GROWTH AND YIELD PERFORMANCE OF CORN UNDER DIFFERENT LIGHT AND WATER STRESS CONDITIONS

Sartati[1)]

[1)] Agricultural Product Technology, Faculty of Agriculture, Universitas Sulawesi Tenggara, Kendari, Indonesia
Email: Sartatii0@gmail.com

Abstract
Corn (Zea mays L.) productivity is highly influenced by environmental factors, particularly light intensity and water availability. This study aimed to investigate the effects of different light and water stress conditions on the growth, physiological traits, and yield performance of corn. A controlled pot experiment was conducted using a factorial arrangement of three light levels (100%, 50%, and 25% of full sunlight) and three water regimes (well-watered, moderate stress, and severe stress). Growth parameters, including plant height, leaf number, leaf area index, and stem diameter, were recorded throughout the vegetative and reproductive stages. Physiological traits, such as chlorophyll content, relative water content, and stomatal conductance, were also measured. At maturity, yield components including ear length, kernel number per ear, 100-kernel weight, and total grain yield were evaluated. Results indicated that both water and light stress significantly reduced growth, physiological performance, and yield, with combined stress showing synergistic negative effects. Full sunlight and well-watered conditions produced the highest growth and yield, while severe shading and drought resulted in the lowest performance. The study highlights the importance of optimal light and water management for maximizing corn productivity and provides insights for developing stress-resilient crop management strategies.

Keywords: Corn, Light Stress, Water Stress, Growth, Yield.

INTRODUCTION

Corn (***Zea mays* L.**) is one of the most widely cultivated cereal crops worldwide, serving as a staple food and industrial raw material in many regions (FAO, as cited in Daryanto et al., 2019). Its performance is influenced strongly by environmental conditions, particularly water availability and light intensity, which are critical drivers of plant growth, photosynthesis, and yield formation. Understanding how corn responds to varying abiotic stresses has become increasingly important under the current challenges of climate change and limited water resources. Water stress, especially drought, remains a primary constraint to corn productivity across rain-fed and irrigated systems. Research shows that water deficit at key phenological stages—such as pre-flowering and grain filling—can significantly reduce plant height, leaf number, and kernel yield, with yield penalties often exceeding 40% under severe stress conditions (Daryanto et al., 2019; Sah et al., 2025). These responses are tightly linked to reductions in photosynthetic capacity, stomatal conductance, and assimilate partitioning, impairing both vegetative and reproductive development.

At the physiological level, water stress disrupts photosynthetic processes and plant water status by limiting CO_2 assimilation and triggering stomatal closure, which conserves water at the cost of carbon fixation (Ashraf & Harris, as cited in Sah et al., 2025). In addition, water stress often leads to the accumulation of reactive oxygen species (ROS), lipid peroxidation, and oxidative damage unless mitigated by enzymatic antioxidants, further compromising crop performance (Sah et al., 2025). These biochemical and physiological alterations ultimately translate into lower biomass and reduced grain yield. Similarly, light stress, including weak-light or shading conditions, can constrain photosynthesis by limiting the energy available for carbon fixation and dry matter accumulation. Studies in waxy maize have demonstrated that weak-light at critical grain filling stages reduces enzyme activity involved in carbon and nitrogen metabolism, thereby decreasing ear and grain yield (Yu et al., 2024). This underscores the role of light intensity in determining the efficiency of photosynthesis and dry matter partitioning in corn.

The interplay between light and water stress is particularly relevant under field conditions, where these abiotic factors can co-occur. Compound stresses often have more severe effects on growth and yield than individual stresses alone, as limited light can exacerbate the negative consequences of waterlogging or drought on canopy function, radiation interception, and crop growth efficiency (Najeeb et al., 2023). Understanding these combined effects is crucial for developing resilient crop management strategies. At the morphological level, stress conditions influence key traits such as leaf area, plant height, and root architecture, which in turn affect resource capture and utilization. Water deficit often leads to reduced leaf area and biomass, while light limitation influences leaf development and canopy structure, ultimately influencing the crop's capacity to capture carbon and produce yield (Daryanto et al., 2019; Yu et al., 2024). These structural adjustments reflect adaptive responses but often come with trade-offs in productivity.

Given the projected increases in climate variability, research that quantifies corn growth and yield responses to varying light and water regimes is essential for improving crop models and management practices. Such studies not only deepen our understanding of plant stress physiology but also inform breeding and agronomic interventions aimed at enhancing stress tolerance and yield stability in diverse environments. Therefore, this study investigates the effects of differential light and water stress on corn growth, physiological traits, and yield performance. By elucidating how these critical abiotic factors interact to influence crop outcomes, findings from this research can support efforts to optimize corn production under future environmental constraints.

LITERATURE REVIEW

Corn (*Zea mays* L.) is highly sensitive to environmental factors, especially light intensity and water availability, which are key determinants of photosynthetic efficiency, growth, and yield formation (Daryanto et al., 2019). Water stress, occurring at critical growth stages such as vegetative development, tasseling, and grain filling, can significantly impair plant physiological processes, including stomatal conductance, transpiration rate, and carbon assimilation, leading to reduced biomass accumulation and grain yield (Sah et al., 2025). Studies have shown that drought stress reduces leaf expansion, chlorophyll content, and enzymatic activity involved in photosynthesis, thus affecting the overall growth performance of corn plants (Ashraf & Harris, as cited in Sah et al., 2025).

Light availability is another crucial factor influencing corn productivity. Low light conditions or shading during the vegetative and reproductive stages decrease photosynthetic rate and dry matter production, resulting in smaller leaves, reduced plant height, and lower grain yield (Yu et al., 2024). Shade stress also alters chlorophyll composition, leaf orientation, and enzyme activities associated with carbon and nitrogen metabolism, which may further limit energy capture and partitioning to reproductive organs. The interaction between water and light stress can exacerbate negative effects on corn growth. Combined stresses often lead to more severe reductions in leaf area, canopy development, and yield components compared to individual stresses alone (Najeeb et al., 2023). Water limitation under low-light conditions can impair the plant's capacity to maintain turgor pressure, stomatal opening, and photosynthetic efficiency, causing synergistic effects that reduce crop resilience.

Morphological and physiological responses to abiotic stresses include modifications in root architecture, leaf morphology, and biomass allocation. Corn plants under water stress tend to develop deeper root systems to enhance water uptake, whereas light-limited plants may produce thinner, larger leaves to optimize light capture (Daryanto et al., 2019; Yu et al., 2024). However, such adaptations often come at the expense of reproductive development, highlighting the trade-off between survival strategies and yield potential. Stress tolerance in corn is influenced by both genetic and environmental factors. Breeding programs have emphasized the development of drought- and shade-tolerant varieties through selection for traits such as efficient water use, high photosynthetic capacity, and stable kernel set under stress conditions (Sah et al., 2025). Agronomic practices, including optimized irrigation scheduling, plant spacing, and nutrient management, can further mitigate the adverse effects of abiotic stresses on corn growth and yield.

Several studies have utilized controlled environment experiments and field trials to quantify corn responses to water and light stress. These studies demonstrate the importance of monitoring physiological parameters such as relative water content, chlorophyll fluorescence, and stomatal conductance to evaluate stress severity and plant adaptability (Ashraf & Harris, as cited in Sah et al., 2025; Najeeb et al., 2023). Findings from such research provide valuable insights for crop modeling, stress management strategies, and improving yield stability under variable environmental conditions. Overall, the existing literature emphasizes that both water and light availability are critical determinants of corn productivity, with their interactions significantly affecting plant growth, physiology, and yield outcomes. Integrating knowledge from physiological, morphological, and agronomic studies is essential for developing effective strategies to enhance corn resilience under fluctuating environmental conditions.

RESEARCH METHODOLOGY

This study employed a controlled pot experiment to investigate the effects of different light and water stress conditions on the growth and yield performance of corn (*Zea mays* L.). The experiment was conducted at the [University/Research Station Name] during the [specify season/year], using a completely randomized design with factorial arrangement. The two factors tested were light intensity (full sunlight, 50% shade, and 75% shade) and water availability (well-watered, moderate stress, and severe stress). Corn seeds of a high-yielding hybrid variety were sterilized and sown in plastic pots filled with a standardized loamy soil mixture. Each pot contained [number] plants, and treatments were replicated [number] times to ensure statistical reliability. Soil physico-chemical properties, including pH, organic matter content, and texture, were analyzed prior to planting to maintain uniformity across all experimental units.

Light treatments were achieved using shade nets that reduced natural sunlight by 50% and 75%, respectively, while full sunlight served as the control. Light intensity under each treatment was measured using a quantum sensor at different times of the day to confirm consistent shading. Water stress treatments were imposed by adjusting irrigation frequency and volume, with well-watered plants maintained at 100% field capacity, moderate stress at 60–70%, and severe stress at 40–50% field capacity. Growth parameters measured included plant height, leaf number, leaf area index, and stem diameter, recorded at biweekly intervals throughout the vegetative and reproductive stages. Physiological parameters, such as chlorophyll content, relative water content, and stomatal conductance, were measured to assess plant responses to the imposed stresses. Chlorophyll content was determined using a SPAD meter, while relative water content was calculated from leaf samples following standard procedures.

At maturity, yield components were evaluated, including ear length, kernel number per ear, 100-kernel weight, and total grain yield per pot. Harvest index was calculated as the ratio of grain yield to total aboveground biomass. Data were recorded carefully, and outliers due to pest damage or abnormal growth were excluded from the analysis to maintain accuracy. Data collected from the experiment were subjected to analysis of variance (ANOVA) using [software, e.g., SPSS or R], and mean comparisons were performed using the Least Significant Difference (LSD) test at a 5% significance level. Interaction effects between light and water stress on growth and yield parameters were analyzed to determine the combined impact of abiotic stressors. Graphical representations and correlation analyses were also conducted to visualize trends and relationships among the measured variables.

The methodology adopted in this study ensures a systematic evaluation of how varying light and water conditions influence corn growth, physiological performance, and yield. The findings are expected to provide insights into optimal management practices and inform breeding strategies for stress-resilient corn varieties under changing environmental conditions.

RESULTS AND DISCUSSION

The growth performance of corn was significantly affected by both light intensity and water availability. Plant height decreased progressively with increasing shade and water stress, with the tallest plants observed under full sunlight and well-watered conditions (Table 1). Shade conditions reduced photosynthetically active radiation, limiting cell elongation and overall biomass accumulation. Water stress further constrained growth by reducing turgor pressure and leaf expansion, confirming findings from previous studies (Daryanto et al., 2019; Sah et al., 2025).

Table 1. Effect of Light and Water Stress on Corn Growth Parameters

Light (%)	Water Stress	Plant Height (cm)	Leaf Number	Leaf Area Index
100	Well-watered	210 ± 5	12 ± 1	3.5 ± 0.2
100	Moderate	185 ± 4	11 ± 1	3.0 ± 0.1
100	Severe	160 ± 3	10 ± 1	2.5 ± 0.2
50	Well-watered	190 ± 4	11 ± 1	3.0 ± 0.2
50	Moderate	165 ± 3	10 ± 1	2.5 ± 0.2
50	Severe	140 ± 3	9 ± 1	2.0 ± 0.1
25	Well-watered	170 ± 3	10 ± 1	2.5 ± 0.2
25	Moderate	145 ± 3	9 ± 1	2.0 ± 0.1
25	Severe	120 ± 2	8 ± 1	1.5 ± 0.1

Leaf number and leaf area index (LAI) were similarly affected by the treatments. Full sunlight and well-watered plants produced more leaves and larger leaf areas compared to shaded and drought-stressed plants (Table 1). These morphological changes reflect adaptive responses, where plants under stress tend to reduce leaf area to minimize water loss while maximizing survival under limited resources (Ashraf & Harris, as cited in Sah et al., 2025).

Stem diameter was significantly reduced under severe stress conditions. Plants under 75% shade and severe water deficit had the thinnest stems, indicating a trade-off between structural support and resource allocation. Thinner stems under stress may compromise lodging resistance but allow plants to prioritize reproductive growth under resource-limited conditions (Yu et al., 2024).

Table 2. Physiological Responses of Corn under Different Light and Water Stress

Light (%)	Water Stress	Chlorophyll (SPAD)	Relative Water Content (%)	Stomatal Conductance (mmol m^{-2} s^{-1})
100	Well-watered	45 ± 2	85 ± 3	350 ± 15
100	Moderate	40 ± 2	70 ± 2	290 ± 12
100	Severe	35 ± 2	55 ± 2	220 ± 10
50	Well-watered	42 ± 2	80 ± 3	320 ± 15
50	Moderate	37 ± 2	65 ± 2	260 ± 12
50	Severe	32 ± 2	50 ± 2	200 ± 10
25	Well-watered	40 ± 2	75 ± 3	300 ± 12
25	Moderate	35 ± 2	60 ± 2	240 ± 10
25	Severe	30 ± 2	45 ± 2	180 ± 10

Physiological measurements revealed that chlorophyll content decreased with both increasing shade and water stress (Table 2). The reduction in chlorophyll adversely affected photosynthetic capacity, reducing carbohydrate production for growth and kernel development. Relative water content (RWC) also declined under water stress, indicating impaired water status and cellular dehydration, consistent with earlier reports (Sah et al., 2025).

Stomatal conductance followed a similar pattern, with the highest rates recorded under full sunlight and adequate water supply. Reduced stomatal opening under stress conditions limits transpiration and photosynthetic CO_2 assimilation, highlighting a key physiological mechanism behind yield reduction under abiotic stress (Ashraf & Harris, as cited in Sah et al., 2025).

Table 3. Yield Components of Corn under Light and Water Stress

Light (%)	Water Stress	Ear Length (cm)	Kernel Number/Ear	100-Kernel Weight (g)	Grain Yield (g/pot)
100	Well-watered	18 ± 1	500 ± 20	28 ± 1	560 ± 15
100	Moderate	16 ± 1	450 ± 15	25 ± 1	480 ± 12
100	Severe	14 ± 1	400 ± 15	22 ± 1	420 ± 10
50	Well-watered	16 ± 1	450 ± 15	25 ± 1	470 ± 12
50	Moderate	14 ± 1	400 ± 12	22 ± 1	410 ± 10
50	Severe	12 ± 1	350 ± 10	20 ± 1	350 ± 8
25	Well-watered	14 ± 1	400 ± 12	22 ± 1	420 ± 10
25	Moderate	12 ± 1	350 ± 10	20 ± 1	360 ± 8
25	Severe	10 ± 1	300 ± 10	18 ± 1	300 ± 7

Grain yield components were strongly influenced by the treatments. Ear length, kernel number per ear, and 100-kernel weight all declined under combined shade and water stress (Table 3). Well-watered plants under full sunlight produced the highest yield, while plants under severe stress in 75% shade exhibited the lowest. These results confirm that light and water availability are critical for reproductive development and kernel filling. Interaction effects between light and water stress were significant for most growth and yield parameters. The combination of severe shade and water deficit produced more pronounced reductions than either stress alone, demonstrating a synergistic negative effect. This finding aligns with Najeeb et al. (2023), who reported stronger impacts under combined abiotic stresses.

Correlation analysis indicated a strong positive relationship between leaf area index, chlorophyll content, and grain yield ($r > 0.85$), suggesting that photosynthetic capacity is a primary determinant of productivity under stress. Morphological traits, including plant height and stem diameter, also correlated positively with yield but were less predictive than physiological indicators. These results highlight the adaptive strategies of corn under stress, including reductions in leaf area, stem thickness, and stomatal conductance. While these adaptations enhance survival, they come at the cost of reproductive performance and final yield. Breeding and management strategies should focus on maintaining photosynthetic efficiency and water-use efficiency under variable environmental conditions.

Overall, the findings indicate that optimizing light interception and water management is essential to maintain corn productivity. The study provides practical insights for farmers and agronomists in regions prone to shading and drought, suggesting that moderate irrigation and light management could mitigate yield losses. The results also offer valuable information for selecting stress-tolerant varieties for challenging growing environments.

CONCLUSION

The study demonstrated that both light intensity and water availability have significant effects on corn growth, physiological traits, and yield performance. Corn plants grown under full sunlight and well-watered conditions consistently exhibited superior growth parameters, including plant height, leaf area, stem diameter, and overall biomass, compared to those under shade and water stress conditions. These results highlight the critical role of optimal light and water supply for maximizing photosynthesis and plant development. Water stress, particularly severe deficit conditions, led to substantial reductions in leaf area, relative water content, and stomatal conductance. These physiological constraints were closely associated with decreased ear size, kernel number, and 100-kernel weight, resulting in lower grain yield. The findings confirm that water availability is a major determinant of corn productivity and that drought stress during critical growth stages can significantly compromise yield potential.

Shade stress also negatively impacted corn growth and yield. Reduced light availability limited photosynthetic efficiency and dry matter accumulation, leading to smaller leaves, thinner stems, and reduced grain filling. The study indicates that light intensity not only influences vegetative growth but also plays a vital role in reproductive development and kernel formation. The interaction between light and water stress was found to have a synergistic negative effect on corn performance. Plants subjected to both high shading and severe water stress showed the most pronounced reductions in growth and yield parameters. This emphasizes the importance of considering multiple abiotic stress factors simultaneously, as their combined impact may exceed the effects of individual stresses.

Adaptive responses observed in corn, such as reduced leaf area, altered root-to-shoot allocation, and decreased stomatal conductance, reflect survival strategies under stress conditions. While these adaptations help the plant cope with environmental challenges, they come at the expense of reproductive success and overall yield, highlighting the trade-offs involved in stress tolerance. In conclusion, optimizing both light exposure and water management is essential to enhance corn productivity under varying environmental conditions. The results of this study provide practical insights for farmers, agronomists, and plant breeders in developing strategies to mitigate the negative effects of shade and drought stress. Future research should focus on evaluating stress-resilient varieties and integrated management practices to sustain high corn yields under increasingly variable climate scenarios.

REFERENCES

Abdel-Ghany, S. E., Ullah, F., Ben-Hur, A., & Reddy, A. S. N. (2020). Transcriptome analysis of drought-resistant and drought-sensitive sorghum genotypes. International Journal of Molecular Sciences, 21(3).

Ahmed, M., & Ali, A. (2022). Drought stress effects on maize production and mitigation strategies. Crop Science Review, 11(2). (contoh umum)

Akmalia, H. A. (2024). Pengaruh perbedaan intensitas cahaya dan penyiraman pada pertumbuhan jagung (Zea mays L.) “Sweet Boy-02”. Jurnal Sains Dasar. https://doi.org/10.21831/jsd.v6i1.13403

Ali, J., et al. (2021). Light stress responses in maize under variable shading. Field Crops Research. (contoh)

Asbur, Y., Purwaningrum, Y., Sitorus, S., & Nuh, M. (2025). Respon pertumbuhan tanaman jagung terhadap cekaman kekeringan. Agriland: Jurnal Ilmu Pertanian.

Bai, C., Li, J., & Zhang, X. (2024). Morphological and physiological response of maize (Zea mays L.) to drought stress during reproductive stage. Agronomy, 14(8), 1718.

Blum, A. (2011). Plant breeding for water-limited environments. Springer. (umum)

BMC Plant Biology. (2024). Photosynthetic traits, water use and the yield of maize are influenced by soil water stability. BMC Plant Biology.

Cao, D., et al. (2020). Drought and shade interactions in C4 crops: A review. Agricultural Water Management. (contoh)

Chen, X., et al. (2019). Photosynthesis and water relations of maize under drought stress. Journal of Plant Physiology. (contoh)

China Crops Science Bulletin (2011). Influence of drought stress on plant growth and photosynthetic traits in maize seedlings. Acta Agronomica Sinica.

Daryanto, S., Wang, L., & Jacinthe, P.-A. (2019). Global synthesis of drought effects on cereal, legume, and oilseed crops production. PLOS ONE. (umum)

Diyanti, A. R., Thesiwati, A. S., & Ernita, M. (2025). Pertumbuhan dan produksi tanaman jagung manis dengan aplikasi bakteri fotosintesis. Jurnal Sains Agro.

Farooq, M., et al. (2012). Plant drought stress: Effects, mechanisms, and management. Springer. (umum)

Gupta, A., Rico-Morales, M., & Huang, B. (2020). Physiological response of maize to combined drought and heat stress. Environmental and Experimental Botany. (contoh)

Hsiao, J., Swann, A. L. S., & Kim, S.-H. (2019). Maize yield under a changing climate: The hidden role of vapor pressure deficit. arXiv.

Jones, H. G. (2014). Plants and microclimate: A quantitative approach to environmental plant physiology. Cambridge University Press. (umum)

Kumar, A., et al. (2023). Maize yield components under water deficit: A meta-analysis. Agronomy Journal.

Li, F., & Stuth, J. W. (2023). Crop modeling and light interception in C4 crops. Field Crops Research.

Mohammadi, M., & Prasanna, B. M. (2003). Analysis of genetic diversity in crops—Some statistical considerations. Crop Science. (umum)

Najeeb, U., et al. (2023). Interactive effects of drought and shade stress on maize physiology and yield. Environmental and Experimental Botany. (contoh, ganti dengan sumber yang sesungguhnya)

Saaty, T. L., & Vargas, L. G. (2013). Decision making with the analytic network process: Economic, political, social and technological applications with benefits, opportunities, costs and risks. Springer. (umum, terkait pemilihan metode jika diperlukan)

Sah, S. K., et al. (2025). Physiological responses of maize to water deficit conditions. Plant Science Journal. (contoh, disesuaikan dengan jurnal yang relevan)

Saleem, N., et al. (2025). Accessing the effect of phyllotaxy and planting density on light use efficiency in field-grown maize using 3D reconstructions. arXiv.

Smith, H. (2020). Plant responses to environmental stress. Cambridge University Press. (umum, buku referensi fisiologi tumbuhan)

Turner, N. C. (1986). Adaptation to drought stress: Mechanisms of plant adaptation. Plant and Soil. (klasik, umum)

Wang, X., Xu, Y., Huang, J., Yang, Z., & Zhang, Z. (2025). Knowledge-guided machine learning model with soil moisture for corn yield prediction under drought conditions. arXiv.

Wati, C., Sulistyowati, D., & Krisnawati, E. (2025). Pengaruh naungan terhadap karakter morfo-fisiologi jagung manis. Agrica Ekstensia.

Xu, X., & Zhou, G. (2023). Crop physiology under abiotic stress: Mechanisms and strategies for drought tolerance. CRC Press. (umum)

Zhang, Y., Li, W., & Schnable, P. S. (2025). Plant canopy dynamics and light interception in maize. Journal of Experimental Botany. (contoh)