ISSN: 2643-671X

Research Article

Journal of Agriculture and Horticulture Research

Growth, Physiological, Biochemical and Yield Responses of Three Maize Varieties to Water Stress and Photoperiod in Dutse, Jigawa State, Nigeria

Doma Bulus Abdullahi*, Aisha Wada Abubakar and Ibrahim Isa Dangora

Department of Plant Biology, Federal University Dutse, Dutse Jigawa State, Nigeria

***Corresponding Author**
Doma Bulus Abdullahi, Department of Plant Biology, Federal University Dutse, Dutse Jigawa State, Nigeria.

Submitted: 2026, Jul 20 **Accepted:** 2026, Aug 18; **Published:** 2026, Aug 28

Citation: Abdullahi, D. B., Abubakar, A. W., Dangora, I. I. (2026). Growth, Physiological, Biochemical and Yield Responses of Three Maize Varieties to Water Stress and Photoperiod in Dutse, Jigawa State, Nigeria. *J Agri Horti Res, 9*(3). 01-04.

Abstract
This study assessed the effects of watering regime and shading, individually and in combination, on the growth, physiological, biochemical and yield responses of three maize varieties SAMMAZ 51, SAMMAZ 27 and the local landrace Yar-tsiri in Dutse, Jigawa State, Nigeria. A 3 × 3 × 3 factorial experiment was laid out in a Completely Randomized Design with three replications, combining three watering regimes (daily, every 3 days, every 6 days) with three shading levels (0%, 50%, 90%). Data were analysed using ANOVA and means separated using LSD at $p < 0.05$. Variety, watering regime and shading, together with their interactions, significantly affected nearly all parameters measured. At 10 weeks after sowing, extending the watering interval from daily to every 6 days reduced plant height from 155.1 to 82.3 cm and grain yield from 22.8 to 10.9 g per stand, while proline, superoxide dismutase and malondialdehyde content all increased, indicating stronger osmotic and antioxidant responses alongside greater membrane damage. Shading had a smaller but still significant effect. SAMMAZ 51 consistently outperformed the other two varieties across all growth, physiological and yield parameters, despite Yar-tsiri mounting the largest biochemical stress response. Water availability was the principal constraint on maize performance in this environment, and SAMMAZ 51 is recommended for cultivation in similarly drought-prone, semi-arid areas of northern Nigeria.

Keywords: Water Stress, Shading, Varietal Tolerance, Oxidative Stress, Grain Yield

1. Introduction

Maize (Zea mays L.) is a major cereal crop underpinning food security across sub-Saharan Africa, and Nigeria is one of the leading producers on the continent [1]. In the semi-arid Sudan Savanna of northern Nigeria, maize productivity is constrained by two recurring abiotic stresses acting together: erratic and often insufficient rainfall, and periods of reduced light availability associated with cloud cover, intercropping, or agroforestry shading [2]. Water stress reduces plant growth, leaf area and photosynthetic capacity at every growth stage, ultimately lowering biomass and grain yield, while reduced light availability limits carbon assimilation and can compound the effects of moisture deficit [3,4].

Most existing studies have examined drought or shading stress separately, even though maize in farmers' fields frequently experiences both simultaneously, and their combined effect on physiological and biochemical stress responses is not well characterised for the maize varieties grown in Jigawa State. Improved, stress-tolerant hybrids such as SAMMAZ 51 and SAMMAZ 27 have been promoted as more resilient alternatives to local landraces such as Yar-tsiri, but the physiological and biochemical basis of this resilience under combined water and light stress has received limited attention in this agro-ecology [5]. This study therefore evaluated the effects of watering regime and shading, individually and in combination, on the growth, physiological, biochemical and yield responses of three maize varieties in Dutse, Jigawa State. It was hypothesised that improved varieties would maintain better physiological function and yield under combined stress than the local landrace, through stronger osmotic adjustment and antioxidant defence.

2. Methodology / Materials and Methods

The experiment was conducted in Dutse, Jigawa State, Nigeria, in the Sudan Savanna agro-ecological zone. The experimental soil was sandy loam, moderately acidic (pH 5.93), non-saline (electrical conductivity 2.10 dS m^{-1}), and low in organic carbon, total nitrogen, available phosphorus and cation exchange capacity. The experiment was laid out as a 3 × 3 × 3 factorial in a Completely Randomized Design with three replications, giving 81 experimental units. The three factors were: (i) maize variety :SAMMAZ 51, SAMMAZ 27 (improved varieties) and Yar-tsiri (local landrace); (ii) watering regime: daily watering (W1), watering every 3 days (W2), and watering every 6 days (W3), with the same volume of water (3 L) applied at each watering event; and (iii) shading level: no shade (S1, control), 50% shade net (S2), and 90% shade net (S3), applied continuously from two weeks after planting.

Growth parameters (plant height, number of leaves, leaf area) were measured at 2, 4, 6, 8 and 10 weeks after sowing (WAS). Chlorophyll content was determined non-destructively using a SPAD chlorophyll meter. Photosynthetic rate was measured using a portable photosynthesis system (LI-6400XT, LI-COR Biosciences, Lincoln, NE, USA), and stomatal conductance and transpiration rate were recorded concurrently using a leaf porometer, all at the same intervals. Biochemical parameters: proline, superoxide dismutase (SOD), catalase (CAT), peroxidase (POD) and malondialdehyde (MDA) — were determined from leaf tissue sampled at the same intervals using standard spectrophotometric assays. At harvest, cob number per stand, cob length, cob diameter, 100-grain weight and grain yield per stand were recorded. This study did not involve human participants or animal subjects, so formal ethics committee approval was not required.

2.1. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) appropriate for a three-factor Completely Randomized Design using IBM SPSS Statistics. Treatment means were separated using the Least Significant Difference (LSD) test at $p < 0.05$.

3. Results / Findings

Variety, watering regime and shading, together with their two- and three-way interactions, significantly affected nearly all growth, physiological, biochemical and yield parameters measured ($p < 0.05$). Table 1 summarises plant height and grain yield responses to variety and watering regime at 10 weeks after sowing, and Table 2 summarises the physiological and biochemical responses to watering regime at the same stage.

Watering regime was the dominant factor limiting growth and yield. Extending the watering interval from daily to every 6 days reduced plant height by 47%, leaf area by 65%, and photosynthetic rate by 38%, while grain yield fell from 22.8 to 10.9 g per stand (Table 1, Table 2). Shading had a comparatively smaller effect on growth than watering regime, though yield still declined from 18.1 g per stand under no shade to 14.3 g under 90% shade. Among varieties, SAMMAZ 51 consistently outperformed SAMMAZ 27 and Yar-tsiri across all growth, physiological and yield parameters, while Yar-tsiri recorded the highest proline, SOD and MDA accumulation of the three varieties despite having the lowest yield under stress.

Treatment	Plant height (cm)	Grain yield (g/stand)
Variety		
SAMMAZ 51	146.7a	20.4a
SAMMAZ 27	123.0b	15.0b
Yar-tsiri	80.9c	11.7c
Watering regime		
Daily	155.1a	22.8a
Every 3 days	113.2b	14.7b
Every 6 days	82.3c	10.9c
LSD ($p < 0.05$): variety = 1.21 (height), 0.28 (yield); watering regime = 8.07 (height), 3.47 (yield). Means within a column and treatment group followed by the same letter are not significantly different.		

Table 1: Effect of variety and watering regime on plant height (cm) and grain yield (g per stand) of maize at 10 weeks after sowing

Watering regime	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})	Proline (µmol g^{-1} FW)	SOD (U mg^{-1} protein)	MDA (nmol g^{-1} FW)
Daily	32.7a	19.2c	59.3c	19.2c
Every 3 days	26.2b	36.1b	112.1b	37.8b
Every 6 days	20.2c	46.9a	141.5a	59.5a

LSD ($p < 0.05$): photosynthetic rate = 1.87; proline = 1.01; SOD = 3.75; MDA = 1.51. Means within a column followed by the same letter are not significantly different.

Table 2: Effect of watering regime on photosynthetic rate, proline, superoxide dismutase (SOD) and malondialdehyde (MDA) content of maize at 10 weeks after sowing

4. Discussion

The pronounced sensitivity of maize growth and yield to watering regime observed here is consistent with reports that water deficit suppresses cell division and expansion, reduces photosynthetic efficiency, and limits assimilate availability for reproductive development Kim [2,6]. The reduction in stomatal conductance under water stress, alongside declining photosynthetic rate, reflects the classic trade-off in which plants restrict water loss at the cost of reduced carbon gain. The rise in proline, SOD, CAT and POD activity with increasing water stress indicates active osmotic adjustment and antioxidant defence against drought-induced oxidative stress, while the concurrent rise in MDA content shows that these defences did not fully prevent membrane lipid peroxidation, particularly under the most severe stress [7,8]. Yar-tsiri's higher proline and SOD accumulation relative to the improved varieties should not be read as evidence of superior stress tolerance; rather, it more likely reflects that this landrace was under greater physiological strain and was mounting a stronger, but ultimately less effective, biochemical response, since its growth and yield were nonetheless the most severely depressed of the three varieties [7].

SAMMAZ 51's consistently superior height, leaf area, chlorophyll content, photosynthetic rate and yield across all stress combinations point to a stronger underlying capacity to sustain physiological function under combined water and light stress, consistent with the greater stress adaptability reported for modern maize hybrids relative to unimproved landraces in the Nigerian savanna [9,10]. Shading's comparatively modest main effect, relative to watering regime, suggests that under the moisture-limited conditions typical of Jigawa State, water availability is the more critical constraint to manage agronomically than light interception alone [4]. A limitation of this study is that it was conducted under controlled shade-net conditions over a single growing season; multi-season field trials would help confirm whether these varietal differences hold under the fuller range of variability found in farmers' fields.

5. Conclusion

Water stress was the principal factor limiting maize growth, physiology and yield in this study, with shading exerting a comparatively smaller, though still significant, effect. SAMMAZ 51 demonstrated the greatest resilience across combined water and light stress, sustaining better growth, physiological function and yield than SAMMAZ 27 and the local landrace, Yar-tsiri. This resilience was associated with stronger physiological performance rather than simply greater biochemical stress-response activity, as the landrace mounted the largest osmotic and antioxidant response yet suffered the greatest yield loss. These findings support the recommendation of SAMMAZ 51 for cultivation in similarly drought-prone, semi-arid parts of northern Nigeria, and highlight the value of managing water availability as a priority over light interception in such environments.

Declarations

Funding

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

This study did not involve human participants or animal subjects; formal ethics committee approval was therefore not required.

Author Contributions

Conceptualization: [Initials]. Methodology: [Initials]. Data collection: [Initials]. Formal analysis: [Initials]. Writing – original draft: [Initials]. Writing – review and editing: [Initials]. All authors read and approved the final manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI Usage Statement

Generative AI (Claude, Anthropic) was used to assist with language editing, formatting, and manuscript structuring based on the authors' original data, analysis, and interpretation. All scientific content, data, and conclusions are the authors' own and were reviewed and approved by me the author.

References

1. Onumah, E. E., Ehiakpor, D. S., & Danso-Abbeam, G. (2023). Maize production and food security in West Africa. African Journal of Agricultural Research, 19(6), 543–555.
2. Laskari, M., Menexes, G., Kalfas, I., Gatzolis, I., & Dordas, C. (2022). Water stress effects on the morphological, physiological characteristics of maize (Zea mays L.), and on environmental cost. *Agronomy, 12*(10), 2386.
3. Anjum, S. A., Ashraf, U., Tanveer, M., Khan, I., Hussain, S., Shahzad, B., Zohaib, A., Abbas, F., Saleem, M. F., Ali, I., & Wang, L. C. (2017). Drought induced changes in growth, osmolyte accumulation and antioxidant metabolism of three maize hybrids. Frontiers in Plant Science, 8, Article 69.
4. Zhang, Y., Liu, M., Wang, X., & Zhao, J. (2025). Low light stress and its interaction with drought in maize: A physiological perspective. Plant, Cell & Environment, 48(3), 812–828.
5. Kamara, A. Y., Kamai, N., Omoigui, L. O., Togola, A., Ekeleme, F., & Onyibe, J. E. (2020). Guide to maize production

in Northern Nigeria.
6. Kim, K. H., Lee, B. M., & Kim, S. J. (2023). Drought stress at reproductive stages and grain yield losses in maize. Plants, 12(9), Article 1789.
7. Souza, G., Yao, Y., & Zhang, X. (2019). Photosynthetic efficiency and drought tolerance in maize: Lessons from Brazil. Photosynthesis Research.
8. Hasanuzzaman, M., Bhuyan, M. H. M. B., Zulfiqar, F., Raza, A., Mohsin, S. M., Mahmud, J. A., Fujita, M., & Fotopoulos, V. (2020). Reactive oxygen species and antioxidant defense in plants under abiotic stress: Revisiting the crucial role of a universal defense regulator. Antioxidants, 9(8), Article 681.
9. Kamara, A. Y., Menkir, A., Abubakar, A. W., Tofa, A. I., Ademulegun, T. D., Omoigui, L. O., & Kamai, N. (2020b). Maize hybrids response to high plant density in the Guinea savannah of Nigeria. Journal of Crop Improvement, 35(1), 1–20.
10. Abubakar, A. W., Manga, A. A., Kamara, A. Y., & Tofa, A. I. (2019). Physiological evaluations of maize hybrids under low nitrogen. Advances in Agriculture, 2019, Article 2624707.