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Field efficacy of brinjal wilt with potential fungicides, biocontrol agents, and plant extracts

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Abstract

Two fungicides viz Carbendazim (@ .1%) and Mancozeb (@ .2%), one biocontrol agent (*Trichoderma viride*) @ 10^8 conidia/ml, and two plants extracts (*Allium sativum* and *Allamanda cathertica*) @15% were investigated against wilt disease of brinjal under field condition. Treatments were evaluated on three varieties susceptible to wilt disease of brinjal. The field trial revealed that Carbendazim showed the highest (V_1=80, V_2=76.8, V_3=78.3) percent reduction of wilt disease, and its efficiency different significantly from the rest of the other treatments. Next *Trichoderma viride* gave the second-highest (V_1=68, V_2=60.6, V_3= 65.2) percent followed by Mancozeb (V_1=60, V_2=46.6, V_3=56.6) percent reduction. Among the two botanical extracts applied *Allium sativum* extract showed (V_1=39.9, V_2=23.1, V_3 =34.7) percent and *Allamanda cathertica* (V_1=27.8, V_2=16.2, V_3=21.6) percent reduction over control. Present research revealed that systemic and sulfur-containing fungicides, bi-agent, and plant extracts have the potential to control wilt disease of brinjal.

Keywords: Brinjal, wilt disease, Fungicides, Biocontrol agent, Plant extracts.

1. Introduction

Brinjal (*Solanum melongena* L.) is one of the most important vegetables that is cultivated around the world belongs to the family Solanaceae. India is considered to be the center of origin of cultivated brinjal from where it spread to other parts of the world. In India, brinjal is mainly grown in the states like West Bengal, Assam, Orissa, Bihar, Gujarat, Maharastra, Andhra Pradesh, and Karnataka, etc. The crop is susceptible to various biotic and abiotic stresses at different stages of growth and development, among them the most significant being wilt disease. It suffers from more than 20 different diseases of which *Fusarium* wilt is the most destructive one throughout the world (Dwivedi & Enespa, 2013). Various workers in different countries of the world evaluated the efficacy of various fungicides and plant extracts against *Fusarium* spp. under laboratory and field conditions (Joseph et al.,2008; Parsa et al.,2013). Membersof *Fusarium* species are ubiquitous soil-borne pathogens of a wide range of horticultural and food crops which cause destructive vascular wilts, rots, and damping-off diseases (Bodah, 2017) *Fusarium oxysporum* is an important, soil-inhabiting ubiquitous fungus, known for its phylogenetic diversity (Xiong & Zhan, 2018).

2. Materials and Methods :

Based on good performance showed at *in vitro* tests two fungicides, one bio-agent, and two plants extracts were selected for their efficacy in controlling wilt disease under natural fields condition.

2.1 Isolation, purification, and identification of *Fusarium oxysporum*.

Wilt disease of brinjal plants was collected from farmers' fields and brought to the pathological laboratory of Botany Department, Gauhati University, Guwahati, Assam. The infected parts were surface sterilized with 0.01% mercuric chloride ($HgCl_2$) solution for 60 seconds and washed 4-5 times in sterilized distilled water to remove the dust particles and surface contaminant. Excess moisture with the bits was removed by placing on sterilized filter paper. The pieces were then transferred to sterilized Petri plates containing Potato Dextrose Agar (PDA) and then incubated at room temperature (28°±1°C). The cultures were purified by the hyphal tip method on PDA 28°±1°C. The pure culture of isolated fungus was prepared by the single spore technique (Riker & Riker, 1936). The pure cultures were maintained on PDA slants and kept in the refrigerator at 4±1°C after plugging.

2.2 In vitro evaluation of fungicides against Fusarium oxysporum

Five fungicides viz. Carbendazim (Bavistin 50 WP), Captaf (Captan -50 wp), Copper oxychloride (Blitox -50 W), Mancozeb (Dithan M-45), and Ridomil MZ-72 (Table 1) at three different concentrations i.e. 0.10, 0.15 and 0.2 percent were tested against the mycelial growth of *F.oxysporum* by Poisoned food technique (Nene & Thapliyal, 1982). Required quantity of individual fungicide was added separately into molten and cooled potato dextrose agar to get the desired concentration of fungicides. 20 ml of the poisoned medium was poured into sterile Petri plates. Mycelial discs of seven mm size from the actively growing culture of the test fungi were cut out by a sterile cork borer and one of such discs was placed aseptically at the center of each agar plate. Control was maintained without adding any fungicides to the medium. Each treatment was replicated thrice. The plates were then incubated for seven days at 28°±1°C and radial colony growth was measured. The percentage of growth inhibition was calculated by using the formula (Vincent, 1947).

$$I = \frac{C-T}{C} \text{ X } 100$$

Where, I= Percent inhibition

C = Radial growth in control

T = Radial growth in treated petriplates.

2.3 In vitro evaluation of biocontrol agents against *Fusarium oxysporum*

The antagonistic activity of *T.harzianum* and *T.viride* was tested against *F. oxysporum* by dual culture technique (Dhingra & Sinclair, 1985). Both biocontrol agents and test fungi were cultured on Potato Dextrose Agar to get fresh and active growth of the fungus. To study the antagonistic activity, the mycelial discs (7 mm) of the test fungus were inoculated at one end of the Petri plates and the potential antagonistic fungus to be screened was placed opposite to it on the other end. Each treatment was replicated

three times. The plates were incubated at 28°±1°C and the zone of inhibition were recorded by measuring the clear distance between the margin of the test fungus and the antagonistic organism. The colony diameter of the pathogen in the control plate was also recorded. The percent inhibition of the growth was calculated using the formula given by (Vincent, 1947). Petri plates inoculated only pathogen served as control.

Percent inhibition:

$$I = \frac{C-T}{C} \text{ X } 100$$

Where I = Percent inhibition
C = Radial growth in control
T=Radial growth in treatment

2.4. In vitro evaluation of plant extracts against *F.oxysporum*

Six antifungal fresh plant materials (Table 2) viz. leaves/cloves/roots/seeds/barks were collected and washed first in tap water and then in distilled water. A hundred grams of fresh sample was chopped and then crushed in a surface-sterilized pestle and mortar by adding 100 ml sterile water (1:1 w/v). The extract was filtered through two layers of muslin cloth. Finally, the filtrate thus obtained was used as a stock solution. To study the antifungal mechanism of plant extracts, the poisoned food technique was used (Nene & Thapliyal, 1982). 5, 10, and 15 ml of stock solution were mixed with 95, 90, and 85 ml of sterilized molten PDA medium respectively to get 5, 10, and 15 percent concentration poisoned media. The medium was thoroughly shaken for uniform mixing of extract. Mycelium of 7 mm size discs from the periphery of actively growing culture was cut out by sterile cork borer and one such disc was placed on the center of each poisoned PDA plate. Controls were also maintained by growing the pathogen on PDA plates. The plates were then incubated at 28±1°C temperature. The radial growth was taken when maximum growth occurred in the control plates. Each treatment was replicated thrice. The efficacy of plant extracts was expressed as the percent of radial growth over the control which was calculated by using the following formula (Vincent, 1947).

$$I = \frac{C-T}{C} \text{ X } 100$$

Where, I = Percent inhibition
C = Radial growth in control
T= Radial growth in treatment
The data were subjected to analysis of variance (ANOVA) for the determination of the main and interactive effects of treatments.

2.5 Preparation of inoculums

Fusarium oxysporum was first grown on a PDA medium and incubated at 28°±1°C for 7 days. One mycelial disc of the fungus was inoculated in 500 ml Erlenmeyer flasks

containing 100 ml of Potato Dextrose Broth (PDB) medium to enhance more sporulation. Then the flasks were incubated at 25°C in a shaking incubator with a periodic shaking at 170 RPM and the spores were collected after 7days.To remove the mycelial mat the culture was poured through a cheese cloth and the final concentration was adjusted at $1x10^6$conidia/ml counted using a hemocytometer.

2.6. Preparation of pot

Earthen pots (30 cm in diameter and 45 cm in height) were used for the experiments. The pots were washed with sterilized water followed by 70 percent alcohol. Garden soils were collected broken into powdery form and removed root bits and other foreign materials. Then the soil was mixed with decomposed cow dung and sand in a ratio of 2:1:1 and sieved through a 4 mm sieve and then sterilized in an autoclave at 15 lb/ $inch^2$ pressure for one hour for three successive days.

2.7. Inoculation of *Fusarium oxysporum*

Brinjal Seeds (cv. Pusa Kranti, Pusa Purple Oval, and Pusa Purple Long) were collected from the central seed godown, Department of Agriculture, Government of Assam, Guwahati. Seeds were surface sterilized by dipping them in 10% sodium hypo chloride separately for 1 min. followed by 70% alcohol for 30 seconds and finally, they were washed several times with sterile distilled water. They were allowed to grow on sterilized sand in earthen flat pots. One-month-old healthy seedlings were selected to receive treatment with *F.oxysporum* f. sp. *melongenae*. All the seedlings except the control were treated with *F.oxysporum* f.sp *melongenae*. Two hundred ml of sterile 7 days old PDB culture @ $1x10^6$ conidia/ml were taken in an Erlenmeyer's flask, the healthy brinjal seedlings were dipped in the PDB culture and the seedlings were then planted to the earthen pot.

2.8. Root-dip method

Healthy brinjal seedlings at the six-leaf stage were uprooted from sterilized soil; wounded roots were submerged for10 min. in a conidial suspension (10^6conidia/ml), while control plants were dipped in sterile tap water. Seedlings were then transplanted into sterilized pots. Symptoms were observed on the plants after inoculation of 3 weeks and the pathogens were re-isolated. This was carried out following the methods (Biles & Martin, 1989).

2.9. Preparation of suspension of *T.viride*

Spore suspension of *T.viride* was prepared from 15 days old culture grown in PDA slants. The spores were suspended in sterile distilled water and the concentration was adjusted to 10^8 conidia/ml using a hemocytometer.

2.9.1. Root treatment

For root treatment, 30 days old brinjal seedlings raised from treated as well as untreated seeds were uprooted and the soil particles adhering to it were removed. The

roots were then dipped in different treatments separately for 30 min and dried for 1 hr. These were then transplanted into the main field following (Raji & Lekha, 2003).

2.9.2. Evaluation of fungicides, biocontrol agent, and plant extracts against *F.oxysporum* under field conditions

The most effective fungicides, biocontrol agent, and plant extracts and their most effective doses were evaluated under field conditions. The study was conducted in the research area of CPCRI, Kahikuchi Guwahati, Assam. The area is used for research trials on different crops. The Experimental area was plowed twice by a tractor-drawn disc plow up to a depth of about 20 cm (Fig 2). Then properly leveled and stubbles were removed by manual labors. All the recommended fertilizers doses such as FYM @ 10 t/ha, N 50 kg/ha, P_2O_5 50 kg/ha, and K_2O 50 kg/ha were applied during the period of study. Three brinjal varieties, Pusa Kranti, Pusa Purple Long, and Pusa Purple Round highly susceptible to wilt disease were sown. The experiment was carried out following a Randomized block design (RBC) with three replications. (Fig.1) Each plot size was 3 m x 1.5 m where row to row and plant to plant distance 75 cm and 60 cm respectively. Seedlings raised from the surface-sterilized certified seeds were transplanted into plots. In each plot, there were 12 plants of one variety. The seedlings were treated with fungicides, plant extracts, and bio-agent in the plots assigned for their treatment before transplantation. Five ml. of 7 days old culture of *Fusarium oxysporum* f.sp. *melongenae* @ $1x10^6$ conidia/ml was poured after 7 days of transplantation of the seedlings near the root system 3 cm below of the topsoil except for the control. The treatments were used as follows, T_1 = Control, (without *F.oxysporum*), T_2 = Inoculated control only *F.oxysporum*, T_3 = Soil treatment + root treatment with Bavistin @ 0.1% + *F. oxysporum*, T_4 = Soil treatment + root treatment with Mancozeb @ 0.2% + *F. oxysporum*, T_5 = Soil treatment + root treatment with *T.viride* @ 10^8 conidia/ml + *F. oxysporum*, T_6 = Soil treatment + root treatment with *Allium sativum* @ 15% + *F. oxysporum*, T_7 = Soil treatment + root treatment with *Allamanda cathertica* @ 15% + *F. oxysporum*.

Soil treatments with fungicides were applied to the soil one month before transplantation of seedlings and subsequent two sprays were given at 9 days intervals (500 ml/plot) as per (Chakraborty et al., 2009). Soil drenching with *T. viride* (10^8conidia/ml) @ 1 lit. /plot was carried out as per the methods (Uddin, 2011) and soil treatments with plant extract @15% doses (500 ml/plot) to the specific plot after the first application two successive applications were made at 7 days interval before transplantation as per the method (Chakraborty et al., 2009). One check plot was maintained that received distilled water.

Percent of wilt incidence was recorded by the following formula:

$$\text{PDI} = \frac{\text{No. of infected plants}}{\text{Total number of plants}} \text{ X } 100$$

The data were expressed as mean values ± SD. The mean values were analyzed by one-way ANOVA. Significant differences between the means of parameters were determined ($P < 0.05$).

3. Results :

ANOVA of in vitro evaluation of fungicidal treatments revealed that the individual effects of treatments and concentrations were found significant (Table3). Fungicides in all the concentrations, i.e. 0.1%, 0.15%, and 0.2%, significantly decreased colony growth of *F. oxysporum* compared to control. Out of five fungicides, two fungicides Carbendazim and Mancozeb were significantly superior to other fungicides. Carbendazim inhibited the colony growth of 98.2% at .2%, 96.6% at .15% and 95.3% at .1% respectively. Similarly, Mancozeb showed 89% inhibition at .2%, 87% at .15% and 74.4% at .1% respectively. Ridomil was found significantly less effective against *F. oxysporum* compared to other treatments. (Table 4).

In vitro evaluation of biocontrol agent revealed that the antagonistic activity of *T.viride* was found more effective than *T.harzianum*. Maximum inhibition was observed (83%) by *T.viride* followed by *T.harzianum* (70.33%). Statistically, the treatment means are found to significantly differ at P=.002(≤.05) (Table 5).

ANOVA of in vitro evaluation of plant extracts indicated that the individual effects of treatments and concentrations were significant (Table 6). Plant extracts having different concentrations significantly inhibited colony growth. Plant extracts of *A.sativum* and *A.cathertica* gave the best result compared to other plant extracts. *A.sativum* and *A.cathertica* at 5%, 10% and 15% concentration inhibited the mycelia growth 70.88%, 83% and 100% and 55.6%, 71.1% and 84% respectively (Table 7). Plant extracts of *R.communis* and *T.arjuna* remained second good. Extracts of *C.alata* showed less effective mycelial growth. All plant extracts were significantly more active at their higher concentrations.

Field evaluation with the different treatments among the three varieties revealed that 100 percent disease incidence was recorded in inoculated control in all the three varieties, which were significantly higher compared to other treatments. It was observed that all the treatments showed a significant ($P \leq 0.05$) difference in their efficacy to control the wilt disease of brinjal under natural field conditions (Table 8). Among the treatments applied, Carbendazim showed the lowest (V_1=8.3, V_2=8.3, V_3=8.3) incidence (PDI) of wilt disease, and its efficiency different significantly from the rest of the other treatments. *Trichoderma viride* gave the second lowest (V_1=13.3, V_2=14.1, V_3=13.3) disease incidence (PDI) followed by Mancozeb (V_1=16.6, V_2=19.1, V_3=16.6). Among the two botanical extracts applied, *Allium sativum* extract showed (V_1=25, V_2=27.5, V_3=25) incidence (PDI) while the extracts of *Allamanda cathertica* recorded (V_1 =30, V_2 =30, V_3=30) incidence (PDI) of wilt disease, which were noticed significantly better overall control (V_1=41.6, V_2=35.8, V_3 =38.3) (Table 9). All the treatments used in the present experiment reduced the incidence of wilt disease over control. Maximum reduction in wilt incidence (V_1=80, V_2=76.8, V_3=78.3) percent was observed in Carbendazim followed by *T.viride* (V_1=68, V_2=60.6, V_3= 65.2) percent and Mancozeb (V_1=60, V_2=46.6, V_3 = 56.6) percent. Botanicals extracts were observed less effective and could only be caused by *Allium sativum* (V_1=39.9, V_2=23.1, V_3 =34.7) percent and *Allamanda cathertica* (V_1=27.8, V_2=16.2, V_3=21.6) percent reduction over

control. The results indicated that Carbendazim, *T.viride,* and Mancozeb were highly effective in controlling the wilt disease of brinjal.
(Fig.4).

4. Discussion

Significant control of wilt disease by Carbendazim in vivo condition is considered as most effective fungicides for controlling of *Fusarium* wilt disease of brinjal. It is observed lowest incidence with the highest reduction of the disease under natural fields condition of all the three varieties is due to its systemic ability which allowed the fungicides to kill the fungus in established infection. The present finding is in agreement with the findings of (De & Chaudhary,1999). Carbendazim (0.1%) was most effective and recorded the least wilt incidence 9.1% over control 57.75% (Sundaramoorthy & Balabaskar, 2013). Successful control of wilt disease through this systemic fungicide might also have resulted because of its good translocation into the tissues of the host. Previous researches have shown that Systemic fungicides are taken up and redistributed through the xylem vessels that translocation in the system of the plant. Carbendazim breaks down the metabolism, delaying the growth and development of the *Fusarium* wilt-pathogen. It also strongly binds with chemical force to microtubules of pathogen and disturbs its ionic concentrations (Iqbal et al., 2010; Naik et al., 2007). Mancozeb is a dithiocarbamate non-systemic agricultural fungicide with a multi-site, protective action on contact. It was concluded that Mancozeb at 0.2% concentration was effective in inhibiting wilt pathogen growth increased plant growth, HR, and offered considerable protection *in vitro* and greenhouse studies (Naziya & Sharada, 2018).

Disease control by *T.viride* may be due to the presence of antifungal metabolites and enzymes produced by this biocontrol agent is cellulose, β-1,3-glucanase, pectinase, and amylase and proteases and chitinase have been reported to be produced by biocontrol agents (Naglot et al., 2015). It has been reported that different species of *Trichoderma* in a plant's rhizosphere improved plant defense against several pathogenic organisms such as viruses, bacteria, and fungi, by stimulating the initiation of different resistance mechanisms mainly encompassing induced systemic resistance (ISR), hypersensitive response (HR) and systemic acquired resistance (SAR) (Harman et al., 2004).

Plant extracts can induce systemic Acquired Resistance (SAR) and control pathogen (Walters et al., 2015). Garlic extracts have been shown to enhance physiology and increase the defense responses against fungal infection (Hayat et al., 2018a). The garlic extracts primarily compose organosulfur compounds such as allicin, diallyl disulfide (DADS), diallyl trisulfide, etc. Garlic biochemicals are recognized to have potent antimicrobial properties by numerous researchers (Hayat et al., 2016; Martins et al., 2016). The bio-activity of aqueous garlic extracts increases the growth and developmental responses of eggplant and induces the defense response of eggplant (Ali et al., 2021). Similarly,from*A.cathertica* contains phenolic compounds, flavonoids, alkaloids, steroids, terpenes, lactones, which have been isolated and proved to be effective against the different fungal pathogen (Petricevich & Vargas, 2019). Aromatic plants extracts contain secondary metabolites like alkaloids, quinines, flavonoids, glycosides, saponins, tannins, and terpenoids that control plant disease (Balakumar et al., 2011). Extracts of *Allium sativum* and *Allamanda* leaf controlled *Fusarium* wilt

disease and increase the yield of tomatoes in field conditions reported (Khatun et al., 2020)

Conclusion :

The present research has shown that the chemical fungicide Carbendazim (Bavistin 50 WP) was found best effective among the treatments for controlling the *Fusarium* wilt disease of brinjal. Moreover, *Trichoderma viride* was also found effective against the disease. Further, mild severities of wilt disease can be controlled using plant extracts.

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References

1. Ali M, Ahmad H, Hayat S, Ghani MI, Amin B, Atif MJ, Wali K, Cheng Z (2021). Application of garlic allelochemicals improves growth and induces defense responses in eggplant (*Solanum melongena*) against *Verticillium dahlia*. *Ecotoxicology and Environmental Safety,* 215 112132www.elsivier.com/locate/ecoenv.
2. Balakumar S, Rajan S, Thirunalasundari T, Jeeva S (2011). Antifungal activity of *Aegle marmelos* (L.) Correa (Rutaceae) leaf extract on dermatophytes. *Asian Pacific Journal of Tropical Biomedicine,* 1 (4):309-312.
3. Biles CL, Martin RD (1989). Local and systemic resistance induced in watermelons by formae specials of *Fusarium oxysporum*. *Phytopathology,* 79: 856-860.
4. Bodah ET (2017)**.** Root rots diseases in plants: a review of common causal agents and management strategies. *Agri. Res. Tech,* 5 (3):555-661
5. Chakraborty MR, Chatterjee NC, Quimio TH (2009). Integrated Management of *Fusarial* wilt of Eggplant (*Solanum melongena*) with soil solarization. *Mycologia Aplicada International,* 21 (1): 25-36.
6. De KR, Chaudhary RG (1999). Biological and chemical seed treatment against lentil wilt*. LENS Newsletters,* 26 (1-2): 28-31.
7. Dhingra OD, Sinclair JB (1985). *Basic Plant Pathology Methods*. CRC press, Florida p. 325.
8. Dwivedi SK, Enespa P (2013). Studies on *Fusarial* wilt pathogen of two vegetable crop fields with emphasis on physico-chemical properties. *Intl. J. Agron. Plant. Prod.,* 4(9): 2130-2137.
9. Harman GE, Howell CR, Viterbo A, Chet I, Lorito M (2004). *Trichoderma* species opportunistic, a virulent plant symbionts. *Nat. Rev. Microbiol,* 2:43–56.
10. Hayat S, Cheng Z, Ahmad H, Ali M, Chen X, Wang M. Garlic from remedy to stimulant (2016). Evaluation of antifungal potential reveals diversity in Phytoalexin allicin content among garlic cultivars; allicin containing aquous garlic extracts trigger antioxidants in Cucumber. *Front.Plant Sci,* 7:1235.

11. Hayat S, Ahmad H, Ali M, Hayat K, Khan MA, Cheng Z (2018a). Aquous garlic extracts as a plant biostimulant enhances physiology , improves crop quality and metabolites abundance and prime the defense responses of receiver plants. *Appl.Sci*, 8:1505.

12. Iqbal LM, Pervez A, Ahmad S, Iftikhar Y, Yasin M, Nawaz A, Ghazanfar MU Dasti AA, Saleem A (2010). Determination of minimum inhibitory concentrations of fungicides against fungus *Fusarium mangiferae. Pak. J. Bot.* , 42(5): 3525-3532.

13. Joseph B, Dar MA, Kumar V (2008). Bioefficacy of plant extracts to control *Fusarium oxysporium* f. sp. *melongenae* incitant of brinjal wilt. *Global J. Biotech. & Biochem.,* 3(2): 56-59.

14. Khatun MJ, Khalequzzaman KM, Naher MS, Neela FA (2020). Management of *Fusarium* wilt of tomato by botanicals and biocontrol agents and their effect on yield. *Bangladesh J. Bot*., 49(1):71-74. 27.

15. Martins N, Petropoulos S, Ferreira ICFR (2016). Chemical composition and bioactive compound of garlic (*Allium sativum* L.) as effected by pre and post harvest condition: a review. *Food Chem,* 211: 41-50.

16. Naglot A, Goswami S, Rahman I, Shrimali DD, Yadav, KK, Gupta VK, Rabha AJ, Gogoi HK, Veer V (2015). Antagonistic Potential of Native *Trichoderma viride* Strain against Potent Tea Fungal Pathogens in North East India. *Plant Pathol J*, 31(3):278-289.

17. Naik MK, Madhukar HM, Rani GSD (2007). Evaluation fungicides against *Fuarium solani*, the casual agent of wilt of chilli. *J. Veg. Sci*, 34(2):173-176.

18. Naziya B, Sharada MS (2018). Inhibitory effects of Mancozeb on growth and stimulation of resistance against Fusarium wilt of brinjal. *The Bioscan,* 13(1):285-290.

19. Nene YL, Thapliyal PN(1982). Fungicides in plant Diseases control. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi p.163.

20. Parsa S, Sahi ST, Jabbar A, Rehman A, Riaz K, Hannan A (2013). Chemical and biological management of *Fusarium oxysporium* f. sp. *melongenae*. *Pak. J. Phytopathol*, 25(2):155-159.

21. Petricevich VL, Vargas RA (2019). *Allamanda cathartica*: A Review of the Phytochemistry, Pharmacology, Toxicology, and Biotechnology. *Molecules,* 24(7):1238

22. Raji P, Lekha BN (2003). *Pseudomonas influorescence* for enhancing plant growth and suppressing sheath blight of rice. 6th International PGPR workshop 5-10 October, Calicut, India.

23. Riker AJ, Riker RS (1936). Introduction to research on plant disease.John's Swift Co.Inc., St.Louis, Chicago, New York, India p.117.

24. Sundaramoorthy S, Balabaskar P (2013). Bio-control efficacy of *Trichoderma* spp against wilt of tomato caused by *Fusarium oxysporum* f.sp. *lycopersici*. *Journal of Applied Biology and Biotechnology,* 1 (3):36-40.

25. Uddin MM, Akhtar N, Islam MT, Faruq AN (2011). Effect of *Trichoderma harzianum* and some selected soil amendments against damping-off disease complex of potato and chilly. *The Agriculturist,* 9 (1 and 2):106-116.

26. Vincent JM (1947). Distortion of fungal hyphae in presence of certain inhibitors. *Nature*. **150**:850.

27. Walters DR, Newton AC, Lyon GD (2015). Induced resistance: Helping plants to help themselves. Biologist 52:28-33.
28. Xiong W, Zhan A (2018) Testing clustering strategies for metabarcoding-based investigation of community-environment interactions *Mol. Ecol Res* , pp.1-13.

Table 1. Details of fungicides used in research trials

Sl. No.	**Trade Name**	**Common Name**
1	Carbendazim	Bavistin 50 WP
2	Captaf	Captan -50 wp
3	Copper oxychloride	Blitox -50 W
4	Mancozeb	Dithan M-45
5	Ridomil MZ-72	Metalaxy-M+chlorothalonil

Table 2**.** Plant materials used against *Fusarium oxysporum*

Sl. No.	**Botanical name**	**Common name**	**Family**	**Parts used**
1	*Allamanda cathertica* L.	Allamanda	Apocynaceae	Leaves
2	*Allium sativum* L.	Garlic	Liliaceae	Bulb
3	*Cassia alata* L.	Dadmordan	Caesalpinaceae	Leaves
4	*Lantana camara* L.	Lantana	Euphorbiaceae	Leaves
5	*Ricinus communis* L.	Castor	Euphorbiaceae	Leaves, Seeds & Roots
6	*Terminalia arjuna* W & A.	Arjun	Combretaceae	Bark

Table. 3. Analysis of variance (ANOVA).

Source of variations	Sum of squares	df	Mean square	F	Sig.
Between Groups	5147.869	4	1286.967		
Within Groups	166.787	10	16.679	77.162	0.000
Total	5314.656	14			

Significant at 1% level, P = .000 (≤ .01)

Table.4. Effect of different concentrations of fungicides on mycelial growth of *Fusarium oxysporum* f.sp.*melongenae*

Sl. No.	Fungicides	Percent inhibition of mycelial growth			
		Concentration (%)			Mean ± SE
		0.1	0.15	0.2	
1.	Carbendazim	95.3	96.6	98.2	96.70 ± 0.83
2.	Captan	74.7	78	80.6	77.76 ± 1.70
3.	Copper oxychloride	80.7	81.8	83.0	81.83 ± 0.66
4.	Mancozeb	74.4	87.0	89.0	83.46 ± 4.56
5.	Ridomil	39.5	40.0	44.8	41.43 ± 1.68
Mean		72.9	76.6	79.1	

Values shown are the mean ± SE of 3 replicates.

Table.5. Effect of two species of *Trichoderma* on mycelial growth of *Fusarium oxysporum* f. sp. *melongenae.*

Sl. No.	*Trichoderma* species	Percent inhibition of mycelial growth
1.	*Trichoderma harzianum*	70.33 %
2.	*T. viride*	83 %

After performing 'test' the treatment means is found to significantly differ at p = 0.002(≤ .05)

Table. 6. Analysis of variance (ANOVA).

Source of variations	Sum of squares	df	Mean square	F	Sig.
Between Groups	5102.062	7	728.866		
Within Groups	1183.610	16	73.976	9.853	0.000
Total	6285.671	23			

Significant at 1% level, P = 0.000 (≤ 0.01).

Table.7.Effect of different concentrations of plant extracts on mycelial growth of *Fusarium oxysporum* f. sp*. melongenae.*

Sl. No.	Plant extracts	Percent inhibition of mycelial growth			
		Concentration (%)			Mean ± SE
		5	10	15	
1.	*Allium sativum* (Bulb)	70.88	83	100	84.62 ± 8.44
2.	*Allamanda cathertica* (Leaf)	55.6	71.1	84	70.23 ±8.20
3.	*Cassia alata* (Leaf)	28	35.1	41.4	34.83 ± 3.87
4.	*Lantana camara* (Leaf)	42.2	46.6	52.2	47.00 ± 2.89
5.	*Ricinus communis* (Leaf)	44.4	49.3	55.	49.70 ± 3.18

6.	*R.communis* (Roots)	58.4	60.8	65.4	61.63 ± 2.14
7.	*R.communis* (Seeds)	56.6	64.1	67	62.56 ± 3.09
8.	*Terminalia arjuna* (Barks)	43	49.1	54.4	48.83 ± 3.29
Mean		49.8	57.38	65	

Values shown are the mean ± SE of 3 replicates.

Table 8. Analysis of variance (ANOVA).

Source of variance	Sum of squares	df	Mean square	F	Sig.
V_1 Between Groups	253.619	6	42.270		
Within Groups	1.333	14	0.095	443.833	0.000
Total	254.952	20			
V_2 Between Groups	245.619	6	40.937		
Within Groups	3.333	14	0.238	171.933	0.000
Total	248.52	20			
V_3 Between Groups	252.000	6	42.000		
Within Groups	2.000	14	0.143	294.000	0.000
Total	254.000	20			

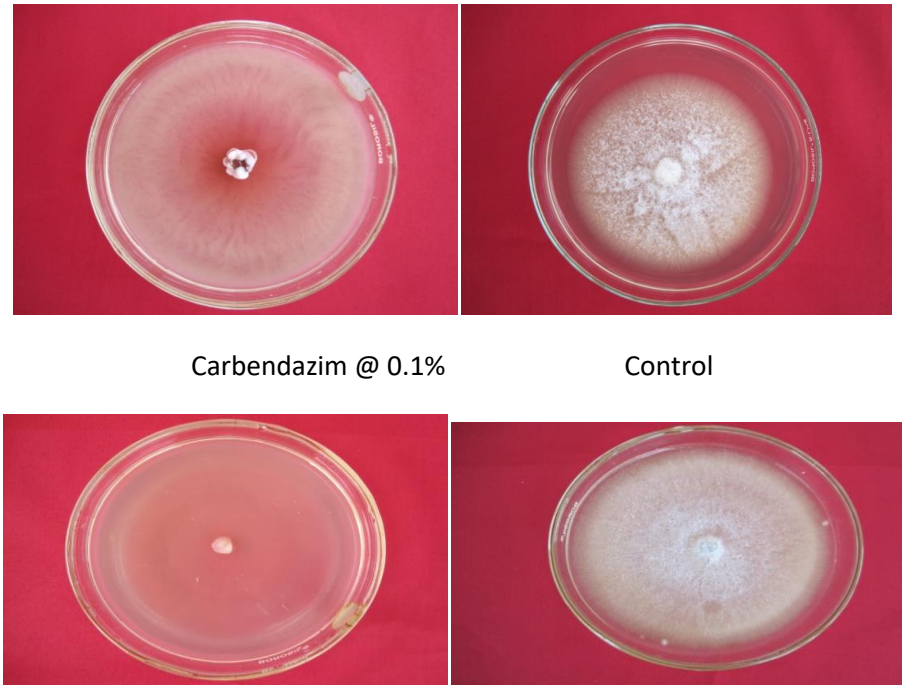
Significant at 1% level, P = 0.000 (≤ 0.01).

Table. 9. Field efficacy of fungicides, *Trichoderma viride* and botanical extracts against *Fusarium* wilt of brinjal under natural field condition of three varieties.

Varieties	Treatments	% disease incidence	% disease reduction over control
V_1	T_1 (Control)	41.6 a	00
	T_2 (Inoculated control)	100 b	00
	T_3 (Carbendazim)	8.3 c	80.0
	T_4 (Mancozeb)	16.6 d	60.0
	T_5 (*T.viride*)	13.3 d	68.0
	T_6 (*Allium sativum*)	25 e	39.9
	T_7 (*A. cathertica*)	30 f	27.8
V_2	T_1 (Control)	35.8 a	00
	T_2 (Inoculated control)	100 b	00
	T_3 (Carbendazim)	8.3 c	76.8
	T_4 (Mancozeb)	19.1 d	46.6
	T_5 (*T.viride*)	14.1 c d	60.6
	T_6 (*Allium sativum*)	27.5 e	23.1
	T_7 (*A. cathertica*)	30 a e	16.2
	T_1 (Control)	38.3 a	00
	T_2 (Inoculated control)	100 b	00

	T_3 (Carbendazim)	8.3 c	78.3
V_3	T_4 (Mancozeb)	16.6 d	56.6
	T_5 (*T.viride*)	13.3 d	65.2
	T_6 (*Allium sativum*)	25 e	34.7
	T_7 (*A. cathertica*)	30 f	21.6

Brinjal varieties: V_1 = Bhola, V_2 = Oval, V_3= Bihari ; values within the same column having a common letter (s) do not differ significantly ($P \leq 0.05$) by DMRT.



Carbendazim @ 0.1% Control

Allium sativum @15% Control

Fig.1. Inhibition of mycelial growth of *Fusarium oxysporum* by fungicides & plant extract using poisoned food technique.

Fig.2. Land preparation by tractor for brinjal cultivation.

Fig.4. Effect of fungicides, *Trichoderma viride,* and botanical extracts against *Fusarium oxysporum* f.sp.*melongenae* of brinjal on field condition.