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Efficacy of biological and chemical treatments for controlling damping off (*Pythium* spp.) of bitter gourd

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Abstract
This study evaluates the efficacy of biological and chemical treatments in controlling damping-off disease (*Pythium* spp.) in bitter gourd (*Momordica charantia*). The experiment was conducted with seven different treatments, including Trichoderma spp., Vitavex, Bavistin, and Mancozeb, applied both as seed and soil treatments. The results indicated that the combined application of Trichoderma soil treatment and Vitavex seed treatment significantly increased germination percentage and reduced the incidence of pre- and post-emergence damping-off. These findings suggest that integrating biological control agents with chemical fungicides can effectively manage damping-off disease and enhance the growth of bitter gourd seedlings.

Keywords: Bitter gourd, damping off, *Pythium* spp., trichoderma, vitavex, bavistin, mancozeb, biological control, chemical fungicides, seed treatment, disease management, seedling growth

Introduction
Bitter gourd (*Momordica charantia*), also known as bitter melon, balsam pear, or African cucumber, is a tropical vine belonging to the family Cucurbitaceae. It is cultivated widely in Asia, Africa, and South America for its medicinal and culinary uses. While the entire plant is edible, bitter gourd is primarily grown for its fruit, which is utilized in various Asian dishes for its slightly bitter taste. In Indian cuisine, the fruit is often blanched, parboiled, or soaked in salt water to reduce bitterness. Additionally, bitter gourd is renowned in indigenous populations across Asia, South America, India, and East Africa for its potential in managing diabetes.

Apart from its culinary and medicinal uses, bitter gourd has gained attention for its nutritional benefits, containing essential nutrients such as iron, magnesium, vitamin C, and potassium. Despite its nutritional value, bitter gourd cultivation faces challenges, particularly in regions like Nepal, where disease, such as damping off caused by *Pythium* species, significantly affects seedling health and reduces productivity.

Damping off is a prevalent disease among vegetable seedlings, particularly during rainy seasons and periods of high soil moisture. It leads to significant seedling mortality, affecting both nursery and main field cultivation. Chemical fungicides have traditionally been used for damping off management, but their overuse poses environmental risks and can diminish farm profits. *Pythium* species, commonly known as water molds, are found worldwide and inhabit diverse habitats, including terrestrial and aquatic environments, cultivated or fallow soil. The genus *Pythium* comprises over 130 recognized species, isolated from various regions globally. While *Pythium* species are generally not host-specific, they can infect a wide range of plant species.

According to Waterhouse and Waterston (1964), the plant pathogen is capable of infecting a wide range of plant species belonging to various families, including but not limited to Amaranthaceae, Amaryllidaceae, Araceae, Basellaceae, Bromeliaceae, Cactaceae, Chenopodiaceae, Compositae, Coniferae, Convolvulaceae, Cruciferae, Cucurbitaceae, Euphorbiaceae, Gramineae, Leguminosae, Linaceae, Malvaceae, Moraceae, Passifloraceae, Rosaceae, Solanaceae, Umbelliferae, Violaceae, Vitaceae, and Zingiberaceae.

Infected seeds may exhibit browning and decomposition, sometimes leading to failure to germinate. Young seedlings often display constriction near the soil line, accompanied by soft, dark lesions, and frequent toppling. Additionally, brown discoloration and thinning of roots can occur, with top lateral root growth becoming more prevalent due to degradation of lower roots. In less severe cases, older plants may experience stunted growth. Fruit rot caused by *Pythium* spp. typically manifests as small water-soaked lesions on mature green or ripe fruit in contact with or near the soil. Certain *Pythium* species have been associated with dark, aerial lesions on tomato stems or leaves.

Biological control offers a sustainable, environmentally friendly approach to disease management. *Trichoderma* strains, renowned for their biocontrol capabilities, have better stress tolerance levels compared to plant pathogens, making them effective biological control agents under field conditions (Papavizas, 1985) [21]. *Trichoderma* spp. exhibit antagonistic behavior towards other fungi and have been shown to effectively control various soil-borne plant pathogens both in greenhouse and field settings (Chet, 1987; Sivan and Chet, 1992) [2, 3]. Additionally, *Trichoderma* application has been linked to increased plant growth and enhanced root development in several plant species, including beans, cucumbers, peppers, and petunias (Baker, 1989; Chang *et al*., 1986; Kleifeld and Chet, 1992; Paulitz *et al*., 1986; Windham *et al*., 1986) [4, 5, 6, 7, 8]. *Trichoderma* -induced growth promotion may result in shorter germination times, increased germination percentage, taller plants, and higher dry weights. Other benefits of *Trichoderma* application include control of minor pathogens, improved nutrient uptake, and secretion of plant growth regulatory factors such as phytohormones (Ousley *et al*., 1993) [9].

Materials and Methods

Location of the experiment site

The experiment was conducted in the sick field of Nepal Polytechnic Institute (NPI) Bhojad-11, Bharatpur, Chitwan during March 1st 2024 to April 18th 2024. Geographically the site was located at 12 km south-west from Bharatpur, the headquarter of Chitwan district, situated at 27 0 41’37.45” north latitude and 84 0 26'58.83” east longitude with an elevation of 213.66 m above mean sea level. In vitro tests were carried out with seed treatment in different types of fungicide (Vitavex, Bavistin and Mancozeb) and bio-control agent (*Trichoderma* sp.) in the plant pathology laboratory and soil application of the biological agent and chemical were done on the seedling grown in research field of Polytechnic Institute (NPI).

Selection of treatments

Total of treatments including control was selected for the experiment. The treatments applied in the field was also used in the laboratory for seed treatment. The details of the treatments are as follows.

Table 1: Details of the treatments used for experiment

S. No.	Treatments	Symbol
1	Seed treatment with 0.1% Vitavex + Soil treatment with *Trichoderma* @ 10^6	T_1
2	Seed treatment with Vitavex @ 2gm kg^{-1}	T_2
3	Seed treatment with Bavistin (Carbrendazim 50%WP) @ 2gm kg^{-1}	T_3
4	Seed treatment with Mancozeb 75%WP @ 2gm kg^{-1}	T_4
5	Soil treatment with *Trichoderma* @ 10^6	T_5
6	Seed treatment with *Trichoderma* @ 10^6	T_6
7	Control	T_7

Seed sample collection: The commonly grown variety White Long was brought from Anamolbiu Private Limited Company, Bharatpur-12 Chitwan.

Collection of fungicide and bio-control agent

Systemic fungicides like Vitavex, and Bavistin and contact fungicides like Mancozeb were collected from the local market of Narayanghat and Unnat Bij Briddi Farmers Group Patihani-5 of Chitwan district and the pure culture of bio-control agent (*Trichoderma* harzianum) was acquired from AFU Rampur Chitwan.

Preparation of *Trichoderma* selective media

The equivalent weight (22 grams) of commercially available PDA powder was suspended in 500 ml of distilled water and kept in the well-sterilized conical flask. It was heated and boiled to dissolve the medium completely. Then it was sterilized by autoclaving at 15lbs pressure (121 ºC) for 15 minutes. After autoclaving it was cooled to 45-50 ºC and aseptically remaining contents i.e. Antibiotics (Streptomycin: 0.25g/lit was added to it and plated aseptically and carefully in 9cm diameter sterilized glass Petri plates @ 20 ml per plate.

Multiplication of *Trichoderma* species

After the *Trichoderma* was brought from AFU Rampur Chitwan, multiplication of culture was done on PDA plates by transferring the spores of *Trichoderma* from the pure culture maintained on the PDA test tubes in aseptic condition in inoculation chamber. Those plates were kept on incubator at 24-25 ºC for one week.

Preparation of *Trichoderma* solution

A fully-grown *Trichoderma* PDA plate was scraped with sterilized cotton to collect spores. Those spores were filtered through muslin cloth and then collected on sterilized beaker; 10 ml of pure solution of *Trichoderma* scraped from single Petri dish was mixed with 90ml of the sterilized distilled water in another test tube to make a solution of 100ml/plot. Second dilution was done in same way and nine dilutions were made respectively.

Preparation of the chemical fungicides

Chemical fungicides like Bavistin, Mancozeb and Vitavex at the rate of 2gm kg -1 were prepared for seed treatment and seed were treated accordingly.

Field layout: The experiment was conducted in one factor RCBD with 3 replications. Seven different treatments were used as mentioned on Table no 1. There were 21 plots with an individual plot size of 50*50 cm. Inter block and inter plot spacing were 50cm and 20cm respectively. Treatments were randomly allocated in experimental units.

Seed treatment: Seed treatment was done in the plant pathology lab of NPI. The required amount of *Trichoderma harzianum* (1ml/gm seed) and seeds from related treatments were kept in a 250 ml conical flask and were shaken mechanically for 10 minutes for proper coating of bio-fungicide. The same procedure was applied for seed treatment with different fungicides.

Application of treatments in the field

Trichoderma soil application was done by soil drenching before the seeds were sown. Spray formulations were sprayed using different hand sprayers for each treatment.

Observation in field: Observation was done on regular basis to record the data of germinated seedlings and to record the data of other parameters (seedling height, root weight, shoot weight), ten sample plants were randomly selected and tagged for further observation.

Germination percentage

Germination percentage is an estimation of the viability of a population of seeds. The equation to calculate germination percentage is:

$$\text{Germination } \% = \frac{\text{No. of seeds germinate}}{\text{total no. of seed sown}} \times 100$$

Disease incidence (damping off)

It is the percentage of diseased seedlings in the sample or population of plants. The equation to calculate disease incidence is:

$$\text{Disease incidence } \% = \frac{\text{No. of infected plants}}{\text{totaal no. of plant in the plot}} \times 100$$

Seedling height

The sampled plant's height was measured thrice in five days' interval after the 11 days of germination by using the meter scale in cm unit and data were recorded.

Root weight and shoot weight: At the very end of the research sampled plants were uprooted, cleaned shoot, and root of the plant was cut and their weight was measured using weight balance separately.

Data collection and analysis; The data were recorded on the basis of different parameters like germination percentage, incidence of damping off, plant height, shoot weight, root weight, and biomass in a scientific manner. All plants were recorded from each experimental unit. The recorded data were tabulated in an Excel data sheet and were analyzed by using the Gen stat software program. The data entry was done to develop an ANOVA table and different treatments were compared through Duncan's multiple range test and correlation analysis was done by SPSS. All the figures and graphs were prepared by using Microsoft Excel 2013.

Results and Discussion

Effectiveness of Chemical Fungicide and Biological Agent Treatments on Bitter Gourd Seed Germination

An analysis of variance (ANOVA) regarding the germination percentage of bitter gourd seeds showed significant variations among the treatments. The mean germination percentage was 95% for the combination of *Trichoderma* soil application and seed treatment with Vitavex, while seed treatment with Bavistin resulted in 84%, and the control group exhibited the lowest germination percentage at 43%. The combined application of Vitavex and *Trichoderma* showed the highest germination percentage. This trend is illustrated in the figure, where *Trichoderma* soil application with Vitavex seed treatment demonstrated the highest increase in germination percentage (120%), followed by Bavistin seed treatment (95%) and Vitavex alone (80%), compared to the control.

Previous studies have shown that *Trichoderma* effectively reduces seedling mortality and root infections in cucumber and bottle gourd, attributed to its ability to produce extracellular lytic enzymes with antagonistic properties. Similarly, Carbendazim (Bavistin) treatment resulted in a notable germination percentage increase (85%). Other fungicides like Benlate, Carbendazim, and Topsin-M have been reported to completely prevent seedling mortality in bottle gourd. Therefore, the highest increase in germination compared to the control was observed with the combination of *Trichoderma* soil treatment and Vitavex seed treatment, followed by Bavistin seed treatment.

Our findings suggest that the combined use of 0.1% Vitavex seed treatment and *Trichoderma* soil treatment yields the most favorable results, likely due to Vitavex's inhibitory effect on seedling mortality and *Trichoderma* 's antagonistic activity promoting healthier seedling production in the nursery.

Table 2: Effect of seed treatment by chemical and biological fungicide on germination of bitter gourd seed

Treatments	Germination %	Increase in Germination %
Seed treatment with 0.1% Vitavex + Soil treatment with *Trichoderma* @ 10^6	95.33f	120.01
Seed treatment with Vitavex @ 2gm kg^{-1}	78.00d	80.01
Seed treatment with Bavistin (Carbrendazim 50%WP) @ 2gm kg^{-1}	84.67e	95.41
Seed treatment with Mancozeb 75%WP @ 2gm kg^{-1}	72.00dbc	66.17
Soil treatment with *Trichoderma* @ 10^6	75.00cd	73.09
Seed treatment with *Trichoderma* @ 10^6	69.00b	59.24
Control	43.33a	
LSD(=0.05)	3.78	
S.Em (±)	2.12	
CoV (%)	2.9	
Grand Mean	73.9	
P-value	<.001	

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV= Coefficient of variation, LSD = Least significance Difference * = significantly different at (p<0.05), ** = highly significantly different at (p<0.01), *** = very highly significantly different at (p<0.001)

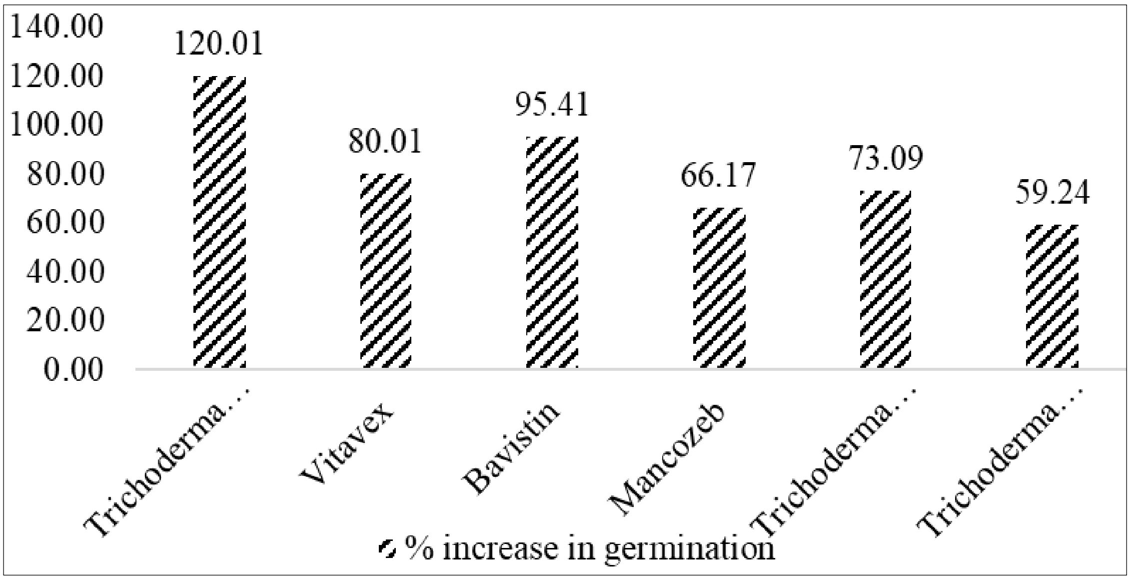

Fig 1: Percentage increase in germination of bitter gourd seeds due to different seed treatments

Efficacy of chemical fungicide and biological agents on seed and soil treatments on damping off disease

For pre-emergence damping-off disease incidence caused by *Pythium* spp., significant differences between treatments were identified through Analysis of Variance (ANOVA). The lowest incidence was observed in seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma*, at 3.33%, followed by seed treatment with Bavistin at 12.67%, and seed treatment with Vitavex at 2gm kg-1 at 18.67%. Similarly, for post-emergence damping-off disease incidence, significant differences were noted between treatments. The lowest incidence was recorded in seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma*, at 1.33%, which was statistically comparable to other treatments, including Seed treatment with Mancozeb 75%WP at 2gm kg-1 (1.33%), Seed treatment with Bavistin (Carbendazim 50%WP) at 2gm kg-1 (2.66%), Seed treatment with *Trichoderma* at 106 (2.67%), Soil treatment with *Trichoderma* at 106 (3.33%), and Seed treatment with Vitavex at 2gm kg-1 (3.33%), except for the control, which had the highest incidence at 12.33%. In the study, the highest reduction in pre-emergence damping-off disease incidence was observed in seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma* (92.49%), followed by seed treatment with Bavistin (71.42%). Similarly, the highest reduction in post-emergence damping-off disease incidence was found in seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma* (89.21%), followed by Seed treatment with Mancozeb 75%WP (89.21%). These results highlight the significant control achieved over pre and post-emergence damping-off of bitter gourd seedlings through various treatments compared to the control.

Studies have shown the effectiveness of *Trichoderma* harzianum in reducing disease incidence and enhancing crop germination. Synthetic fungicides act by inhibiting pathogens either through the destruction of their cell membrane or by inhibiting their metabolic processes, making them highly effective. *Trichoderma* species possess the ability to produce extracellular lytic enzymes responsible for their antagonistic activity, which contributes to their effectiveness in disease control. The combined antagonistic effects of *Trichoderma* and the inhibitory effects of Vitavex were found to be the most effective in controlling both pre-emergence (92%) and post-emergence (89%) damping-off caused by Fusarium and *Pythium* spp.

Table 3: Effect of seed treatment by chemical and biological fungicide on disease incidence of pre and post damping off disease of bitter gourd in seedling stage

Treatments	**% Pre-Emergence DI**	**% Disease Control**	**% Post Emergence DI**	**Disease control**
Seed treatment with 0.1% Vitavex + Soil treatment with *Trichoderma* @ 10^6	3.33a	92.49	1.33a	89.21
Seed treatment with Vitavex @ 2gm kg^{-1}	18.67c	57.88	3.33a	72.99
Seed treatment with Bavistin (Carbrendazim 50%WP) @ 2gm kg^{-1}	12.67b	71.42	2.66a	78.43
Seed treatment with Mancozeb 75%WP @ 2gm kg^{-1}	26.67de	39.84	1.33a	89.21
Soil treatment with *Trichoderma* @ 10^6	21.67cd	51.12	3.33a	72.99
Seed treatment with *Trichoderma* @ 10^6	28.33e	36.09	2.67a	78.35
Control	44.33f		12.33b	
LSD(=0.05)	5.89		3.35	
S.Em (±)	2.7		1.32	
CoV (%)	14.9		42.2	
Grand Mean	22.24		3.86	
P-Value	<.001		<.001	

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV= Coefficient of variation, LSD=Least significance Difference, * = significantly different at (p<0.05), ** =highly significantly different at (p<0.01), *** = very highly significantly different at (p<0.001)

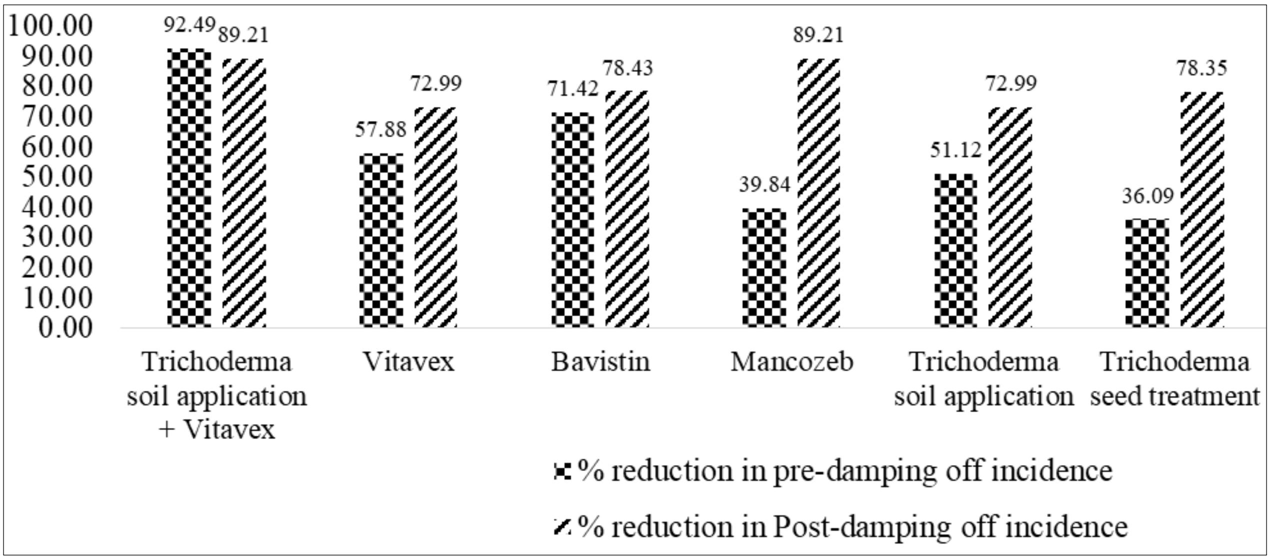

Fig 2: Percentage reduction in pre and post emergence damping off disease incidence of bitter gourd due to different seed treatments

Efficacy of chemical fungicides and biological agent treatments against damping off disease (*Pythium spp.*) on plant height of bitter gourd in seedling stage

Plant height measurements were taken on the 11th, 16th, and 21st days following germination, with initial measurements recorded on the 11th day and subsequent measurements made every 5 days thereafter. Significant differences in mean plant height were observed across various treatments. The tallest plants were observed in treatments involving *Trichoderma* soil application combined with Vitavex seed treatment, followed by sole *Trichoderma* soil treatment on the 11th, 16th, and 21st days of observation. By the 21st day after germination, plant height varied significantly among treatments compared to the control. The tallest plants were observed in the treatment involving seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma*, reaching 28.05 cm, followed by sole soil treatment with *Trichoderma* at 27.48 cm. Conversely, plants in the control group exhibited the shortest height at 14.44 cm. Figure 4 provides a visual representation of plant height across observation dates, demonstrating consistently taller plants in the treatment involving seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma*, followed by sole soil treatment with *Trichoderma*.

These findings are corroborated by previous studies, which have reported the positive effects of *Trichoderma* spp. on the growth and development of seedlings in various crops, including cabbage, cucumber, lettuce, and cotton. The enhanced growth response observed in several plants, particularly vegetables, following the application of *Trichoderma* spp. to pathogen-free soil, has also been documented by Baker (1989), Chang *et al*. (1986), and Kleifeld and Chet (1992) [4, 5, 6].

The results of the present experiment suggest that the combination of *Trichoderma* soil application with Vitavex seed treatment yielded the best outcomes among the tested treatments. This may be attributed to the dual effect of Vitavex in reducing seed-borne pathogens and *Trichoderma* in stimulating the plant's defense mechanisms against pathogens, thereby promoting the establishment of a healthy and robust root system, ultimately resulting in vigorous plant growth.

Table 4: Effect of seed treatment by chemical and biological fungicide on plant height of bitter gourd in seedling stage

Treatments	Plant Height at 11 days	Plant Height at 16 days	Plant Height at 21 days
Seed treatment with 0.1% Vitavex + Soil treatment with *Trichoderma* @ 10^6	10.47b	16.61f	28.05d
Seed treatment with Vitavex @ 2gm kg^{-1}	9.25b	11.73c	21.55c
Seed treatment with Bavistin (Carbrendazim 50%WP) @ 2gm kg^{-1}	9.91b	11.17b	19.43b
Seed treatment with Mancozeb 75%WP @ 2gm kg^{-1}	9.86b	12.24c	20.06b
Soil treatment with *Trichoderma* @ 10^6	10.32b	15.444e	27.48d
Seed treatment with *Trichoderma* @ 10^6	8.98b	13.47d	21.59c
Control	6.83a	9.24a	14.44a
LSD(=0.05)	1.52	0.5471	0.88
S.Em (±)	0.699	0.2511	0.404
CoV (%)	9.1	2.4	2.3
Grand Mean	9.38	12.84	21.8
p-value	0.003	<.001	<.001

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV= Coefficient of variation, LSD=Least significance Difference, * = significantly different at (p<0.05), ** =highly significantly different at (p<0.01), *** = very highly significantly different at (p<0.001).

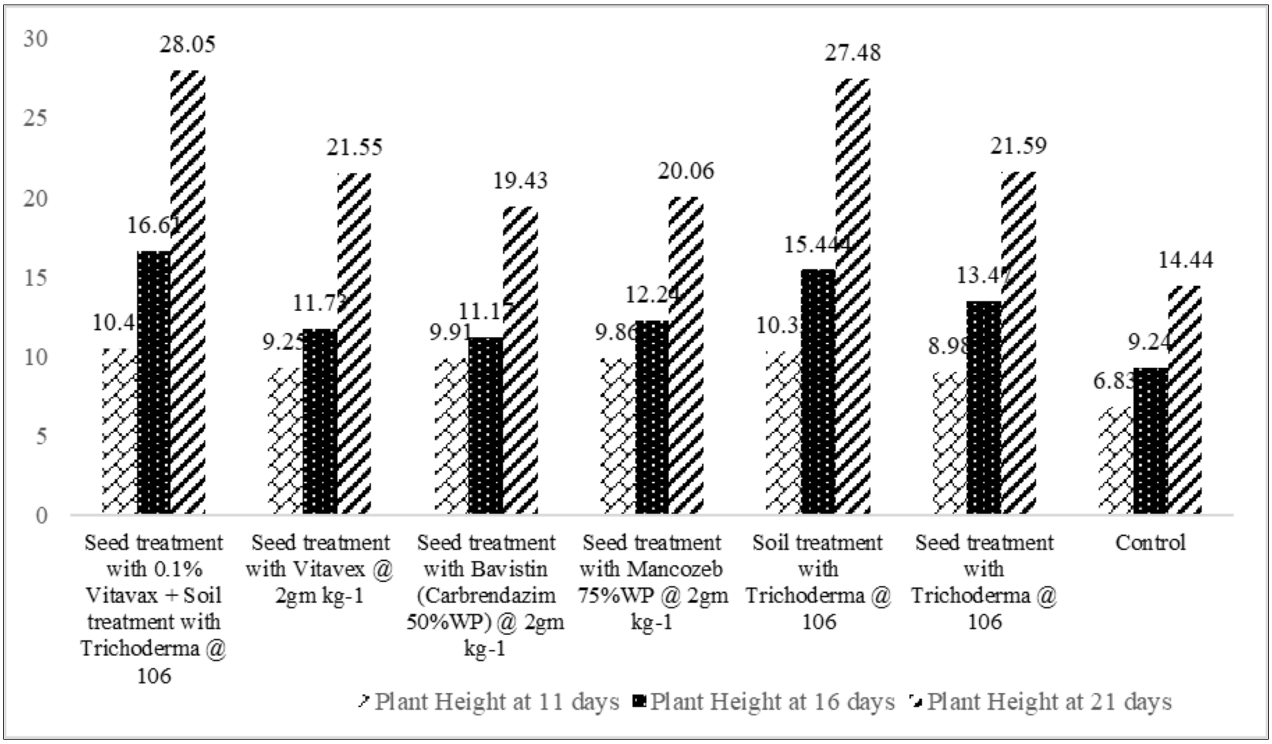

Fig 3: Effect of treatments on plant height of the bitter gourd seedlings against damping off disease caused by *Pythium* spp.

Efficacy of chemical fungicide and biological agents against damping off disease (*Pythium spp.*) on root weight, shoot weight and biomass of bitter gourd in seedling stage

At 21 days after sowing (DAS), when seedlings were ready for transplantation, the fresh root weight and shoot weight of sampled bitter gourd seedlings were measured simultaneously. Analysis of variance of both root weight and shoot weight indicated significant differences between the treatments. The highest root weight and shoot weight were recorded in seed treatment with 0.1% Vitavex combined with soil treatment using *Trichoderma*, at 0.35 grams and 7.08 grams respectively, resulting in a total biomass of 7.44 grams. This was followed by seed treatment with Vitavex, with a root weight of 0.22 grams and shoot weight of 5.53 grams, totaling 5.75 grams (see Table 5). Conversely, the control group exhibited the lowest root weight (0.09 grams) and shoot weight (2.13 grams), with a total biomass of 2.23 grams (refer to Figure %). The combined treatment of vitavex and *Trichoderma* resulted in the highest biomass of bitter gourd seedlings, statistically comparable to treatments involving vitavex, bavistin, and *Trichoderma* soil treatments, respectively.

Previous studies by Elad *et al*. (1986) [8], have demonstrated the use of microbial antagonists to mitigate the adverse effects of pesticides on Fusarium spp. infecting roots. Additionally, the application of *Trichoderma* spp. has been shown to reduce disease development in plants and promote plant vigor. Increased growth responses in plants are often assessed by measuring parameters such as length, leaf area, and dry weight, as reported by Chang *et al*. (1986) [5] and Kleifeld and Chet (1992) [6]. *Trichoderma* harzianum has been identified as particularly effective in reducing seedling mortality and root infection in cucumber and bottle gourd. In some instances, *Trichoderma* has been found to penetrate and inhabit the plant root cortex, leading to increased levels of lignin in roots and shoots, as well as enhanced activities of hydrolytic enzymes such as 13-1-3-glucanase and chitinase. These findings suggest that *Trichoderma* stimulates the plant's defense mechanisms. The production of robust seedlings that are more resistant to soil-borne plant pathogenic fungi benefits both producers and farmers. The application of beneficial microorganisms such as *Trichoderma* spp. during seedling preparation in nurseries enhances plant growth and aids in the biological control of diseases, offering positive benefits such as the stimulation of plant defense mechanisms and increased plant vigor.

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV= Coefficient of variation, LSD=Least significance Difference, *= significantly different at (p<0.05), ** =highly significantly different at (p<0.01), *** = very highly significantly different at (p<0.001).

Table 5: Effect of seed treatment by chemical and biological fungicide on root weight, shoot weight and biomass of bitter gourd in seedling stage

Treatments	Root Weight (gm)	Shoot Weight (gm)	Biomass (gm)
Seed treatment with 0.1% Vitavex + Soil treatment with *Trichoderma* @ 10^6	0.35c	7.08c	7.44c
Seed treatment with Vitavex @ 2gm kg^{-1}	0.22b	5.53bc	5.75bc
Seed treatment with Bavistin (Carbrendazim 50%WP) @ 2gm kg^{-1}	0.19ab	3.8ab	3.99ab
Seed treatment with Mancozeb 75%WP @ 2gm kg^{-1}	0.23b	4.84abc	5.07abc
Soil treatment with *Trichoderma* @ 10^6	0.26b	4.54abc	4.81abc
Seed treatment with *Trichoderma* @ 10^6	0.24b	4.00ab	4.25ab
Control	0.09a	2.13a	2.23a
LSD(=0.05)	0.09	2.6	2.68
S.Em (±)	0.0437	1.19	1.23
CoV (%)	23.2	32.1	31.5
Grand Mean	0.23	4.57	4.8
P-value	0.003	0.037	0.033

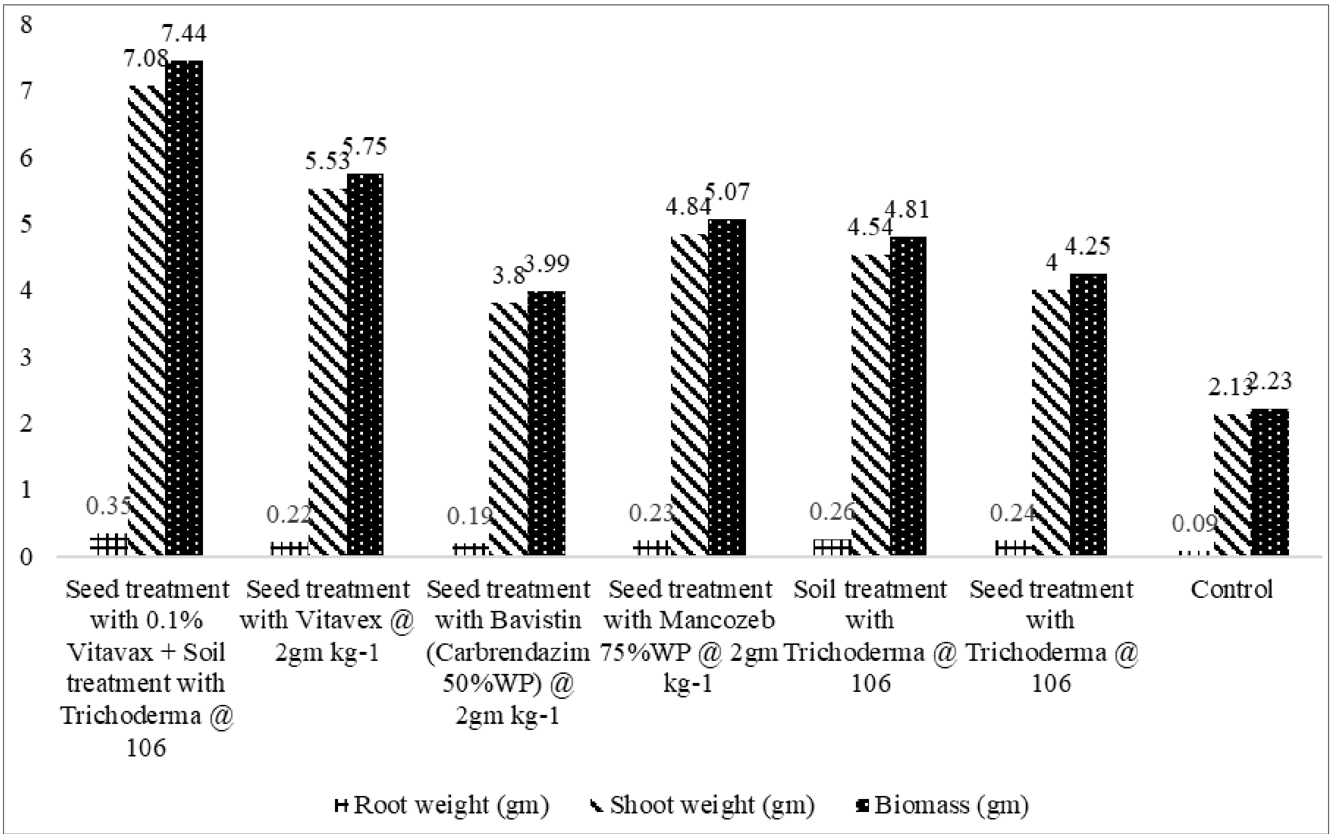

Fig 4: Effect of treatments on root and shoot weight of the bitter gourd seedlings against damping off disease caused by *Pythium spp*

Conclusion

Damping-off disease poses a significant threat to vegetable crop productivity, often resulting in substantial losses. *Pythium* spp. infection can lead to complete crop loss by destroying seedlings in the nursery. This study aimed to identify effective chemical and biological control agents to mitigate damping-off disease and promote healthy bitter gourd seedling growth in Bharatpur, Nepal.

The application of Trichoderma in soil combined with Vitavex seed treatment yielded the most promising results among all treatments. However, using Trichoderma solely in soil also resulted in a significant reduction in both pre and post-emergence disease incidence, leading to higher germination percentages, increased plant height, and the development of healthy root systems. Thus, the combined application of Trichoderma in soil with chemical fungicides such as Vitavex and Bavistin demonstrated significant reductions in disease incidence while promoting both shoot and root growth of seedlings. This could be attributed to the inhibitory effects of chemical fungicides and Trichoderma on soil and seed-borne pathogens, as well as the hormonal effects produced by Trichoderma, stimulating vigorous root and shoot growth in bitter gourd seedlings.

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