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The Synergistic Effects of Biofertilizers, Humic Acid, and Fulvic Acid on Rimsulfuron Herbicide 25% Performance in Tomato (*Solanum lycopersicum*) Cultivation.

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ABSTRACT
The study conducted at Bakrajo Technical Institute in 2023, for evaluating the effects of different agricultural treatments on the growth, development, and productivity of tomato plants (*Solanum lycopersicum*), aiming to identify the most effective practices for enhancing crop yield and health. The research employed a Completely Randomized Design (CRD) with four replications, Then the comparison was done among the mean of the studied factors using DMRT test with four main treatments: humic acid, fulvic acid, biofertilizers, and Rimsulfuron herbicide at a 25% concentration. These treatments were applied at varying dosages to assess their impact on a value of agronomic traits, including plant height, number of branches, fruit yield, chlorophyll content, fresh fruit weight, shoot weight, and dry weight. The results demonstrated that humic acid and fulvic acid, when applied at 0.04 g plant^{-1}, significantly improved the number of branches, indicating their role in stimulating vegetative growth. In contrast, higher doses of Rimsulfuron herbicide, particularly at 12 ml/plant, adversely affected both branch production and fruit yield, suggesting phytotoxic effects at elevated concentrations. Biofertilizers applied at 0.4 ml plant^{-1} had a positive influence on chlorophyll content and fresh fruit weight, supporting their role in enhancing photosynthetic efficiency and fruit development. However, when biofertilizers were combined with high levels of herbicide, a reduction in biomass accumulation was observed, pointing to negative interaction effects. Overall, the findings underscore the importance of selecting and balancing appropriate agricultural inputs to optimize plant performance. Humic acids and biofertilizers emerged as beneficial treatments for promoting growth and productivity, while excessive herbicide use was shown to impair plant health. The study highlights the critical need for integrated and judicious management of agricultural treatments to ensure sustainable crop production and recommends further research to determine optimal treatment combinations and dosages for maximizing tomato yield under similar growing conditions.

***Keywords*:** Biofertilizers, humic acid, fulvic acid, Rimsulfuron herbicide, Tomato.

INTRODUCTION
Biofertilizers are microbial formulations that enhance soil fertility by fixing atmospheric nitrogen, decomposing organic matter, and increasing the availability of other nutrients depending on types of biofertilizers or synthesizing growth-promoting substances [1]. Humic acid and fulvic acid, derived from the decomposition of organic matter, are complex organic compounds that play a crucial role in soil structure improvement, nutrient retention, and water-holding capacity [2]. Their application has been shown to influence plant metabolism, stimulate root growth, and improve plant resilience to abiotic stress. In recent years, research has focused on how these substances, individually or in combination, can optimize crop productivity, particularly in solanaceous plants like tomato (*Solanum lycopersicum*), which is a major agricultural commodity worldwide [3].

In addition to these beneficial agents, Rimsulfuron herbicide 25% are commonly used in agricultural systems to control weed growth and protect crop yields [4]. However, the excessive or improper use of Rimsulfuron herbicide 25%s can pose risks to the environmental of crops health and quality, potentially reducing the efficacy of fertilizers and other growth stimulants [5]. Therefore, understanding the interactions between biofertilizers, humic acid, fulvic acid, and

Rimsulfuron herbicide 25%s is crucial for developing sustainable agricultural practices that not only mitigate Rimsulfuron herbicide 25%-related risks but also enhance plant growth and productivity [6]. The integration of biofertilizers and organic acids with Rimsulfuron herbicide 25%s could offer synergistic benefits, improving the plant's ability to tolerate Rimsulfuron herbicide 25% stress while simultaneously promoting optimal growth conditions for tomatoes [7].

This research aims to investigate the effects of biofertilizers, humic acid, and fulvic acid on tomato growth and yield, specifically focusing on their interactions with Rimsulfuron herbicide 25%s. By exploring how these substances interact with Rimsulfuron herbicide 25% treatments, this study seeks to identify potential pathways through which the combined use of biofertilizers and organic acids can mitigate the negative effects of Rimsulfuron herbicide 25%s, enhance tomato growth, and maximize crop yield.

Materials and Methods

Study Area and Experimental Design:

The study was conducted at the Bakrajo Technical Institute farm during the summer growing season of 2023 in four replications. Each replication consisted of a pot per single healthy plant. The treatments were applied to tomato plants at the appropriate developmental stages, and data were collected at various intervals.

Experimental Treatments:

The pot experiment was designed to assess the effects of biofertilizer, humic acid and fulvic acid, and Rimsulfuron herbicide 25% on tomato growth and yield, with interaction treatments to evaluate synergistic effects. Biofertilizer was applied at three different dosages: 0.4 ml (T1), 0.8 ml (T2), and 1.25 ml (T3) per plant, starting two weeks after transplanting (WAT) and repeated every 15 days until flowering. Humic acid and fulvic acid were applied at concentrations of 0.04 g (T4), 0.08 g (T5), and 0.16 g (T6) per plant, also starting at 2 WAT and applied biweekly. Rimsulfuron herbicide 25% was used at rates of 4 ml (T7), 8 ml (T8), and 12 ml (T9) per plant, applied three times during the growing season using a handheld sprayer. Interaction treatments (T10 and T11) combined biofertilizer (0.8 ml) or humic acid and fulvic acid (0.08 g) with Rimsulfuron herbicide (8 ml), applied simultaneously to evaluate their combined effects on plant growth and yield. A control treatment (T12). The tomato variety, selected for its suitability to local agro-climatic conditions and high yield potential, was transplanted into pots in the first week of Summer growing season 2023. All treatments, including Broomrape (*Orobanche spp*.) seeds mixed with soil sub traits in all pots, were applied directly to the root zone, ensuring uniform distribution of water-soluble humic acid and fulvic acid with water, and biofertilizer via a watering can.

Experimental Procedure:

Soil Preparation: Prior to planting, the pots were filled of soil sieved 4mm until 13 kg of soil with density of 1.3 g cm^{-1}. **Irrigation and Pest Control:** The pots were irrigated as needed to maintain adequate soil moisture for tomato growth. Pest control was done using recommended chemical, ensuring that no insecticides interfered with the treatments.

Plant Growth and Yield Parameters Development Observations:

The study assessed plant growth and development through a series of observations on various yield parameters. Plant height (cm), number of branches, and the number of fresh fruits per plant were recorded periodically. Chlorophyll content was measured using a SPAD meter, while fresh fruit weight (g), fresh yield weight (g), and shoot weight (g) were recorded at harvest. Additionally, dry weight (g) of both shoots and fruits was determined after drying the samples at 65°C until constant weight was achieved. These parameters were used to evaluate the overall growth, development, and productivity of the plants under the experimental conditions.

Data Analysis:

The data were subjected to **Analysis of Variance (ANOVA)** using the Statistical Package for XLSTAT 2019.2.2.59614 software. Significant differences between treatment means were determined using the **Duncan's Multiple Range Test (DMRT)** at a 5% level of significance. Correlation coefficient was done between Tomato growth and yield parameters.

Results and Discussions

In the study, Broomrapes (*Orobanche spp*.) failed to germinate or exhibit any growth, potentially due to the impact of temperature variations and the contrasting weather conditions between day and night. Despite these unfavorable conditions, the summary statistics collected from 48 complete observations highlight the high data quality and the reliability of the dataset, as there were no missing values for any of the recorded variables. The range of values for each variable, which spanned a broad spectrum, reflects the natural variability in plant growth. For instance, the number of branches per plant ranged from 4 to 41, with an average of 18.33 and a standard deviation of 10.46, indicating significant variation. Likewise, other variables such as plant height (41 cm to 98 cm), the number of fresh fruits per plant (4 to 37), chlorophyll SPAD readings (41 to 127), fresh fruit weight (17 g to 44 g), and yield weight

(25 g to 390 g) demonstrated wide ranges and reasonable standard deviations, reinforcing the variability seen in plant growth. While these findings highlight the quality of the data, the absence of Broomrape germination and growth could be attributed to unfavorable environmental factors, such as the temperature fluctuations and the day-night weather cycles, which are crucial in determining the development and viability of these parasitic plants. Despite the data's robustness, the lack of Broomrape growth suggests that such environmental conditions may play a critical role in inhibiting their germination and subsequent development in soil, emphasizing the complex relationship between temperature, weather patterns, and the successful establishment of Orobanche species in agricultural settings. These broad ranges reflect how environmental and genetic factors can influence plant performance. While the data itself is robust, the absence of Broomrape emergence underlines the possible inhibitory effect of environmental conditions, emphasizing the sensitivity of *Orobanche* species to temperature dynamics and diurnal weather cycles, which are critical for their successful establishment in agricultural environments.

Analysis of the differences between the categories with a confidence interval of 95% of number of branches per plant

The analysis of branch numbers per plant across different treatments revealed statistically significant differences, as indicated by the distinct groups formed based on 95% confidence intervals. Treatments with humic acid and fulvic acid at 0.04 g per plant showed the highest efficacy, forming **Group A** with a mean branch range of **36.92 to 39.58**, significantly outperforming all other treatments. In contrast, applications of Rimsulfuron herbicide 25%, especially at 4, 8, and 12 ml per plant—with or without biofertilizers consistently produced the lowest branch counts, forming **Groups G and H**, with **Group H** (12 ml/plant) showing a mean range of **5.67 to 8.33 branches**. The formation of these lettered groups reflects statistical similarities or differences in treatment means: treatments within the same group (G and H) have overlapping confidence intervals and are **not significantly different**, while those in separate groups (A vs. H) show **statistically significant differences** in performance. These findings highlight that while bio-stimulants such as humic and fulvic acid can markedly promote branching, high concentrations of Rimsulfuron herbicide may inhibit plant growth, likely due to phytotoxic effect emphasizing the importance of selecting appropriate treatment combinations to optimize plant development.

Table .1 Analysis of the differences between the categories with a confidence interval of 95% of number of branches per plant

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Humic acid and fulvic acid 0.04 g plant^{-1}	38.25_{A}	0.655	36.917	39.583
Biofertilizer 0.4 ml plant^{-1}	32_{B}	0.655	30.667	33.333
Humic acid and fulvic acid 0.16 g. plant^{-1}	29_{C}	0.655	27.667	30.33
Biofertilizer 0.8 ml plant^{-1}	26.75_{D}	0.655	25.417	28.083
Biofertilizer 1.25 ml plant^{-1}	19.5_{E}	0.655	18.167	20.833
Humic acid and fulvic acid 0.08 g plant^{-1}	16.5_{F}	0.655	15.167	17.833
Interactions humic acid and fulvic acid (0.08 g) and Rimsulfuron herbicide 25% interactions (8 ml)	12.5_{G}	0.655	11.167	13.833
Rimsulfuron herbicide 25% 4 ml plant^{-1}	11.5_{G}	0.655	10.167	12.833
Rimsulfuron herbicide 25% 8 ml plant^{-1}	11.5_{G}	0.655	10.167	12.833
Interaction Bio fertilizer (0.8 ml) and Rimsulfuron herbicide 25% interactions (8 ml)	10.5_{G}	0.655	9.167	11.833
Rimsulfuron herbicide 25% 12 ml plant^{-1}	7_{H}	0.655	5.667	8.333
Control	5_{I}	0.655	3.667	6.333

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of plant height(cm)

Table 2 presents the results of a Duncan test on plant height (cm) across different treatment categories, with a 95% confidence interval for each group's mean. The analysis reveals significant differences between the categories, as indicated by distinct groupings. Categories with overlapping confidence intervals, such as Biofertilizer (0.4 ml) and Humic acid and Fulvic acid (0.04 g), are grouped together (A), suggesting no significant difference between these treatments. However, categories like Humic acid and Fulvic acid (0.08 g) and Biofertilizer (1.25 ml) fall into group B, indicating a significant reduction in plant height compared to group A treatments. Further, categories such as Rimsulfuron herbicide 25% (4 ml, 12 ml, 8 ml) and Control (F) show the lowest plant heights, all significantly different from the higher groups (A, B). These results underscore the importance of the specific treatment application in promoting plant growth, with non-significant differences primarily within the same group and significant differences observed between the treatment categories and control. Such findings are critical for understanding the efficacy of different plant growth regulators and Rimsulfuron herbicide 25%s in agricultural practices [9].

Table 2. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of plant height(cm)

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Biofertilizer 0.4 ml plant^{-1}	95.2 $_A$	1.8	91.4	99.0
Humic acid and fulvic acid 0.04 g plant^{-1}	94.8 $_A$	1.8	91.0	98.5
Humic acid and fulvic acid 0.08 g plant^{-1}	86.3 $_B$	1.8	82.5	90.0
Biofertilizer 1.25 ml plant^{-1}	84.5 $_B$	1.8	80.7	88.3
Interactions humic acid and fulvic acid (0.08 g) and Rimsulfuron herbicide 25% interactions (8 ml)	75.8 $_C$	1.8	72.0	79.5
Humic acid and fulvic acid 0.16 g plant^{-1}	75.3 $_C$	1.8	71.5	79.0
Biofertilizer 0.8 ml plant^{-1}	66.3 $_D$	1.8	62.5	70.0
Interaction Biofrtilizer(0.8 ml) and Rimsulfuron herbicide 25% interactions (8 ml)	65.8 $_D$	1.8	62.0	69.5
Rimsulfuron herbicide 25% 4 ml plant^{-1}	54.8 $_E$	1.8	51.0	58.5
Rimsulfuron herbicide 25% 12 ml plant^{-1}	53.8 $_E$	1.8	50.0	57.5
Rimsulfuron herbicide 25% 8 ml plant^{-1}	51.8 $_E$	1.8	48.0	55.5
Control	43 $_F$	1.8	39.2	46.8

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of number of fresh fruits per plant

In analyzing Table 3, which compares the number of fresh fruits per plant across various treatments using a 95% confidence interval, the results show significant differences between categories. The highest number of fruits per plant was observed in the "Humic acid and fulvic acid 0.04 g.plant^{-1}" category (35.5 fruits), which significantly outperformed other treatments, as indicated by the grouping with "A". This treatment is followed by "Biofertilizer 0.4 ml. plant^{-1}" (30.3 fruits), which belongs to group "B", while the "Biofertilizer 0.8 ml. plant^{-1}" (26.8 fruits) falls into group "C". Categories with lower LS means, such as "Rimsulfuron herbicide 25% 8 ml. plant^{-1}" (6.8 fruits) and the control (5.0 fruits), are grouped together in the "F" group, indicating that these treatments were not effective in enhancing fruit yield. The significant differences are primarily driven by the superior performance of humic acid and fulvic acid treatments, highlighting their positive role in fruit production. On the other hand, the Rimsulfuron herbicide 25% and interaction treatments were less effective, showing non-significant roles in improving fruit yields. These results suggest that humic acid and fulvic acid applications hold the most significant and positive impact on fruit production, while Rimsulfuron herbicide 25%s and interactions involving them exhibit the least effectiveness [10].

Table 3. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of number of fresh fruits per plant

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Humic acid and fulvic acid 0.04 g. plant^{-1}	35.5 A	0.7	34.2	36.8
Biofertilizer 0.4 ml plant^{-1}	30.3 B	0.7	28.9	31.6
Biofertilizer 0.8 ml plant^{-1}	26.8 C	0.7	25.4	28.1
Humic acid and fulvic acid 0.08 g plant^{-1}	23.3 D	0.7	21.9	24.6
Biofertilizer 1.25 ml plant^{-1}	22.5 D	0.7	21.2	23.8
Humic acid and fulvic acid 0.16 g plant^{-1}	21.8 D	0.7	20.4	23.1
Rimsulfuron herbicide 25% 4 ml plant^{-1}	13.5 E	0.7	12.2	14.8
Interaction Biofrtilizer(0.8 ml) and Rimsulfuron herbicide 25% interactions (8 ml)	12.8 E	0.7	11.4	14.1
Interactions humic acid and fulvic acid (0.08 g) and Rimsulfuron herbicide 25% interactions (8 ml)	12.5 E	0.7	11.2	13.8
Rimsulfuron herbicide 25% 12 ml plant^{-1}	11.5 E	0.7	10.2	12.8
Rimsulfuron herbicide 25% 8 ml plant^{-1}	6.8 F	0.7	5.4	8.1
Control	5 F	0.7	3.7	6.3

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of chlorophyl Spad reading

In Table 4, the chlorophyll SPAD readings are analyzed across different treatment categories, with each treatment's mean, standard error, and 95% confidence interval reported. The Duncan test reveals significant differences between categories, denoted by grouping letters (A, B, C, D, E). The most significant and positive role in enhancing chlorophyll content is observed in the Biofertilizer 0.4 ml plant^{-1} category (122.6 SPAD), which is significantly higher than other treatments, as indicated by its classification in group A, compared to group B, C, D, and E. The treatments involving Rimsulfuron herbicide 25%s and humic/fulvic acid, particularly those with higher Rimsulfuron herbicide 25% concentrations (e.g., 12 ml plant^{-1}), show significantly lower SPAD readings, suggesting a negative impact on chlorophyll content. This differentiation supports the hypothesis that biofertilizers play a crucial positive role in improving plant chlorophyll levels, while Rimsulfuron herbicide 25% and humic acid treatments tend to reduce chlorophyll synthesis, highlighting their relatively non-significant or negative effects on plant health, particularly at higher doses [11]. The statistical significance is based on the Duncan test, confirming that the difference between treatments in groups A and B are notable and impactful at a 95% confidence interval.

Table 4. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of chlorophyl Spad reading

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Biofertilizer 0.4 ml plant^{-1}	122.6 A	1.7	119.1	126.0
Interactions humic acid and fulvic acid (0.08 g) and Rimsulfuron herbicide 25% interactions (8 ml)	88.2 B	1.7	84.8	91.7
Biofertilizer 0.8 ml plant^{-1}	84.3 B	1.7	80.8	87.7
Interaction Biofertilizer (0.8 ml) and Rimsulfuron herbicide	74.5 C	1.7	71.0	78.0

25% interactions (8 ml)				
Biofertilizer 1.25 ml plant^{-1}	70.4_{C}	1.7	66.9	73.8
Humic acid and fulvic acid 0.04 g plant^{-1}	70_{C}	1.7	66.5	73.5
Rimsulfuron herbicide 25% 12 ml plant^{-1}	57_{D}	1.7	53.5	60.5
Humic acid and fulvic acid 0.08 g plant^{-1}	54.9_{D}	1.7	51.4	58.3
Rimsulfuron herbicide 25% 8 ml plant^{-1}	53.2_{D}	1.7	49.7	56.7
Humic acid and fulvic acid 0.16 g plant-^{1}	44.9_{E}	1.7	41.4	48.3
Rimsulfuron herbicide 25% 4 ml plant^{-1}	44.3_{E}	1.7	40.8	47.7
Control	41.8_{E}	1.7	38.3	45.2

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of one fresh fruit weight(g)

The results presented in Table 5 provide a comprehensive analysis of the effects of various agricultural treatments on the fresh fruit weight of plants, with a 95% confidence interval. The Duncan's multiple range test revealed significant differences across treatment categories, as indicated by the distinct grouping of means. The highest fresh fruit weight was observed in the group treated with Biofertilizer at 0.4 ml plant^{-1} (42.8 g), followed closely by Rimsulfuron herbicide 25% at 12 ml plant^{-1} (41.5 g), both falling into group "A." In contrast, the group with the control treatment exhibited the lowest mean weight (18.5 g), grouped in "G." Other treatments, such as different concentrations of Biofertilizer, Humic acid and fulvic acid, and Rimsulfuron herbicide 25%, showed varying impacts, with Biofertilizer at 1.25 ml plant^{-1} (38.8 g) and Rimsulfuron herbicide 25% at 8 ml plant^{-1} (35.3 g) being significantly different from those with lower fruit weights ($p < 0.05$). Notably, interactions between Biofertilizer and Rimsulfuron herbicide 25% (8 ml), as well as Humic acid and fulvic acid (0.08 g) with Rimsulfuron herbicide 25%, were associated with lower fruit weights (25.5 g), indicating possible inhibitory effects or suboptimal synergies. These results highlight the importance of treatment concentration and the possible antagonistic interactions between components in achieving optimal fruit weight. The statistical significance of these findings is crucial for refining agronomic practices, especially in terms of balancing biofertilizer, Rimsulfuron herbicide 25%, and humic acid applications for maximum crop yield. The study's findings are aligned with recent trends in sustainable agriculture, where precision in treatment dosage plays a pivotal role in enhancing productivity and minimizing environmental impacts [12].

Table 5. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of one fresh fruit weight(g)

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Biofertilizer 0.4 ml plant^{-1}	42.8_{A}	0.8	41.1	44.388
Rimsulfuron herbicide 25% 12 ml plant^{-1}	41.5_{A}	0.8	39.9	43.138
Biofertilizer 1.25 ml plant^{-1}	38.8_{B}	0.8	37.1	40.388
Rimsulfuron herbicide 25% 8 ml plant^{-1}	35.3_{C}	0.8	33.6	36.888
Humic acid and fulvic acid 0.04 g plant^{-1}	31.3_{D}	0.8	29.6	32.888
Biofertilizer 0.8 ml plant^{-1}	31.3_{D}	0.8	29.6	32.888
Humic acid and fulvic acid 0.16 g plant^{-1}	29.8_{D}	0.8	28.1	31.388
Rimsulfuron herbicide 25% 4 ml plant^{-1}	26.3_{E}	0.8	24.6	27.888

Interaction biofertilizer (0.8 ml) and Rimsulfuron herbicide 25% interactions (8 ml)	25.5 EF	0.8	23.9	27.138
Interactions humic acid and fulvic acid (0.08 g) and Rimsulfuron herbicide 25% interactions (8 ml)	25.5 EF	0.8	23.9	27.138
Humic acid and fulvic acid 0.08 g plant^{-1}	23.3 F	0.8	21.6	24.888
Control	18.5 G	0.8	16.9	20.138

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of fresh yield weight (g)

The analysis presented in Table 6 evaluates the fresh yield weight (g) of various treatment categories, with a 95% confidence interval, using Duncan's Multiple Range Test to identify significant differences among them. The results reveal that the highest fresh yield was observed in the "Herbicide 4 ml plant^{-1}" category (382.8 g), significantly outperforming all other treatments. In contrast, the control group (114.5 g) exhibited the lowest yield, with significant differences observed between it and all other categories. The grouping analysis indicated that the herbicide at 4 ml and a combination of biofertilizer (0.8 ml) and herbicide interactions (8 ml) showed similar performance, both in group "A". Other combinations of biofertilizers and humic acid treatments yielded progressively lower values, with significant differences as compared to the top-performing categories. These findings underscore the efficacy of specific herbicide and biofertilizer treatments in enhancing plant yield, with biofertilizer concentrations and humic acid doses showing diminishing returns. The results support the use of optimized herbicide and biofertilizer formulations to maximize agricultural productivity, aligning with recent research on sustainable farming practices [13]. Among all measured traits, the control group also recorded the lowest values for key growth indicators, including the number of branches per plant (4), plant height (41 cm), number of fresh fruits (4), chlorophyll SPAD reading (41), fresh fruit weight (17 g), and total yield weight (114.5 g), confirming the limiting effect of untreated conditions on plant performance.

Table 6. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of fresh yield weight (g)

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Herbicide 4 ml plant^{-1}	382.8 A	18.4	345.2	420.3
Interaction biofertilizer (0.8 ml) and herbicide interactions (8 ml)	364 A B	18.4	326.5	401.5
Biofertilizer 0.4 ml plant^{-1}	341 A BC	18.4	303.5	378.5
Biofertilizer 1.25 ml plant^{-1}	310.3 BCD	18.4	272.7	347.8
Humic acid and fulvic acid 0.08 g plant^{-1}	288 CDE	18.4	250.5	325.5
Herbicide 12 ml plant^{-1}	264.5 DEF	18.4	227.0	302.0
Biofertilizer 0.8 ml plant^{-1}	233.3 EFG	18.4	195.7	270.8
Humic acid and fulvic acid 0.16 g plant^{-1}	212.5 FGH	18.4	175.0	250.0
Humic acid and fulvic acid 0.04 g plant^{-1}	189 GH	18.4	151.5	226.5
Interactions humic acid and fulvic acid (0.08 g) and herbicide interactions (8 ml)	178.3 GH	18.4	140.7	215.8
Herbicide 8 ml plant^{-1}	167.3 HI	18.4	129.7	204.8
Control	114.5 I	18.4	77.0	152.0

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of shoots weight (g)

The analysis of shoot weight (g) across different categories, as indicated in Table 7, shows significant variation in plant growth responses to various treatments, with a 95% confidence interval. Treatments involving herbicide and humic/fulvic acids at varying concentrations (4 ml plant^{-1} , 0.16 g/plant, 0.04 g/plant) resulted in higher shoot weights, with mean values between 792.5 and 817.8 g, indicating comparable effects and grouping them into category A. In contrast, biofertilizer applications at lower concentrations (0.4 ml plant^{-1} to 1.25 ml plant^{-1}) and interactions between biofertilizer (0.8 ml) and herbicide (8 ml) were associated with significantly reduced shoot weights (587.8 g for biofertilizer 1.25 ml plant^{-1}), forming categories B and C. The lowest shoot weight was recorded in the control group (422.3 g), supporting its classification in category D. These findings emphasize the complex interplay between plant growth stimulants and inhibitors, where higher herbicide concentrations may inhibit growth, while humic acid and fulvic acid supplementation promotes robust plant development. Recent studies corroborate these results, suggesting that humic substances can enhance nutrient uptake and stress tolerance [14], while higher herbicide dosages, particularly in combination with biofertilizers, may disrupt plant physiology, leading to reduced biomass [15]. The results underscore the importance of optimal application rates for achieving maximum growth and minimizing detrimental interactions. Notably, the control group also recorded the lowest values across all measured traits, including number of branches (4), plant height (41 cm), number of fresh fruits (4), chlorophyll SPAD reading (41), fresh fruit weight (17 g), total yield weight (114.5 g), and shoot weight (422.3 g), reflecting the limited growth potential in untreated conditions.

Table 7. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of shoots weight (g)

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Herbicide 4 ml plant^{-1}	817.8 A	28.2	760.5	875.038
Humic acid and fulvic acid 0.16 g plant^{-1}	792.5 A	28.2	735.2	849.788
Humic acid and fulvic acid 0.04 g plant^{-1}	785 A	28.2	727.7	842.288
Biofertilizer 0.4 ml plant^{-1}	775.8 A	28.2	718.5	833.038
Herbicide 12 ml plant-1	774.3 A	28.2	717.0	831.538
Humic acid and fulvic acid 0.08 g plant^{-1}	765 A	28.2	707.7	822.288
Interaction Biofertilizers (0.8 ml) and herbicide interactions (8 ml)	642.5 B	28.2	585.2	699.788
Biofertilizer 0.8 ml plant^{-1}	603.8 BC	28.2	546.5	661.038
Biofertilizer 1.25 ml plant^{-1}	587.8 BC	28.2	530.5	645.038
Herbicide 8 ml plant^{-1}	554.8 BC	28.2	497.5	612.038
Interactions humic acid and fulvic acid (0.08 g) and herbicide interactions (8 ml)	552.5 C	28.2	495.2	609.788
Control	422.3 D	28.2	365.0	479.538

Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of dry weight(g)

The results presented in Table 8, which assesses the effects of various treatments on dry weight (g) with a 95% confidence interval, indicate significant differences across the treatment groups. The highest dry weight was observed in the Herbicide 4 ml/plant and Humic acid and fulvic acid 0.16 g/plant treatments, both of which significantly outperformed other groups, with means of 245.3 g and 237.8 g, respectively. These groups share similar LS means and confidence intervals, placing them in Group A. The treatments involving biofertilizers, such as Biofertilizer 0.4 ml/plant and Biofertilizer 0.8 ml/plant, demonstrated reduced dry weight (232.7 g and 181.1 g, respectively) and were statistically distinct from the higher-performing groups, categorized as Groups B and C. The interaction between biofertilizer (0.8 ml) and herbicide (8 ml) showed an even further reduction in dry weight, with an LS mean of 192.8

g, placing it in Group B. The lowest dry weight was observed in the control group (126.7 g), which was significantly different from all other treatments. These findings reflect the varying efficacy of agricultural inputs, with Rimsulfuron herbicide 25% and humic substances leading to higher biomass production, while biofertilizers and certain interactions may exert inhibitory effects, possibly due to competition or altered nutrient dynamics [16]. Statistical analysis, including the Duncan test, confirms that these differences are significant, providing valuable insights into optimizing plant growth strategies through precise treatment combinations [17].

Table 8. Applications / Duncan / analysis of the differences between the categories with a confidence interval of 95% of dry weight(g)

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)
Herbicide 4 ml plant^{-1}	245.3 A	8.4	228.1	262.5
Humic acid and fulvic acid 0.16 g plant^{-1}	237.8 A	8.4	220.6	254.9
Humic acid and fulvic acid 0.04 g plant^{-1}	235.5 A	8.4	218.3	252.7
Biofertilizer 0.4 ml plant^{-1}	232.7 A	8.4	215.5	249.9
Herbicide 12 ml plant^{-1}	232.3 A	8.4	215.1	249.5
Humic acid and fulvic acid 0.08 g plant^{-1}	229.5 A	8.4	212.3	246.7
Interaction biofertilizers (0.8 ml) and herbicide interactions (8 ml)	192.8 B	8.4	175.6	209.9
Biofertilizer 0.8 ml plant^{-1}	181.1 BC	8.4	163.9	198.3
Biofertilizer 1.25 ml plant^{-1}	176.3 BC	8.4	159.1	193.5
Herbicide 8 ml plant^{-1}	166.4 BC	8.4	149.2	183.6
Interactions humic acid and fulvic acid (0.08 g)_ and herbicide interactions (8 ml)	165.8 C	8.4	148.6	182.9
Control	126.7 D	8.4	109.5	143.9

Correlation Coefficient Analysis Between Agricultural Variables: Branch Count, Plant Height, Fruit Production, and Biomass Metrics"

The correlation coefficient analysis in Table 9 highlights the interrelationships between key agricultural variables such as branch count, plant height, fruit production, and biomass metrics. Significant positive correlations were observed, particularly between the number of branches and number of fresh fruits per plant (r = 0.914*), as well as between plant height and number of fresh fruits per plant (r = 0.842*), suggesting that greater vegetative growth correlates with higher fruit yield. These findings are consistent with recent studies that emphasize how robust vegetative structures, such as increased branch count and plant height, support higher fruit production in crops [18]. However, chlorophyll SPAD readings showed weaker relationships with other variables, indicating its limited role in directly predicting biomass or fruit yield. Interestingly, although there was a positive association between fresh fruit weight and various other variables, it remained modest (r values ranging from 0.289 to 0.451), suggesting that fruit size is influenced by a combination of factors rather than a singular agronomic trait. Furthermore, shoot weight and dry weight showed a significant positive correlation (r = 0.524), reinforcing the notion that biomass accumulation in shoots is a key indicator of overall plant health and yield potential [19,20]. The lack of strong correlation between fresh yield weight and other variables underscores the complexity of predicting yield solely based on vegetative traits, highlighting the need for multi-variable models in precision agriculture(Rouault et al., 2024).

Table 9. "Correlation Coefficient Analysis Between Agricultural Variables: Branch Count, Plant Height, Fruit Production, and Biomass Metrics"

Variables	Number of	Plant Height(	Number of fresh fruits	Chlorophyl Spad	One fresh fruit	Fresh yield	Shoots weight	Dry weigh

	branches	cm)	per plant	reading	weight(g)	weight(g)	(g)	t(g)
Number of branches	1							
Plant Height(cm)	0.765	1						
Number of fresh fruits per plant	0.914	0.842	1					
Chlorophyl Spad reading	0.456	0.579	0.492	1				
One fresh fruit weight(g)	0.335	0.289	0.332	0.451	1			
Fresh yield weight(g)	0.020	0.228	0.217	0.250	0.235	1		
Shoots weight (g)	0.427	0.394	0.506	0.041	0.309	0.524	1	
Dry weight(g)	0.427	0.394	0.506	0.041	0.309	0.524	1.000	1

Values in bold are different from 0 with a significance level alpha=0.05

Conclusion

In conclusion, the evaluation of different treatments on plant growth parameters such as branch number, plant height, fruit production, chlorophyll content, and yield high lights the importance of selecting the right inputs to optimize plant performance. Humic and fulvic acids, especially at 0.04 g/plant, consistently showed beneficial effects, promoting growth across several traits, including increased fruit production and chlorophyll content. These results support existing research indicating that humic substances improve nutrient uptake and stress tolerance. In contrast, treatments with Rimsulfuron herbicide 25%, particularly at higher doses, negatively affected plant growth, reducing branch number, height, and yield, likely due to phytotoxic effects.

Additionally, analysis of traits like fruit weight, shoot weight, and dry weight further emphasizes the need for balanced application rates. Excessive use of biofertilizers or Rimsulfuron herbicide can lead to reduced biomass and lower productivity. The study underscores the importance of precise and moderated use of agrochemicals to maximize yield without compromising plant health. These findings provide practical guidance for sustainable agricultural practices and suggest that future research should focus on optimizing treatment combinations and dosages to enhance crop outcomes while reducing adverse effects.

Recommendations

[1]. **Long-Term Effects of Humic and Fulvic Acids:** Future research should examine how humic and fulvic acids affect soil structure and microbial diversity over time to support sustainable farming.

[2]. **Optimal Concentrations of Rimsulfuron Herbicide:** Studies should identify herbicide thresholds that control weeds effectively without harming tomato growth, possibly by testing lower doses.

[3]. **Synergistic Effects of Biofertilizers and Enhancers:** Research could explore combining biofertilizers with agents like PGPR to enhance tomato yield and plant resilience.

[4]. **Impact on Fruit Quality:** Future studies should assess how treatments influence tomato nutrition, flavor, and shelf life to better understand quality outcomes.

[5]. **Interaction with Environmental Factors:** Expanding trials to variable field conditions can reveal how climate and soil factors influence treatment effectiveness in different regions.

[6]. **Organic Alternatives to Herbicides:** Research should investigate organic weed control methods as sustainable alternatives to synthetic herbicides like Rimsulfuron.

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التأثيرات التآزرية للأسمدة الحيوية، وحمض الهيوميك، وحمض الفولفيك على أداء مبيد الأعشاب ريمسولفورون بتركيز 25٪ في زراعة الطماطم(*Solanum lycopersicum*) .

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الخلاصة

جريت هذه الدراسة في معهد بكرجو التقني عام 2023 بهدف تقييم تأثير المعاملات الزراعية المختلفة على نمو وإنتاجية نباتات الطماطم ***(Solanum lycopersicum)***، بهدف تحديد أجود المعاملات التي تُحسن المحصول و انتاجية النبات. استخدمت الدراسة تصميمًا عشوائيًا كاملاً ***(CRD)*** مع أربع مكررات، وتمت مقارنة متوسطات المعاملات المدروسة باستخدام اختبار دنكن ***(DMRT).*** تضمنت المعاملات الرئيسية الأربعة: حمض الهيوميك، حمض الفولفيك، الأسمدة الحيوية، ومبيد الأعشاب ريمسولفورون بتركيز 25٪، وتم تطبيق هذه المعاملات بجرعات متفاوتة لتقييم تأثيرها على مجموعة من الصفات الزراعية، بما في ذلك ارتفاع النبات، وعدد الأفرع، وإنتاجية الثمار، ومحتوى الكلوروفيل، ووزن الثمرة الطازجة، ووزن الانتاج، والوزن الجاف**.**أظهرت النتائج أن حمض الهيوميك وحمض الفولفيك عند استخدامهما بتركيز 0.04 غرام/نبتة،نتائج جيدة بشكل ملحوظ عدد الأفرع، مما يشير إلى دورهما في تحفيز النمو الخضري. وعلى النقيض من ذلك، فإن الجرعات العالية من مبيد ريمسولفورون، وخاصة بتركيز 12 مل/نبتة، أثرت سلبًا على إنتاج الأفرع وغلة الثمار، مما يدل على تأثيراته السامة في التركيزات المرتفعة. أما الأسمدة الحيوية عند استخدامها بتركيز 0.4 مل/نبتة فقد أثرت إيجابيًا على محتوى الكلوروفيل ووزن الثمرة الطازجة، مما يدعم دورها في تعزيز كفاءة التمثيل الضوئي وتطور الثمار**.** مع ذلك، عند دمج الأسمدة الحيوية مع مستويات عالية من المبيد، لوحظ انخفاض في تراكم الكتلة الحيوية، مما يشير إلى وجود تأثيرات تفاعلية سلبية. وبشكل عام، تؤكد النتائج على أهمية اختيار وتوازن المدخلات الزراعية المناسبة لتحقيق أفضل أداء للنبات. وقد برز حمض الهيوميك والأسمدة الحيوية كمعاملات مفيدة في تعزيز النمو والإنتاجية، في حين أن الإفراط في استخدام مبيد الأعشاب ثبت أنه يضر بصحة النبات. وتُبرز الدراسة الحاجة الماسة إلى إدارة متكاملة وحكيمة للمعالجات الزراعية لضمان إنتاج محاصيل مستدامة، وتوصي بإجراء المزيد من الأبحاث لتحديد التركيبات والجرعات المثلى من المعالجات بهدف تعظيم إنتاج الطماطم في ظروف نمو مماثلة**.**

الكلمات المفتاحية: الأسمدة الحيوية، حمض الهيوميك، حمض الفولفيك، مبيد الأعشاب ريمسولفورون، الطماطم.