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Article

Effect of Different Levels of Urea and the *Trichoderma harzianum* Biofungicide on Tomato Growth and Resistance to *Rhizoctonia solani* Root Rot

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Abstract: A field experiment was conducted in the aeroponic beds of the College of Medicinal and Industrial Plants at Kirkuk University during the 2023-2024 season on the tomato crop Lycopersicon esculentum Mill. The experiment aimed to study the effect of adding different levels of urea on tomato growth, yield, and resistance to Rhizoctonia solani (root rot). Urea was applied at levels of 0, 80, 160, and 240 kg ha^{-1}. For comparison, the fungus Trichoderma harzianum was applied at rates of 25 and 50 cm^3/L. The soil was prepared for planting. The soil was fertilized with the above urea levels and with both phosphorus and potassium at a level of 80 kg P/ha in the form of superphosphate and 120 kg K/ha, respectively. Then the soil was contaminated with the fungus Rhizoctonia solani, and the tomato seedlings were transplanted on 10/18/2023 The study was conducted using a factorial experiment and a randomized complete block design (RCBD) with three replications. The results showed that the urea level (160 kg/ha) was significantly superior to the other levels in giving the highest plant height, dry weight, chlorophyll content, nitrogen, phosphorus, and potassium concentrations in the tomato plant, among other studied traits. The 240 level negatively affected the studied traits. The results also showed that a concentration of (50) cm3/L of the biopesticide led to a significant increase in all studied growth traits. The interaction between nitrogen fertilization and the addition of the biopesticide T. harzianum significantly affected all studied traits at the combination (160 kg/ha + 50 cm3/L)

Keywords: Urea fertilization; Trichoderma harzianum; Tomato growth; Rhizoctonia solani; Root rot resistance

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Introduction

The tomato crop (Solanum lycopersicum L) is one of the most important vegetable crops globally in terms of cultivated area and economic and nutritional importance [1]. Its importance lies in the fact that it is a rich source of minerals, vitamins, organic acids, essential amino acids, dietary fiber, and vitamins A and C. It also contains minerals such as iron and phosphorus, in addition to pigments such as beta-carotene and lycopene [2], [3]. In addition to its medicinal importance, tomatoes also have numerous industrial uses, such as in the production of pastes, juices, and other products (Bose and Some, 1986). Like other crops, tomatoes are susceptible to various pathogens [4]. Among the most significant of these diseases are soilborne pathogenic fungi, which are considered among the most dangerous and damaging fungi to tomatoes. This is because they are often hidden from human view, and their symptoms usually appear on the foliage only after they have completely destroyed the root system [5], thus increasing their severity. It is characterized by its ability to resist unfavorable conditions and to remain in the soil and on the remains of infected plants for a long period (Sisic, 2018). One of the most important of these diseases is root rot disease caused by the causative agent Rhizoctonia solani, which belongs to the phylum Deuteromycotina [6], [7]. The fungus R. solani, which is one of the most common and damaging diseases in tomatoes that causes a decrease in the quality and production of the tomato crop, is one of the important causes of seed rot and seedling death in Iraq. The fungus attacks tomato seeds in their bud before germination and newly growing seedlings, leading to seedling death before and after emergence (Pre- and Post-emergence Damping Off), root rot, stem base rot, and seed rot and decay [8], [9]. The longer the germination of the seeds is delayed, the greater the likelihood of them becoming infected with the disease. After that, the fungus attacks the roots and attacks plants above the soil surface, infecting other plant parts such as pods, fruits, leaves, and stems. The fungus R. solani has several means of penetrating the tissues of the hosts it infects directly through natural openings or by forming appressoria [10]. It also attacks seedlings after emergence at the stem-root junction, causing symptoms to appear as small, reddish-brown spots. These spots merge as the infection progresses, forming ulcers that surround the crown at soil surface level, leading to seedling death. The fungus responsible is R. solani. Roots: It has been found that root hairs and root tips are more sensitive to infection than the main root. The presence of the disease is indicated by the yellowing of the upper leaves of the plant, followed by wilting of the plant or premature death during the growing season [11], [12], [13]. When the root system of the tomato plant is infected with the pathogen R. solani, it hinders its ability to absorb nutrients and negatively affects tomato productivity [14]. To obtain plants with high resistance to such diseases, good fertile nutrition is required. Its significant contribution to the synthesis of these compounds underscores its pivotal impact on plant growth and productivity [15]. Nitrogen is closely related to carboxyl capacity and electron transport rate in plant photosynthesis, and an appropriate dose of nitrogen can enhance enzyme activity and chlorophyll content in plant leaves, thus improving the photosynthetic process [16]. In addition to its significant contribution to reducing root rot, many studies have shown that good nitrogen nutrition greatly reduces the incidence of this disease [17]. Since root rot affects old and weak plants, nitrogen increases the strength and resilience of the plant and delays its maturation, thus reducing plant infection. Due to the conflicting results and the strong correlation between fertilization strategy and plant health There is a clear need for applied studies designed to evaluate the effect of multiple, specific nitrogen levels on tomato growth and yield characteristics, including plant height, nitrogen concentration in the plant and in the soil after planting, as well as phosphorus and potassium concentrations. Therefore, this study aimed to determine the effect of adding nitrogen to nutrient-poor soils, including nitrogen, on tomato crop growth and its resistance to Rhizoctonia spp. root rot. Despite the modern trends in adopting biological pesticides and alternative control methods such as agricultural control and fertilization to increase plant immunity, which are considered an alternative to chemical control, biological pesticides have been adopted as a result of the positive results achieved by biological control [18]. Among the most commonly used organisms in biological control is the fungus Trichoderma harzianum, due to the ease of its isolation, its rapid reproduction, its lack of need for special nutritional requirements, its positive effect on the growth of many plants, as well as its inhibitory effect on many plant pathogens [19], [20]., The use of integrated management methods, including biological control and fertilization, enhances the opportunity to achieve effective resistance to plant diseases, as integrated resistance relies on the use of several methods to combat diseases instead of relying on a single method to avoid or reduce the impact of plant pathogens, provided that there is no conflict between these methods used [21]

Materials and Method

This study was conducted in the aeroponic beds of the College of Medicinal and Industrial Plants at Kirkuk University during the 2023-2024 growing season. Soil samples were collected from the study area before planting at depths of (0-25) cm. The samples were then air-dried and sieved through a sieve with a diameter of 2 mm. The preliminary analyses listed in Table (1) were performed on them, where electrical conductivity (EC), soil pH, cation exchange capacity (CEC), available phosphorus, available potassium, organic matter, and potassium in the soil leachate were estimated as described in Page et al. (1982) [22]. Available nitrogen was estimated according to the method of Bremner and Edwards (1965) [23]. Soil texture was estimated using the absorbent method described in Black (1965) [24].

Table (1) Some physical and chemical properties of the soil used in the experiment

Characteristic	Unit	Value
Sand	$g.kg^{-1}$	459
silt		308
Clay		233
Soil Texture		Loam
PH	-	7.34
EC	dS/m	2. 13
CEC	$cmol.kg^{-1}$	16.31
Organic matter	$g.kg^{-1}$ soil	10.02
CO_3	$g.kg^{-1}$ soil	364.66
Available Potassium	$mg.kg^{-1}$	174.98
Available Nitrogen		22.34
Available Phosphorus		6.93

The pathogenic fungus Rhizoctonia Solani

The pathogenic fungus R. Solani was obtained from the Agricultural and Biological Research Center - Iraqi Ministry of Agriculture, where it was identified by the research center based on morphological and microscopic characteristics and using the taxonomic keys ([25], [26].

Preparation of the fungal isolate R. Solani inoculum:

The inoculum was prepared using local millet seeds, Panicum miliaceum L., which were washed thoroughly and soaked for 6 hours. A set of 250 ml flasks was prepared, and 50 g of millet seeds were placed in each flask. The flasks were then sterilized with a steam sterilizer at 121°C, 1 atmosphere, for one hour and left to cool. Each flask was inoculated with 5 discs (5 mm diameter) of a 7-day-old fungal colony. The flasks were incubated at a temperature of (27 ± 2 °C) for 15 days, shaking the flasks every 3 days to distribute the fungal inoculum [27], [28]. They were then stored in the refrigerator until use.

The bio-fungus Trichoderma harzianum

The fungus was obtained from the National Center for Bio-Pesticide Testing - Iraqi Ministry of Agriculture, where the trade name was Biocont, and it was used according to the recommendations on the package.

The soil was plowed, and then furrows were opened to a depth of 30-40 cm. Inoculum of the fungal isolate R. solani, loaded onto millet seeds, was added to the treatments requiring the addition of the pathogenic fungal inoculum at a rate of 1% w/w for each treatment, except for the control treatment. The inoculum was left for three days with constant moisture. Afterward, the biofungible fungus T. harzianum was added and left for four days. During this period, seeds of the Super Read hybrid tomato variety were sown in polystyrene trays inside a plastic greenhouse. When the plants reached the five-true-leaf stage, they were transplanted to the field on 18/10/2023, planted in two rows 1.5 m apart, with approximately 40-50 cm between rows, in the same locations where the fungal isolate and biofungible fungicide were added. Nitrogen fertilizer in the form of urea (46%) was added at levels of (0, 80, 160, 200) kg.ha-1 in two applications at the beginning of planting and at the flowering stage. A fungicide of the type T. harzianum was added at a rate of 0, 25 and 50 cm3.L-1. The replicates were sprayed with the bio-pesticide three times at a 15-day interval during the growing season. The first dose was applied 15 days after planting [29]. Pathogenic fungal cultures were purchased and kept in millet extract agar medium and incubated under laboratory conditions at a temperature of 25 + 3. After 48 hours, the fungal hyphae were removed and then transferred to potato dextrose agar medium (PDA) and stored at a temperature of 24-26°C [30], [31]. Subsequently, the soil was contaminated with pathogenic fungi prior to planting in order to induce infection. The experimental units were fertilized with phosphorus and potassium using concentrated triple superphosphate and potassium sulfate at a rate of 80 kg P/ha and 120 kg K/ha, respectively. Phosphorus was applied in a single dose at planting, while potassium was applied in two doses: the first at flowering and the second at the beginning of fruit set. These fertilizers were applied according to established recommendations. Crop management practices, including drip irrigation, salt removal, insect control, hoeing, weeding, and other operations, continued until the end of the season. The studied characteristics were then analyzed: Plant height (cm): The height of the plant was measured from the soil surface to the tallest point using a measuring tape, and the average height per plant was calculated. Dry weight: This was determined by taking the plants, cleaning them of dust, and then drying them in an electric oven at a temperature of 65-70°C until the weight stabilized. The dry weight was then measured using a sensitive three-point balance, and the average weight per plant was calculated (Al-Sahaf, 1989). Chlorophyll content was measured using a SPAD device, and the severity of infection was assessed using the following equation described in Castro et al. (2017) [32]:

DSI (%) =[Σ Diseases grade × number of plants of this Diseases grade) / (maximum Diseases grade × total number of plants)] × 100

The concentration of nitrogen, phosphorus, and potassium in the dry weight of the tomato plant was calculated, as was the nitrogen content remaining in the soil after planting. The experiment was designed according to the randomized complete block design (RCBD) with three replicates for each treatment and according to the LSD design with the least significant difference at a probability level of 5% [33].

Result and Discussion

Plant Height:

The results in Table (2) show that adding different levels of urea and concentrations of the fungicide T. harzianum led to a clear increase in the height of tomato plants grown in soil contaminated with Rhizoctonia solani. The addition of urea levels led to a significant increase of 64.03%, 102.65%, and 90.06% for levels (A1, A2, A3) respectively, compared to the treatment without addition (A0). This indicates the importance of nitrogen fertilizer in plant growth, as nitrogen addition stimulates cell division and elongation through its participation in chlorophyll biosynthesis, thus enhancing the ability to photosynthesize [34]. In addition to its importance in enhancing plant resistance to disease, particularly root rot, it works to increase the activity of defensive enzymes such as peroxidase and polyphenol oxyrase, as well as enhancing the production of resistance-associated proteins (PR-Proteins) [35]. The results also show that level A2 is the best level in giving the best plant height index, while at level A3, the indicators began to decrease. This is evidence that high levels of urea gave a greater chance of disease infection because high levels of urea lead to a rapid increase in vegetative growth, which leads to the formation of soft tissues with thin cell walls that are easily penetrated by pathogens, especially Rhizoctonia solani [36]. The effect of adding the biopesticide T. harzianum was found to be that increasing the concentration of the biopesticide led to a significant increase in plant height, with increases of (128.82%, 152.21%) for levels (B1, B2), respectively. This indicates that increasing the concentration of the biopesticide reduced the severity of the disease and increased the plant's response to nitrogen nutrition. This is consistent with the findings of Elad et al. (1999), especially since the fungus T. harzianum possesses a high competitive ability due to its rapid growth and high reproductive capacity [37] Alternatively, this fungus may have attacked the pathogenic fungus and reduced inoculum production, thus lowering the infection rate. Or, T. harzianum may produce certain enzymes outside the attacking cell wall, such as chitinases, β-1,3-glucanases, and cellulose, which are important characteristics of the biopesticide fungus [38]. The interaction effect showed that the combination (A2B3) resulted in the highest plant height (100.09 cm), compared to the combination without the addition (A0B0), which resulted in the lowest plant height (40.05 cm).

Table (2) Effect of nitrogen fertilizer and the biopesticide T. harzianum on tomato plant height (cm)

Nitrogen levels (A) kg ha^{-1}	(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L			Mean
	0	25	50	
0	40.05	45.07	48.13	**44.41**
80	65.11	73.22	80.23	**72.85**
160	80.09	90.12	100.09	**90.10**
240	73.21	85.04	95.00	**84.41**
Mean	**64.61**	**73.36**	**80.86**	
L.S.D	(A) =4.8	(B) =4.2	A×B=8.5	

Plant Dry Weight:

Table (3) shows that nitrogen fertilization with urea has a significant effect on the dry weight of tomato plants. The application levels significantly outperformed the control treatment, yielding average dry weights of 42.02, 59.81, and 54.58 g/plant for levels A1, A2, and A3, respectively, compared to the no-application treatment which yielded an average of 18.00 g/plant. These represent increases of 133.44%, 232.27%, and 203.22% for the three levels, respectively. The superiority of the nitrogen fertilization levels is attributed to the vital role of nitrogen in the synthesis of amino acids, cell membranes, and vitamins, including the B vitamins, which collectively contribute to increased plant height, number of leaves, and fresh weight**.** Or this increase may be due to nitrogen absorption, especially since urea fertilizer is highly soluble in water and therefore in the soil solution, making it easier for the plant to absorb [39]. The results also show that this response is evident even though the soil is contaminated with fungi and there is a high probability of many plants being infected with root rot. However, it did respond, which means that nitrogen nutrition led to strengthening the plant and increasing its resistance to the disease, even when the bio-fungicide T. harzianum was not added. This, in turn, contributes to reducing disease incidence**.** Despite this response, the results show that the dry weight of the tomato plant began to decrease. This indicates that the A2 level became excessive, leading to an increased likelihood of root rot. Excessive nitrogen fertilization reduces the carbon-to-nitrogen ratio in plant tissues, limiting the allocation of carbon to plant and defensive compounds such as lignin and phenols. Consequently, cell walls become less rigid and more susceptible to enzymatic degradation by pathogens. This aligns with the findings of Huber and Thompson (2019), who found that high nitrogen levels may reduce the accumulation of structural carbohydrates and promote woody tissue growth, thereby increasing the host plant's susceptibility to root pathogensAs for the effect of the concentrations of the biopesticide T. harzianum, the results show that the use of the biopesticide led to a significant increase in the dry weight of the tomato plant, with increases of 22.39% and 41.06%, compared to the treatment of no addition, which gave the lowest dry weight of 38.49 g/plant. The reason may be attributed to the fact that it leads to a reduction in infection by the pathogen through the secretion of antifungal compounds and the breakdown of the wall of the causative fungus, which leads to a reduction in the severity of infection and thus an increase in dry weight [40], [41]. As for the effect of the interaction, the combination (A2B3) gave the highest dry weight of 68.67 g/plant and an increase of 348.23% compared to the control treatment (A0B0), which gave the lowest dry weight of 15.32 g/plant. The reason is that it increased the ability to absorb nutrients through the secretion of organic acids and the production of enzymes to increase nitrogen absorption and make it more efficient, thus stimulating root growth or making the nutrients available for absorption. This is similar to the results, in addition to increasing microbial activity in the root area (Contreras et al., 2009) Table (3) Effect of adding nitrogen fertilizer and the biopesticide T. harzianum on the dry weight of the tomato plant (g/plant) .

Table (3) Effect of adding nitrogen fertilizer and the biopesticide T. harzianum on the dry weight of the tomato plant (g/plant)

Nitrogen levels (A) kg ha^{-1}	(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L			Mean
	0	25	50	
0	15.32	18.03	20.65	**18.00**
80	35.26	42.54	48.34	**42.04**
160	50.33	60.43	68.67	**59.81**
240	43.06	55.23	65.45	**54.58**
Mean	**35.99**	**44.05**	**50.77**	
L.S.D	(A) =4.2	(B) =3.6	A×B=7.1	

Chlorophyll content:

Table (4) shows that there is a significant effect on chlorophyll content when different levels of nitrogen are added. Levels (A1, A2, and A3) gave chlorophyll content of (42.14, 50.23, and 46.35) (SPAD) for all levels respectively, with increases of 39.21%, 65.93%, and 53.12% compared to the treatment without addition, which gave the lowest chlorophyll content of 30.27 (SPAD). This response may be attributed to the role of nitrogen as one of the essential components of the chlorophyll molecule in the plant. The chlorophyll content of leaves can be determined through the nitrogen element, most of which is found in the leaves, and there is a positive relationship between nitrogen content and chlorophyll in the leaf [42] This response appears even though the plant is grown in soil contaminated with the Rhizoctonia solani fungus, which causes root rot. Consequently, symptoms of disease and weakness appear on the plant, which may lead to its death. Herein lies the importance of nitrogen in increasing the plant's ability to resist disease, even under conditions of not using a biopesticide. Nitrogen works to increase root mass and root length and improve cell wall thickness as a result of increased synthesis of proteins and enzymes, while also increasing the ability to compensate for damaged tissues (Petra Marschner, 2012). As for the effect of the biopesticide, the results showed that there was a significant increase in chlorophyll content with increasing concentration of the biopesticide, as the concentrations (B1 and B2) gave a chlorophyll content of (42.89 and 45.77) SPAD, with percentage increases of (12.63 and 20.19)% compared to the treatment of no addition (B0), which gave the lowest chlorophyll content of (38.08) SPAD. This is similar to the results of the researcher [43]. As for the interaction, the results showed that the combination (A2B3) gave the highest chlorophyll content in the tomato plant, reaching (54.72) (SPAD), while the combination (A0B0) gave the lowest chlorophyll content, reaching (28.33) (SPAD). Al-Salihy et al. (2022) stated that the interaction between the biopesticide and fertilization leads to an increase in nitrogen transport within the plant and the activity of the enzymes responsible for its assimilation in the plant.

Table (4) Effect of nitrogen fertilizer and the biopesticide T. harzianum on the chlorophyll content of the tomato plant (SPAD).

Nitrogen levels (A) kg ha^{-1}	(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L			Mean
	0	25	50	
0	28.33	30.09	32.39	**30.27**
80	38.23	42.34	45.87	**42.14**
160	45.11	50.87	54.72	**50.23**
240	40.65	48.29	50.11	**46.35**
Mean	**38.08**	**42.89**	**45.77**	
L.S.D	(A) =2.6	(B) =2.1	A×B=4.3	

Infection Severity:

The results in Table (5) show that adding different levels of nitrogen and concentrations of the fungicide T. harzianum led to a significant decrease in the severity of infection of tomato plants by the fungus Rhizoctonia solani. Adding levels (A1, A2, A3) led to a decrease in infection severity of (21.94, 13.39, 17.49)% for the three levels respectively, with reduction percentages of (39.57, 63.12, 51.83)% respectively, compared to the treatment without addition (A0). This indicates the importance of nitrogen fertilizer in increasing plant resistance to diseases and reducing infection severity. Adding nitrogen, especially urea, leads to an increase in soil pH, which creates unfavorable conditions for the activity of the fungus Rhizoctonia solani. Thus, increasing urea levels inhibits fungal activity and consequently reduces the severity of infection of the plant by this fungus [44]. This shows that the reduction in application intensity at level A2 was greater than at the other levels, indicating that this level is the optimal nitrogen level for obtaining disease-resistant plants with good growth characteristics. As for the effect of adding the biopesticide T. harzianum, it was found that increasing the biopesticide concentration led to a significant decrease in infection severity. Concentrations (B1 and B2) resulted in reductions of (21.48)% and (15.01)%, respectively, with reduction rates of (29.22)% and (50.54)%.

This indicates that increasing the concentration of the biopesticide reduced the severity of the disease and controlled the fungus, resulting in healthy plant growth unaffected by the fungus. This finding is similar to that of [45], who demonstrated that the fungus activates the plant's immune system by stimulating defense genes, such as the salicylic acid pathway. This is further supported by competition for nutrients, as the fungus exhibits rapid growth and parasitism, penetrating and breaking down the hyphae of the pathogen using enzymes like chitinase. Regarding the interaction effect, the combination (A2B3) resulted in the highest reduction in infection severity (6.98%) compared to the combination (A0B0), which resulted in an infection severity of (45.32%(

Table (5) effect of nitrogen fertilizer and the biopesticide T. harzianum on the severity of Rhizoctonia solani disease in tomato plants (%).

Nitrogen levels (A) **kg ha^{-1}**	**(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L**			**Mean**
	0	**25**	**50**	
0	45.32	35.54	28.09	**36.31**
80	30.43	20.87	14.54	**21.94**
160	20.54	12.65	6.98	**13.39**
240	25.12	16.89	10.46	**17.49**
Mean	**30.35**	**21.48**	**15.01**	
L.S.D	(A) =4.8	(B) =4.2	A×B=8.5	

Nitrogen concentration in dry matter:

The results in Table (6) show that the levels of nitrogen fertilization (urea) have a highly significant effect on the percentage of nitrogen in the vegetative part. Level (A2) outperformed the other levels, giving the highest percentage of nitrogen in dry matter, reaching (3.71%), while the lowest percentage of nitrogen was at level (A0), reaching (2.28%). This high response to nitrogen fertilizer application may be related to the low content of available nitrogen. As shown in Table (1), the nitrogen levels are below the critical limits. This also indicates that adding urea increased the nitrogen concentration in the soil solution, which was clearly and significantly reflected in the amount of nitrogen absorbed. This is evidence that the nitrogen level (160 kg/ha) was optimal for plant growth and increased disease resistance. As for level A3, the results show that the nitrogen concentration began to decrease significantly. This means that at the level of (200 kg/ha), symptoms of toxicity begin to appear on the plant, making it weak and more susceptible to disease. The reason is also attributed to the fact that high levels of nitrogen promote tissue sap and increase the concentration of free amino acids, thus providing a suitable nutrient environment for fungal colonization. This is consistent with what Maywald et al. indicated, that excessive nitrogen fertilization was generally associated with increased disease severity in many fungal infections. Regarding the effect of the biopesticide, the results showed a significant increase in nitrogen concentration with increasing biopesticide concentration. Concentrations (B1 and B2) yielded nitrogen concentrations of (1.70 and 1.81%), respectively, representing increases of (8.28 and 15.28%) compared to the no-add treatment (B0), which yielded the lowest concentration of (1.57%). As for the interaction, the results indicated that the combination (A3B3) produced the highest nitrogen concentration in tomato plants at (2.25%), while the combination (A0B0) produced the lowest concentration at (1.10%). These results were similar to those obtained by [46].

Table (6) Effect of nitrogen fertilizer and the biopesticide T. harzianum on the concentration of nitrogen in the dry matter of the tomato plant (%)

Nitrogen levels (A) kg ha^{-1}	**(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L**			**Mean**
	0	**25**	**50**	
0	2.10	2.25	2.50	**2.28**
80	2.50	2.66	2.83	**2.66**
160	3.08	3.95	4.10	**3.71**
240	2.90	3.10	3.25	**3.08**
Mean	**2.64**	**2.99**	**3.17**	
L.S.D	(A) = 0.15	(B) = 0.12	A×B= 0.24	

Phosphorus Concentration in Dry Matter:

Table (7) shows that nitrogen fertilization levels have a significant effect on the percentage of phosphorus in the dry matter of the vegetative part of the tomato plant. Levels (A1, A2, and A3) yielded phosphorus concentrations of (0.19, 0.26, and 0.22)%, respectively, with increases of (35.71, 85.71, and 57.14)% compared to the no-fertilization treatment, which yielded the lowest phosphorus concentration of (0.14)%. This is attributed to the positive interaction between nitrogen and phosphorus, which leads to increased phosphorus uptake through increased root growth, thus increasing the roots' ability to absorb and translocate phosphorus. Additionally, the pH decreases as a result of ammonium absorption, thereby increasing the solubility of phosphorus compounds and phosphate fertilizers added to the soil. On the other hand, increased phosphorus absorption led to the formation of the energy compound ATP, the availability of which increases the activity of the defensive enzymes Polyphenol oxidase and Peroxidase [29], [31]. From the table, we also note that at level (A3), the phosphorus concentration index in the tomato plant began to decrease. This indicates that the high levels of urea have weakened the plant and made it less resistant and more susceptible to diseases, especially root rot. This is attributed to the fact that the high level of urea has inhibited the synthesis of enzymes associated with defense, including peroxides and polyphenol oxidase, which weakens the plant's resistance mechanisms. This is consistent with what Cardoso and Segundo (2025) mentioned Regarding the effect of the biopesticide, the results showed a significant increase in phosphorus concentration with increasing biopesticide concentration. Concentrations (B1 and B2) yielded phosphorus concentrations of (0.22% and 0.24%), respectively, representing increases of (29.41% and 41.17%) compared to the non-additional treatment (B0), which yielded the lowest concentration of (0.17%), similar to the results of Mabrouk et al. (2022). As for the interaction, the results showed that the combination (A3B3) yielded the highest phosphorus concentration in the tomato plant at (0.30%), while the combination (A0B0) yielded the lowest concentration at (1.12%). Kashyap et al. (2017) demonstrated that T. harzianum secretes organic acids and produces the enzyme phosphatase, which helps convert organic phosphates into mineral phosphates that are more easily absorbed by the plant. Plant.

Table (7) Effect of nitrogen fertilizer and the biopesticide T. harzianum on the concentration of phosphorus in the dry matter of the tomato plant (%).

Nitrogen levels (A) kg ha^{-1}	(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L			Mean
	0	25	50	
0	0.12	0.14	0.16	**0.14**
80	0.16	0.19	0.22	**0.19**
160	0.20	0.26	0.32	**0.26**
240	0.15	0.24	0.29	**0.22**
Mean	**0.15**	**0.20**	**0.24**	
L.S.D	(A) = 4.8	(B) = 4.2	A×B= 8.5	

Potassium concentration in dry matter:

The results in Table (8) show that adding different levels of nitrogen and concentrations of the pesticide T. harzianum led to a significant increase in potassium concentration in the tomato plant. Adding levels (A1, A2, A3) led to an increase in the plant's potassium content of (3.80, 4.57, 3.73)% for the three levels respectively, with increases of (13.77, 36.82, 11.67)% respectively, compared to the treatment without addition (A0.)This is because the abundance of nitrogen stimulates the growth of the root system by increasing the root mass, increasing the number of root hairs, and improving the activity of the plasma membrane. This increases the ability of the roots to absorb potassium from the soil solution, and in turn, potassium strengthens the cell walls, which hinders the penetration of the fungus into the root tissues and increases the activity of defense enzymes that reduce the spread of infection in the root and stem (Bayindir and kucukyumuk, 2025) The table also shows that potassium concentration at level A3 has begun to decrease, indicating that this level is where symptoms of toxicity are starting to appear, meaning it is above the critical limit for the plant. Therefore, the plant is weak, and since it is grown in soil contaminated with Rhizoctonia solani, infection is easy and likely. This is attributed to the fact that excessive nitrogen fertilization has altered the microbial balance in the root zone and stimulated the production of enzymes that break down the fungal cell wall, ultimately increasing the virulence of the pathogens. This is consistent with what Sharma (2020) stated. Elevated urea levels may negatively affect physical defense mechanisms such as cell wall strengthening and antibody synthesis, thus facilitating greater colonization by the pathogen and increasing disease severity. Regarding the effect of adding the biopesticide T. harzianum, it was found that increasing the biopesticide concentration led to a significant increase in potassium concentration. Concentrations (B1, B2) showed significant increases of (1.87 and 2.03)% respectively, with increases of (10.00 and 19.41)%. This indicates that increasing the biopesticide concentration led to increased disease resistance, fungal control, and eradication, resulting in healthy growth without fungal influence. As for the effect of the interaction, it was found that the combination (A2B3) gave the highest potassium concentration of (2.45)% compared to the combination (A0B0) which gave an injury intensity of (1.30)%, which is similar to what was mentioned by the researcher Vinale et al 2008.

Table (8) Effect of nitrogen fertilizer and the biopesticide T. harzianum on the concentration of potassium in the dry matter of the tomato plant (%)

Nitrogen levels (A) kg ha^{-1}	(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L			Mean
	0	25	50	
0	3.00	3.40	3.62	**0.14**
80	3.60	3.85	3.95	**0.19**
160	4.32	4.57	4.83	**0.26**
240	3.52	3.75	3.94	**0.22**

Mean	3.61	3.89	4.08	
L.S.D	(A) = 0.18	(B) = 0.14	A×B=0.29	

Residual Nitrogen After Planting:
The results in Table (9) show that nitrogen fertilization and the addition of the biopesticide T. harzianum have a significant effect on the amount of residual nitrogen after planting. The application levels significantly outperformed the control treatment, yielding average residual nitrogen of 21.92, 36.55, and 52.00 g/plant for levels (A1, A2, and A3), respectively, compared to the no-application treatment, which yielded an average of 18.00 mg N/kg soil. These represent increases of 80.85%, 201.56%, and 329.04% for the three levels, respectively. This is attributed to the effect of adding nitrogen fertilizer to the experiment for the tomato crop. At low levels of nitrogen, plant uptake is relatively high compared to the amount added, so the amount of nitrogen lost by washing or volatilization decreases. At high levels of addition, the plant becomes physiologically saturated, washing losses increase, and ammonia volatilization may increase, resulting in a clear increase in the amount of nitrogen remaining after harvest [35]. As for the effect of the concentrations of the biopesticide T. harzianum, the results show that increasing the concentration of the biopesticide led to a decrease in the amount of nitrogen remaining in the soil after planting, with decrease rates of 16.01% and 24.80% compared to the treatment of no addition, which gave the highest amount of nitrogen remaining, amounting to 35.47 mg N/kg soil. The reason for this decrease is attributed to the fact that increasing the concentrations of the biopesticide inhibited the activity of the fungus, which led to the production of healthy, disease-free plants with a strong root system that absorbs appropriate amounts of nitrogen. Therefore, there is a decrease in the amount of residual nitrogen and an increase in the amount of nitrogen absorbed compared to the treatment without adding the biopesticide. This means that the activity of the fungus was high, which led to the infection of the plant, resulting in the production of a plant infected with the fungus and not containing a strong vegetative and root system. Therefore, the plant did not absorb enough nitrogen, and in contrast, the amount of nitrogen remaining in the soil after planting is large. As for the interaction effect, the combination (A3B3) yielded the highest dry weight of 45.13 mg N/kg soil, representing a 241.37% increase compared to the control treatment (A0B0), which yielded the lowest residual nitrogen of 13.22 mg N/kg soil [13].

Table (10) effect of nitrogen fertilizer and the biopesticide T. harzianum on residual nitrogen after tomato planting (mg N/kg soil).

Nitrogen levels (A) kg ha^{-1}	**(B) Biopesticide levels (T. harzianum) (B) cm^3/100 L**			**Mean**
	0	**25**	**50**	
0	13.22	12.12	11.04	**12.12**
80	25.34	21.09	19.33	**21.92**
160	43.12	35.32	31.21	**36.55**
240	60.22	50.65	45.13	**52.00**
Mean	**35.47**	**29.79**	**26.67**	
L.S.D	(A) = 6.5	(B) = 5.20	A×B= 10.80	

Conclusion
The level of nitrogen fertilization (urea) significantly affected the characteristics of the study by strengthening the plant's vegetative and root system and increasing its resistance to diseases at the level (160 kg N/ha), which represented the optimal level for obtaining the best growth through a healthy, disease-resistant plant. In contrast, the higher levels (200 kg N/ha) led to a decrease in growth indicators and an increase in the severity of root rot disease. The concentrations of the bio-pesticide T. harzianum

significantly affected all the characteristics of the study except for the disease incidence rate, which it negatively affected.
Recommendations:
- Use nitrogen fertilization at a level of 160 kg N/ha to obtain the best growth indicators for the tomato crop and increase its resistance to root rot disease, with the addition of small concentrations of the biofungicide T. harzianum to obtain the best yield and healthy, disease-resistant plants.

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