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Biopesticides for crop growth and crop protection

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A B S T R A C T

Tablets made of garlic bulbs and allamanda leaves tremendously increased germination and reduced damping-off, seed rot, seedling blight and tip over of vegetables (egg-plant, tomato, chilli) in the nursery and leaf blight, anthracnose, fruit rot, root knot and leaf curl/mosaic of tomato and carrot in the field. Aqueous solution of garlic and allamanda tablet sprayed at 1:1, 1:2, 1:3, 1:3, 1:4, 1:5 conc. increased seed germination by 45-60%, completely eliminated damping-off, seedling blight and tip over and increased seedling vigour by 22-50%. The tablets retained the similar range of action over aging up to 90 days. Both garlic and allamanda tablets displayed similar inhibitory action against damping-off and seedling blight pathogens, *Phomopsis vexans* and *Sclerotium rolfsii*. In the field, garlic and allamanda spray reduced leaf blight severity by 84-86% and fruit rot by 91%. Severities of nematode and virus infection were also reduced significantly with allamanda spray. Active compounds in allamanda leaves have been separated and identified. Formulated trichoderma effectively controlled soil-borne diseases including root-knot nematode. Mahogany oil spray reduced infestation of stem borer, leaf hoppers of rice; shoot & fruit borer of brinjal and fruit flies of vegetables. Biopesticides (formulated trichoderma) and bio-agents (bracon, trichogramma, ladybird beetle) and sex pheromone are in the pipeline for commercial use.

***Keywords**:* Garlic and allamanda tablets, biopesticides, bioagents, vegetable diseases.

Introduction

Most vegetables (egg-plant, tomato, chilies, cole crops etc.) are needed to raise seedlings in the nursery for their transplantation in the field. In the nursery bed, diseases like seed rot, damping-off, tip over and seedling blight attack vegetable seedlings. These diseases cause germination failure, low germination rate, abnormal seedlings, damping-off and seedling death bringing heavy toll to the growers. Fungi and few bacteria and nematode cause most of these nursery diseases. Fungi like *Sclerotium rolfsii, Fusarium oxysporum, Phomopsis vexans, Rhizoctonia solani, Pyhtium* spp. and *Phytophthora* spp. are the main causes of the seedling diseases in the nursery. These fungi are mainly soil-borne, often carried by seeds and sometimes transmitted by seeds (*P. vexans* in egg-plant). Seed treatment followed by soil treatment is the options for the control of these diseases. If not controlled in the nursery, the seedlings carry the inocula to the field contributing to the development of field diseases like leaf blight and fruit rot. So vegetable diseases need to be controlled in two phases- in the nursery and in the field.

Use of host resistance is usually the most feasible and economical disease control strategy. However, crops and cultivars/varieties

resistant to those nursery diseases have never been available. Applications of chemical (mainly fungicides) in the nursery bed have been successful in combating seedling diseases. Chemical coated seeds and/or soils drenching with fungicides have been in long time use against those seedling debacles in the nursery. Use of pesticides as a whole is discouraged as it provokes environment (soil, air and water) pollution, and makes plant products to some extent unpalatable. Therefore, alternatives to pesticides are desired.

Plant health management is now considered as a young approach, which aimed at the proper use of IPM components with emphasis on environment, economics and social acceptance (Cook 2000). Understanding the mechanisms and exploration of bioagents and botanicals as biocontrol agents in our agro-ecosystem has got importance for plant health management. Many plants and plant products have been reported to be antimicrobials against plant pathogenic fungi (Bowers *et al.* 2000; Lawson *et al.* 1998; Grayer *et al.* 1994). Plant extracts might be a substantial alternative of chemical pesticides in controlling vegetable diseases in the nursery and in the field. The paper reports the use of bio-agents and botanicals for management of nursery diseases of egg-plant, tomato and field diseases of egg-plant, chili, okra and carrot.

Materials and Methods

Garlic (*Allium sativum* L) bulbs or allamanda (*Allamanda cathertica* L) leaves crushed with equal amount of water (1:1) in a mortar were blended and sieved through cheesecloth to get the extract. The extracts immediately mixed with starch material were put in a locally made frame to get the tablets prepared. The tablets were packaged in a self –adhesive cellophane bag and stored at room temperature (25 ± 2°C).

Bioassay of the tablets

Fungicidal properties of the tablets were evaluated against *P. vexans* and *Sclerotium rolfsii* using growth inhibition technique (Cup method and Disc method) (Islam 2001; Nene & Thaplial, 1993; McKeen *et al.* 1986). Inhibition of mycelial growth and sporulation was measured.

Seed treatment with tablets

Tablets were crushed and dissolved in water (tablet: water = 1:4 w/v) for 15 min. Seeds were soaked in the tablet solution (seed: solution= 1:1.5 w/v) for 30 min, liquid drained off, shade dried and sown in the soil. Tablet solution thus prepared was considered as 1:1, which was diluted in water to 1:2, 1:3, 1:4, and 1:5.

Sowing tablet treated seeds in the tray soil

Tray substratum was prepared by mixing soil, sand and decomposed cow dung in the proportion of 2:1:1 and sterilized with 4% formalin (40%) at 20 ml/kg of soil (Dasgupta 1998) and the prepared soil was heaped in square block. The soil heap was covered with a polyethylene sheet for 4 hours. The soil heap was then shoveled everyday for 7 days to give-off the gas. Surface sterilized plastic sheet (35 x 25 cm^2) was filled up with the sterilized soil. Seeds of egg-plant cv Dohazari G or tomato cv Marglove treated with garlic or allamanda and

untreated farmers' seeds (control) were sown. Watering was done to maintain soil moisture. Shade was provided to save the young and delicate seedlings from heavy shower and scorching sunlight. Two hundred seeds were sown in one tray and four replications were maintained in each treatment.

Soil drenching with tablets

Tablets solutions in different concentration were sprayed onto the root zone of young seedlings at 50ml/tray, repeated twice in one month.

Field spray of tablets

Tablet solutions prepared as described above were sprayed at flowering and fruiting stage as pre-inoculation (before 24 hr of inoculation) and post-inoculation sprays (after 24 hr of inoculation). The spraying was done with the help of a hand sprayer to cover whole surface of plant leaf, flower and fruits. An amount of 50 ml solution was sprayed in one plant. Precautions were taken to avoid drifting of spray materials to neighbouring plants with polythene barrier. All leaves and fruits in an egg-plant were inoculated with *P. vexans* before and after 24hr of spray with tablet solution. Spore suspension of *P. vexans* (10^7 spores/ml) was sprayed on the leaves and fruits of egg-plant with an atomizer at 70 ml/plant. The inoculated plants were kept covered with moist polyethylene bags for 24 hr.

Data collection

In the nursery, percentage seed germination, seed rot, damping off, seedling blight and tip over were recorded over a period of 14 days after emergence. After expression of symptoms on leaf and fruit in the field, data were collected at an interval of 10 days on percent leaf infection, percent flower infection, percent leaf area diseased and percent fruit area diseased.

Assessment of disease incidence and severity

Assessment of disease incidence and severity was calculated following the procedures and formula as described by Islam (2001) and Singh (1984).

Experimental Design and data analysis

Complete Randomized Design (CRD) was followed for the laboratory and the net house experiments. Randomized Complete Block Design (RCBD) was followed for all the field experiments. Compilation of the experimental data and analyses were done by the computer MSTAT program and following the statistical procedures of Gomez and Gomez (1993).

Costing

Costing of application of integrated approaches for management of Phomopsis blight and fruit rot of egg-plant was done based on the current market price of input, rate of hiring labour and agricultural machineries. Price of the field produce was determined on the basis of current market value. Estimation of Benefit Cost Ratio (BCR) was done according to Gittinger (1982) and Islam *et al.* (2004) using the following formula.

Identification of active compounds in Garlic bulbs and Allamanda leaves

Extract of garlic bulb and allamanda leaves were made in water as well as in a number of solvents (ranging from less polar to highly polar). The

solvents were diethyl ether, methylene chloride and ethyl alcohol. These refluxing extracts of methylene chloride were used in column chromatography to separate the compounds in garlic bulb and allamanda leaf. These refluxing extracts and the separated compounds were tested for their inhibitory effect against *Phomopsis vexans* and *Sclerotium rolfsii*. IR spectrum and ^{1}H-NMR and ^{13}C-NMR were taken to determine the functional groups and proton and carbon-skeleton (partial) of the compounds. The IR spectra were recorded as thin liquid film (Chloroform, $CHCl_3$) on a Perkin-Elmer 782 Spectrometer at BCSIR Laboratory, Dhaka. The ^{1}H-NMR and ^{13}C-NMR were recorded in $CDCl_3$ solvent and TMS as standard on a 400 MHZ Bruker, (Switzerland) Spectrometer.

Results

Bioassay of the tablets against Phomopsis vexans and Sclerotium rolfsii

Garlic tablet produced the largest inhibition zone (5.7 cm dia.) arresting the spore germination and mycelial growth of both *P. vexans* and *S. rolfsii* followed by that of allamanda tablet (5.5cm dia) in disc method. Similarly, both the tablets completely controlled the mycelial growth in cup method.

Seeds of tomato treated with garlic tablet solution at different conc. reduced seed-borne fungal infection showing a continued rise in reduction of seed-borne fungal infection with increase in conc. of tablet solution. At tablet conc. 1:3, seed-borne fungi like *Aspergillus* spp., *Penicillium* spp., and *Fusarium* spp. almost eliminated completely (Fig. 1).

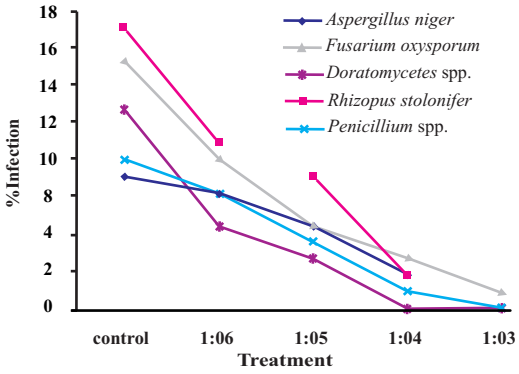

Fig 1. Effect of dose of garlic tablet on the incidence of seed-borne fungi of Tomato

Effect of Seed treatment with tablets on nursery diseases

Seeds treated with both garlic and allamanda tablets germinated faster and significantly in higher percentage than the non-treated seeds. Both the tablets retained disease inhibition efficacy up to 90 days after preparation. Concentration of tablet solution did not affect the efficacy. Seed germination varied from 78 - 100% against *P. vexans* and 80- 93% against *S. rolfsii* for different age and concentration of the tablet solution (Figure 2). No damping off or seedling blight or tip over were observed in the tray soil sown with tablet treated seeds against 4-5% damping off, 2-3% seedling blight and 1-2% tip over in untreated seeds. In *P. vexans* inoculated seeds, the damping off was 12% and it was 21 % in *S. rolfsii* inoculated seeds (Table 1).

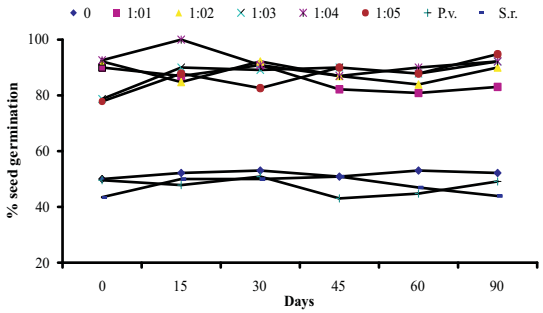

Fig 2. Effect of aging of garlic tablet at different concentrations on seed germination of eggplant

Beyond 90 days, the aging effect of tablets was observed to get declined. Seed germination percentage was continually reduced with time although the antimicrobial action of the tablets was retained up to 150 days (Figs. 3- 4).

Table 1.
Efficacy of garlic and allamanda tablets treatment of seeds of egg-plant enhancing seed germination and reducing seedling diseases in tray soil

Conc.	Seed germination (%)					Damping - off (%)				
	Fresh	15 days	30 days	45 days	60 days	90 days	Fresh	15 days	30 days	45 days	60 days	90 days
00	50.0	52.0	53.0	51.0	53.0	52.0	5.0	4.0	4.0	5.0	4.0	4.0
1:1	90.0	87.0	91.0	82.0	81.0	83.0	0.0	0.0	0.0	0.0	0.0	0.0
1:2	92.0	85.0	92.0	87.0	84.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0
1:3	78.5	90.0	89.0	90.0	88.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0
1:4	92.5	100.0	91.0	87.0	90.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0
1:5	78.0	88.0	82.8	90.0	88.0	95.0	0.0	0.0	0.0	0.0	0.0	0.0
P. v.	49.5	48.0	51.0	43.0	45.0	49.0	10.0	12.0	10.0	11.0	10.5	12.0
S. r.	43.5	50.0	50.0	51.0	47.0	44.0	12.0	21.0	17.0	13.0	17.0	16.0

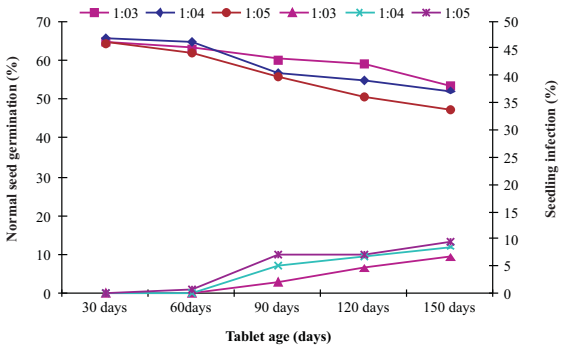

Fig 3. Effect of garlic tablet (different concentration) of different age on seed germination and seedling infection by *Phomopsis vexans*

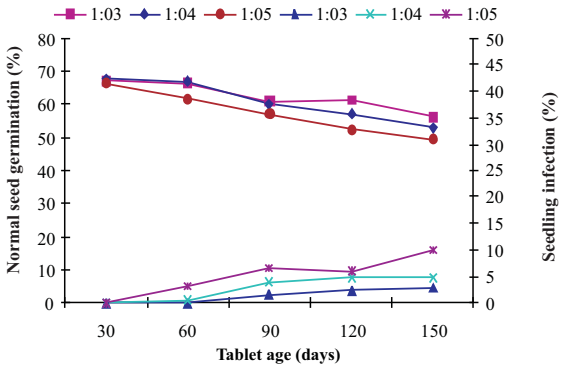

Fig 4. Effect of garlic tablet (different concentration) of different age on seed germination and seedling infection by *Sclerotium rolfsii*

The efficacy of garlic and allamanda tablets in enhancing seed germination and inhibiting nursery diseases were compared with other seed treating agents. The highest seed germination was recorded in garlic that was statistically identical with hot water treatment, Bavistin, allamanda, *Trichoderma harzianum* CP and *Trichoderma harzinum*-T22. The lowest seed germination but far better than control was recorded in *Trichoderma* sp. EP proceeded by vitavax-200. The damping off of seedlings was completely controlled by garlic that was statistically similar with the effect of hot water, allamanda and *Trichoderma harzianum* CP. In controlling tip over and seedling blight, the performance of the agents was in similar trend of damping off to some extent. Considering the overall effect it was revealed that the selected agents had the potentials to act against *Phomopsis vexans*/*Sclerotium rolfsii* in the nursery (Table 2).

Table 2.
Effect of seed treatment with different agents for controlling *Phomopsis vexans* in egg-plant seedlings in the net house

Treatments	Seed germination (%)	Damping-off (%)	Tip over (%)	Seedling blight (%)
Hot Water (56 °C 15 min)	85.50 ab	0.62 cd	1.00 fg	0.62 ef
Bavistin (0.1%)	87.00 a	1.50 b	1.25 eg	1.25 cd
Vitavax 200 (0.3%)	82.50 b	2.00 b	3.50 b	3.75 b
Garlic Tablet (1:1)	87.50 a	0.00 d	0.87g	0.00 f
Allamanda Tablet (1:1)	85.00 ab	1.12 bd	1.50 df	0.87 df
Trichoderma harzianum CP	84.00 ab	1.12bd	1.75 ce	1.25 cd
Trichoderma harzianum T22	83.50 ab	1.25 bc	2.00 cd	1.00 ce
Trichoderma sp. EP	82.00 b	1.50 b	2.75 c	1.50 c
Control	56.00 c	12.25 a	13.75 a	14.50 a
CV(%)	3.19	17.74	11.03	12.50

Figures with common letters do not differ significantly at P=0.05.

Integrated effect of selected IPM components in controlling nursery diseases of egg-plant caused by Phomopsis vexans

The IPM components that were found promising against *Phomopsis vexans* in the laboratory and also in the net house were again evaluated for their integrated effect in controlling damping off, tip over and seedling blight in the nursery. All the treatment combinations showed significantly ($P \leq 0.05$) better performance against *Phomopsis vexans* in controlling nursery diseases over control (Table 3). Considering the treatment effect against the nursery diseases and increasing seed germination, the treatment combination of apparently healthy seed, treated seed with garlic bulb and treated soil with *T. harzianum* CP was recorded the best treatment. Statistically similar effect was observed in case of treatment combination with allamanda, and seed treatment with hot water.

Table 3.
Integrated effect of IPM components against *Phomopsis vexans* of egg-plant in the net house

Treatment	Seed germination (%)	Damping-off (%)	Tip over (%)	Seedling blight (%)
Farmers' seeds x Garlic tablet	88.7	0.17	0.25	0.17
Farmers' seeds x Allamanda tablet	87.3	0.50	0.58	0.42
Apparently Healthy seeds x Garlic tablet	93.8	0.0	0.0	0.0
Apparently Healthy seeds x Allamanda tablet	92.1	0.0	0.0	0.0
Farmers' seeds x Bavistin 50WP (0.1%)	87.2	0.33	0.42	0.33
Apparently Healthy seeds x Bavistin 50WP (0.1%)	90.7	0.33	0.25	0.33
Farmers' seeds x Hot water treatment	85.8	0.67	0.42	0.50
Apparently Healthy seeds x Hot water treatment	90.5	0.25	0.17	0.17
Farmers' seeds x *T. harzianum* CP	83.9	5.25	1.83	3.33
Apparently Healthy seeds x *T. harzianum* CP	85.6	1.58	0.83	1.08
Control (Farmer's seeds, untreated)	64.5	27.25	17.75	14.25
CV(%)	12.96	18.25	13.12	11.08

Effect of Field spray of tablets on leaf blight and fruit rot of egg-plant

Both the garlic and allamanda tablet solution proved effective in controlling phomopsis blight and fruit rot of egg-plant (Table 4). Pre-inoculation spray always showed significantly better performance in every treatment than the post-inoculation spray. Higher spray concentration (1: 1) performed better result than the lower one (1: 2) (Table 4).

Table 4.

Effect of field spray of garlic and allamanda tablets in different doses against *Phomopsis vexans* in controlling leaf blight and fruit of egg-plant

Treatment	Leaf blight severity (%)	Fruitrot severity (%)
Pre-inoculation spray-garlic tablet	4.06	5.06
Post-inoculation spray - garlic	5.31	6.72
Pre-inoculation spray-allamanda tablet	4.41	5.05
Post-inoculation spray-allamanda tablet	5.33	6.61
Control	27.60	52.57

Effect on anthracnose of Chilli

Leaf anthracnose of chili, die-back of twig and fruit infection were reduced by 92.3 - 93.6%, 96.7-98.3% and 98.6 - 99% respectively by garlic spray and 92.3 - 95.2%, 94.3 - 95.5% and 94.9 - 97.4% by allamanda spray for different ages of the tablets. Yield of chili was increased by 72% in garlic/allamanda tablet sprayed plot against 72.5% increase in fungicide spray (Table 5).

Table 5.

Effect of Garlic and allamanda spray on chili anthracnose

Treatment	Age of the tablet (days)	Leaf anth-racnose severity	Die-back (% twig affected)	Fruit rot severity (%Fruit infected)	Yield (t/ha)
Garlic (1: 3)	Fresh	1.310	0.563	0.325	8.33
	15	1.533	0.834	0.376	7.85
	30	1.283	0.887	0.292	8.15
	45	1.394	0.689	0.354	8.07
	60	1.425	1.041	0.401	7.98
Allamanda (1:3)	Fresh	0.951	1.514	0.758	6.94
	15	1.265	1.814	1.059	7.25
	30	1.412	1.723	1.512	7.15
	45	1.537	1.912	1.439	7.02
	60	1.448	1.818	1.510	7.00
Fild 25EC	(0.05ml/l)	0.90	0.563	0.268	8.35
Control		19.98	33.49	29.48	4.84

Effect on leaf curl/mosaic of tomato

Percentage of leaves showing leaf curl and mosaic of tomato was reduced by 46 and 37% respectively with allamanda tablet spray. Length of branches of tomato plants increased by 117 and 70% as against leaf curl and mosaic infected plants. Number of fruits per plant was increased by 414% with allamanda tablet spray (Figs. 6-7).

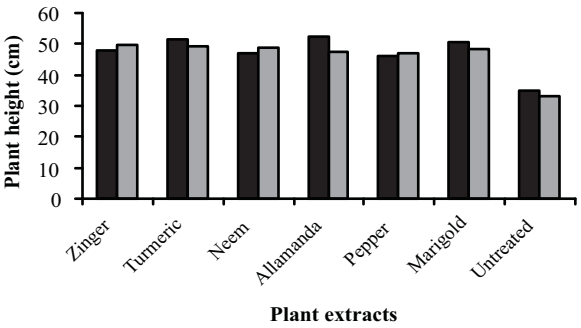

Fig 6. Effect of allamanda tablet spray on the plant height (cm) of tomato as affected by leaf curl and mosaic virus

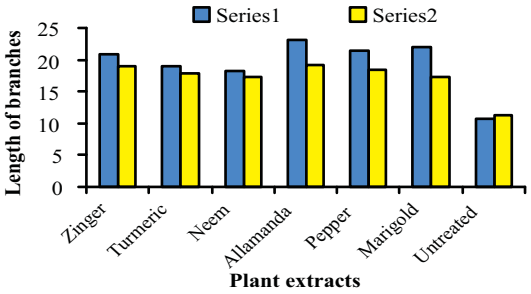

Fig 7. Effect of allamanda tablet spray on the length of branches of tomato as affected by leaf curl and mosaic virus

Integrated effect of selected IPM components in controlling Phomopsis vexans causing Phomopsis blight and fruit rot of egg-plant in the field (Cultivar Dohazari)

All the treatment combinations showed significantly better performance over control. The combined treatment effect in controlling the disease in terms of reducing leaf infection, PDI (Leaf), flower infection, PDI (fruit) and increase of yield varied significantly (Table 6). The highest effect against the disease was recorded in case of the treatment combination of soil treatment with *T. harzianum* and garlic tablet spray where leaf blight severity was reduced by 83.3% and fruit rot severity was reduced by 93.3%, and 340.3 % yield increase was achieved over control and the effect was statistically identical with the treatment combination of soil treatment with *T. harzianum* T22 and allamanda spray or Bavistin spray.

Effect on root knot nematode

Number of galls (per 10g of root) was reduced by 60% in carrot and 50% in pea through use of allamanda tablet (Fig. 5).

Table 6.
Integrated effect of selected IPM components in controlling *Phomopsis vexans* causing leaf blight and fruit rot of egg-plant in the field

Treatment	Leaf Blight severity (%)	Fruit rot severity(%)	Yield increase over control (%)
T. harzianum CP + Garlic spray	5.66	3.68	340.3
T. harzianum CP + Allamanda spray	6.45	4.12	313.7
T. harzianum T22 + Garlic spray	5.76	3.88	329.5
T. harzianum T22 + Allamanda spray	6.76	4.36	297.8
T. harzianum CP + Bavistin spray	11.28	7.29	281.3
T. harzianum CP + *T. harzianum* CP spray	11.83	7.61	158.9
Control	33.98	54.61	(1.39t/ha)

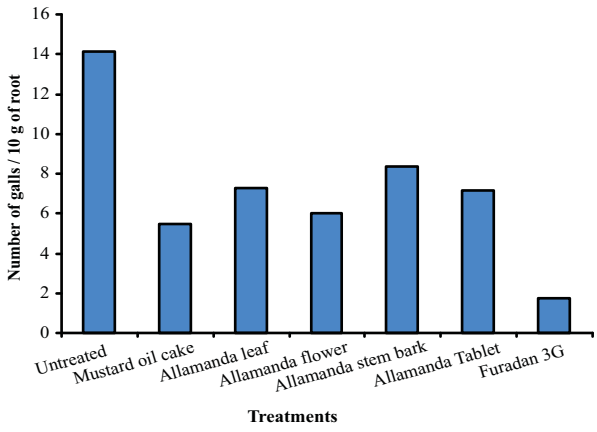

Fig 5. Effect of different treatments on the galling incidence of pea inoculated with *M. javanic*a

The experiments with all 13-treatment combinations were repeated in the succeeding cropping season. Results similar to that of previous year's experiment were obtained. Considered the overall effect of the IPM components against *Phomopsis vexans* it was revealed that field spraying with either garlic (1: 1) or allamanda (1: 1) or Bavistin (0.1%) in combination with soil treatment with formulated *T. harzianum* CP or *T. harzianum* T22 proved to be effective approach for controlling phomopsis blight and fruit rot of egg-plant in the field.

Costing

Cost analysis' was done and Benefit Cost Ratio (BCR) of the management practices applied in the integrated experiment was estimated (Islam *et al.* 2004; Gittinger 1982) and presented in the Table 7. Estimation showed that treatment combination comprising soil treatment with, *harzianum* CP followed by spraying of Allamanda tablet yielded the highest return (BCR = 3.96) where TK. 2.96 could be earned investing TK. 1.00. Benefit Cost Ratio was estimated 3.87 and 3.73, respectively for the other promising treatment combinations *T. harzianum* T22/allamanda tablet spray, and *T. harzianum* / bavistin spray.

Effect of Tablets on Brinjal Shoot & Fruit Borer (BSFB)

Neem tablet spray reduced shoot infestation by 35.8% and fruit infestation by 42.3%. Garlic or allamanda were not effective (Fig. 8).

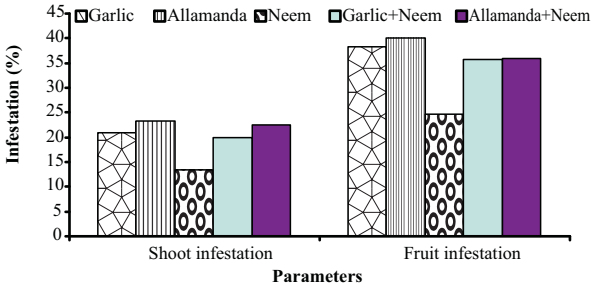

Fig 8. Effect of tablets on different infestation parameters in shoot and fruit borer of egg-plant

Table 7.
Benefit-Cost ratio of use of use of garlic and allamanda tablets

Treatment	Benefit-cost ratio (BCR)
T. harzianum CP + Garlic spray (1:1)	2.60
T. harzianum CP + Allamanda spray (1:1)	3.96
T. harzianum CP + Bavistin spray (0.1%)	3.73
T. harzianum T22 + Garlic spray (1:1)	2.54
T. harzianum T22 + Allamanda spray (1:1)	3.87
T. harzianum T22 + Bavistin spray (0.1%)	3.73

Formulated Trichoderma

Formulated trichoderma acted better than trichoderma suspension in reducing collar rot of egg-plant and regeneration of the plants (Fig. 9).

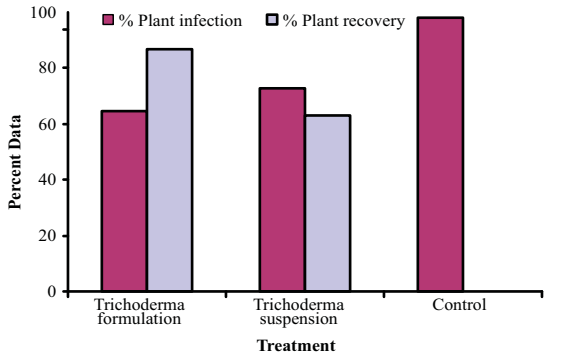

Fig 9. Effect of biopesticide on % plant infection and % plant recovery of two month aged egg-plant

Rhizosphere soils of egg-plants were treated with formulated trichoderma at different days after inoculation with *Sclerotium rolfsii* starting at 24 h up to 14 days. Treatment after 9 days of inoculation helped complete regeneration of the plants. Treatment after 7-8 days could regenerate plants by 86-93%. Thus the trichoderma needs at least 7 days of incubation for its antagonistic action to start (Table 8; Fig. 10- 11).

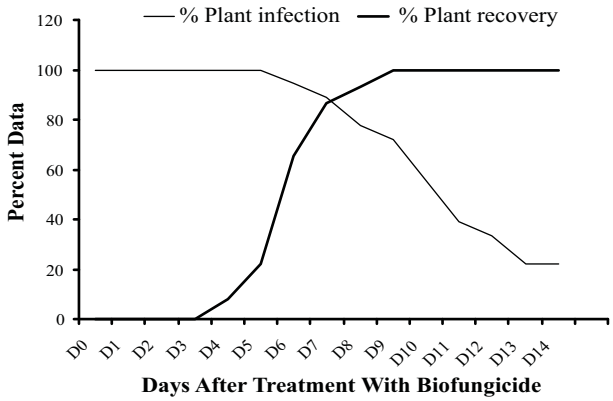

Fig 10. Effect of incubation period of formulated *Trichoderma* against *S. rolfsii*

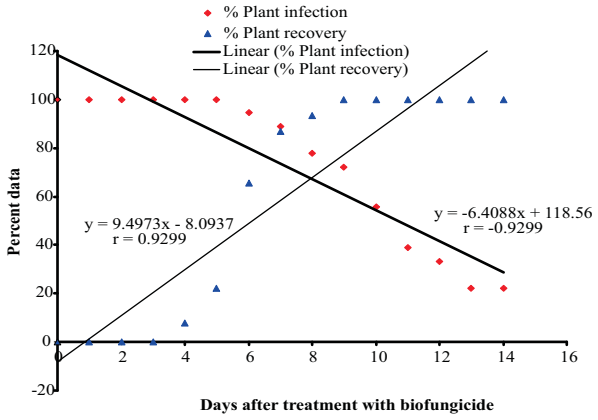

Fig 11. Effect of length of time after treatment with biopesticide on the percent infection and percent recovery in eggplant var. Dohazari inoculated with *S. rolfsii*

Table 8.
Determination of incubation period of *Trichoderma* to act as antagonist against *Sclerotium rolfsii*

Treatment	% Plant infection	% Plant recovery
D_0	100.00a	00.00d
D_1	100.00a	00.00d
D_2	100.00a	00.00d
D_3	100.00a	00.00d
D_4	100.00a	8.03cd
D_5	100.00a	22.22c
D_6	94.44a	65.56b
D_7	88.87ab	86.67a
D_8	77.78bc	93.33a
D_9	72.22c	100.00a
D_{10}	55.56d	100.00a
D_{11}	38.89e	100.00a
D_{12}	33.33e	100.00a
D_{13}	22.22e	100.00a
D_{14}	22.22e	100.00a
Control	100.00a	00.00d
Level of significance	0.01	0.01
LSD	15.53	14.41
CV	9.18%	11.68%

D= Days after treatment with biopesticide. Number of plants counted is 18 (eighteen) in each treatment. Figure in the column having common letter (s) do not differ significantly.

Effect of Mahogany oil on insect pest management

Spray of Mahogany oil reduced rice stem borer and green leaf hoppers by 65-80%, white flies and shoot & fruit borer of egg-plant by 70-75%, and aphids, white flies and epilachna beetle by 80-100% (Table 9).

Private organizations like Ispahani Biotech and Safe Agro Biotech have their progress in the

production of bio-agents for limited commercial supply (Table 10).

Discussion

Botanicals against plant pathogens

Garlic and allamanda tablets (1:1) completely arrested the mycelial growth and spore germination of *Phomopsis vexans/Sclerotium rolfsii* and produced large inhibition zones (5.7 cm and 5.5 cm dia., respectively) in *in vitro* tests. In the nursery, garlic tablet completely controlled damping off and seedling blight and enhanced seed germination to 87.50 %. Allamanda tablet also reduced damping off, tip over and seedling blight by 91 %, 90 % and 94 %, respectively. In the field condition, both garlic and allamanda bulb spray effectively controlled Phomopsis blight and fruit rot of egg-plant reducing leaf, flower and fruit infection significantly. The findings of the present investigation are well supported by the findings of Kuprasvile (1996), Panda *et al*. (1996) and Mohanty *et al*. (1995) who reported that the allamanda leaf extract inhibited the growth of *Phomopsis vexans* significantly. Meah (2003) reported that garlic bulb extract controlled the nursery diseases in the net house and reduced the fruit infection of egg-plant by 71 - 75 % in the field. Islam (2004) found 76 - 100 % inhibition of mycelial growth of *Phomopsis vexans* by garlic bulb and allamanda leaf extracts.

Other workers have reported the efficacy of garlic bulb extract in controlling other pathogens. Assadi and Behroozin (1987) found garlic extract effective against *Fusarium* spp. Alice and Rao (1987) observed that garlic extract reduced the seed borne infection of *Drechslera oryzae* in rice seed. Ahmed & Sultana (1984) recorded the inhibition of spore germination of seed borne *Macrophomina phaseolina, Botryodiplodia theobromae* and *Colletotrichum chorcori* when seeds were

Table 9.
Effect of Mahogany oil on insect pest management

Crops	Insect pest	Reductbn(%)
Rice	Stem borer, leaf folders, green leaf hoppers	65-80
Eggplant	White flies, Shoot & fruit borer	70-75%
Beans, cucumbers, cowpeas, gourds	Aphids, white flies, Epilachna beetles,	80-100%

Table 10.
Biotech agents supplied for field trial (ISPAHANI BIOTECH LAB)

Institution/Agency Received the Bioagents	Number of lures for cucurbits	Number of lures for BSFB	Number of lures for Mango	*Trichogramma* (in g)	*Bracon* (in jars)
BARI	38,770	4,400	805	64	80
DAE	8,775	3,365	6,500	-	-
NGO	2,875	2,545	1,680	125	-
Total	50,415	12,215	9,880	189	80

treated with garlic extract. Several other reports also support the antifungal activity of garlic extract in controlling plant pathogens (Hossain *et al.* 1993; Fakir & Khan, 1992; Lakhmanan, 1990; & Mia *et al*. 1990). Tiwari *et al*. (2002) reported that *Allamanda cathertica* acted as antidermatophytic agent against fungi. Inhibition of pathogenic fungi by garlic bulb extract might be due to the presence of antimicrobial compounds in the extract. It has been reported that the antibiotic substance present in garlic is the allyl compound of allyl thiosulphate (Cavallito *et al*. 1944). It is also reported that garlic contains an amino acid alliin which on crush transferred into allicin by the action of allicinase enzymes and this allicin is toxic to the microorganism (http//www.gourmetgarlicgardens.com/pill.htm). Reports on the toxic compounds of allamanda leaf are not available. However, it has been reported that allamanda leaf contains some substances toxic to the organisms (Hwang 2001). Plumieride, one of the compounds separated from allamanda leaf extract at IPM Lab has been proved effective against plant pathogenic fungi *Phomopsis vexans, Rhizoctonia solani, Sclerotium rolfsii, Fusarium oxysporum and Phytophthora capsici* (Rahman 2009).

Integrated effect of IPM component

Apparently healthy seed treated with garlic or allamanda tablets (1:1) or bavistin (0.1%) or hot water (56°C- 15 minutes) and sown in soil treated with *T. harzianum* CP or *T. harzianum,* T22 were the best combination of IPM components against *Phomopsis vexans* in raising seedlings of eggplant in the nursery. In the standing crop, spraying with either garlic (1:1) or allamanda tablets (1:1) or Bavistin 0.1 % in combination with soil treatment with formulated *T. harzianum* CP or *T. harzianum*T22 was the best effective approach for management of Phomopsis blight and fruit rot of egg-plant.

Potentials of the IPM components proved effective against *P. vexans* in *in situ* and *in vivo* tests in the present investigation have successfully been reflected in the integration experiment. As our ultimate goal is to develop a biologically based management program replacing the dependence on environment polluting chemicals we may pick up the eco-friendly components from the integrated approaches, as there are alternative options.

No concrete reports on management of Phomopsis blight and fruit rot of egg-plant are available in the literature. However, the components like selection of apparently healthy seed, plant extracts, hot water seed treatment, bio-agents and fungicides that were found effective against *Phomopsis vexans* in the present investigation were well supported by the previous workers. Cost analysis of management practices applied for the integrated experiment in the field revealed that the Benefit Cost Ratio (BCR) of garlic bulb based treatment combinations were lower (2.20 - 2.60) than allamanda (3.87 - 3.96) or *Trichoderma* (2.24 - 3.67) or Bavistin (2.98 - 3.73) combinations. This is because of higher market price of garlic bulb. In that case,

spraying of garlic could be substituted with allamanda extract in the field, as the effect of both allamanda and garlic based treatment combinations in controlling the disease was statistically similar.

Use of apparently healthy seeds in combination of seed treatment with garlic/allamanda tablet solution could be a nice option for healthy vegetable seedling production. Spraying of garlic (1:1) or allamanda tablets (1:1) combined with soil treated with *harzianum* CP or *harzianum* T22 could be used eco-friendly in controlling phomopsis blight and fruit rot of egg-plant, anthracnose of chili, root knot nematode and leaf curl /mosaic in the field.

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