EFFECT OF *Trichoderma harzianum* ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.)

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Abstract: The fact that radish grows readily and is available for use three to six weeks after planting makes it a favorite crop for kitchen gardens. For encouraging crop development, *Trichoderma harzianum* is utilized as an active ingredient in a variety of commercially available biofertilizers and biopesticides. The experiment was performed in Horticulture Research Farm, The University of Agriculture Peshawar in the year, 2020. The arrangement of experiment was done in Randomized Complete Block Design (RCBD) with three replicates. *Trichoderma harzianum* was applied to the radish field before sowing of radish at the concentrations of T1 control (0 kg ha^{-1}), T2 (2 kg ha^{-1}), T3 (4 kg ha^{-1}) and T4 (6 kg ha^{-1}). The different parameters studied were plant height (cm), number of leaves plant^{-1}, leaf length (cm), plant fresh weight (kg), root length (cm), root weight (kg), root diameter (mm), and yield ha^{-1} (tons). Radish growth and yield were significantly affected by different concentrations of *Trichoderma harzianum*. The statistical analysis showed the best results were obtained when the *Trichoderma harzianum* was applied with the rate of T4 (6 kg ha^{-1}) in all studied parameters. Maximum plant height (68.425 cm), number of leaves plant^{-1} (15.333), leaf length (40.033 cm), plant fresh weight (0.4283 kg), root length (35.052 cm), root weight (0.2782 kg), root diameter (49.694 mm), and yield tonnes ha^{-1} (22.803 tons) was recorded with T4 (6 kg ha^{-1}). While minimum results were recorded in T1 (control) in all studied parameters. It is concluded that *Trichoderma harzianum* should be applied with the rate of 6 kg ha^{-1} for a satisfactory yield of radish.

Keywords: *Trichoderma harzianum*, Radish, Growth, Yield, Biofertilizer.

1. INTRODUCTION

The radish (*Raphanus sativus* L.) is a member of the Brassicaceae family. The Latin word "radix," or root, is the source of the English term "radish". The Indo-Pakistani subcontinent and central China are the radish's native lands. It is cultivated for its "fleshy edible roots, which are consumed raw in salads or cooked as vegetables". Radish growth and yield are highly reliant on soil and climate factors. For each variety to operate at its best, the soil and climate conditions varied. One of the key agro-techniques that affects the development and output of radish is nutrition. The crop's nutritional needs are influenced by soil type, soil fertility, agro-climatic conditions, and variety. The root development should be swift and unbroken because this crop has a short lifespan and grows quickly. Therefore, optimal fertilization using organic, inorganic, and biofertilizers is necessary for the development of high-quality radish (Dhanajaya, 2007). Because it is simple to cultivate and available for use three to six weeks after sowing, radish is a favorite crop for kitchen gardening. It is pleasant, avoids constipation, stimulates hunger, and has a cooling effect. Although it may be cultivated in various types of soil, radish thrives in sunny, fertile, and humid environments. A total yield of 156,665 tonnes were produced in Pakistan over an area of 9,600 hectares, while in KP the total area under cultivation was 1030 hectares with a total production of 12135 tonnes (Fruit, vegetable, and condiments statistics of Pakistan, 2017-18). The main radish-producing areas have been identified as Sheikhupura, Sahiwal, Rahim Yar Khan, Toba Tek Singh, and Okara. Although immature, young, green pods are also used as vegetables by a huge population. It is commonly used as a root vegetable. Native cultivars tend to be whiter than introduced varieties and have roots that are triangular or cylindrical in form. Few studies have been published on the phenotypic variety of radish germplasm, and less research has been done on its genetic variability (Anonymous, 2020). There are several more medical benefits of radish as described by Chaudhry (1979), It has 94.4 g of moisture, 0.7 g of protein, 0.10 g of fat, 0.6 g of minerals, 0.8 g of fiber, 17 mg of calories, 9 mg of oxalic acid, 22 mg of phosphorus, 0.4 mg of iron, 33 mg of sodium, 138 mg of sodium, 5 mg of vitamin A, 0.06 mg of thiamine, 0.02 (Khushk and Hisbani, 2003).

Nearly all temperate and tropical soils contain 101 to 103 propagules per gram of *Trichoderma*, an asexually reproducing fungus species that can be cultured under normal laboratory conditions. These species have been seen to colonize both woody and herbaceous plants, according to the sexual teleomorph (genus Hypocrea). However, there are several *Trichoderma* strains, the majority of which are biocontrol strains without sexual phases in nature, clonal, sometimes heterokaryotic vegetative forms of fungus persist both alone and in communities that most likely developed independently during the asexual stage. *Trichoderma* is a powerful antibiotic maker as well as a strong opportunistic invader. This is true even in environments where there is intense competition for resources like space, nutrition, and light (Schuster and Schmoll, 2010; Herrera and Chet, 2004; Montero *et al*., 2011). A variety of commercially marketed biofertilizers and biopesticides have *T. harzianum* as an active ingredient (Lorito *et al*., 2010). *Trichoderma* species have the capacity to both antagonize a variety of soil-borne plant pathogens and to lessen the frequency of illnesses brought on by these pathogens in a variety of crops (Monte, 2001). Through competition for resources and rhizosphere colonization, *T. harzianum* T35 also manages *Fusarium oxysporum* (Tjamos *et al*., 1922). Some *Trichoderma* isolates generate siderophores, which are powerful iron chelators that also prevent the development of other fungi (Chet and Inbar, 1997).

Keeping in view the potential of *Trichoderma harzianum* on improving the growth and yield of various crops, the present study was designed with the following objectives: (1) To evaluate the effect of *Trichoderma harzianum* on the growth and yield of radish. (2) To determine the best level of *Trichoderma harzianum* for better growth and yield of radish.

II. MATERIALS AND METHODS

The experiment was conducted on the "effect of *Trichoderma harzianum* on growth and yield of Radish (*Raphanus sativus* L.) at Horticulture Research Farm, The University of Agriculture, Peshawar, Pakistan in December, 2020.

Soil analysis

Using an auger (30 mm in diameter), soil samples were randomly collected from various fields, then examined in the soil science lab at the University of Agriculture Peshawar.

Table 1: Results of Soil analysis of experimental plot.

Soil Analysis	Unit	Concentration
pH	-	7.3
Electrical Conductivity	dSm^{-1}	0.32
Organic Matter	%	1.2
N content	%	0.12
AB-DTPA extractable P content	mg kg^{-1}	3.26

Preparation of the Field

In order to have a well-organized supply of irrigation water, the area was leveled properly. The variety used in the research was 40-days. According to statistical design, the experimental plot was split into smaller plots, each one measuring 1.22 m^{-2}. Each plot was divided into ridges that were 60 cm apart for seeding. Plants were thinned and spaced 10 cm apart (recommended plant-to-plant spacing for radish).

Experimental Design

The trial was laid out in Randomized Complete Block Design (RCBD) and replicated thrice. The experiment consisted of a single factor; T1 control (0 kg ha^{-1}), T2 (2 kg ha^{-1}), T3 (4 kg ha^{-1}), and T4 (6 kg ha^{-1}).

Parameters studied.

Data were recorded on the following parameters:

Plant height (cm)

Six plants were chosen at random from each treatment and replication, and their heights were measured with measuring tape and their average was determined.

Number of leaves $plant^{-1}$

Six plants were randomly chosen from each treatment in each replication, after which the average number of leaves per plant was determined.

Leaf length (cm)

By removing leaves from a chosen plant of each treatment and measuring the length using a measuring tape, the average leaf length was estimated.

Plant fresh weight (kg)

Six plants were chosen at random from each treatment in each replication, and their weight was measured using a digital balance after that their average was determined.

Root length(cm)

Using a measuring tape, the root lengths of six young plants of each treatment were measured, and an average was determined.

Root weight (kg)

Six newly harvested plants' roots of each treatment were weighed using a digital balance, and the average was then determined.

Root diameter (mm)

Using a digital vernier caliper, the diameter of the roots of six randomly chosen plants was measured, and the average was then calculated.

Yield ha^{-1} (tons)

The yield of each plot was converted to tons ha^{-1} with the help of the given formula;

$$\text{Yield ha}^{-1}\text{ (tons)} = \frac{\text{Yield per plot(kg)} \times 10000\text{m}^2}{\text{Plot area (m}^2) \times 1000\ \text{(Kg)}}$$

Statistical analysis

Utilizing analysis of variance methods advised for the randomized complete block design, data were statistically evaluated. After significant F-test findings, the least significant difference test was used to compare the means (Steel and Torrie, 1984).

III. RESULTS

Plant height (cm)

Data on plant height are shown in Table 2, which demonstrates how varied levels of *Trichoderma harzianum* treatment had a significant impact on radish plant height. T4 had the tallest plants, measuring 68.425 cm at 6 kg ha^{-1}, followed by T3 (67.54 cm) at 4 kg ha^{-1}, while the control had the shortest plants, measuring 62.095 cm.

Number of leaves $plant^{-1}$

Table 2 data on leaf number per plant revealed that varying levels of *Trichoderma harzianum* had a significant effect on leaf number. T4 (6 kg ha^{-1}) had the highest (15.33) number of leaves, followed by T3 (14.00) at 4 kg ha^{-1}, and control had the lowest (11.67) number of leaves.

Leaf length (cm)

Table 2 showed that leaf length was significantly affected by the various levels of *Trichoderma harzianum* treatment. The maximum leaf length (40.03 cm) was found at T4 (6 kg ha^{-1}), followed by T3 (35.50 cm) at 4 kg ha^{-1}, while the lowest leaf length (30.472 cm) was found in control.

Plant fresh weight (kg)

The fresh plant weight of the radish was significantly affected by the different levels of *Trichoderma harzianum*, according to statistical analysis of the data (Table 2). T4 reported the highest fresh plant weight (0.43 kg at 6 kg ha^{-1}), followed by T3 (0.37 kg at 4 kg ha^{-1}), and control recorded the lowest (0.28 kg).

Root length (cm)

The root length of the radish was significantly affected by the different levels of *Trichoderma harzianum* treatment, according to the mean results shown in Table 2. The control had the shortest root length, measuring at 27.31cm, while T4 had the longest roots, measuring 35.05 cm at 6 kg ha^{-1}, followed by T3 root length, measuring 33.61 cm at 4 kg ha^{-1}.

Table 2: Influence of *Trichoderma harzianum* on the growth parameters of radish.

Trichoderma harzianum Levels (kg ha^{-1})	Plant height (cm)	No. of leaves	Leaf length (cm)	Fresh plant weight (kg)	Root length (cm)
0	62.09 c	11.67 c	30.47 d	0.279 c	27.30 d
2	63.17 bc	13.00 bc	33.23 c	0.32 bc	30.96 c
4	67.54 ab	14.00 ab	35.50 b	0.37 ab	32.89 b
6	68.43 a	15.33 a	40.03 a	0.43 a	35.05 a
LSD ($P<0.05$)	2.040	0.561	0.455	0.031	1.060

Root weight (kg)

The root weight in Table 3 indicates that the radish was considerably affected by the level of *Trichoderma harzianum*. T4 had the greatest root weight (0.28 kg) at 6 kg ha^{-1}, followed by T3 (0.23 kg) at 4 kg ha^{-1}, while the control had the lowest root weight (0.18 kg).

Root diameter (mm)

The root diameter of the radish was significantly affected by the different levels of *Trichoderma harzianum* treatment, as shown in Table 3. T4 had the maximum root diameter (49.69 mm) when 6 kg ha^{-1} of *Trichoderma harzianum* was applied, followed by T3 (46.84 mm) at the rate of 4 kg ha^{-1}, and control had the minimum root diameter (40.64 mm).

Yield ha^{-1} (tons)

Statistically analyzed data in Table 3 showed that different levels of *Trichoderma harzianum* significantly influenced the yield ha^{-1} of the radish. The highest yield ha^{-1} was recorded in T4 (22.80 tonnes ha^{-1}) at 6 kg tones/ha^{-1}, followed by T3 (19.23 ton ha^{-1}) at 4 kg ha^{-1}, while the minimum yield was recorded in control which was 15.418 ton ha^{-1}.

Table 3: Influence of *Trichoderma harzianum* on yield parameters of radis

Trichoderma harzianum Levels (kg ha^{-1})	Root weight (kg)	Root diameter (mm)	Yield (tons $hecter^{-1}$)
0	0.18 b	40.64 d	15.42 b
2	0.21 b	43.17 c	17.20 b
4	0.23 ab	46.84 b	19.22 ab
6	0.27 a	49.69 a	22.80 a
LSD (P<0.05)	0.023	0.9903	4.625

IV: DISCUSSION

When growing radish, *T. harzianum* was applied as a biocontrol agent. The results of this study add to our understanding of *T. harzianum* effects on radish yield and growth, as well as its potential use in sustainable agriculture. The treatment of the various *Trichoderma* isolates increased the acai palm seedlings' height, collar diameter, number of leaves, root size, leaf area, and aerial part dry mass (Campos *et al*., 2020). *Trichoderma* facilitates the release of nutrients from the soil or organic matter and promotes the intake and transport of minerals (Brown, 1974). Auxins generated by Trichoderma species can also encourage the development of new roots and plant growth (Contreras *et al*., 2009). The capacity of critical nutrients to be supplied for strong and flourishing growth may have resulted in morphological modifications in the plant canopy and an increase in the number of leaves,

respectively (Ali *et al*., 2015). Sucrose produced from plants has been found to be a crucial resource that *Trichoderma* cells use to promote root colonization, the coordination of defensive systems, and a rise in the efficiency of leaf photosynthesis (Vargas *et al*., 2009). According to Ousley *et al.*, (1997), after conducting an experiment to test the potential of *Trichoderma spp.* as a reliable plant growth stimulator, they found that six different strains of *Trichoderma spp*., when applied as a dried powder from a liquid fermentation in molasses/yeast medium, consistently promoted the growth of lettuce (*Latuca sativa* L.) seedlings grown in a peat-sand potting compost in the greenhouse. At 0.75% or 1% w:w concentrations, strains WT, 92, 20, and 75 increased shoot dry weight by up to 26%.

Certain bioactive metabolites may immediately enhance the absorption of certain elements in the roots, including Ca, Fe, K, Mg, Mn, P, and Zn (Woo *et al.*, 2014). However, these metabolites are primarily in charge of directly promoting root development and growth, which increases the soil environment's surface area and root extension and enhances nitrogen use efficiency (vinale *et al.*, 2013), by employing techniques similar to those of other advantageous microorganisms in the root community (such as arbuscular mycorrhiza and plant growth-promoting rhizobacteria). According to Windham *et al.,* (1986), *Trichoderma spp.* generated a growth-regulating factor that accelerated seed germination and increased the dry weight of shoots and stems. According to Baker (1998) *Trichoderma spp*. induced plant growth responses appeared to be caused by both the management of small infections and the creation of a growth-regulating factor. The inside of the plant root was found to have *T. harzianum* penetration and colonization (Yedidia, 1999). The ability of *T. harzianum* to boost the effectiveness of nutrient transfer from the compost to the roots in a fashion like mycorrhizal effects may thus be one potential mechanism for greater plant development (Ousley *et al.,*1994). By encouraging root development through phytohormones, *Trichoderma* species can operate as biostimulants of root growth. This improves nutrient uptake and increases resistance to biotic stressors. Phuwiwat and Soytong (1999) found that when the quantity of *Trichoderma harzianum* used was raised, plant growth and yield steadily rose in the planting medium with *Trichoderma harzianum* addition. The total fresh and dry weights of Chinese radishes enhanced above the control by 77.47 and 56.31 percent, respectively, indicating a significant improvement in growth and yield.

V: CONLLUSIONS AND RECOMMENDATIONS

From the experimental results, it is concluded that; the application of different levels of *Trichoderma harzianum* at the rate of 6 kg ha^{-1} significantly increased all the growth and yield parameters in radish. Based on the experimental results, It is recommended that the application of *Trichoderma harzianum* at the rate of 6 kg ha^{-1} is recommended to obtain better growth and yield of radish. Further research is suggested to explore the higher concentrations of *Trichoderma harzianum* radish and other vegetables in the valley of Peshawar.

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