit number of BARI begun 12 at different DAT

At 80 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (2) followed by T_3 (1.667), T_6 (1.33), T_4 (1), T_2 (1), T_5 (1). Plant inoculated with *P. vexans* only (cotrol) showed the lowest fruit number (0.33) (Table 19). At 100 DAT BARI begun 12, among all the upgrade biofungicie, T_1 applied showed the highest fruit number (2.66) followed by T_4

(1.33), T_3 (1), T_5 (1), T_6 (1), T_2 (1). Plant inoculated with *P. vexans* only (control) showed the lowest fruit number (0.33) (Table 19). At 120 DAT BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (1.66) followed by T_4 (1), T_6 (1), T_3 (0.667), T_5 (0.667), T_2 (0.667). Plant inoculated with *P. vexans* only (control) showed the lowest fruit number (0.11) (Table 19).

Table 19. Efficacy of formulated biofungicide on plant fruit number of BARI begun 12 at different DAT

Treatments	Plant fruit number at different DAT		
	80 DAT	**100 DAT**	**120 DAT**
T_0	0.33c±0.57	0.71c±0.57	0.11c±0.57
T_1	2a±0.57	2.66a±1.52	1.66a±0.57
T_2	1bc±1.15	1b±1.15	0.66bc±1
T_3	1.67b±0.57	1b±1.15	0.67bc±0.57
T_4	1bc±1.15	1.33b±1.15	1b±1
T_5	1bc±0.57	1b±0.57	0.67bc±0.57
T_6	1.33bc±1.15	1b±0.57	1b±1
T_7	1.33bc±0.57	1.33ab±1	1b±0.57
LSD($p \leq 0.05$)	1.117	0.71	0.79

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.11. 14 Efficacy of formulated biofungicide on the plant shoot weight (g), root length (cm), root weight (g) of BARI begun 8 at 120DAT

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest shoot weight (350.33 g) followed by T_4 (292.67 g), T_6 (219.0 g), T_2 (211.33 g), T_5 (209.9 g), T_3 (203.9 g). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (125 g). (Table 20)

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest root length (28.333 cm) followed by T_4 (26.333 gm), T_6 (26.00 cm), T_5 (24.667 cm), T_2 (23.33 cm), T_3 (22.333 cm). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (15.0 cm) (Table 20)

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest root weight (74.0 g) followed by T_6 (52.0 g), T_4 (51.0 g), T_3 (48.0 g), T_2 (46.0 g), T_5 (42.0 g). Plant inoculated with *P. vexans* (T_0) showed the lowest shoot weight (21.0 g) (Table 20)

Table 20. Efficacy of formulated biofungicide on the plant shoot weight (g), root length (cm), root weight (g) of BARI begun 8 at 120 DAT

Treatments	Shoot weight (g)	Root length (cm)	Root weight (g)
T_0	125.67 h±1.15	15.0f±1.0.57	21.00g±0.76
T_1	350.33a±1.51	28.333a±0.57	74.0a±0.85
T_2	211.33d±1.15	23.33d±0.3	46.0±0.72
T_3	203.0 f±1	22.33d±0.4	48.0c±1
T_4	292.67b±1.15	26.33b±0.5	51.00c±0.95
T_5	209.0e±1	24.667c±0.6	42.00e±0.52
T_6	219.0 c±1	26.0 b±1	52.00b±0.64
T_7	149.0g±1	18.33e±0.57	26.00f±1.078
LSD ($p \leq 0.05$)	1.96	1.22	1.73

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 16: Root of BARI begun 8 affected by different treatment.

4.11.15 Efficacy of formulated biofungicide on the plant shoot weight (g), root length (cm), root weight (g) of BARI begun 12 at 120DAT

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest shoot weight (376.33 g) followed by T_6 (369.00 g), T_5 (361.0 g), T_4 (338.0 g), T_2 (327.33), T_3 (249.0 g). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (230 g) (Table 21)

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest root length (41.0 cm) followed by T_5 (33.3 cm), T_6 (33.00 cm), T_3 (32.0 cm), T_2 (29 cm), T_4 (25.667 cm). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (24.333 cm) (Table 21)

In BARI begun 12, among all the upgrade biofungicide, T_1 biofungicide applied showed the highest root weight (399.37 g) followed by T_2 (347.67 g), T_6 (299.33 g), T_5 (235.0 g), T_3 (229.0 g), T_4 (186 g). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (149.0 g) (Table 21)

Table 21. Efficacy of formulated biofugicide on the plant shoot weight (g), root length (cm), root weight (g) of BARI begun 12 at 120 DAT

Treatments	Shoot weight (g)	Root length (cm)	Root weight (g)
T_0	230.67h±1.154	24.33e±1	149.0h±1
T_1	376.33a±1.52	41.0a±1.1	399.67a±0.57
T_2	337.33f±1.54	29d±0.57	347.67b±1.54
T_3	249.0g±1	32.0bc±0.95	229.0 e±1.04
T_4	338.33e±1.15	24.67e±0.46	186.0 g±0.72
T_5	361.0c±0.76	33.33b±0.57	235.0d±1.02
T_6	369.0b±1.02	33.0b±1.01	299.33c±0.57
T_7	349.0d±0.68	30.0bc±0.34	194.of±1.07
LSD ($p \leq 0.05$)	1.96	1.41	1.6

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 17: Root of BARI begun 12 affected by different treatment.

4.11.16 Efficacy of formulated biofungicide on plant fruit weight/fruit (g), fruit length (cm), fruit diameter (cm), no. of fruits/ plants of BARI begun 8 at 120 DAT

In BARI begun 8, among all the upgrade biofungicide, applied showed the highest fruit weight (73 g) followed by T_3 (60.4 g), T_4 (57.467 g), T_6 (49.5 g), T_5 (42.33 g), T_2 (40.667 g). Plant inoculated with *P. vexans* only (control) showed the lowest fruit weight (40.0 g) (Table 22)

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest fruit length (24.667 cm) followed by T_3 (23.133 cm), T_6 (21.1 cm), T_5 (20.33 cm), T_4 (19.0 cm), T_7 (18.467 cm). Plant inoculated with *P. vexans* only (control) showed the lowest fruit length (17.0 cm) (Table 22)

In BARI begun 8, among all the upgrade biofugicide, T_1 applied showed the highest fruit diameter (9.333cm) followed by T_5 (8.933 cm), T_6 (8.933 cm), T_3 (8.733 cm), T_2 (8.66 cm), T_4 (8.5 cm). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (6 cm) (Table 22)

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (12) followed by T_4 (11), T_6 (10.77), T_3 (9.66), T_2 (9.33), T_5 (9.33). Plant inoculated with *P. vexans* only (control) showed the lowest shoot weight (7.667) (Table 22).

Table 22. Efficacy of formulated biofungicide on plant fruit weight/fruit (g), fruit length (cm), fruit diameter (cm), no. of fruits/ plants of BARI begun 8 at 120 DAT

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Total fruit number
T_0	40.0d±1	17e±1	6d±0.57	7.67d±0.57
T_1	73.0a±1	24.67±a1.52	9.33a±0.57	12a±1
T_2	40.67d±0.52	18.0de±1.8	8.67b±1.54	9.33c±0.57
T_3	60.4b±1.52	23.133ab±2	8.73b±0.49	9.66c±1.15
T_4	57.47b±1.28	19.0cde±1.73	8.5b±0.86	11b±1
T_5	42.33d±2.08	20.33cd±2.08	8.93ab±0.90	9.33c±0.57
T_6	49.5c±3.5	21.1bc±0.43	8.93ab±1.1	10.77c±1.52
T_7	48.67c±1.52	18.47cde±1.74	7c±1.25	10c±1
LSD ($p \leq 0.05$)	3.07	2.7992	1.57	1.49

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 18: Fruit affected by different treatment in BARI begun 8

4.11.17 Efficacy of formulated biofungicide on plant fruit weight/fruit (g), fruit length (cm), fruit diameter (cm), no. of fruits/ plants of BARI begun 12 at 120 DAT

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit weight (304.0 g) followed by T_4 (256.0 g), T_5 (164.67 g), T_3 (154.0 g), T_2 (131.0 g), T_6 (119.0 g). Plant inoculated with *P. vexans* only (control) showed the lowest fruit weight (85.33 g) (Table 23)

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit length (20.0 cm) followed by T_4 (18.667 cm), T_3 (14 cm), T_5 (13.667.0 cm), T_6 (13 cm), T_2 (11.0 cm). Plant inoculated with *P. vexans* only (control) showed the lowest fruit length (8.0 cm) (Table 23)

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit diameter (24.767 cm) followed by T_4 (24 cm), T_3 (21.0 cm), T_5 (20.667cm), T_2 (20 cm), T_6 (19.33 cm). Plant inoculated with *P. vexans* only (control) showed the lowest fruit diameter (17.533 cm) (Table 23)

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the highest fruit number (11) followed by T_4 (10), T_5 (8.33), T_6 (8.0), T_2 (7.33), T_3 (7.33). Plant inoculated with *P. vexans* only (control) showed the lowest fruit number (5.667) (Table 23)

Table 23. Efficacy of formulated biofungicidenon plant fruit weight/fruit (g), fruit length (cm), fruit diameter (cm), no. of fruits/ plants of BARI begun 12 at 120 DAT

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Total fruit number
T_0	85.33h±1.15	8.0d±1	17.53c±1.74	5.67d±0.57
T_1	304.0a±1.15	20.0a±2	24.77a±2.61	11a±1
T_2	131.33f±1.52	18.67a±1.73	20.0bc±1	7.33c±1.15
T_3	154.0e±1.52	14.0b±2	21.0b±1.73	7.33c±1.15
T_4	256.0b±1.52	18.67a±1.15	24.0a±1.32	10b±0.57
T_5	164.67d±2.64	13.67bc±1.52	20.67b±1.54	8.33c±0.57
T_6	119.33g±1	13.0bc±2	19.33bc±1.54	8c±1
T_7	183.0c±2.08	15.0bc±2	23.33a±1.6	7.67c±0.57
LSD ($p \leq 0.05$)	2.149	2.977	2.79	1.499

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

Figure 19: Fruit affected by different treatment in BARI begun 12

4.11.18 Efficacy of formulated biofungicide on yield (Kg/plant) of brinjal

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the maximum yield per plant (2.21 Kg/plant) followed by T_3 (1.85 Kg/plants), T_4 (1.776 Kg/plant), T_2 (1.72 Kg/plant), T_6 (1.67 Kg/plant), T_5 (1.584 Kg/plant). Plant inoculated with *P. vexans* only (control) showed the minimum yield per plants (0.619 Kg/plant) (Fig. 20)

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the maximum yield per plant (3.0 Kg/plant) followed by T_4 (2.29 Kg/plants), T_5 (1.823 Kg/plant), T_2 (2.076 Kg/plant), T_3 (1.773 Kg/plant), T_6 (1.4566 Kg/plant). Plant inoculated with *P. vexans* only (control) showed the minimum yield per plants (0.569 Kg/plant) (Fig. 20)

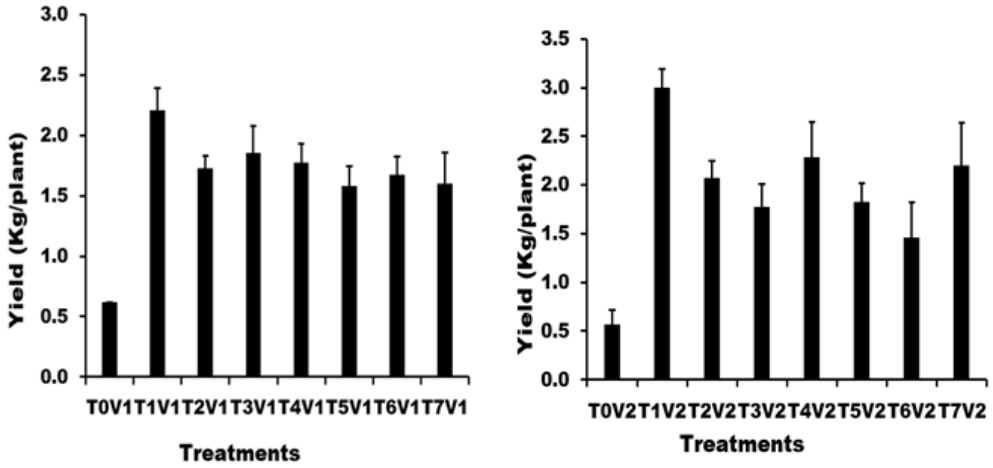

Figure 20: Efficacy of formulated biofungicide on yield (Kg/plant) of brinjal

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb)

4.11.19 Relation between phmopsis blight severity (%) and yield (Kg/plant) of brinjal

In the regression equation, Phomopsis blight incidence (%) was considered as independent and plant leaf number as dependent variable. A negative relation was existing between the Phomopsis blight incidence (%) and yield (Kg/plant). Due to Phomopsis blight (%) maximum yield loss occurred in BARI begun 8 (2.2501 %) and BARI begun 12 (2.759 %) was observed. The regression also showed that, for the unit increase in Phomopsis blight incidence (%), yield (Kg/plant) reduction of BARI begun 8 (0.7924 %) and BARI begun 12 (0.6897 %) will be showed in fig. 21.

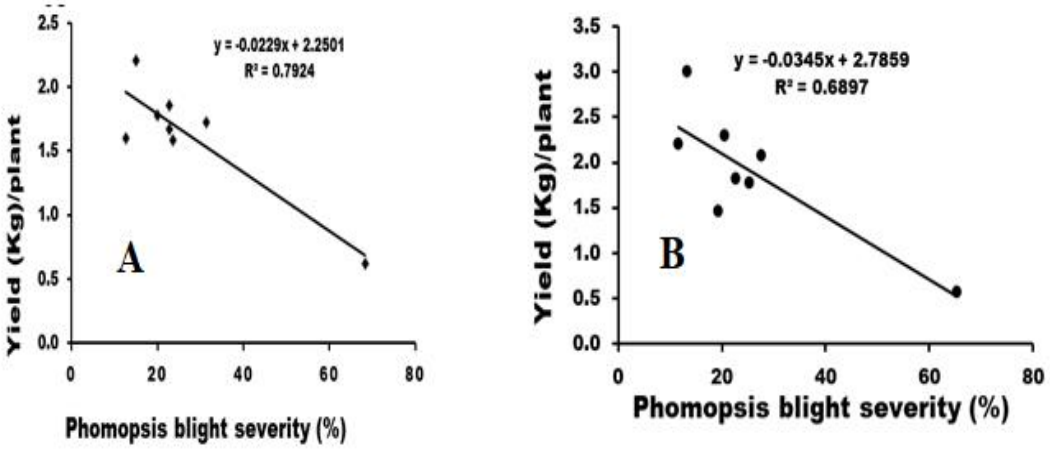

Figure 21: Relation between Phomopsis blight severity (%) and yield (Kg/plant) (A. BARI begun 8 and BARI begun 12

4.12.1 Efficacy of formulated biofungicide on chlorophyll content (mg m^{-2}) of brinjal leaf of BARI begun 8

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the higher amount of chlorophyll-a content in leaf (715.2 mg m^{-2}) followed by T_6

(675.57 mg m^{-2}), T_4 (456.43 mg m^{-2}), T_5 (318.6 mg m^{-2}), T_2 (308.43 mg m^{-2}), T_3 (299.42 mg m^{-2}). Plant inoculated with *P. vexans* only (control) showed the lower amount of chlorophyll-a content in leaf (233.32 mg m^{-2}) (Table 24).

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the higher amount of chlorophyll-b content in leaf (164.47 mg m^{-2}) followed by T_6 (150.77 mg m^{-2}), T_4 (64.837 mg m^{-2}), T_5 (64.8 mg m^{-2}), T_2 (48.6 mg m^{-2}), T_3 (41.4 mg m^{-2}). Plant inoculated with *P. vexans* only (control) showed the lower amount of chlorophyll-b content in leaf (35.757 mg m^{-2}) (Table 24).

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the higher amount of total chlorophyll content in leaf (880.23 mg m^{-2}) followed by T_6 (820.57 mg m^{-2}), T_4 (521.77 mg m^{-2}), T_5 (384.73 mg m^{-2}), T_2 (357.73 mg m^{-2}), T_3 (341.12 mg m^{-2}). Plant inoculated with *P. vexans* only (control) showed the lower amount of total chlorophyll content in leaf (269.43 mg m^{-2}) (Table 24).

Table 24. Efficacy of formulated biofungicide on chlorophyll content (mg m^{-2}) of brinjal leaf of BARI begun 8

Treatments	Chlorophyll-a	Chlorophyll-b	Total Chlorophyll
T_0	233.32h±0.34	35.76g±0.15	269.43h±0.66
T_1	715.2a±0.1	164.47a±0.15	880.23a±0.66
T_2	308.43f±0.21	48.6e±0.26	357.43f±0.39
T_3	299.42g±0.32	41.4f±0.62	341.12g±0.98
T_4	456.43d±0.35	64.837d±0.06	521.77 d±0.81
T_5	318.6e±0.1	64.800d±0.03	384.73e±1.09
T_6	675.57b±0.25	150.77b±1.38	820.57b±0.99
T_7	532.99c±0.34	113.1 c±1.67	644.97c±0.94
LSD ($p \leq 0.05$)	0.4479	1.3987	1.463

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.12.2 Efficacy of formulated biofungicide on chlorophyll content (mg m^{-2}) of brinjal leaf of BARI begun 12

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the higher amount of chlorophyll-a content in leaf (778.82 mg m^{-2}) followed by T_4 (722.64 mg m^{-2}), T_5 (655.97 mg m^{-2}), T_6 (596.9 mg m^{-2}), T_3 (570.93 mg m^{-2}), T_2 (223.17 mg m^{-2}). Plant inoculated with *P. vexans* only (contro) showed the lower amount of chlorophyll-a content in leaf (187.4 mg m^{-2}) (Table 25).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the higher amount of chlorophyll-b content in leaf (141.44 mg m^{-2}) followed by T_4 (141.03 mg m^{-2}), T_6 (114.03 mg m^{-2}), T_5 (104.30 mg m^{-2}), T_3 (100.83 mg m^{-2}), T_2 (19.517 mg m^{-2}). Plant inoculated with *P. vexans* only (control) showed the lower amount of chlorophyll-b content in leaf (8.790 mg m^{-2}) (Table 25).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the higher amount of total chlorophyll content in leaf (920.27 mg m^{-2}) followed by T_4 (863.33 mg m^{-2}), T_5 (760.27 mg m^{-2}), T_6 (710.60 mg m^{-2}), T_3 (701.83 mg m^{-2}), T_2 (243.83 mg m^{-2}). Plant inoculated with *P. vexans* only (control) showed the lower amount of total chlorophyll content in leaf (15.55 mg m^{-2}) (Table 25).

Table 25. Efficacy of formulated biofungicide on chlorophyll content (mg m^{-2}) of brinjal leaf of BARI begun 12

Treatments	Chlorophyll-a	Chlorophyll-b	Total Chlorophyll
T_0	187.40h±0.1	8.79f±0.16	185.55h±0.82
T_1	778.64a±0.39	141.44a±0.24	920.27a±0.15
T_2	223.17g±0.21	19.517e±0.05	243.83g±1.52
T_3	570.93e±0.15	100.83d±0.55	701.83e±1.28
T_4	722.64b±2.48	141.03a±1.52	863.33b±1.74
T_5	655.97c±1.11	104.3c±0.2	760.27c±0.97
T_6	596.9d±0.86	114.03b±1.14	710.6d±0.56
T_7	520.53f±0.21	100.55d±0.17	621.21f±0.08
LSD ($p \leq 0.05$)	1.78	1.23	1.83

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.12.3 Efficacy of formulated biofungicide on total phenol content (mg/100 g) in fruit, total soluble solids (°Brix), firmness (Kg/min), pH of BARI begun 8

In BARI begun 8, among all the upgrade biofugicide, T_1 applied showed the higher percentage of total phenol content in fruit (8.894 mg/100 g) followed by T_5 (8.0977 mg/100 g), T_4 (5.53 mg/100 g), T_3 (5.3233 mg/100 g), T_6 (5.17 gm/100 g), T_2 (4.619 gm/100 g). Plant inoculated with *P. vexans* only (control) showed the lower amount of phenol content in fruit (1.822 mg/100 g) (Table 26).

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the maximum percentage of TSS in fruit (6.433°Brix) followed by T_3 (5.533 °Brix), T_4 (4.7667 °Brix), T_5 (4.7667 °Brix), T_6 (4.7 °Brix), T_2 (4.5667 °Brix), T_7 (4.233°Brix). Plant inoculated with *P. vexans* only (control) showed the lower percentage of TSS in fruit (4.1667 °Brix) (Table 26).

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the higher grade of firmness in fruit (2.8133Kg/min) followed by T_4 (2.53 Kg/min), T_6 (2.39 Kg/min), T_2(2.38 Kg/min), T_3 (2.296 Kg/min), T_5 (2.16 Kg/min). Plant inoculated with *P. vexans* only (control) showed the lower firmness in fruit (2.133 Kg/min) (Table 26).

In BARI begun 8, among all the upgrade biofungicide, T_1 applied showed the higher amount of pH in fruit (6.64) followed by T_4 (6.51), T_2 (5.67), T_3 (5.6367), T_6 (5.62), T_5 (5.48). Plant inoculated with *P. vexans* only (control) showed the lower firmness in fruit (4.83) (Table 26).

Table 26. Efficacy of formulated biofungicide on total phenol content (mg/100 g) in fruit, total soluble solids (°Brix), firmness (Kg/min), pH of BARI begun 8

Treatments	Total phenol (mg/100 g)	TSS (°Brix)	Firmness (Kg/min)	pH
T_0	1.823h±0.001	4.1667d±0.152	2.133d±0.155	4.833e±0.1
T_1	8.894a±0.002	6.433a±0.057	2.81a±0.087	6.546a±0.064
T_2	4.617g±0.001	4.5667cd±0.152	2.38bc±0.206	5.68c±0.156
T_3	5.3233e±0.015	5.533b±0.75	2.29bcd±0.037	5.637c±0.061
T_4	5.52d±0.01	4.7667c±0.0577	2.53b±0.175	6.513a±0.072
T_5	8.0977b±0.002	4.7667c±0.208	2.16cd±0.075	5.48d±0.075
T_6	5.1743f±0.002	4.7cd±0.3	2.39bc±0.17	5.62c±0.055
T_7	5.943c±0.001	4.23cd±.32	2.23cd±0.065	6.12c±0.041
LSD ($p \leq 0.05$)	0.0114	0.57	0.23	0.12

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.12.4 Relation between Phomopsis blight severity (%) and total phenol content (mg/100 g) in fruit, total soluble solids (°Brix), firmness (Kg/min) of BARI begun 8

In the regression equation, total phenol content (mg/100 g), total soluble solid (^{0}Brix) and firmness (Kg/min) was considered as independent and Phomopsis blight severity (%) as dependent variable. A negative relation was existing between the Phomopsis blight severity (%) and total phenol content (mg/100 g), total soluble solid (^{0}Brix) and firmness (Kg/min). Due to Phomopsis blight severity (%) was observed maximum total phenol content (63.509 mg/100 g), total soluble solid (78.336 ^{0}Brix) and firmness (117.14 Kg/min) loss occurred in BARI begun 8. The regression also showed that, for each unit increase in total phenol content (0.62 mg/100 g), total soluble solid (0.1978 ^{0}Brix) and firmness (0.2315 Kg/min). a phomopsis blight reduction of BARI begun 8 will be shown in fig. 22.

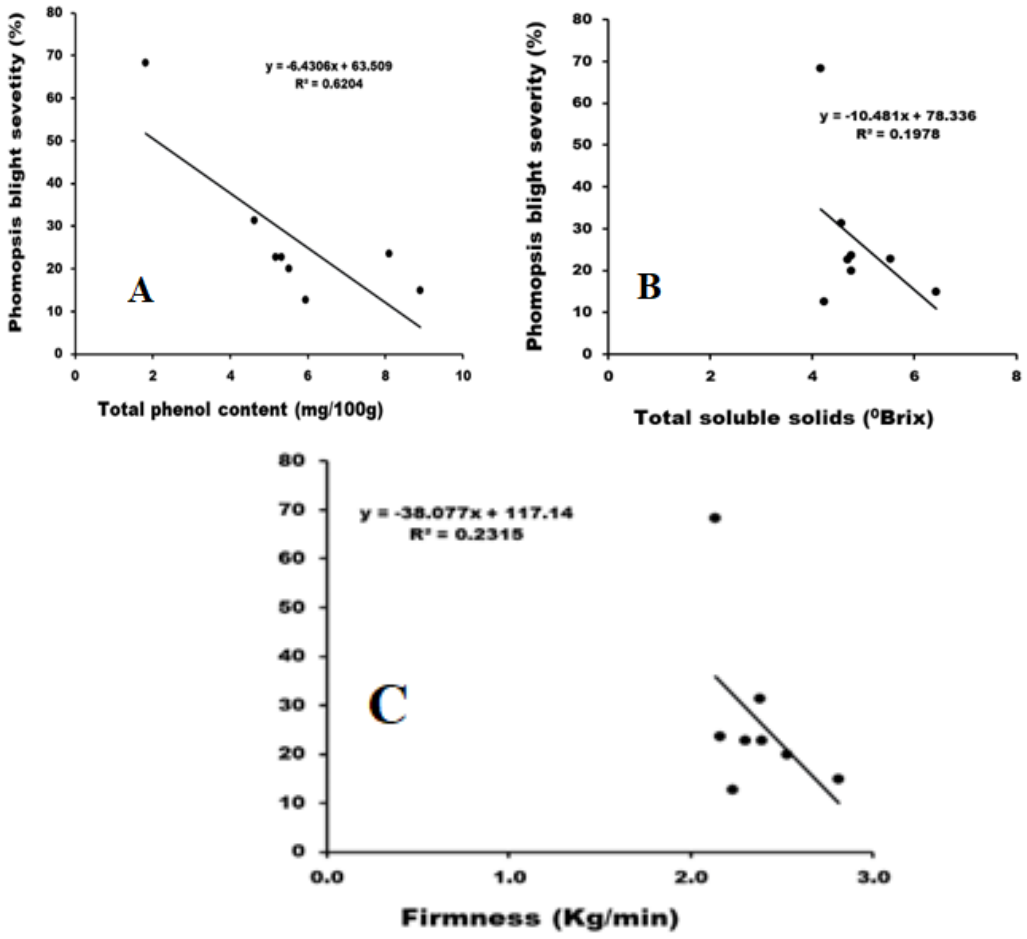

Figure 22: Relation between Phomopsis blight severity (%) and (A. Total phenol content (mg/100 g) B.TSS (^{0}Brix) C. Firmness (Kg/Min) of BARI begun 12

4.12.5 Efficacy of formulated biofungicide on total phenol content (mg/100 g) in fruit, total soluble solids (°Brix), firmness (Kg/min), pH of BARI begun 12

In BARI begun 12, among all the upgrade biofungucide, T_1 applied showed the higher percentage of phenol content in fruit (8.0467 mg/100 g) followed by T_4 (6.0970 mg/100 g), T_3 (5.34 mg/100 g), T_6 (5.233 mg/100 g), T_5 (5.08 gm/100 g), T_2 (5.01 gm/100 g). Plant inoculated with *P. vexans* only (control) showed the lower amount of phenol content in fruit (2.487 mg/100 g) (Table 27).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the maximum percentage of TSS in fruit (6.4 °Brix) followed by T_6 (5.133 °Brix), T_5 (5.033 °Brix), T_3 (5.033 °Brix), T_2 (4.3667 °Brix), T_4 (4.233 °Brix). Plant inoculated with *P. vexans* only (control) showed the lower percentage of TSS in fruit (4.100 °Brix) (Table 27).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the higher grade of firmness in fruit (2.9933Kg/min) followed by T_4 (2.800Kg/min), T_3 (2.5433 Kg/min), T_6 (2.4667 Kg/min), T_2 (2.4167 Kg/min), T_5 (1.96 Kg/min). Plant inoculated with *P. vexans* only (control) showed the lower firmness in fruit (1.8833 Kg/min) (Table 27).

In BARI begun 12, among all the upgrade biofungicide, T_1 applied showed the higher amount of pH in fruit (6.28) followed by T_3 (5.53), T_6 (5.33), T_2 (5.42), T_5 (5.3367), T_4 (5.32). Plant inoculated with *P. vexans* only (control) showed the lower firmness in fruit (4.86) (Table 27).

Table 27. Efficacy of formulated biofungicide on total phenol content (mg/100 g) in fruit, total soluble solids (°Brix), firmness (Kg/min), pH of BARI begun 12

Treatments	Total phenol (mg/100g)	TSS (°Brix)	Firmness (Kg/min)	pH
T_0	2.487h±0.001	4.1c±0.1	1.8833d±0.073	4.866d±0.1
T_1	8.0467a±0.00115	6.4a±0.3	2.9933a±0.7767	6.2867a±0.064
T_2	5.0100g±0.01	4.3667c±0.057	2.4167c±0.1375	5.42c±0.030
T_3	5.347d±0.001	5.033b±0.0577	2.5433c±0.0981	5.533b±0.0577
T_4	6.097b±0.001	4.33c±0.1	2.8b±0.130767	5.32c±0.030
T_5	5.088f±0.001	5.033b±0.57	1.96d±0.09	5.33c±0.0577
T_6	5.233e±0.003	5.133b±0.404	2.466c±0.11547	5.533c±0.0577
T_7	5.51c±0.01527	4.3667c±0.41	2.7367b±0.0709	5.32c±0.03055
LSD ($p \leq 0.05$)	0.0114	0.4934	0.1766	0.1007

Means followed by different letter(s) in the coloum are significantly different according to Duncans's multiple range test at p=0.05. T_0 (only *P. vexans*); T_1 (Pea with of potato starch based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_2 (Pea bran with of tryptone based formulated *B. cereus* HSTUB 17 followed by Spraying that formulation suspension); T_3 (Pea bran with yeast extract based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_4 (Pea bran with potato starch and yeast extract based formulated HSTUB 17 followed by spraying that formulation suspension.); T_5 (Pea bran with potato starch and tryptone based formulated *B. cereus* HSTUB 17 followed by spraying that formulation suspension.); T_6 (Pea bran with potato starch and tryptone and yeast extract based formulated *B. cereus* HSTUB 17 followed by that formulation suspension); T_7 (Mancozeb).

4.12.6 Relation between Phomopsis blight severity (%) and total phenol content (mg/100 g) in fruit, total soluble solids), firmness (Kg/min) of BARI begun 12

In the regression equation, total phenol content (mg/100 g), total soluble solid (^{0}Brix) and firmness (Kg/min) was considered as independent and Phomopsis blight severity (%) as dependent variable. A negative relation was existing between the Phomopsis blight severity (%) and total phenol content (mg/100 g), total soluble solid (^{0}Brix) and firmness (Kg/min). Due to Phomopsis blight severity (%) was observed maximum total phenol content (76.004 mg/100 g), total soluble solid (81.352 ^{0}Brix) and firmness (104.38 Kg/min) loss occurred in BARI begun 12. The regression also showed that, for each unit increase in total phenol content (0.71 mg/100 g), total soluble solid (0.2468 ^{0}Brix) and firmness (0.5353 Kg/min). a phomopsis blight reduction of BARI begun 12 will be shown in fig. 23.

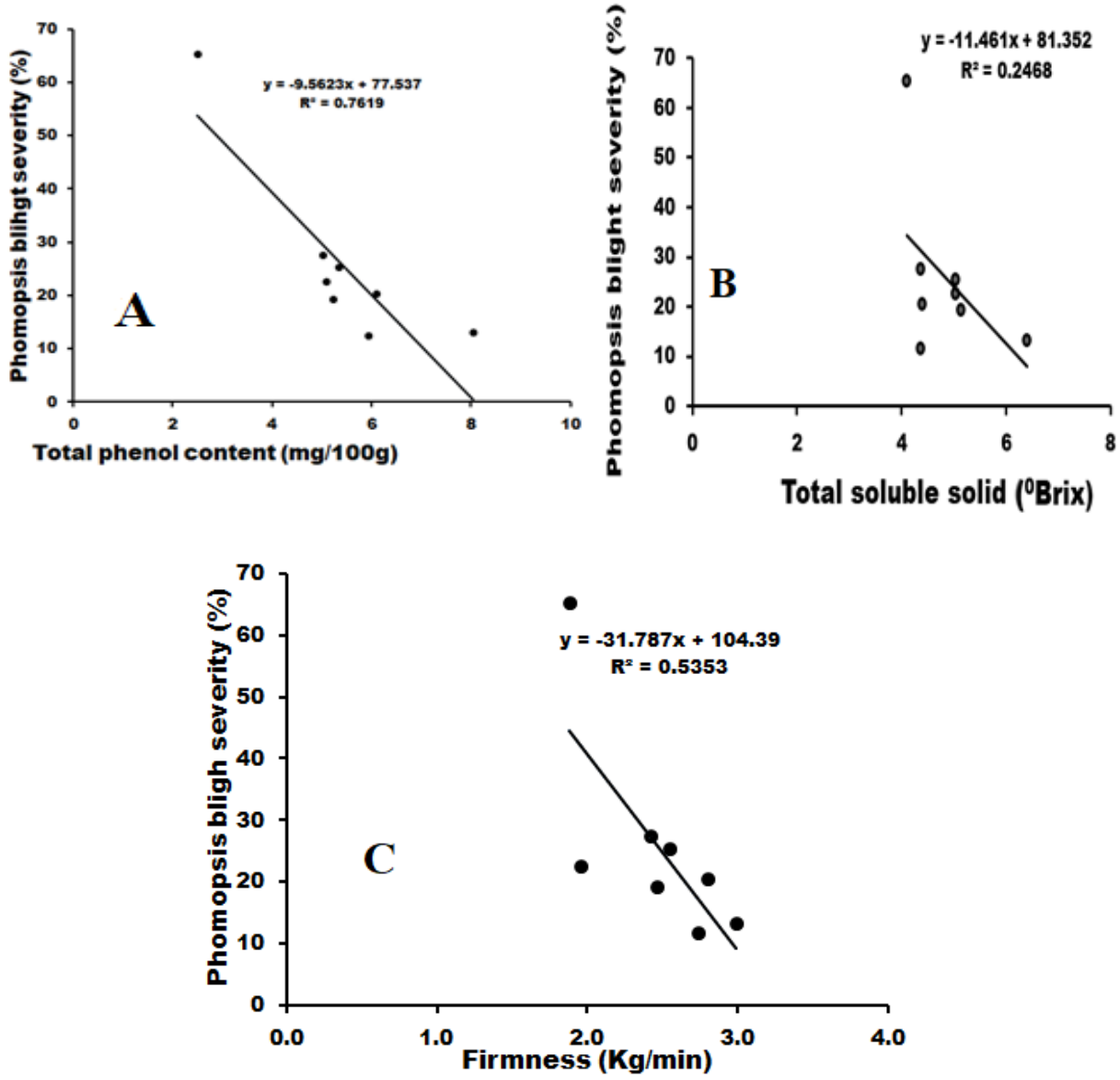

Figure: 23 Relation between Phomopsis blight severity (%) and (A. Total phenol content (mg/100 g) B.TSS (^{0}Brix) C. Firmness (Kg/Min) of BARI begun 12

4.13 Shelf life of formulated biofungicide of in different storage condition

The shelf life of pea bran with potato starch based, pea bran with tryptone based, pea bran with yeast extracts based, pea bran with potato starch and yeast extracts based, pea bran with potato starch and tryptone based, pea bran with

potato starch and tryptone and yeast extracts based formulated *B. cereus* HSTUB 17 were examined in different conditions A. wooden shelve condition (room temperature). B. refrigerated condition (4 ℃). In case wooden shelve storage condition the colony density of all formulated products was found to increase

From first day to 60 days. After 30 days the population of all storage product increase {pea bran with potato starch based (533 to 745.33 CFU/mL)}, {pea bran with tryptone based (476 to 700 CFU/mL)}, {pea bran with yeast extracts based (400 to 716.33 CFU/mL)}, {pea bran with potato starch and yeast extracts based (317 to 563 CFU/mL)}, {pea bran with potato starch and tryptone based (394 to 450 CFU/mL)}, {pea bran with potato starch and tryptone and yeast extracts based (343 to 508 CFU/mL)} from its initial populations. After 60 days the populations of all formulated products decreased and viable cell was found up to 240 DAS. However, among all the formulated bio-fungicides higher bacterial populations were found in pea bran with potato starch-based formulation and lowest bacterial populations was found in pea bran with potato starch with tryptone-based formulation (Fig. 24)

From first day to 90 days. After 30 days the population of all storage product increase {pea bran with potato starch based (457 to 856 CFU/mL)}, {pea bran with tryptone based (476 to 933 CFU/mL)}, {pea bran with yeast extracts based (680 to 1260 CFU/mL)}, {pea bran with potato starch and yeast extracts based (650 to 1160 CFU/mL) }, {pea bran with potato starch and tryptone based (690 to 1026 CFU/mL)}, {pea bran with potato starch and tryptone and yeast extracts based (457 to 1200 CFU/mL)} from its initial populations. After 90 days the populations of all formulated products decreased and viable cell was found up to 240 DAS. However, among all the upgrade formulated *B. cereus* higher bacterial populations was found in pea bran with yeast extracts-based formulation and lowest bacterial populations were found in pea bran with potato starch- based formulation (Fig. 24)

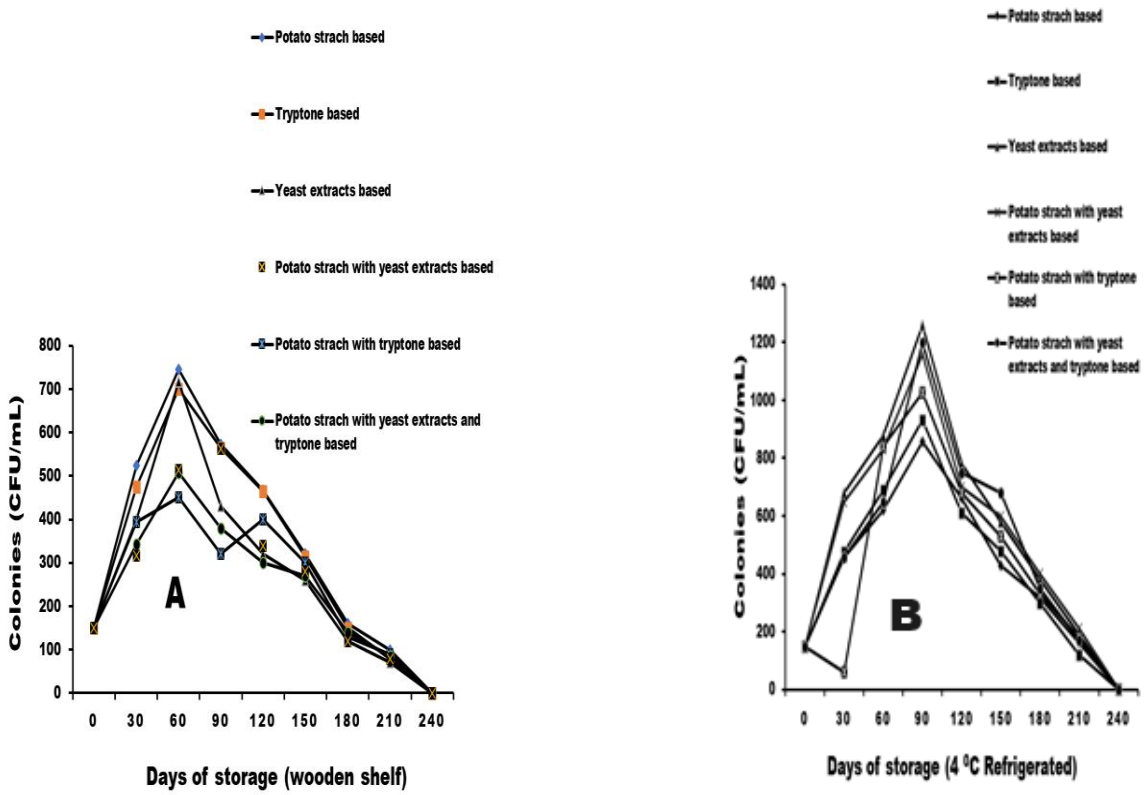

Figure: 24 Shelf life of formulated biofungicide composed with *B. cereus* HSTUB 17 in different stage condition; A. Wooden shelves B. Refrigerated condition (4 ℃).

CHAPTER V

DISCUSSION

Phomopsis leaf blight/fruit rot caused by *P. vexans* is an important disease to be regarded the most destructive disease of Brinjal (*Solanum melongena*). Farmers of Bangladesh are facing a lot of losses due to this disease in brinjal. Farmer using chemicals which are harmful in many ways. According to Ahmed *et al.* chemicals have many negative consequences for humans, the environment, soil, and water. It has been observed that improper and heavy use of fungicides also develops resistance to plant pathogens. For that reasons people around are worried about the harmful effects of chemical fungicides to control various diseases. That's why farmers are now showing interest to manage plant disease by biological means.

Biological management strategies now showing the alternatives way to chemical control to manage disease. Now a days, bacteria playing an important role as a biocontrol agent. (Reddy *et al.* 2018). Bacterial produces colony and inhabit internal plant tissues without causing any apparent damage. Within the plant, these bacteria exert multiple beneficiary effects, including direct stimulation of plant growth by the action of phytohormones or the production of metabolites. However, bacterial endophytes also protect their plant host through biocontrol pathogens or by inducing plant innate immune system. (Morales-Cedeno *et al.* 2021). Since *P. vexans* is reason for Phomopsis blight/fruit rot of brinjal, the study's objective was to evaluate the upgrade formulated biofungicide for the management of phomopsis blight of brinjal in pot condition.

In vitro testing between *B. cereus* HSTUB 17 and *P. vexans* showed inhibitory effects against *P. vexans*. *P. vevans* mycelium growth was inhibited by *B. subtilies* and *P. fluorescens* using dual culture methods (Jakatimath *et al.* 2019).

Plant beneficial bacteria have different mode of action to suppress fungal pathogen growth. Among them bacteria produce diffusible molecules, both antimicrobial molecules and siderophores; production of various volatile organic compounds; produce hydrolytic enzymes and other mechanisms to induction to systematic resistance, triggering an interaction of different level and inhibit the fungal growth (Rocio *et al.* 2021). Some compounds present in *B. cereus* Including indole-3-acetic acid (IAA) and aminocyclopropane-1-carboxylic acid (ACC), biologically active substances enzymes and total soluble sugar that reduces fungal growth and help in plant growth promotion (Kulkova *et al.* 2023).

The upgraded formulation biofungicide of *B. cereus* HSTUB 17 was developed by using pea bran with potato starch based, pea bran with tryptone based, pea bran with yeast extract based, pea bran with potato starch and yeast extract based, pea bran with potato starch and tryptone based, pea bran with potato starch and tryptone and yeast extract based. However, all the used upgraded formulated biofungicide were reduced Phomopsis blight severity in both leaf and fruit. Among all the formulated product, pea bran with potato starch based formulated biofungicide followed by spraying that formulation suspension reduced maximum Phomopsis blight severity (%). Bacteria suppress pathogen growth via various mechanisms, such as antibiosis production, nutrient and space competition and systemic resistance. Bacteria also contributes to plant growth. Bacteria also produces secondary metabolites (Lee *et al.* 2023). *B. cereus* improved plant by solubilized phosphate and synthesis phytohormones (IAA cytokinin, and abscisic acid), and osmolyte (proline and sugar). That increase plant growth by reducing disease. *B. cereus* also increase in seed germination percentage. Shoot length ad root length. It also increases Chlorophyll-a, chlorophyll-b and total chlorophyll content (Akther *et al.* 2021).

In this study biofungicide also increased seed germination percentage, plant height compared to control, shoot weight root length and root weight compare to control. Also increases Chlorophyll-a, chlorophyll-b content and total chlorophyll content. The higher amount phenolic content is association with antioxidant capacity as well as higher resistance against diseases (Kandoliya and Vakharia 2013). In this study all the upgraded formulated biofungicide increase total phenolic content, total soluble solid and firmness. All the applied formulation were also found increase different agronomic traits of brinjal including plant growth.

CHAPTER VI

SUMMARY AND CONCLUSION

Brinjal (*Solanum melongena)* is one of the most important vegetable crops in Bangladesh duo to its taste and nutritional value. Brinjal plays a great role in the support the livelihoods of small-farm owners because it can be harvested and sold weekly. Sustainable production of brinjal is constrained by various diseases of that is phomopsis blight is most important. Biological control of plant disease is a viable alternative method to chemical control because their eco-friendly nature in low cost. The potentially of the isolated and developed formulated *B. cereus* HSTUB 17 against Phomopsis blight of brinjal caused by *P. vexans* as well as its shelf life in different storage condition was studied. *B. cereus* HSTUB 17 showed the repressive effects against *P. vexans* in *in vitro* by the formation of a clear zone of repression. *B. cereus* HSTUB 17 was further used to upgraded a variety of formulated biofungicide using pea bran with potato starch based, pea bran with tryptone based, pea bran with yeast extract based, pea bran with potato starch and yeast extract based, pea bran with potato starch and tryptone based, pea bran with potato starch and tryptone and yeast extract based biofungicide. The upgrade formulated biofungicide of were applied to control Phomopsis blight of brinjal in pot condition. Among all the applied biofungicide, pea bran with potato starch based formulated biofungicide followed by spraying that formulation suspension showed the maximum reduction of Phomopsis blight incidence (%) and phomopsis blight severity (%); maximum the plant height (cm), shoot weight (g), root length (cm), root weight (g), number of leaf/plant, number of branch/plants, number of fruit per plants, fruit weight (g), fruit length (cm), fruit diameter (cm), yield (Kg/plant) and maximum number of flowering per plant in both varieties. The biochemicals analysis of brinjal leaf also revealed the higher chlorophyll-a (mg m^{-2}), chlorophyll-b (mg m^{-2}) and total chlorophyll (mg m^{-2}). The biochemical analysis

of brinjal fruit also revealed the higher phenol content (mg/100 g), higher total soluble solids (^{0}Brix), higher grade 0f firmness (Kg/min), and higher pH by the application of formulated biofungicide in both brinjal varieties.

The upgraded formulated biofungicide of were packed (@ 50 g/polyethylene bag) and stored in two stages condition *viz.*, A. wooden shelves (room temperature) B. refrigerated (4 ℃). In case of wooden shelve condition among all the upgraded formulated biofungicide higher bacteria populations were found in pea bran combination of potato starch based biofungicide and lowest bacterial populations was found in pea bran of potato starch and tryptone based upgraded biofungicide. In case of refrigerator among all the upgraded formulated biofungicide of higher bacterial populations were found in pea bran with yeast extracts based biofungicide and lowest bacterial populations was found in pea bran with potato starch based biofungicide. The overall findings of study evidence the by using various carrier materials as substrate for the commercialization, the obtained *B. cereus* HSTUB 17 may be used to make bio-fertilizer and bio-fungicides. However, before final recommendation to the farmers, field and location specific trials need to conduct.

REFERENCES

Akther N, Ilyas N, Yasmin H, Sayyed RZ, Hasnain Z, Elsayed EA, and Enshasy HA. 2021. Role of *Bacillus ceresus* in improving the Growth and Phytoextrability of *Brassica nigra* (L.) K. Koch in Chromium Contaminated Soil. Molecules. 26(6):1569.

Anon DI.1949. Copper enzymes in isolated chloroplasts phenol oxidase in *Beta vulgaris.* Plant physiology. 24: 1.

Ahmed H, Sharma S, Kumar A, Sharma A & Rana T. 2022. The Perspective of Induced Resistance In Brinjal against *Phomopsis vegans* Causing Phomopsis Blight. Biopesticides International. 18(1):9-21.

Bangladesh Bureau of Statistics (BBS), (2022-23).

Bhanushree N, Saha P, Tomar BS & Munshi AD. 2023. Phomopsis blight in eggplant and strategies to manage through resistance breeding. The Journal of Horticultural Science and Biotechnology. 97(1):34-45.

Bhat M, Anwar A, Mughal MN, Mohiddin F, Makhdoomi M, Bhat AF, Fayaz U.2019. Morpho-cultural and pathological variability in *Phomopsis vexans* causing leaf blight and fruit rot of brinjal in Kashmir. Indian Phytopathology. 72: 225–233.

Chakravarty G, Kalita MC. (2011). Comparative evaluation of organic formulations of *Pseudomonas fluorescens* based biopesticides and their application in the management of bacterial wilt of brinjal (*Solanum melongena L.*) African Journal of Biotechnology. 10(37):7174-7182.

Chowdhary B and Gaur K. 2009. The development and regulation of Bt. Brinjal In India (eggplant/Aubergine). The International Service for the Acquisition of Agri-biotech Applications. 38:102.

Dewan S. (2023). Development Of formulated *Serratia marcescens* HSTUB 8 For the Eco-friendly Management of Phomopsis blight of brinjal. University Of Hajee Mohammad Science and Technology University, Dinajpur.

de Almeida Lopes KB, Carpentieri-Pipolo V, Fira D, Balatti PA, López SMY, Oro TH, Stefani Pagliosa E, Degrassi G. 2018. Screening of bacterial endophytes as potential biocontrol agents against soybean diseases. Journal of Applied Microbiology. 125(5):1466–1481.

FAO (Food and Agriculture Organization). 2023. FAO Production Year book. Basic Data Unit, Statistics Division, FAO, Rome, Italy.

Gomez KA and Gomez AA. 1984. Statistical procedures for agricultural research. 2nd ed. John Wiley and Sons, New York. 5(1-2): 202-215.

Guzmán-Guzmán P, Kumar A, de Los SVS, Parra-Cota FI, Orozco-Mosqueda MDC, Fadiji AE, Hyder S, Babalola OO, Santoyo G. 2023. *Trichoderma Species*: Our Best Fungal Allies in the Biocontrol of Plant Diseases. Plants. 12 (3):432.

Gogoi M & Basumatary M. 2018. Estimation of the chlorophyll concentration in seven Citrus species of Kokrajhar district, BTAD, Assam, India. Tropical Plant Research. 5(1): 83–87.

Harman GE, Howell CR, Viterbo A, Chet I and Lorito M. 2004. *Trichoderma species*—opportunistic, avirulent plant symbionts. Nature Reviews Microbiology. 2: 43–56.

Hazarika DJ, Goswami G, Gautom T, Parveen A, Das P, Barooah M, Boro RC. 2019. Lipopeptide mediated biocontrol activity of endophytic *Bacillus subtilis* against fungal phytopathogens. BMC Microbiology. 19(1):71.

Hossain M, Islam M, Uddin M, Arifuzzaman S, Hasan G. 2013. Control of Phomopsis Blight of Egg Plant through Fertilizer and Fungicide Management. International Journal of Agricultural Research, Innovation and Technology. 3(1): 66–72.

Heng Z, You Q, Li Z, Sun B, Xu X, Li Y, Li Z, Wang H, Gong C, Xu X, Li T. 2023. The first genome sequence of *Phomopsis vexans*: a fungal pathogen causing Phomopsis blight in eggplant. Biologia. 78: 543-548.

Huang C, Wang T, Chung T, Chen C. 2004. Identification of an Antifungal Chitinase from a Potential Biocontrol Agent, *Bacillus cereus 28-9*. Journal of Biochemistry and Molecular Biology. 38 (1): 82-88.

Islam M & Meah M. 2012. Association of *(Phomopsis vexans*) with Eggplant *(Solnanum melongena*) Seeds, Seedlings and its Management. The Agriculturist. 9(1-2):8–17.

Islam SK and Pan S. 1990. Efficacy of humidity and temperature on Phomopsis fruit rot of brinjal (*Solnanum melongena*) Environment and Ecology. 8(4):1309-1310.

Joy M, Jacob J, Smitha KP, Nair RV. 2004. Inhibitory effects of cashew (*Anacardium occidentale* L.) on polypathogenic fungi. Allelopathy Journal. 13(1):47-56.

Jakatimath SP, Mesta RK, Mushrif SK, Birander IB and Ajjiappalavar PS. 2017. *In vitro* evalution of fungicides, botanicals and bio-agents against *Phomopsis vexans*, the causal agent of fruit rot of brinjal. Journal of Pure and Applied Microbiology. 11(1):229-235.

Jasca JE, Seok KA, Suraini L, Chun YA, Jurani R, Sano D, Dan S, Hamassaki K, Azam KN, Tamrin ML. 2021. Antifungal Prospect of *Bacillus cereus* Postbiotic on Crustacean Pathogen, *Lagenidium thermophilum*. Biocontrol Science. 26(4):201-205.

Kalda, T.S., Swarup V. and Choudhury, B. 1977. Resistance to Phomopsis blight in eggplant. Vegetable Science. 4:90-101.

Kamla T and Indira S. 2014.Molecular characterizational of *Trichoderma harzianum* strains from Manipur and their bio-control potential against *Pythium ultimum*. International Journal of Current Microbiology and Applied Sciences. 3:258-270.

Kamble PN, Giri SP, Mane RS & Tiwana A. 2015. Estimation of Chlorophyll content in young and adult leaves of some selected plants. Universal journal of environmental research and technology. 5(6): 306−310.

Khadiri M, Boubaker H, Askarne L, Ezrari S, Radouane N, Farhaoui A, Hamss H, Tahiri A, Barka EA, Lahlal R. 2023. *Bacillus cereus B8W8* an effective bacterial antagonist against major postharvest fungal pathogens of fruit. Postharvest Biology and Technology. 200:112315.

Kulkova I, Dobrznski J, Kowalczyk P, Belzecki G. 2023. Plant Growth promoting Using *Bacillus cereus*. International Journal of Molecular Sciences. 24(11):9759.

Kumar S, Biswas SK and Kumar N. 2023. Efficacy of biocontrol agents and plant extracts against Phomopsis blight of brinjal caused by *Phomopsis vexans* (Sacc. & Syd.) in vitro. The Pharma Innovation Journal. 12(10): 2090-2093.

Lemessa F and Zeller W. 2006. Isolation and characterization of *Ralstonia solanacearum* strains from Solanaceae crops in Ethiopia. Journal of Basic Microbiology. 47: 40-49.

Lee J, Kim S, Jung H, Koo BK, Han JA and Lee HS. 2023. Exploiting Bacterial Genera as Biocontrol Agents: Mechanisms, Interactions and Applications in Sustainable Agriculture. Journal of Plant Biology. 66:485-498.

Martin FW and Rhodes AM. 1979. Subspecific grouping of eggplant Cultivars. Euphytica. 28: 367-383.

Manda RR, Addanki V, A Srivastava S. 2020. Phomopsis blight of *Solanam melongena*-brinjal/eggplant. Plant Cell Biotechnology and Molecular Biology. 21(55-56): 7-12.

Mahadevakumar S and Janardhana GR. 2016. Plant Pathology & Quarantine. 6(1): 5-12.

Meah MB, Das BH, Siddiqua MK, and Nasir M. (1998). Screening of Brinjal Varieties against Phomopsis rot. Bangladesh Journal of Plant Pathology. 14(1-2):25-28.

Meah MB, Hossain MD and Islam MR. 2003. Development of an integrated approach for management of phomopsis blight and fruit rot of eggplant in Bangladesh. Annual Research Report Department of Plant Pathology, BAU, Mymensingh, Bangladesh. 57.

Meng-Jie LIAO, Hong-Kai WANG, Chun-Hao JIANG, Jian-Hua GUO. 2019. Mechanism of M60 family peptidase of Bacillus cereus AR156 involved in biocontrol against Meloidogyne incognita. Microbiology China. 46(1): 84-92.

Morales-Cedeno LR, Orozco-Mosqueda MDC, Loeza-Lara PD, Parra-Cota FI, de Los SVS and Santoyo G. 2021. Plant growth-promoting Bacterial endophytes as biocontrol agents of pre-and post-harvest disease Fundamentals, method of application and future perspectives. Microbial Research. 242:126612.

Miljakovic D, Marinkovic J and Balesevic-Tubic S. 2020. The Significance of *Bacillus spp*. in in Disease Suppression and Growth Promotion of Field And Vegetable crops. Microorganisms. 8:7.

O'Brien PA. 2017. Biological control of plant diseases. Australasian Plant Pathology. 46:293-304.

Purewal SS. (1957). Vegetable cultivation in North India. Indian Council of Agricultural Research. 11(1):71-74.

Quamruzzaman A, Islam F, Uddin MN & Chowdhury MAZ. 2019. Performance of Green Type Eggplant in Relation of Insect and Diseases. American Journal Of Plant Sciences. 10(1):139-146.

Qulsum U, Islam M, Chowdhury EK, Hossain MS, and Hassan M. 2023. Management of bacterial wilt (*Rastonia solanacearum*) of brinjal using *Bacillus cereus*, *Trichoderma harzianum* and *Calotropis gigantea* consortia in Bangladesh. Egyptian Journal of Biological Pest Control. 33:74.

Rahman MF, Islam MR, Rahman T and Meah MB. 2010. Biochemical Chatacterization of *Rastonia solancearum* causing bacretial wilt of Brinjal. Journal of Progressive Agriculture. 21(1 - 2): 9-19.

Romeiro RS, Filho RL, Macagnan D, Garcial FAO, Silva HSA. 2010. Evidence that the biocontrol agent *Bacillus cereus* synthesizes protein that can elicit increased resistance of tomato leaves to *Corynespora cassiicola*. Tropical Plant Pathology. 35 (1): 11-15.

Rocio RC, Jose DFF and Rahul R. 2021. Mechanisms of Action of Microbial Biocontrol Agents against *Botrytis cinerea*. Journal Fungi. 7(12):1045.

Reddy PYN, Janker SS and Dahiya OS. 2018. Management of Fruit Rot of Brinjal Caused by *Phomopsis vexans*. International Journal of Current Microbiology and Applied Sciences. 7:5119-5124.

Rohini, Gowtham HG, Hariprasad P, Singh S B, Niranjana SR .2016. Biological control of Phomopsis leaf blight of brinjal (*Solanum melongena L.*) with combining phylloplane and rhizosphere colonizing beneficial bacteria. Biological Control. 101: 123-129.

Sadasivam S & Manikam A. 1996. Biochemical Methods, 2nd edition. New Age International Pvt. Ltd., New Delhi. 2:124-126.

Shahzad S Rajput AQ and Khanzada MA. 2018. Effect of different organic substrates and carbon and nitrogen sources on growth and shelf life of *Trichoderma harzianum*. Journal of Agricultural Science and Technology. 16:731-745.

Shimu SA. 2023. Formulation of *Bacillus cereus* HSTUB 17 for the management of Anthracnose of chilli. Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Sivakumar G, Rangeshwaran R and Sriram S. 2011. Screening and identification of potential Bacillus spp. for the management of bacterial wilt of brinjal. Journal of Biological Control. 25 (3): 229-235.

Silva RN, Monteiro VN, Steindorff AS, Gomes EV, Noronha EF. (2019). Trichoderma /pathogen/plant interaction in pre-harvest food security. Fungal Biology. 123(8):553-583.

Saikia S, Dutta H, Saikia D & Mahanta CL. 2012. Quality characterization and estimation of phytochemicals content and antioxidant capacity of aromatic pigmented and non-pigmented rice varieties. Food Research International. 46(1):334-340.

Surovi TA. 2022. Development of formulated *Serratia marcescens* HSTUB 8 and *Entrobacter ludwiggi* HSTUB 16 for the Eco-friendly management of *Phomopsis vexans*. Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Sumoni A. 2023. Formulation of *Enterobacter cloacea* HSTUB 12 for the management of anthracnose of chilli (*Capsicum annum* L.). Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Thompson CH and Kelly CW. 1957. Vegetable Crops. Mcgraw-Hill Book Company. New York. 501.

Thesiya MR, Rakholiya KB and Lokesh R. 2020. Isolation, Cultural and Morphological Characterization of *Phomopsis vexans* (Sacc. And Syd.) Hartr, causing Stem Blight and Fruit Rot of Brinjal. International Journal of Current Microbiology and Applied Sciences. 9(7):2851-2859.

Tumpa F, Sultana A, Alam M, Khokon M. (2017). Bio-stimulation by seed priming with Bacillus subtilis for suppressing seed-borne fungal pathogens of vegetables in Bangladesh. Journal of Bangladesh Agricultural University. 14(2): 177-184.

Udayashankar AC, Nayaka C, Archana B, Laksmeesha TR, Niranjana SR, Lund OS, Prakash HS. 2019. Specific PCR-based detection of *Phomopsis vexans* the cause of leaf blight and fruit rot pathogen of *Solanum melongena L*. Letters in Applied Microbiology. 69(5): 358–365.

Vos C M, De Cremer K, Cammue BP, De Coninck B. 2015. The toolbox of *Trichoderma spp*. in the biocontrol of *Botrytis cinerea* disease. Molecular Plant Pathology. 16(4):400-412.

White T, Bruns T, Lee S, Taylor J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. New York, Academic Press. 315–322.

Xie F, Zhou H, Xiao R, Zhang C, Zhong J, Zhou Q, Liu F, Zhu H. 2022. Discovery and exploration of widespread infection of mycoviruses in *Phomopsis vexans*, the causal agent of phomopsis blight of eggplant in China. Frontiers in Plant Science. 10(13):996862.

Xu Y, Chen M, Zhang Y, Wang M, Wang Y, Huang Q, Wang X, Wang G. 2014. The phosphotransferase system gene ptsI in the endophytic bacterium *Bacillus cereus* is required for biofilm formation, colonization, and biocontrol against wheat sharp eyespot. FEMS Microbiology Letters. 354 :142–152.

Zhang YP, Uyemoto, Kirkpatrick BC. 1998. A small scale procedure for extracting nucleic acids from woody plants infected with various phytopathogens for PCR assay. Journal of Virological Methods. 71: 45–50.

Zheng YK, Miao CP, Chen HH, Huang FF, Xia YM, Chen YW, Zhao LX. 2017. Endophytic fungi harbored in Panax notoginseng: Diversity and potential as biological control agents against host plant pathogens of root-rot disease. Journal of Ginseng Research. 41(3):353-360.

Zhou H, Ren ZH, Zu X, Yu X, Zhu H, Li X, Zhong J, Liu E. 2021. Efficacy of Plant Growth-Promoting Bacteria *Bacillus cereus* YN917 for Biocontrol of Rice Blast. Frontiers in Microbiology. 12: 684888.