Response of tomato plants to three different levels of urea and chemical control in suppressing root rot disease caused by the fungus *Rhizoctonia solani* improving growth characteristics, and increasing yield.

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Abstract

The current research work was performed in the greenhouses of the College of Medicinal and Industrial Plants of the University of Kirkuk. The purpose of the work was to evaluate the response of tomatoes to three urea fertilizer levels (80, 160 and 200 kg·ha^{-1}) and two concentrations (0.1 % and 0.15 %) of the chemical fungicide Beltanol (contains the active component of 8-hydroxyquinoline sulfate 50%) against root rot disease caused by Rhizoctonia solani and improve certain growth and productivity characteristics. The research was performed using the RCBD design (three replicates). The characteristics investigated included disease severity, yield, weight of fruits, root length, leaf number, and leaf area. The research results showed a significant influence of the level of urea, fungicide concentrations, and the interaction between them on all the investigated characteristics. In terms of the response to the investigated characteristics, the level of urea fertilizer of 160 kg ha^{-1} was found to be the best; it gave the minimum mean severity of infection (15.16 %) and the maximum mean values for the yield (1.014 kg plant^{-1}), weight of fruits (45.94 g), and root length (24.38 cm). In addition, the use of this level of fertilizer also gave the maximum mean values for the leaf number (28.11 leaves plant^{-1}) and leaf area (860.71 cm^2 plant^{-1}). The use of the Beltanol fungicide at a concentration of 0.15 % lowered the mean severity of infection to 16.85 % and increased the growth and yield characteristics compared to the control (without the fungicide). The interaction between the 160 kg ha^{-1} urea fertilizer level and 0.15 % of the Beltanol fungicide concentration gave the best results. It gave the minimum severity of infection (8.10 %) and maximum values for the fruit weight, root length, leaf number, and leaf area (48.31 g, 29.43 cm, 32.00 leaves plant^{-1} and 987.37 cm^2 plant^{-1}), respectively. The maximum total yield (1.077 kg plant^{-1}) was achieved at the urea level of 160 kg ha^{-1} together with the fungicide concentrations of 0.1 % and 0.15 %. Therefore, it can be concluded that the application of the 160 kg ha^{-1} urea level and the Beltanol fungicide at a concentration of 0.15 % is the optimal treatment against the root rot caused by the fungus R. solani in tomato plants.

Keywords: Tomato; *Rhizoctonia solani*; Urea; Root rot.

Introduction

The tomato crop (*Solanum lycopersicum L.*) belongs to the genus *Solanum* within the Solanaceae family and ranks as the second most produced vegetable globally, following the potato (FAO, 2022). Global production is estimated at 120 million metric tons across 3.7 × 10^6 hectares (Al-Jatlawi, 2024). Its importance lies in its status as a rich source of amino acids, vitamins C and

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A, and minerals such as phosphorus and iron; it is also rich in dietary fiber (FAO, 2003; Wilcox et al., 2003; Sgherri et al., 2008; Borguini & Torres, 2009; Olaniyi et al., 2010). Furthermore, tomatoes contain lycopene, a substance that helps mitigate the harmful effects of free radicals—agents believed to contribute to cancers such as prostate, gastric, and pancreatic cancer (Bramly et al., 2000; De Stefani et al., 2000). Their nutritional value is derived from the fruit, which can be consumed either cooked or fresh (Obaid, 2016). This crop is susceptible to numerous soil-borne fungal diseases, most notably *Rhizoctonia solani*. This pathogen causes root rot and seedling blight, leading to significant losses ranging from 25% to 100%, depending on disease-conducive conditions and infection severity; it results in a reduction of the fresh weight of both the shoot and root systems, as well as emergence failure (Solanki et al., 2022). Nitrogen nutrition plays a crucial role in enhancing crop growth; urea serves as a primary and cost-effective nitrogen source due to its rapid solubility and availability to the plant (Tesfay et al., 2019). However, the physiological relationship between urea fertilization levels and disease resistance is complex; balanced application promotes rapid root growth, enabling roots to escape zones of active soil-borne infection (Siddiqui and Akhtar, 2008), whereas excessive urea fertilization causes physiological imbalances, resulting in succulent, dense growth with thin cell walls that are easily penetrated by pathogen enzymes (Khattabi et al., 2004). Furthermore, chemical pesticides continue to play a vital role in integrated management programs aimed at eliminating or mitigating the impact of soil-borne plant pathogens, enhancing root nutrient uptake efficiency, and consequently improving plant growth (Agrios, 2005). Accordingly, this study was designed to evaluate the response of tomato plants to four different levels of urea fertilizer combined with the chemical pesticide Beltanol—which contains the active ingredient 8-hydroxyquinoline sulfate (50%)—in order to determine the optimal combination for effectively suppressing root rot caused by the pathogen *Rhizoctonia solani*, enhancing vegetative and root growth parameters, and securing a superior, consistent yield in terms of both quantity and quality.

Materials and Methods



The Pathogenic Fungus *Rhizoctonia solani*

Fungal Isolate and Taxonomic Identification: A virulent isolate of *Rhizoctonia solani* was sourced from the Agricultural and Biological Research Center of the Iraqi Ministry of Agriculture. The isolate was examined through a combination of cultural, morphological, and microscopic characteristics to confirm its taxonomic identity. The identification process was carried out according to the diagnostic characteristics and taxonomic criteria

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outlined by Watanabe (2010), Summerell (2006).

Preparation of the Fungal Inoculum:

The fungus *R. solani* was cultured on local millet seeds (*Panicum miliaceum* L.). The seeds were washed and soaked for 6 hours, then drained. Subsequently, 50 g of millet was placed into sterile 250 ml flasks and autoclaved at 121°C and 1 atm pressure for one hour. After cooling, the seeds were inoculated with the pathogen by adding five 0.5 cm-diameter discs—taken from the margins of a 7-day-

old colony—to each flask. The flasks were incubated at 25 ± 2°C, with periodic shaking



and mixing every 2–3 days to ensure uniform fungal distribution (Dewan, 1989).

An image showing the growth of the pathogenic fungus *R. solani* on millet seeds.

Field Experiment

This study was conducted in mid-March in raised beds containing loamy soil at the College of Medicinal and Industrial Plants, University of Kirkuk. The soil was prepared for planting by tilling and pulverizing it to ensure aeration; weeds were removed, and the surface was leveled. The soil was then sterilized using a 5% formalin solution to eliminate soil-borne pathogens and covered with polyethylene sheeting for 48 hours. After removing the cover, the soil was left for 10–14 days to allow the formalin to dissipate completely before planting. Subsequently, furrows were opened to a depth of 30–40 cm, and an inoculum of the *R. solani* fungal isolate was applied. Millet seeds were inoculated with the pathogenic fungus at a rate of 1% (w/w)—applied individually to each treatment, excluding the control—and incubated for three days under constant moisture. Seeds of the 'Super Red' tomato hybrid were sown in polystyrene trays within a plastic greenhouse; upon reaching the five-true-leaf stage, the seedlings were transplanted to the field. They were planted in two rows, with 1.5 m between rows and 40–50 cm between plants, positioned exactly where the fungal isolate had been applied. Nitrogen fertilizer was applied in the form of urea (46%) at rates of 0, 80, 160, and 200 kg/ha^{-1} Applications were made in two installments: at the start of planting and during the flowering stage. The fungicide Beltanol—containing the active ingredient 8-hydroxyquinoline sulfate (50%)—was applied at concentrations of 0%, 0.1%, and 0.15%; the replicates were sprayed three times at 15-day intervals throughout the growing season. Experimental units received phosphorus and potassium fertilization in the form of triple superphosphate and potassium sulfate, respectively, at rates equivalent to 80 kg P ha^{-1} and 120 kg K ha^{-1}. The entire phosphorus dose was incorporated at planting, while potassium was supplied in two applications, with the first applied at flowering and the second at the beginning of fruit set. All fertilizer applications were

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conducted in accordance with recommended agronomic practices. Throughout the growing period, routine crop management practices were maintained, including drip irrigation system maintenance, salt leaching, pest management, hoeing, weed removal, and other necessary cultural operations until the completion of the growing season.

Studied Traits

The following traits were measured and evaluated:

Disease Severity: Disease severity was calculated 30 days after planting using a five-grade disease scale: 0 = healthy plant; 1 = secondary root rot; 2 = secondary and primary root rot, with partial rotting at the stem base; 3 = complete rotting of all roots and the stem; 4 = plant death. Disease severity was calculated using McKinney's (1923) formula.

$$\text{Injury severity percentage} = ((\text{Number of plants at grade } 0 \times 0) + \ldots + (\text{Number of plants at grade } 4 \times 4))/(\text{Total number of plants examined} \times 4)\ x\ 100$$

Leaf area (cm^2), number of leaves, root length (cm), number of fruits, and total yield (kg/plant) were also calculated.

Experimental Design and Statistical Analysis

A Randomized Complete Block Design (RCBD) was employed with three replicates per treatment, and differences between means were tested using the Least Significant Difference (L.S.D.) at the 5% probability level (Al-Zubaidi and Al-Jubouri, 2016).

Results and Discussion

Severity of Infection

The results presented in Table (1) indicate that the various nitrogen levels, different concentrations of the fungicide Beltanol, and the interaction between them significantly affected the severity of root rot disease caused by the fungus *R. solaniin* tomato crops. The control treatment recorded the highest severity of fungal infection (38.38%), compared to the nitrogen levels (N80, N160, and N200), which showed severity rates of 24.046%, 15.16%, and 19.56%, respectively. These findings align with the observations of Gupta et al. (2022), who noted that nitrogen deficiency reduces the efficiency of physiological and biological processes within the plant, thereby limiting growth and diminishing the formation of defense compounds and immune responses against pathogens. The lower severity of infection observed at the N160 level (15.16)—compared to the N80 (24.046) and N200 (19.56) levels—is attributed to the fact that balanced nutrition enhances growth efficiency and tolerance to biotic stress. Conversely, excessive fertilization leads to the formation of succulent tissues that are easily penetrated by pathogens (Machado et al., 2022). Furthermore, balanced nutrition contributes to boosting the efficiency of chemical and physical defense mechanisms, as well as the synthesis of resistance-related proteins and enzymes (Mur et al., 2017). The results also demonstrated that the fungicide Beltanol had a significant effect in reducing disease severity; severity levels reached 23.565 and 16.85 at concentrations of 0.1% and 0.15%, respectively, compared to 32.45 for the control treatment. Increasing the concentration led to inhibition of the pathogen, a finding consistent with the results reported by Badr et al. (2024). Regarding the interaction between nitrogen

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levels and Beltanol fungicide concentrations, the results showed that the control treatment recorded the highest disease severity (47.42), compared to the treatment combining the N160 nitrogen level with the 0.15% fungicide concentration, which recorded a severity of 8.10. This indicates that balanced nutrition—which enhanced the efficiency of physiological processes—combined with the use of the higher fungicide concentration, resulted in reduced disease severity.

Table (1) Effect of adding different levels of urea and two concentrations of the fungicide Beltanol on the severity of tomato root rot caused by the fungus *R. solani*.

Beltanol (8-Hydroxyquinoline sulfate 50%)	**Nitrogen levels (kg/ha)**				**The Rate**
	0	**80**	**160**	**200**	
0	47.42	32.53	22.64	27.22	**32.45**
%0.1	37.64	22.97	14.75	18.90	**23.565**
%0.15	30.1	16.64	8.10	12.56	**16.85**
The Rate	**38.38**	**24.046**	**15.16**	**19.56**	
L.S.D (0.05)	A×B=8.3 B=4.2 A=2.8				

Yield (kg/plant)

According to the findings in Table (2), it was clear that the nitrogen significantly affected the yield as the average yields in treatments N80, N160 and N200 were 0.851 kg/plant, 1.014 kg/plant and 0.826 kg/plant, respectively, when compared to the average yield in the control treatment (0.512 kg/plant). This happens since nitrogen is known to enhance vegetative growth, and increases leaf surface area, hence improving the process of photosynthesis, leading to an increase in carbohydrate production, which gets translocated to the fruit and thus increases yield (Mao et al., 2024). It is also important to note that the pathogen affects the reduction in yield, since the fungal pathogen R. solani attacks the roots of the plants, making it difficult for them to absorb water and nutrients, and thus affects the productivity of the plant (Mogazy et al., 2024). The maximum average yield was seen in the N160 level, where the average yield was 1.014 kg/plant when compared to other levels. This occurs due to the fact that the level provides the plant with balanced nutrition, which leads to an increase in yield; on the other hand, over-fertilization led to the reduction of yield, since there is a high allocation of the photosynthates to vegetative growth at the expense of fruit formation (Shewangizaw et al., 2024). When it comes to the fungicide Beltanol, it increased the yield significantly. The control average was 0.680 kg/plant, while the yield was 0.82 kg/plant at 0.1% concentration (B) and it went up to 0.92 kg/plant at 0.15% concentration. This increase in yield was due to the indirect effects of the fungicide since it helped to minimize the effect of the fungus *R. solani* on the plant, thus helping the plant in the efficient absorption of water and nutrients through its roots. Concerning the interaction between the levels of urea and the concentrations of the pesticide, the lowest yield was seen in the control treatment (0.357 kg/plant), while the highest yield was achieved when the pesticide concentrations were combined with the N160 urea level (1.077 kg/plant).

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Table (2) Effect of adding different levels of urea and two concentrations of the pesticide Beltanol on yield (kg/ha)

Beltanol (8-Hydroxyquinoline sulfate 50%)	Nitrogen levels (kg/ha)				The Rate
	0	80	160	200	
0	0.357	0.760	0.890	0.713	**0.680**
%0.1	0.517	0.797	1.077+	0.897	**0.822**
%0.15	0.663	0.920	1.077	0.943	**0.901**
The Rate	0.512	0.826	1.014	0.851	
L.S.D (0.05)	**A×B = 0.1585 B = 0.0915 A = 0.0792**				

Fruit Weight (g)

From the results presented in Table (3) above, it is evident that the applied treatments had a significant influence on the fruit weight. The average fruit weight of the nitrogen treatments (N80, N160 and N200) was 37.08g, 45.94g and 39.82g, respectively, against 28.09g for the control treatment. Particularly, the N160 level gave the highest average fruit weight. This result is in agreement with the results of Bello t al. (2024), which states that with the increment in nitrogen levels there is the improvement in growth characteristics and components like fruit weight due to the increase in nutritional condition of the plant by balanced fertilization, hence improving the productive nature of the plant as well as fruit formation by increasing the photosynthates allocation. However, an increment in the nitrogen levels does not necessarily imply an increment in plant production efficiency (Sachin et al., 2024). Concerning the chemical fungicide Beltanol, the applied concentrations exhibited a significant effect on the average fruit weight compared to the control treatment; where the average fruit weight of 0.1% and 0.15% concentrations was 37.43g and 42.54g, respectively, against 33.24g for the control. The application and increment in the fungicide concentration indirectly increased the average fruit weight because of the reduction of the virulence of the pathogen; hence, increased the roots' efficiency in water and nutrients absorption, leading to the increase in average fruit weight (Sachin et al., 2024). As regards the interaction treatments, the pathogen *R. solani* caused reduction in average fruit weight (g) in which the control treatment had an average fruit weight of 20.92g. Conversely, the highest average fruit weight was recorded in (N160, B0.15%) treatment with average fruit weight of 48.31g, then (N16, 0.1%) treatment with average fruit weight of 46.46g, followed by (N160) treatment with average fruit weight of 43.05g. This is because the optimum nitrogen usage provided ideal plant nutrition, while the fungicide reduced the effect of the pathogen.

Table (3): Effect of adding different levels of urea and two concentrations of the fungicide Beltanol on fruit weight (g).

Beltanol (8-Hydroxyquinoline sulfate 50%)	Nitrogen levels (kg/ha)				The Rate
	0	80	160	200	
0	20.92	36.53	43.05	32.45	**33.24**
%0.1	27.90	39.00	46.46	36.34	**37.43**
%0.15	35.46	43.93	48.31	42.46	**42.54**
The Rate	**28.09**	**39.82**	**45.94**	**37.08**	

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L.S.D (0.05)	**A×B = 8.9508 B = 5.1678 A = 4.4754**

Root Length (cm)

From the results shown in Table (4), there was an observed effect of the Nitrogen levels and the chemical pesticide. Root lengths means of N200, N160, and N80 were 11.79, 24.38, and 20.35 cm respectively compared to 9.76 cm for the control treatment. The explanation of this is the function of Nitrogen in the production of tissue and proteins; its balanced addition increases the growth of roots systems and hence the ability of the plant to obtain nutrients due to the direct relationship between root length and efficiency in the acquisition of water and Nitrogen (Feng et al., 2024). Zhang et al. (2024) have also established that the levels of Nitrogen affects tomato root morphology and the improvement of nutritional status leads to the enhancement of root length; hence the better performance of the N160 level when compared to other treatments. Regarding the effect of the fungicide Beltanol, it had an effect on mean root length, which reached 16.05 cm and 19.84 cm at concentrations of 0.1% and 0.15% respectively compared to 13.81 cm in the control treatment. This fungicide contributed to reducing the effects of the infection of the pathogen *R. solani*, thus maintaining the root system and hence mean root length—an observation that concurs with findings by Majeed et al. (2023). The pathogen limits the growth of the plant, while chemical control has reduced infection and enhanced the growth of tomato plants. Regarding interactions of treatments, control treatment had the lowest mean root length (8.43 cm), while the (N160 + 0.15% Beltanol) treatment had the highest mean root length (29.43 cm). The balanced fertilization together with the higher fungicide concentration has mitigated the effects of the *R. solani* fungus; additionally, balanced nutrition created ideal conditions for growth.

Table (4): Effect of adding different levels of urea and two concentrations of the fungicide Beltanol on root length (cm).

Beltanol (8-Hydroxyquinoline sulfate 50%)	**Nitrogen levels (kg/ha)**				**The Rate**
	0	**80**	**160**	**200**	
0	8.43	10.25	19.77	16.76	**13.81**
%0.1	9.97	11.02	23.93	19.30	**16.05**
%0.15	10.87	14.09	29.43	24.97	**19.84**
The Rate	**9.76**	**11.79**	**24.38**	**20.35**	
L.S.D (0.05)	**A×B = 4.826 B = 2.7865 A = 2.4131**				

Number of Leaves

The obtained results in Table (5) reveal the significance of the influence of urea level and concentrations of Beltanol fungicide. The average number of leaves in cases of N80, N160, and N200 levels is 24.00, 28.11, and 21.00 leaves/plant, respectively. At the same time, in the control treatment, the value is 15.00 leaves/plant. It is possible to explain the findings because of the importance of nitrogen in the structure of chlorophyll, enzymes, amino acids, and proteins. These components are responsible for stimulating cell division and elongation. Thus, there is the formation of new leaves, and there is the improvement of the photosynthesis effectiveness, which is vital for sustaining vegetative growth (Sachin et al., 2024). The maximum average number of leaves (28.11 leaves/plant) is in case of N160 level, while it is lower at N200 level – 24.00 leaves/plant. The explanation is that

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there is a possibility of a change in the distribution of photosynthates in case of excess nitrogen levels. Also, there is a non-linear curve of plant reaction on nitrogen (Bello et al., 2024). As regards the fungicide Beltanol, it positively influenced the average number of leaves; in cases of 0.1% and 0.15% concentrations, the value is 22.33 and 24.83 leaves/plant, respectively. In the control treatment, the number is 18.92 leaves/plant. According to the research results, the fungicide helps to minimize the influence of the pathogen R. solani. Thus, there is an increase in the efficiency of nutrient absorption from the roots, and it results in the improved vegetative growth. There is a significant interaction effect between nitrogen and chemical pesticide Beltanol. The maximum number of leaves (32.00 leaves/plant) was achieved in the treatment (N160 + 0.15% Beltanol) in comparison to the control treatment where the number is 12.67 leaves/plant. The positive influence of the combination of balanced nitrogen level and appropriate chemical pesticide concentration resulted in minimizing the influence of the pathogen *R. solani.*

Table (5): Effect of adding different levels of urea and two concentrations of the pesticide Beltanol on the number of leaves per plant.

Beltanol (8-Hydroxyquinoline sulfate 50%)	**Nitrogen levels (kg/ha)**				**The Rate**
	0	**80**	**160**	**200**	
0	12.67	18.67	24.00	20.33	18.92
%0.1	15.67	21.67	28.33	23.67	22.33
%0.15	16.67	22.67	32.00	28.00	24.83
The Rate	15.00	21.00	28.11	24.00	
L.S.D (0.05)	**A×B = 3.831 B = 2.2118 A = 1.9155**				

Leaf Area (cm²)

The data in Table (6) shows that the urea level, Beltanol fungicide, and their interaction had significant influence on the leaf area of the tomato plants. The mean leaf area in the N200, N160, and N80 treatments was 760.04, 860.71, and 676.96 cm2/plant, respectively, whereas the mean leaf area for the control treatment was 657.58 cm2/plant. The mean leaf area was highest in the N160 level than any of the others. This result is consistent with those obtained by Sun et al. (2023). Application of various amounts and types of nitrogen on tomato plants affects growth, photosynthetic performance, and the production of plant products. In addition, nitrogen has an effect on the pathogen *R. solani*, whereby adequate nutrition promotes the efficacy of chemical and physical defense systems and resistance protein/enzyme production (Mur et al., 2017). As for the chemical fungicide Beltanol, the mean leaf area in concentrations of 0.1% and 0.15% was 739.67 cm2/plant and 875.18 cm2/plant, respectively, and in the control, group was 601.62 cm2/plant. Treatment with the fungicide – especially in the 0.15% concentration – significantly inhibited the growth of the pathogen in the roots and facilitated nutrient and water absorption in the plants; therefore, there was enhanced vegetative growth and increased leaf area. As for the interaction between the urea level and the fungicide, the highest mean leaf area was observed in the (N160 + 0.15% Beltanol) treatment and was equal to 987.37 cm2/plant, compared to the 482.42 cm2/plant in the control treatment. This result is consistent with findings obtained by

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Maaoui et al. (2025); the combined application of the fungicide and nitrogen may cause synergistic effects, which help suppress the pathogen *R. solani* and ensure proper nutrition of the plant, hence stimulating its vegetative growth and increasing mean leaf area.

Table (6) Effect of adding different levels of urea and two concentrations of the pesticide Beltanol on leaf area (cm^2).

Beltanol (8-Hydroxyquinoline sulfate 50%)	**Nitrogen levels (kg/ha)**				**The Rate**
	0	**80**	**160**	**200**	
0	482.42	643.48	735.00	545.57	**601.62**
%0.1	666.09	753.53	859.76	679.31	**739.67**
%0.15	824.23	883.11	987.37	806.01	**875.18**
The Rate	**657.58**	**760.04**	**860.71**	**676.96**	
L.S.D (0.05)	**A×B = 152.25 B = 87.901 A = 76.125**				

Conclusions

1. A urea application rate of 160 kg ha^{-1} yielded the best results in reducing disease severity and improving growth and yield characteristics compared to other rates.

2. The chemical fungicide Beltanol, at a concentration of 0.15%, was more effective than the 0.1% concentration in reducing disease severity and enhancing growth and yield.

3. The interaction between 160 kg ha^{-1} of urea and 0.15% Beltanol achieved the highest efficiency in controlling the fungus *Rhizoctonia solani* and improving all studied parameters.

4. Excessive urea fertilization (200 kg ha^{-1}) resulted in a reduced response compared to the optimal rate of 160 kg ha^{-1}.

5. The study demonstrated that integrating balanced nitrogen fertilization with chemical control is an effective strategy for mitigating root rot disease and increasing tomato productivity.

Recommendations

1. It is recommended to apply urea at a rate of 160 kg ha^{-1} when cultivating tomatoes under conditions similar to those of this study.

2. It is recommended to use the fungicide Beltanol at a concentration of 0.15%, adhering to the recommended dosages and application timings, to achieve optimal disease control.

3. It is recommended to avoid excessive nitrogen fertilization, given its negative impact on growth efficiency, yield, and disease resistance.

4. It is recommended to investigate combining Beltanol with biological control agents or other agricultural practices within integrated disease management programs to enhance control efficacy and reduce reliance on chemical pesticides.

5. It is recommended to study the effects of urea in combination with other nitrogen sources, or with organic and bio-fertilizers, to improve nitrogen use efficiency, minimize losses, and increase tomato plant productivity.

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