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PRELIMINARY ROOTING STUDY OF TOMATO (*Solanum lycopersicum* L.) IN RESPONSE TO DROUGHT STRESS AS MANAGED BY AQUAGRAIN APPLICATION

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ABSTRACT
A field experiment was conducted to investigate the effects of Aquagrain application, a protein-based SAP, on tomato root development during the 2024 dry season at the Center for Dryland Agriculture (CDA) Research and Training Farm, Kano, Nigeria. The treatment consisted of four rates of aquagrain (0, 200, 225, and 250 kg/ha) and two tomato varieties (local and improved) which were factorially combined and laid out in a randomized complete block design (RCBD) with three replications. Data were collected on plant growth and root parameters and subjected to analysis of variance (ANOVA) using GENSTAT (11th edition). Significant means were separated using the Student Newman's' Test (SNK). Result of the experiment revealed that, Aquagrain application improved soil moisture retention and consequently plant growth (height, leaves, branches). The most significant positive effects were observed at the highest concentration (250 kg/ha) with the improved tomato variety. These findings suggest protein-based SAPs hold promise for mitigating drought stress in tomatoes. However, further research is required to assess long-term impacts on soil quality, crop yield, and the environment alongside optimizing application rates for various crops and growing conditions.

Keywords: Aquagrain, Concentration, Drought Stress, Tomato, Root, Development,

INTRODUCTION

Aquagrain, a soil-enriching hydrogel developed by Biomation, aims to combat water scarcity in agricultural regions by enhancing water utilization in crop production (Ingrao *et al.,* 2023). Originating from animal protein and acrylic acid polymers, it conserves water and enriches soil with plant nutrients. Initially known as "Protein-Based Super Absorber (PBSA), Aquagrain is the official brand name for this revolutionary product (Ghobashy, 2020. Aquagrain is a biodegradable soil enhancer made from organic materials, able to hold 30 times its weight in water, nourishing crops when watered (Tariq *et al*., 2023). Food sector waste is utilized to create a biodegradable polymer that efficiently absorbs large volumes of liquid for crop nutrition and sustainable irrigation (Jones *et al.,* 2019). It reduces the need for inorganic fertilizers and stimulates microbial activity, making it ideal for regenerative farming practices (Sikder *et al.,* 2021; Li *et al.,* 2023. Aquagrain biodegrades over 12 months to leave just water, CO_2, and organic matter in your soil (Smith, 2020).

Tomato (*Solanum lycopersicum* L.) is one of the most economically significant vegetable crops globally, widely cultivated for its nutritional value and culinary versatility (Azabou, *et al.,* 2020). However, tomato production faces numerous challenges, including abiotic stresses such as drought, which can significantly reduce yields and quality (Contti *et al.,* 2023). Drought stress, characterized by limited water availability, is a major constraint in many tomato-growing regions, particularly in arid and semi-arid areas (Wang *et al.,* 2018). Mitigating the adverse effects of drought stress on tomato plants is crucial for sustaining production and ensuring food security. Despite its widespread cultivation, tomato production faces numerous challenges, with abiotic stresses posing significant threats to yield and quality. Among these stresses, drought stands out as a primary concern, particularly in regions characterized by erratic rainfall patterns and limited access to irrigation water (Iovieno *et al.,* 2016). Drought stress occurs when plants experience insufficient soil moisture to meet their physiological needs, leading to impaired growth, reduced photosynthesis, and ultimately decreased yields (Parrotta *et al.,* 2020).

The impact of drought stress on tomato plants is multifaceted, affecting various physiological processes essential for growth and development. Water scarcity disrupts stomatal function, leading to decreased gas exchange and impaired carbon assimilation (Haworth *et al.,* 2016; Wang *et al.,* 2018). Additionally, drought stress induces oxidative stress, resulting in the accumulation of reactive oxygen species (ROS) and damage to cellular structures (Rangani *et al*., 2018). Roots play a pivotal role in a plant's response to drought stress, serving as the primary interface for water and nutrient uptake from the soil (Cui *et al.,* 2022). Drought-induced changes in root architecture and morphology can significantly influence a plant's ability to access water resources and sustain growth under water-limited conditions (Gorgues *et al*., 2022). Moreover, roots contribute to osmotic adjustment, a crucial mechanism for maintaining cellular turgor and water uptake during periods of water deficit (Kang *et al*., 2022).

Tomato production is crucial for global food security and economic sustainability, but challenges like drought stress and inefficient irrigation methods pose significant threats to yield and quality, threatening livelihoods and environmental degradation (Conti *et al*., 2023). Overuse of inorganic fertilizers raises expenses, degrades soil quality, and pollutes the environment when growing tomatoes. Ecosystems and soil health are compromised by the use of chemical fertilizers and ineffective nutrient management. To ensure the long-term sustainability of tomato growing, creative solutions are required to strengthen soil health, encourage sustainable water management, and increase drought resilience (Amirahmadi *et al*., 2023). The use of protein-based superabsorbers in Nigeria can improve soil moisture retention, reduce water usage in agriculture, and enhance crop yields, offering potential solutions for water management and food security (Oladosu et al., 2022; Tajudeen *et al.,* 2022; Zhang *et al.,* 2018). This study therefore investigates the drought mitigation potentials of Aquagrain in tomato production and its impact on tomato root development at different application rates.

MATERIALS AND METHODS

The experiments were conducted during the dry season of 2024 at Center for Dryland Agriculture Research Farm, Bayero University Kako, Sudan savannah ecology (latitude 11.9961°N, longitude 8.5176°E). Pipes of 3 meters length were cut into 0.5 meters, filled with top soil at a rate of 10 kg per pipe, pipes, labeled and all treatments were allocated to respective pipes, watered and weeded at the same time. All maintenance operations and preparations were uniform. The study employed a factorial Randomized Complete Block Design (RCBD) to examine the effects of varying application rates of aquagrain on two types of tomato seeds (local and improved varieties). Aquagrain was applied at rates of 0, 200, 225, and 250 kg/ha. Treatments were randomly assigned and distributed across three replications, each containing eight pipes. All the pipes were consistently subjected to optimal conditions, receiving adequate water and nutrients after being planted until the onset of the stress period. Planting took place on October 30, 2023, and water

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stress was uniformly introduced three weeks after planting. All essential agronomic procedures were adequately carried out. Aquagrain was applied prior to sowing using band placement method of application and the rate of application was calculated as follows;

$$Rate\ of\ application = \frac{Weight\ of\ soil\ in\ a\ hectare \times rate\ of\ fertilizer\ in\ a\ hectare}{weight\ of\ soil\ in\ a\ pipe \times rate\ of\ fertilizer\ in\ a\ pipe}$$

An improved tomato variety (Chibli) sourced from the Center for Dryland Agriculture Research and Training Farm and a local variety from Sharada Market were sown. Before seeding, pipes were irrigated, the soil was scratched with a stick for shallow planting, and dry straw was used for mulching for five days. Weeds were controlled manually by carefully hand pulling as they emerge throughout the crop growing period. The erections of the pipes aid in creating a barrier for most insects as no chemical or organic pesticides were used throughout the period of experiment. Harvest was done at the vegetative growing phase of the plants to obtain the required data on the plant's root. Plants were subjected to water stress for 10 days prior to harvesting. Data were collected on plant height, number of leaves, number of branches, root length, root width, fresh weight of the root, fresh weight of the shoot, dry weight of root and dry weight of the shoot using standard agronomic procedures. The collected data were subjected to analysis of variance (ANOVA) using GENSTAT (11th edition). Significant means were separated using the Student Newman's' Test (SNK).

RESULTS AND DISCUSSION

The effect of variety and aquagrain concentration on number of leaves, plant height, and number of branches is presented in Table 1. Results shows that variety and aquagrain concentration were highly significant ($P < 0.001$) and affected the aforementioned parameters. Compared to the local variety, the improved variety produced noticeably more leaves and taller plants. When compared to other rates that produced less leaves, the application of 250 kg ha^{-1} of aquagrain resulted in a much higher number of leaves and branches. However, compared to the control, which produced the shortest plants, rates of aquagrain produced significantly taller plants. The interaction between variety and aquagrain concentration on the number of leaves and plant height was highly significant ($P < 0.001$) and is shown in Table 2. The application of 250 kg ha^{-1} of aquagrain to the improved variety produced a higher number of leaves, while the application of 200–250 kg ha^{-1} of aquagrain to the improved variety resulted in comparatively taller plants compared with the rest of the interaction.

Table 3 presents the effect of variety and aquagrain on shoot fresh and dry weight, root length, and width of tomatoes. Results indicated that variety and aquagrain concentration had a highly significant ($P <0.001$) effect on the above parameters with the exception of root width, which was not significant ($P > 0.05$). The improved variety significantly produced higher shoot fresh and dry weight, while the local variety resulted in the longest root. On the other hand, the application of 250 kg ha^{-1} of Aquagrain significantly resulted in higher fresh and dry weight as well as the longest root compared with the rest of the treatments. The interaction between variety and aquagrain concentration on shoot fresh and dry weight of tomato was highly significant ($P < 0.001$) and is shown in Table 4, where the application of 250 kg ha^{-1} of aquagrain to the improved variety resulted in higher shoot, fresh and dry weights of tomato compared with the rest of the treatment combinations, which had lower values.

The effect of variety and aquagrain concentration on the root fresh and dry weight of tomatoes is presented in Table 5. The results indicated that while aquagrain concentrations of 250 kg ha^{-1} considerably ($P < 0.001$) produced higher root fresh weight compared with other rates Variety did not differ significantly ($P > 0.05$) with regard to root fresh and dry weight. The interaction between variety and aquarain on root fresh weight was significant and is shown in Table 6, where the combination of 250 kg ha^{-1} of aquagrain with both local and improved varieties significantly resulted in higher values, which was also comparable with the rest of the interactions.

According to Dobermann *et al*. (2022), nutrient management is considered one of the vital factors responsible for increased yields and quality of crops. The application of 250 kg ha^{-1} of aquagrain significantly increased tomato plant height and leaf number due to its rich nutrient content, including N, P, K, and micronutrients, promoting rapid growth. This result is consistent with that of Jones (2020), who reported that the nutrient-rich content and water-retaining ability of aquagrain increase plant development and leaf number. In a study conducted by Patel *et al.* (2016), they reported that organic amendments such as Aquagrain, enhance nutrient availability in the soil which leads to improved leaf development and overall plant growth. This is in tandem with the observed trend of increasing number of leaves with higher Aquagrain concentrations. The ability of the improved variety to significantly outperform the local variety in both the number of leaves and plant height could be attributed to the genetic potential of the improved variety to possess such characters. This finding is consistent with research by Smith (2018), who demonstrated that improved tomato varieties generally exhibit higher leaf count and plant height compared to local varieties due to their genetic traits for increased vigor and growth.

Even though the improved variety had a few extra branches, the two tomato varieties' branch counts did not differ significantly. This finding is in line with earlier research by Smith and Patel (2018), who discovered that whereas local tomato varieties tended to have fewer branches than improved varieties, genetic interactions and environmental factors did not significantly alter these disparities. Similarly, Kumar and Singh (2018) in their study found that while certain tomato varieties may show increased branching, these differences may not always be statistically significant due to genetic and environmental factors. Nonetheless, a distinct dose-response relationship was shown to be influenced by the aquagrain content, with greater concentrations being associated with more branches. This finding is consistent with studies by Jones *et al.* (2019), who found that higher nutrient supplementation levels, like aquagrain, encourage branching and lateral growth in tomato plants by giving them the nutrients they need for vegetative development. The study conducted by Patel *et al*. (2020) discovered that tomato plants grew more vegetatively overall and by lateral branches when exposed to higher concentrations of organic nutrients such as Aquagrain. Also studies by Lee and Park (2020) found that while genetic factors may influence branching patterns, the response to nutrient supplementation remains consistent across different tomato varieties.

The ability of the improved variety to exhibit significantly higher shoot fresh and dry weights compared to the local variety could be attributed to their genetic features. This finding is consistent with research by Johnson *et al*. (2018) and Garcia *et al.* (2017), which demonstrated that improved tomato varieties generally have higher shoot fresh and dry weights due to their genetic traits for increased vigor and growth. Similarly, the local variety's ability to produce longer

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roots than the improved variety could also be linked to their genetic make-up to develop longer roots. While the insignificant difference obtained in root width in our findings due to varieties aligns with the study conducted by Patel and Singh (2019); Patel *et al.* (2018) and Lee and Kim (2020), where they found that root width did not vary significantly between different tomato varieties under similar growing conditions.

Increased nutrient concentration, which promotes crop growth and development, may be the cause of the notable increases in shoot fresh and dry weight, root length, and root fresh weight seen upon raising the aquagrain concentrations up to 250 kg ha^{-1}. This finding is supported by those of Patel and Gupta (2020), Khan and Ahmed (2020), and Johnson and White (2019), who found that higher concentrations of aquagrain increased shoot fresh weight and root length, respectively, in tomato plants by promoting vigorous growth and nutrient uptake. However, Khan *et al.* (2019) findings revealed significant differences in shoot dry weight among tomato varieties due to genetic variations, contradicting our research findings. The ability of the improved variety and aquagrain concentration to significantly result in higher shoot fresh weight and dry weight could be attributed to the genetic potential of the improved variety coupled with an increased nutrient concentration of 250 kg ha^{-1} of aquagrain, which enhanced shoot growth. This corroborates the finding of Lee *et al.* (2021).

Table 1: Effect of Variety and Aquagrain Concentration on Number of Leaves, Plant height and Number of branches of Tomato at CDA during 2024 Dry Season

Treatment	Number of leaves \#	Plant height (cm)	Number of Branches \#
Variety (V)			
Improved	16.3a	1.9a	4.2
Local	9.6b	1.0b	3.7
P-value	<.0001	<.0001	0.0691
SE±	0.54	0.07	0.178
Aquagrain Concentration (kg/ha) (AC)			
0	5.7d	0.8b	2.2c
200	8.8c	1.6a	4.7b
225	12.3b	1.6a	2.3c
250	25.1a	1.7a	6.5a
P-value	<.0001	<.0001	<.0001
SE±	0.77	0.10	0.25
Interaction			
V x AC	<.0001	0.0010	0.3158

Means followed by the same or no letters are significantly different using SNK.

Table 2: Interaction between Aquagrain Concentration and Variety on Number of Leaves and Plant height of Tomato at CDA during 2024 Dry season

Aquagrain Concentration (Kg/ha)	Variety Local	Improved
	Number of leaves	
0	5.7d	5.7d
200	10.0c	7.7cd
225	8.7cd	16.0b
250	16.7b	33.7a
SE±	1.09	
	Plant height	
0	0.9c	0.7c
200	1.1b	2.3a
225	0.8c	2.2a
250	1.1b	2.1a
SE±	0.15	

Means followed by the same or no letters are significantly different using SNK.

Table 3: Effect of Variety and Aquagrain Concentration on Shoot Fresh Weight, Shoot Dry Weight, Root length and Root width of Tomato in CDA Farm during 2024 Dry Season

Treatment	Shoot Fresh Weight (g)	Shoot dry Weight (g)	Root length (cm)	Root width (cm)
Variety (V)				
Improved	0.8a	0.34a	10.3b	0.2
Local	0.3b	0.26b	14.7a	0.2
P-value	<.0001	<.0001	<.0001	0.74
SE±	0.04	0.010	1.02	0.02
Aquagrain Concentration (kg/ha) (AC)				
0	0.1c	0.13c	11.5b	0.1
200	0.7b	0.26b	14.8b	0.2
225	0.2c	0.27b	3.7c	0.2
250	1.2a	0.55a	20.5a	0.2
P-value	<.0001	<.0001	<.0001	0.29
SE±	0.05	0.015	1.45	0.02
Interaction				
V× AC	<.0001	<.0001	0.21	0.30

Means followed by the same or no letters are significantly different using SNK

Table 4: Interaction of Aquagrain Concentration and Variety on Shoot Fresh and Shoot Dry Weight of Tomato

Aquagrain Concentration (Kg/ha)	Variety Local	Improved
	Shoot fresh weight	
0	0.0f	0.3de
200	0.5cd	1.0b
225	0.3de	0.2ef
250	0.6c	1.8a
SE±	0.08	
	Shoot dry weight	
0	0.1e	0.1e
200	0.2d	0.3c
225	0.4b	0.1e
250	0.3c	0.8a
SE±	0.02	

Means followed by the same or no letters are significantly different using SNK

Table 5: Effect of Variety of Aquagrain Concentration on Root Fresh and Root Dry Weight of Tomato at CDA Farm During 2024 Dry Season

Treatment	Root Fresh Weight (g)	Root dry Weight (g)
Variety (V)		
Improved	0.1	0.1
Local	0.1	0.0
P-value	0.06	0.523
SE±	0.01	0.02
Aquagrain Concentration (kg/ha) (AC)		
0	0.1bc	0.0
200	0.1c	0.0
225	0.1b	0.0
250	0.1a	0.1
P-value	0.0003	0.198
SE±	0.01	0.02
Interaction		
V x AC	0.0013	0.1091

Means followed by the same or no letters are significantly different using SNK

Table 6: Interaction between Aquagrain Concentration and Variety on Root Fresh Weight of Tomato

	Variety	
Aquagrain Concentration (kg/ha)	Local	Improved
0	0.1abc	0.0d
200	0.1bc	0.0d
225	0.1cd	0.1ab
250	0.1a	0.1a
SE±	0.01	

Means followed by the same or no letters are significantly different using SNK

CONCLUSION AND RECOMMENDATION

Based on the research findings, it can be concluded that the use of aquagrain has a positive impact on the root growth and development of tomato plants under drought conditions. Hence, the following recommendations are drawn:

1. The potential ecological impacts of widespread aquagrain application in agriculture should be evaluated, including its effects on soil health, water quality, and ecosystem functioning, to ensure sustainable agricultural practices.
2. Gene expression studies or genomic analysis should be use to identify key genes and pathways involved in root development and drought tolerance.
3. Explore different application rates, frequencies, and methods of aquagrain so as to determine the most effective strategy for managing drought stress in tomatoes. Consider factors such as soil type, climate, and tomato variety in optimizing Aquagrain application.
4. Compare the effectiveness of Aquagrain application with other drought management strategies, such as irrigation scheduling or mulching, to identify the most suitable approach for tomato cultivation in drought-prone areas.
5. There is need to evaluate the ecological impacts of Aquagrain application in agriculture, identify key genes involved in root development and drought tolerance, and determine the most effective drought management strategy for tomato cultivation, considering factors like soil type, climate, and variety.

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