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RESEARCH ARTICLE

MORINGA (*Moringa oleifera* Lam) AS A PROBABLE HERBAL GROWTH AGENT OF TOMATO PLANT

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ABSTRACT

Despite the fact that *Moringaoleifera* extracts can enhance plant growth, improve yield, and increase resilience to abiotic and biotic stresses its effects on tomato plant growth have not been extensively researched. Hence, this study sought to investigate the potential of *Moringaoleifera*extracts as aherbal growth agent of tomato plants. The study was conducted in Cape Coast. Three concentrations of Moringa leaf, bark and root were used as experimental set up whereas water was used as control. Plant height, number of leaves, leaf length and number of stem branches were determined. Means were compared by using two way analysis of variance (ANOVA). Leaf extract influenced the highest plant height (13. 99±0.15) followed by root (13.86±0.1), bark (13.33±0.13) and the control (9.25±0.76). The differences among the treatment means were statistically significant (F =29.40974; P<0.05). Though, all the Moringa extracts promoted longer leaf length, the differences among the treatment means were not statistically significant (p>0.05). The indication is that Moringa leaf, root and bark extracts promise to be tomato plant vegetative growth promoters. However, there is the need to undertake confirmation studies and to determine the exact content of the Moringa plant that does the promotion of tomato plant parts.

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INTRODUCTION

Plant growth agents are also known as plant growth regulators or biostimulants. They are compounds that influence and enhance plants' physiological and metabolic processes, leading to improved growth, yield, and resilience (Nephali *et al*., 2020). These substances play a critical role in regulating cell division, elongation, and differentiation, as well as improving nutrient uptake and stress resistance (Taiz *et al*., 2015). In modern agriculture, where sustainable crop production is vital to meet increasing global food demands, growth agents have become indispensable tools for optimizing plant performance. They are particularly relevant in overcoming challenges such as declining soil fertility, pest pressures, and abiotic stress (Taiz *et al*., 2015). Growth agents can be broadly classified into synthetic and natural types. Synthetic agents, including chemical formulations of auxins, gibberellins, cytokinins, and ethylene, have long been used in agriculture for targeted crop management (Fahad *et al*., 2015). However, excessive reliance on synthetic agents has raised environmental and health concerns, including soil toxicity, water contamination, and reduced microbial biodiversity. These issues have catalyzed interest in eco-friendly and sustainable alternatives, such as bio-based agents and natural/organic compounds (Hamid*et al.,* 2021). These natural agents, derived from biological sources such as microorganisms, composts, and plant extracts, hold immense potential for replacing synthetic chemicals while maintaining crop productivity and soil health (Rady & Mohamed, 2015). Herbal growth agents derived from plants and their extracts represent an innovative approach within natural growth promoters. Moreover, El-Ramady (2022) emphasized that these agents are rich in bioactive compounds such as flavonoids, phenolics, alkaloids, and essential oils, which stimulate plant growth, improve nutrient efficiency, and enhanced resistance to environmental stressors. Plant-based agents like neem (*Azadirachtaindica*), garlic (*Allium sativum*), and moringa (*Moringaoleifera*) have been extensively studied for their dual role as growth promoters and pest deterrents (Mgembe, 2023). These herbal extracts act as natural biostimulants that enhance root and shoot development, promote nutrient assimilation and reduce crop dependency on chemical inputs. The advantages of herbal growth agents are multifaceted. Being biodegradable and environmentally safe (Mgembe, 2023), these agents align with the principles of organic and regenerative farming. Additionally, herbal agents stimulate soil microbial activity, improving soil fertility and contributing to a more sustainable agroecosystem (De Corato, 2020). By integrating herbal growth agents into agricultural practices, farmers can achieve higher yields with minimal ecological impact, making them vital for sustainable farming. Among these, Moringa (*Moringaoleifera*) (Figure 1), commonly referred to as the "miracle tree," has gained prominence due to its rich nutrient profile and bioactive compounds. Moringa leaf extracts are abundant in phytohormones, antioxidants, and essential amino acids, which have shown remarkable effects on plant growth and stress tolerance (Zulfiqar *et al*., 2020; Sadak *et al*., 2024).

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Research has demonstrated that Moringa applications enhance seed germination, root elongation, shoot biomass, and overall crop productivity, particularly in horticultural crops like tomatoes (Zulfiqar *et al*., 2020).

Source: https://www.amazon.com/Moringa-Plant-Oleifera-Rooted-Inches/dp/B0CG5R7L23

Figure 1. Moringa plant

The excessive reliance on synthetic pesticides and growth agents in agriculture has resulted in significant environmental and health concerns, including soil degradation, water contamination, biodiversity loss, and food safety issues due to chemical residues (Fahad *et al*., 2015). These challenges are particularly pronounced in tomato (*Solanumlycopersicum*) cultivation, where high susceptibility to pests and diseases drives the heavy use of chemical inputs (Rouphael & Colla, 2020). *Moringa oleifera*, known for its phytohormones, antioxidants, and essential nutrients has shown potential as a natural biostimulant. Studies indicate that Moringa extracts can enhance plant growth, improve yield, and increase resilience to abiotic and biotic stresses (Rady & Mohamed, 2015). However, while its benefits are well-documented in nutrition and medicine, its effects on plant growth, specifically tomatoes, are under-researched. This study seeks to fill this gap by evaluating the efficacy of Moringa extracts in enhancing tomato plant growth, compared to a control.

Purpose of the Study: The study aimed to assess the potential of *Moringaoleifera* extracts as aherbal growth agent of tomato plants.

Research objectives

The specific objectives of the study were to:

1. Evaluate the effect of *Moringa oleifera*extracts on the height of tomato plants.
2. Determine the impact of Moringa extracts on the number of leaves on tomato plants.
3. Assess the influence of Moringa extracts on the number of branches of tomato plants.
4. Measure the effect of Moringa extracts on leaf length of tomato plants.

Hypotheses

Null Hypotheses (H_0)

H_{01}: There is no statistically significant effect of Moringa extracts on the height of tomato plants.

H_{02}: Moringa extracts do not significantly affect the number of leaves on tomato plants.

H_{03}: The number of branches on tomato plants is not significantly influenced by Moringa extracts.

H_{04}: Moringa extracts have no significant effect on the leaf length of tomato plants.

Alternative Hypotheses (Ha)

Ha1: There is statistically significant effect of Moringa extracts on the height of tomato plants.

Ha2: Moringa extracts do significantly affect the number of leaves on tomato plants.

Ha3: The number of branches on tomato plants is significantly influenced by Moringa extracts.

Ha4: Moringa extracts have significant effect on the leaf length of tomato plants.

MATERIALS AND METHODS

The study was conducted in Cape Coast as described by Hordzi (2024). Similarly, seedling beds were raised as in Hordzi (2024). Pectomech tomato variety seeds were obtained from seed sellers in the Cape Coast Metropolis and raising of seedlings done as described by Hordzi (2024). A plot of land measuring 50m by 50 m was prepared in the school farm of Holy Child Senior High School in Cape Coast**.** The plot was divided into 10 blocks and each block divided into 10 sub-blocks. One meter was left between two blocks and two sub-blocks respectivelyto reduce the effect of each of the treatments blown by wind from influencing the results on untargeted block and sub-block. Each sub-block measured four (4) meters by four (4) meters. Randomized complete blocking was used. Transplanting of seedlings was done as in Hordzi (2024). Furthermore, Moringa extracts were prepared as in Hordzi (2024). Each Moringa extract (leaf, bark and root) had three concentrations (C1, C2 and C3) as experimental set ups and water as control and applied as described by Hordzi (2024).

Data collection: Under this study, growth refers to plant height, number of leaves, number of stem branches and leaf length. For each treatment and control experiment, 10 plants were randomly selected and labelled for data collection. The plant height was measured by using a graduated ruler. This was accomplished by measuring the plant from its ground-level base to its point of terminal growth. Every two weeks, the height of the selected plants was measured, and the mean height calculated by dividing the sum of the heights by the number of plants. The number of branches on each plant was counted and recorded each week. This was done for five weeks. The average number of stem branches per treatment per week was estimated by dividing the total number of branches per week by total number of plants (ten).The average number of stem branches per treatment was determined by dividing the total mean for five weeks by five. To determine mean number of leaves per treatment, all opened leaves (leaving out leaf buds that are not opened) of each plant was counted. The sum of all leaves from the ten plants was divided by 10. The mean number of leaves per treatment was determined by dividing the total means for the five weeks by five. On each sampling day, five leaves were randomly sampled from five randomly sampled plants, making a total of 25 leaves. A graduated ruler was used to measure the length of each leaf without destruction. Measurements were taken from the petiole's base to the tip of each leaf. Average leaf length was determined by dividing the sum for the 25 leaves by 25. The average leaf length per treatment was determined by dividing the total mean for the five weeks by five.

Data analysis: Data collation was done by using SPSS Version 26. Means were compared using two way analysis of variance (ANOVA). Turkey's test was done where means were significant at $p = 0.05$.

RESULTS AND DISCUSSION

The data in Table 1 indicate that the mean plant height was highest in tomato plants treated with leaf extract (13.99 cm), followed by root extract (13.86 cm) and bark extract (13.33 cm). In contrast, the control group recorded a significantly lower mean plant height (9.25 cm). These differences were confirmed in Table 2, where the differences among the treatments were statistically significant ($F = 29.41$, $P < 0.05$). Thus, the null hypothesis was rejected and the alternate hypothesis accepted. However, there was no statistically significant difference among neither the concentrations nor the interactions between treatment types and concentrations ($p>0.05$). Here, the null hypothesis was accepted and the alternate hypothesis rejected. This shows that the observed variations in plant height were primarily attributable to the type of extract used.The lack of significant effects of concentration and interactions ($P > 0.05$) implies that the growth-promoting effect of Moringa extracts is concentration-independent within the tested range.

This could be attributed to the higher concentration of bioactive compounds such as zeatin (a natural cytokinin) in Moringa leaves compared to the bark and root (Yasmeen, 2011). Also, according to Taiz and Zeiger (2010), cytokinins are known to delay senescence, enhance photosynthetic activity, and promote shoot growth in plants. Thus, the application of Moringa leaf extract likely stimulated greater physiological activity and biomass accumulation in the treated tomato plants.Although bark and root extracts resulted in lower plant heights than leaf extract, their performance was still significantly superior to the control. This indicates that these extracts also contain bioactive compounds beneficial for plant growth. According to Fahey (2005) Moringa bark and root extracts contain alkaloids, phenolics, and flavonoids, which may contribute to stress tolerance, nutrient uptake, and enhanced growth in plants. The findings indicate that Moringa extracts significantly enhance the height of tomato plants. The results presented in Table 3 show that tomato plants treated with Moringa extracts exhibited a significantly higher number of leaves compared to the control group. Leaf and root extracts performed similarly, with mean values of 58.08 and 58.15 respectively while bark extract

Table 1. Mean effects of treatments on plant height (cm)

Treatment	Mean per concentration			Mean of means
	C1	C2	C3	
Leaf	14.61±033	13.80±0.12	13.57±0	13.99±0.15a
Bark	13.39±0.24	13.37±0.03	13.22±0.13	13.33±0.13a
Root	14.47±0.27	13.59±0.01	13.52±0.02	13.86±0.1a
Control	9.08±0.79	9.32±0.70	9.35±0.80	9.25±0.76b

Key: C1 = concentration 1, C2 = concentration 2; and C3 = concentration 3
Note: Difference between means with the same letters in a column are not significant
Source: Researcher fieldwork

Table 2. ANOVA results of the effects of treatments on plant height

Source of Variation	SS	df	MS	F	P-value	F crit
Type of treatment	237.6396	3	79.21321	29.40974	6.12E-11	2.798061
Concentration	1.485942	2	0.742971	0.275845	0.760125	3.190727
Interaction	6.405537	6	1.06759	0.396367	0.877726	2.294601
Error	129.2848	48	2.693434			
Total	374.8159	59				

Source: Researcher fieldwork

Table 3. Mean effects of treatment on number of leaves

Treatment	Mean per concentration			Mean of means
	C1	C2	C3	
Leaf	59.26±0.11	58.44±1.22	56.55±0.10	58.08±0.48a
Bark	55.23±0.24	56.32±0.08	54.28±0.28	55.28±0.2a
Root	59.15±0.04	58.73±0.58	56.61±0.07	58.15±0.23a
Control	37.47±0.27	40.04±0.27	36.28±0.27	37.93±0.27b

Key: C1 = concentration 1, C2 = concentration 2; and C3 = concentration 3
Note: Difference between means with the same letters in a column are not significant
Source: Researcher fieldwork

Table 4. ANOVA results for effects of extracts on the number of leaves

Source of Variation	SS	df	MS	F	P-value	F crit
Type of treatment	4393.089	3	1464.363	4.100909	0.011388	2.798061
Concentration	61.98525	2	30.99263	0.086794	0.917009	3.190727
Interaction	31.15108	6	5.191847	0.01454	0.999985	2.294601
Error	17139.96	48	357.0825			
Total	21626.19	59				

Source: Researcher fieldwork

These findings are consistent with previous studies reporting the growth-promoting properties of *Moringa oleifera*. Moringa leaves are rich in plant hormones such as cytokinins and auxins, which stimulate cell division and elongation, thereby enhancing plant growth (Mashamaite*etal*., 2022). In addition, the presence of micronutrients, amino acids, and antioxidants in Moringa extracts could have contributed to improved nutrient uptake and physiological processes, leading to increased plant height (Makkar & Becker, 1997).Among the treatments, leaf extract consistently showed the highest mean plant height across all concentrations.

yielded a slightly lower mean (55.28). The control group produced a substantially lower mean of 37.93. ANOVA results in Table 4 confirm that the type of treatment had a statistically significant effect on the number of leaves ($F = 4.10$, $P = 0.011$), indicating the positive impact of Moringa extracts on this parameter. The observed increase in the number of leaves for Moringa extracts aligns with previous studies highlighting the growth-promoting properties of *Moringa oleifera*. Moringa is rich in bioactive compounds, such as cytokinins and other plant hormones that promote cell division, delay leaf senescence, and enhance photosynthetic efficiency (Mashamaite *et* *al.,* 2022). These factors likely contributed to the significant increase in the number of leaves observed in treated plants compared to the control.Additionally, Moringa's bio-stimulatory effects could be attributed to its role in improving soil microbial activity and nutrient cycling when applied as a foliar spray or soil amendment (Sani & Yong, 2021). Enhanced microbial activity and nutrient availability may have further accelerated the growth and development of leaves in treated tomato plants, as reported by Liao and Xia (2024) on plant-soil-microbe interactions. Leaf and root extracts demonstrated superior performance in promoting leaf proliferation, with their effects being comparable. Moringa leaves are known to contain higher concentrations of cytokinins and phenolic compounds compared to the bark and root (Yasmeen, 2011), which enhance chlorophyll synthesis and overall leaf growth. Similarly, root extract has been reported to contain secondary metabolites like alkaloids and flavonoids that can enhance nutrient uptake and stress tolerance in plants (Fahey, 2005). While the bark extract also significantly increased the number of leaves compared to the control, its effect was less pronounced than that of leaf and root extracts. Bark extracts contain bioactive compounds like saponins and phenolics but in lower concentrations compared to the leaves (Makkar & Becker, 1997). This could explain its relatively moderate performance in stimulating leaf production. The control group recorded the lowest number of leaves, with a mean of 37.93. This significant difference underscores the efficacy of Moringa extracts as growth enhancers. The plants from the control group likely lacked the bioactive stimulation provided by the extracts, leading to reduced leaf proliferation.Based on the findings, the null hypothesis two (H_{02}) was rejected. Moringa extracts significantly increased the number of leaves in tomato plants. These findings strongly affirm the growth-enhancing potential of Moringa extracts, particularly for sustainable agriculture and the development of eco-friendly plant growth promoters.

As shown in Table 5, plants treated with Moringa leaf extract exhibited the highest mean number of branches (11.35), followed by bark extract (9.69) and root extract (9.65). The control group recorded the lowest mean (8.13). These trends indicate that Moringa extracts may promote lateral branching to some extent, with leaf extract being the most effective treatment. This aligns with prior studies suggesting that the bioactive compounds in Moringa, such as cytokinins, auxins, and gibberellins, stimulate lateral shoot development (Mashamaite*et al*., 2022). Cytokinins, in particular, are known to influence apical dominance and promote the formation of lateral branches by reducing the dominance of the main shoot apex (Taiz & Zeiger, 2010). Moringa leaf extract, being rich in cytokinins, likely contributed to the relatively higher branching observed in this treatment.The bark and root extracts exhibited moderate effects on branch proliferation, with mean values of 9.69 and 9.65, respectively. While these treatments were superior to the control, they were less effective than the leaf extract. This may be attributed to lower concentrations of growth-promoting compounds like cytokinins in the bark and root compared to the leaves (Makkar & Becker, 1997). Bark and root extracts may also contain secondary metabolites, such as tannins and alkaloids, that could influence plant growth differently or inhibit branching at certain concentrations (Yasmeen, 2011). Although the treatments improved branch proliferation compared to the control group, ANOVA results from Table 6 revealed that the effects were not statistically significant ($F = 1.03$, $P > 0.05$).The lack of statistical significance in the ANOVA results ($P > 0.05$) suggests that the observed differences in the number of branches between treatments and concentrations could be due to random variation rather than a true effect of the treatments. Additionally, the F-values for treatment type (1.03) and concentration (0.13) were relatively low, further supporting this conclusion. It is possible that conditionssuch as environmental factors or the duration of treatment application

Table 5. Mean effects of extracts on the number of branches

Treatments	Mean per concentration			Mean of means
	C1	C2	C3	
Leaf	11.82±0.08	11.41±0.04	10.81±0.07	11.35±0.06
Bark	10.18±0.03	9.98±0	8.91±0.01	9.69±0.01
Root	9.77±0.04	9.79±0.24	9.39±0.1	9.65±0.13
Control	7.74±0.08	8.85±0.08	7.80±0.08	8.13±0.08

Key: C1 = concentration 1, C2 = concentration 2; and C3 = concentration 3
Note: Difference between means with the same letters in a column are not significant
Source: Researcher fieldwork.

Table 6. ANOVA results of the effects of extracts on number of branches

Source of Variation	SS	df	MS	F	P-value	F crit
Type of treatment	77.81233	3	25.93744	1.025863	0.389534	2.798061
Concentration	6.49375	2	3.246875	0.128419	0.879786	3.190727
Interaction	5.012917	6	0.835486	0.033045	0.999831	2.294601
Error	1213.61	48	25.28354			
Total	1302.929	59				

Source: Researcher fieldwork

Table 7. Effects of extracts on leaf length

Treatment	Mean per concentration			Mean of means
	C1	C2	C3	
Leaf	5.31±0.01	5.35±0.05	4.75±0.04	5.14±0.03
Bark	5.30±0.03	4.19±0.01	4.12±0.03	4.54±0.02
Root	4.95±0.02	5.05±0	4.28±0.01	4.76±0.01
Control	3.50±0.01	3.87±0.01	3.49±0.01	3.62±0.01

Key: C1 = concentration 1, C2 = concentration 2; and C3 = concentration 3
Note: Difference between means with the same letters in a column are not significant
Source: Researcher fieldwork

Table 8. ANOVA results of the effects of the extracts on leaf length (cm)

Source of Variation	SS	df	MS	F	P-value	F crit
Type of treatment	19.70392	3	6.567973	1.523763	0.220343	2.798061
Concentration	1.800769	2	0.900384	0.208888	0.81222	3.190727
Interaction	4.813346	6	0.802224	0.186115	0.97932	2.294601
Within	206.8974	48	4.310363			
Total	233.2155	59				

Source: Researcher fieldwork

influenced the results and masked potential treatment effects. Therefore, the null hypothesis (H_{03}) is accepted indicating that the number of branches in tomato plants is not significantly influenced by Moringa extracts. The results presented in Tables 7 and 8 examine the effects of different plant extracts (leaf, bark, and root) on the leaf length of test plants across three concentration levels (C1, C2, and C3). The mean leaf length for plants treated with leaf extracts (5.14 cm) was consistently higher than those treated with bark (4.54 cm) and root extracts (4.76 cm). Zulfiqar *et al*. (2020)suggest that leaf extracts often contain higher concentrations of bioactive compounds like phytohormones, antioxidants, and secondary metabolites that promote cell elongation and overall plant growth. Leaves are primary sites for photosynthesis and may possess higher metabolic activity, providing a broader spectrum of growth-promoting compounds compared to bark and roots. Across all treatments, the concentration levels (C1, C2, and C3) did not exhibit significant differences in their impact on leaf length. This result implies that the efficacy of the extracts does not strongly depend on the concentration range tested. The ANOVA results in Table 8 indicate that the type of treatment had no statistically significant effect on leaf length ($F = 1.52$, $P = 0.22$), and neither did concentration levels ($F = 0.21$, $P = 0.81$). Furthermore, the interaction between treatment type and concentration was also not significant ($F = 0.19$, $P = 0.98$). These results suggest high variability within the dataset and indicate that, while the extracts showed numerical differences in leaf length compared to the control, these differences were not statistically significant at the tested confidence level. Therefore, based on the findings presented, the analysis failed to reject the null hypothesis (H_{04}) that *Moringa* extracts have no significant effect on the leaf length of tomato plants is accepted.

CONCLUSIONS AND RECOMMENDATIONS

Though all the Moringa extracts enhanced tomato plant height, the leaf extract promised to be the best. In any case if enhancing tomato plant height is desirable for any special purpose, any of the Moringa extract can be used. This notwithstanding, there is the need for more research into the phenomenon of Moringa extracts boosting tomato plant height as well as other vegetables so that the appropriate dosage can be applied if the need arises. It is further evident that Moringa extracts are capable of stimulating increased number of tomato leaves. However, root and leaf extracts appear to be more promising. Therefore, it may be better using Moringa root and leaf extracts to multiply the number of leaves in tomato plants if need be. The findings also suggest that Moringa extracts may promote lateral branching to some extent, with leaf extract being the most effective treatment. Meanwhile, *Moringa* extracts have no significant effect on the leaf length of tomato plants. However, Moringa leaf, bark and root extracts on large scale prove to be tomato plant eco-friendly plant growth promoters for sustainable agriculture and development. Therefore, to fully exploit this for tomato crop production, the Ministry of Agriculture and the Agricultural Extension Service need to team up with researchers to further ascertain the viability of the use of Moringa extracts as tomato plant growth enhancers and the probable benefits that it can bring.

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