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Research article

Assessment of Drought Tolerance of Tomato Varieties under Different Levels of Irrigation

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Abstract
The study assessed the drought tolerance between two varieties of tomato (F1 Mona and F1 Nala) under water stress conditions using different levels of irrigation. Pot experiment was carried out during dry season at Centre for Dryland Agriculture (CDA) Faculty of Agriculture, Bayero University Kano, within the Sudan savannah zone of northern Nigeria. The tomato varieties were subjected to three different levels of irrigation, viz watering after 2 ,4 and 6 days respectively. The experiment was arranged in Complete Randomised Design with three replications. Data was collected on growth parameters (plant height, number of leaves, number of branches and stem girth) and analyzed using GenStat statistical software and significant treatment means were separated using Student-Newman-Keuls test (SNK) at 5% probability level. The results revealed drastic reduction in the growth parameter (plant height, number of leaves, number of branches and stem girth) among all the varieties as the days to irrigation increases. Reduction was more pronounced in F1 Mona variety than F1 Nala which indicates that the latter variety is more tolerant to drought stress than the former variety which appeared to be more susceptible to water stress.

Keywords:: Drought, Tolerance, Tomato, Varieties, Irrigation

Introduction

Tomato (*Solanum lycopersicum L.*) is one of the most important vegetable crops in the world, second only to potato (FAO, 2021a). The estimated total World production for tomatoes in 2022 was 186,107,972 metric tonnes, a decrease of 1.7% from 189,281,485 tonnes in 2021. China was by far the largest producer accounting for nearly 37% of global production (Anonymous, 2024). It is well documented that tomato plays a critical role in meeting domestic nutritional food requirements, generation of income, foreign exchange earnings and creation of employment (Geoffrey, 2014) in Africa and globally. Tomato is one of the most popular and widely grown vegetables in the world. The first reason for this is that tomatoes are beneficial to our heath and are good sources of provitamins, β carotene, and vitamin C. The second reason is that tomatoes are particularly rich sources of lycopene, which is a very powerful antioxidant and helps prevent the development of many forms of cancer (Evgenidis *et al*., 2011). Daily consumption of tomato products may provide a superb combination of healthy substances such as minerals, vitamins, flavonoids, and antioxidant compounds like lycopene, beta-carotene, and lutein (Ahamed *et al*., 2022). Tomato is particularly susceptible to water shortage because prolonged water deficit limits growth and yield of the harvest. Both vegetative and reproductive stages of tomato cultivars can be severely affected by drought, which inhibits seed development, reduces stem and fruit growth (Farooq *et al*., 2005). Photosynthesis also reduces due to the dropping of CO_2 in crops grown under drought stress.

Water deficit is one of the major challenges of the 21st century, and agriculture is both the cause and the victim. About 70% of global available water is used for agricultural practices (FAO, 2021a). Water is fundamental for the life of plants in all the physiological processes (Farooq *et al*., 2009) while drought triggers a multitude of different responses affecting morphological and molecular traits in each phenological phase of plant growth (Wang *et al*., 2020).

Drought also affects mitosis and consequently plant development reducing both cell number and expansion (Anjum *et al*., 2005). These events lead to a reduction in plant growth and yield thereby lowering the revenues of the crop. At present, drought is a major threat to sustainable food production which reduces the crop yields up to 70 percent (Xu *et al*., 2023). Hence, of all the abiotic stresses, drought is considered as the supreme destructive (Gosal *et al*., 2009). Increasing aridity of semi-arid regions together with limited water resources has led to an exigent necessity for improving crop drought resistances (Passioura, 2007).

Drought stress significantly affect photosynthesis, and restricts the normal function of metabolic pathways, such as nitrogen fixation (Chaves *et al*., 2009). Drought is by far the leading environmental stress in agriculture that limits the global productivity of major crops by directly reducing plant potential yield (Mishra *et al*., 2021), but indirectly influence crop interactions with biotic factors.

Addressing drought in agricultural practices is crucial for ensuring the sustainability and resilience of our food systems. This requires implementing various strategies, such as adopting drought-tolerant crop varieties, improving water management practices, and developing innovative irrigation technologies (FAO, 2021b).

The challenge of ensuring food security in the face of increasing water scarcity necessitates a detailed exploration of crop responses to drought stress. Assessing drought tolerance in two tomato varieties through varying irrigation levels seeks to investigate the impact of water scarcity on growth, and physiological parameters. The justification for assessing drought tolerance between two tomato varieties under varied irrigation levels lies from the urgent need to address global water scarcity and its impact on agriculture. As climate change intensifies, understanding how specific tomato cultivars respond to water stress becomes vital for sustainable food production. Hence, the study was aimed to contribute to the scientific knowledge of crop resilience in order to guide the farmers in selecting drought-tolerant tomato varieties that adapt favourably in the study area.

Materials and Methods

The experiment was carried out during dry season at Centre for Dryland Agriculture (CDA), Bayero University Kano, within the Sudan savannah zone of northern Nigeria. The treatment consisted of two varieties of tomato (F1 NALA and F1 MONA) which were subjected to three different levels of irrigation; watering after 2, 4 and 6 days respectively with three replications. The two tomato varieties (F1 NALA and F1 MONA were examined at 4, 6, and 8 weeks after transplanting [WAT]).The experimental design was Complete Randomized Design (CRD). Nursery establishment was carried out using 4 buckets measuring 0.5m in height were filled with top soil were used as nursery pots in which the seedlings were raised. The buckets were watered for three days before sowing the seeds in order to support the germination of seeds.

Sowing

The seed of the two tomato varieties were broadcasted inside two pots each and were lightly covered with sand. The beds were watered before and after sowing, and watering continued after germination. Weeds were removed by hand pulling to prevent competition with crops for nutrients, light and space. Eighteen (18) pots were filled as main pots with soil for the two varieties subjected to three levels of irrigations using watering can for three days before transplanting. Transplanting was done 5 weeks after sowing and seedlings were transplanted at three stands per pot. The seedlings were subjected to water stress by watering after 2, 4 and 6 days at 2 weeks after transplanting. The study was conduced for a period of two months for the two varieties covering nursery and pot practices.

Data Collection and Analysis

Data were collected on plant height, number of leaves, number of branches and stem girth. The data collected from the research was subjected to analysis of variance (ANOVA), using the GenStat package and significant treatment means were separated using Student-Newman-Keuls (SNK) test at 5% probability level.

Results

Plant Height (cm)

The result in Table 1 exhibited a drop in plant height over time in both F1 NALA and F1 MONA across different weeks and irrigation levels. Significant differences in plant height was observed at all time points ($P < 0.05$), with F1 NALA consistently taller than F1 MONA.

Concerning irrigation levels, plant height significantly decreased with increasing duration of drought stress (P < 0.001). Notably, plant height was highest after 2 days of drought stress and declined progressively over subsequent time points. The interaction between varieties and irrigation levels did not have a significant effect on plant height (P > 0.05), suggesting a consistent response to drought stress.

Table 1. Assessment of Tomato Varieties Drought Tolerance on Plant Height (cm)

Treatment	4WAT	6WAT	8WAT
Varieties			
F1 NALA	16.19	13.67	11.22
F1 MONA	13.89	10.44	8.22
SE	0.781	1.132	1.005
P-value	0.015	0.018	0.014
Irrigation Level			
After 2 Days	20.5c	18.33b	15.5b
After 4 Days	14.08b	10.33a	8.25a
After 6 Days	10.53a	7.50a	5.42a
SE	0.956	1.392	1.231
P-value	<.001	<.001	<.001
Interaction			
V x I	0.254	0.407	0.799

Mean in the same column, having the same letters are do not have significant difference at p=0.05 using student Newman Keuls test.

Number of Leaves

The result of evaluation on tomato drought tolerance based on the number of leaves across different weeks and irrigation levels is presented in Table 2. Both F1 NALA and F1 MONA exhibited a decrease in the number of leaves over time suggesting reduced drought tolerance. However there were significant differences between the varieties at 4WAT (P = 0.006), with F1 NALA having fewer leaves compared to F1 MONA. At later time points, these differences were not significant (P > 0.05).

Regarding irrigation levels, the number of leaves decreased significantly with increasing duration of drought stress (P < 0.001). Specifically, the number of leaves was highest after 2 days of drought stress and declined progressively thereafter. The interaction between varieties and irrigation levels did not have a significant effect on the number of leaves (P > 0.05).

Table 2. Assessment of Tomato Varieties Drought Tolerance on Number of Leaves per Plant

Treatment	4WAT	6WAT	8WAT
Varieties			
F1 NALA	25.22	19.44	17.22
F1 MONA	29.11	22.56	12.56
SE	1.129	1.832	1.519
P-value	0.006	0.12	0.831
Irrigation Level			
After 2 Days	37.10c	32.67b	27.33b
After 4 Days	26.83b	17.01a	14.13a
After 6 Days	17.67a	13.33a	10.83a
SE	1.382	2.244	1.861
P-value	<.001	<.001	<.001
Interaction			
V x I	0.18	0.903	0.744

Mean in the same column, having the same letters are do not have significant difference at p=0.05 using student Newman Keuls test.

Number of Branches per Plant

The two varieties exhibited a decrease in the number of branches over time, indicating reduced drought tolerance (Table 3). However, there were no significant differences between the varieties at any time point (P > 0.05). In terms of irrigation levels, the number of branches significantly decreased as the duration of drought stress increased (P < 0.05). Specifically, the number of branches was highest after 2 days of drought stress and declined progressively over subsequent time points. The interaction between varieties and irrigation levels had no significant effect on the number of branches (P > 0.05).

Table 3. Assessment of Tomato Varieties Drought Tolerance on Number of Branches per Plant

Treatment	4WAT	6WAT	8WAT
Varieties			
F1 NALA	5.89	5.22	4.44
F1 MONA	5.67	4.56	3.78
SE	0.351	0.372	0.268
P-value	0.541	0.103	0.032
Irrigation Level			
After 2 Days	6.67b	6.**43**b	4.83b
After 4 Days	5.**2**5a	4.67a	4.17b
After 6 Days	5.17a	4.**53**a	3.33a
SE	0.48	0.455	0.328
P-value	0.014	0.004	0.003
Interaction			
V x I	0.09	0.379	0.066

Mean in the same column, having the same letters are do not have significant difference at p=0.05 using student Newman Keuls test.

Stem Girth (mm)

Both F1 NALA and F1 MONA showed fluctuations in stem girth over time (Table 4), with significant differences observed at 4WAT (P = 0.002). Specifically, F1 MONA had a larger stem girth compared to F1 NALA at this time point. However, these differences were not significant at later time points (P > 0.05). The stem girth significantly varied across different durations of drought stress (P < 0.05) where it was found to be higher after 2 days of drought stress and decreased gradually over subsequent time points. The interaction between varieties and irrigation levels was not significant effect on stem girth (P > 0.05), indicating a consistent response to drought stress by the tomato varieties tested.

Table 4. Assessment of Tomato Varieties Drought Tolerance on Stem Girth (mm)

Treatment	4WAT	6WAT	8WAT
Varieties			
F1 NALA	3.18	4.64	2.80
F1 MONA	4.33	3.64	3.31
SE	0.279	1.05	0.511
P-value	0.002	0.368	0.338
Irrigation Level			
After 2 Days	4.62b	6.58b	3.97a
After 4 Days	3.67a	3.15a	2.59a
After 6 Days	2.97a	2.69a	2.61a
SE	0.342	1.286	0.626
P-value	0.002	0.025	0.085
Interaction			
V x I	0.183	0.171	0.439

Mean in the same column, having the same letters are do not have significant difference at p=0.05 using student Newman Keuls test.

Discussion

Drought poses a significant threat to global food security by impacting crop production and agricultural livelihoods (FAO, 2021a). Its effects can be far-reaching, causing decreased soil moisture, reduced water availability for irrigation, and increased plant stress, ultimately leading to significant yield losses (Drought, 2024).

Among various crops, tomatoes are particularly susceptible to drought stress due to their shallow root systems and high-water requirements (Wang *et al*., 2020). The assessment of tomato drought tolerance across various growth parameters reveals significant understandings into the response of two tomato varieties, F1 NALA and F1 MONA, to drought stress at different stages of growth. Both varieties displayed a consistent trend of decreasing performance in terms of number of leaves, number of branches, stem girth, and plant height as the duration of drought stress increased. This decline in growth parameters highlights the negative impact of drought stress on tomato plants and highlights the importance of effective irrigation management to mitigate these effects.

The ability of tomato varieties to tolerate drought is influenced by genetic factors. Research has identified several genes associated with drought tolerance, such as those regulating stomatal closure, osmo-protectant synthesis, and antioxidant defense mechanisms (Xu *et al*., 2023). The response of tomato plants to drought stress varied depending on the duration of stress, with the most significant reductions in growth parameters observed after longer periods of drought. This highlights the progressive nature of drought stress and the importance of timely irrigation interventions to mitigate its adverse effects on plant growth and productivity.

Notably, F1 NALA generally displayed greater growth characteristics in terms of plant height and number of branches (by about 15%) compared to F1 MONA while the latter was higher than the former in terms of number of leaves and stem girth (by about 12%) across all irrigation levels and time intervals. The reduction in growth parameters as the stress continues was more pronounced in F1 MONA than F1 NALA, thereby making latter more tolerant to drought than the former.

Similarly, the number of leaves, stem girth and number of branches showed decreasing trends over time as the stress continued for both varieties, which was similar to the earlier findings of Breda *et al*. (2006) and later McDowell *et al.* (2011) which stated that; water stress is problematic for plant growth and development as it limits access to the resources required for photosynthesis to take place due to stomatal closure and the reduction of internal water transport. Irrigation plays a critical role in mitigating the negative impacts of drought on agricultural production, including tomato cultivation (Smith *et al*., 2020). By providing supplemental water, irrigation helps to maintain soil moisture levels, ensuring a reliable source of water for plant growth and development. Adequate water availability counteracts physiological stress responses in plants, allowing them to maintain photosynthesis, growth, and fruit production (Jones, 2022). For mitigating drought stress, irrigation can contribute to increased tomato yields in terms of quantity and quality (Li *et al*., 2018), and enhance water use efficiency. Using modern irrigation techniques, like drip irrigation, can deliver water directly to the root zone, thereby minimizing water loss through evaporation and maximizing its use by the plants (FAO, 2021b).

Conclusion

The empirical insights gleaned from this study furnish a nuanced understanding of the complex interplay between genotype and environmental stressors, notably drought, in shaping the growth dynamics of tomato varieties. Evident varietal disparities in response to varying irrigation regimens underscore the imperative for cultivar-specific management protocols to harness innate resilience and bolster productivity under adverse climatic conditions. Noteworthy, reductions in pivotal growth parameters (plant height and stem girth) underscore the profound impact of prolonged water deficit on morphological attributes, necessitating proactive interventions to mitigate yield losses and ensure agronomic sustainability. Furthermore, the discernment of F1 NALA's heightened tolerance elucidates promising avenues for the development of drought-resilient cultivars through targeted breeding initiatives. Hence, the findings of this study revealed the significant role of precision irrigation technologies and sustainable agronomic practices in optimizing resource utilization and ensuring crop resilience in water-scarce agroecosystems.

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