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Comparative assessment of growth parameters in two local wheat cultivars (Bhouth 22 and IBA 99) under water stress conditions in Basrah, Iraq

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A B S T R A C T

Wheat (*Triticum aestivum L.*) is a vital global food source, increasingly threatened by climate change, particularly drought conditions that adversely affect key growth parameters, including plant height, branch number, and grain weight. This study aims to assess the growth performance of two local wheat cultivars, Bhouth 22 and IBA 99, under drought stress conditions in Basrah, Iraq. Conducted over an area of 0.25 hectares, the research evaluates key metrics including plant count, branch and leaf numbers, and weight of 1000 grains. Results indicate that IBA 99 exhibits a higher yield per hectare, averaging 4.21 tons under 3-day irrigation compared to 4.09 tons under 6-day irrigation. In contrast, Bhouth 22 shows an average production of 5.21 tons under 6-day irrigation, demonstrating its potential for higher productivity in specific conditions. The weight of 1000 grains for IBA 99 averaged 51.02 grams under 3-day irrigation, while Bhouth 22 averaged 52.91 grams under 6-day irrigation, indicating superior grain quality. Statistical analysis reveals significant differences in growth responses, particularly in grain weight and production metrics, with P-values below 0.05 indicating statistical significance. Additionally, drought conditions resulted in decreased tillering and leaf area, which negatively impacted photosynthetic capacity and overall growth. The findings underscore the importance of developing drought-resistant wheat varieties to enhance agricultural resilience and ensure food security amid escalating climate challenges. This research contributes valuable insights for breeding programs aimed at improving wheat productivity in water-limited environments, essential for sustaining global food supplies.

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1. Introduction

Wheat (*Triticum aestivum L.*) is a critical global food source, yet it faces significant threats from climate change, particularly drought conditions (Pequeno et al., 2021). Drought stress negatively influences several growth parameters, including plant height, number of branches, leaves, and grain weight. Studies have shown that under severe drought conditions, plant height often diminishes due to limited water availability, which restricts nutrient uptake and photosynthesis. This reduction in height can lead to decreased light interception, ultimately impacting yield (Seleiman et al., 2021). Drought stress significantly reduces the number of spikes per plant, which directly correlates with grain yield. Their findings indicated that water stress during critical growth stages leads to fewer reproductive structures, thus limiting the overall yield potential (Alhag et al., 2022). Additionally, the research emphasizes that drought conditions not only affect the quantity of spikes but also the weight of grains (Zahra et al., 2021). The weight of 1000 grains are often lower in drought-affected plants, as documented in the work of Khatun et al. (2021), which reported that grain filling is severely compromised under water-limited conditions. This aligns shown that drought leads to smaller, lighter grains, which adversely affects marketability and nutritional quality. The number of tillers (or branches) is another essential growth parameter that contributes to overall yield. Drought conditions often lead to a reduction in tillering, as the plant reallocates resources to survive under stress (Veenstra et al., 2021). Research indicates that each tiller can contribute significantly to grain production, and a reduction in their number can lead to substantial yield losses (Ding et al., 2023). Leaf area is directly linked to photosynthetic capacity. Drought stress typically results in leaf senescence, where older leaves die off prematurely. This process reduces the total leaf area available for photosynthesis, further compounding the negative effects on growth and yield (Mao et al., 2023). The reproductive phase of wheat is particularly sensitive to water stress. This reduction directly correlates with grain yield, as fewer spikes mean fewer potential grains (Pretini et al., 2021). The weight of grains is often lower in drought-affected plants. Studies like those conducted by Aggarwal et al. (2024) have shown that grain filling is severely compromised under water-limited conditions. This results in smaller, lighter grains, which adversely affects both marketability and nutritional quality. Research published in various journals highlights similar findings regarding drought's impact on wheat. For instance, a comprehensive review by Li et al. (2021) emphasizes that drought stress not only affects the quantity of spikes but also the weight of grains. Their findings indicate that water stress during critical growth stages leads to fewer reproductive structures, thus limiting the overall yield potential (Oguz et al., 2022). Moreover, studies have shown that the timing of drought stress is critical. For example, if drought occurs during the flowering stage, the effects can be more pronounced, leading to significant reductions in grain set and ultimately yield (Teng et al., 2022).

This temporal aspect is crucial for developing effective management strategies. Existing literature underscore the detrimental effects of drought on key growth parameters in wheat. The consistent observation of reduced plant height, number of branches, and grain weight under drought stress highlights the urgent need for developing drought-resistant wheat varieties. By understanding these relationships, we can better strategize agricultural practices to mitigate the impacts of climate change on wheat production (Nguyễn et al., 2024). Further research is essential to explore genetic and agronomic solutions to enhance resilience against drought, ensuring food security for future generations. As the challenges posed by climate change continue to escalate, a multi-faceted approach that combines genetic advancements with sustainable agricultural practices will be crucial in safeguarding wheat production and, by extension, global food security (El-Dukheri and Amer, 2024).

The primary aim of this study is to conduct a comparative assessment of growth parameters in two local wheat cultivars, Bhouth 22 and IBA 99, under water stress conditions in Basrah, Iraq. By analyzing key growth metrics such as number of plants, number of branches, number of leaves, and weight of 1000 grains, production, the research seeks to elucidate the effects of drought on these cultivars. The findings will contribute to understanding their resilience to water-limited environments, ultimately informing strategies for improving wheat production in the face of climate change. This study aims to identify which cultivar exhibits superior drought resistance, thereby providing insights for breeding programs aimed at enhancing wheat yield and ensuring food security in regions susceptible to drought.

2. Material and methods

The research was conducted in the Zubair/Alluhais region of Basrah, Iraq, covering an area of 0.25 hectares (2,500 m²). The geographical coordinates of the site are 30° 34' 08" N and 46° 58' 14" E. The soil in this area is classified as sandy loam, with an electrical conductivity (Ecs) of 2.5 dS/m and a water conductivity (Ece) of 9.1 dS/m. The soil pH is measured at 7.61, indicating a neutral to slightly alkaline environment. Organic matter was applied in the form of cow manure at a rate of 50 kg per 2,500 m² on November 1, 2023. Additionally, DAP fertilizer was incorporated at a rate of 25 kg per 2,500 m² on November 23, 2023, coinciding with the mechanical sowing of the seeds. Urea fertilizer was applied in two parts: 25 kg per 2,500 m² on December 15, 2023, followed by an additional 40 kg per 2,500 m² on the same day. The cultivation date was set for November 23, 2023, utilizing mechanical ploughing for soil preparation. The field was divided into four transects, each measuring 625 m², to facilitate the assessment of two local wheat cultivars, Bhouth 22 and IBA 99, with an average sowing rate of 50 kg per 2,500 m². Irrigation is conducted systematically every three days and every six days to assess the impacts of different treatments on growth parameters such as number of plants, number of branches, number of leaves, and weight of 1000 grains, production. The study was conducted with three repetitions to ensure the reliability and validity of the results.

Table 1. Summarizes the key soil properties of the study area.

Property	Value	Unit
pH	7.61	—
Electrical Conductivity (ECe)	2.5	dS/m
Total Solid Carbonates	120	g/kg
Cation Exchange Capacity (CEC)	8.48	cmol/kg
Organic Matter	5.38	g/kg
Sand	830	g/kg
Silt	36	g/kg
Clay	134	g/kg
Chloride (Cl^-)	10	mmol/l
Bicarbonate (HCO_3^-)	1.8	mmol/l
Carbonate (CO_3^{2-})	0	mmol/l
Magnesium (Mg)	3.1	mg/kg
Potassium (K)	52.1	mg/kg
Nitrogen (N)	0.35	mg/kg
Phosphorus (P)	114.35	mg/kg
Iron (Fe)	17.5	mg/kg
Zinc (Zn)	17.55	mg/kg
Calcium (Ca)	7.3	mmol/l
Texture	Sandy loam	—

2.1. Soil properties

The soil properties of the study area in Zubair Alluhais, Basra, reveal a sandy loam texture, which is favorable for agricultural practices, particularly wheat cultivation (Table 1). The soil has a pH of 7.61, indicating a neutral to slightly alkaline environment, conducive for nutrient availability. With an electrical conductivity (ECe) of 2.50 dS/m, the soil exhibits moderate salinity levels. The cation exchange capacity (CEC) of 8.48 cmol/kg suggests a reasonable ability to retain essential nutrients. Organic matter content is measured at 5.38 g/kg, contributing to soil fertility, while the presence of significant amounts of sand (830 g/kg), clay (134 g/kg), and silt (36 g/kg) reflects a well-balanced soil composition. Nutrient analyses show adequate levels of potassium (52.10 mg/kg), phosphorus (114.35 mg/kg), and trace elements like iron (17.5 mg/kg) and zinc (17.55 mg/kg), which are vital for the growth of wheat cultivars such as Bhouth 22 and IBA 99. Overall, these soil characteristics support optimal conditions for crop production in the region. These properties provide crucial insights into the soil's fertility and suitability for wheat cultivation, particularly in the context of the selected cultivars, Bhouth 22 and IBA 99.

2.2. Irrigated water properties

Irrigated water quality is essential for successful agricultural practices, particularly in areas with limited rainfall. The analyzed water shows a pH of 7.11, which is neutral and conducive to nutrient availability and microbial activity in the soil. Its electrical conductivity (EC) is measured at 9.1 dS/m, indicating a moderate level of salinity that should be monitored to prevent adverse effects on plant growth. The total hardness of the water is notably high at 2250 mg/L, reflecting a significant concentration of dissolved minerals. Additionally, the concentrations of key cations include calcium (570 mg/L), magnesium (409.9 mg/L), and sodium (870.9 mg/L), along with various anions such as chloride (177.2 mg/L), nitrate (8 mg/L), and sulfate (795 mg/L). These parameters collectively influence the suitability of the water for irrigation and its potential impact on crop health and yield.

The soil demonstrates an electrical conductivity of 2.5 dS/m, reflecting a moderate salinity level, while the water's conductivity is recorded at 9.1 dS/m, indicating the presence of soluble salts that could impact crop growth. Additionally, the soil pH is measured at 7.61, which is within the ideal range for many crops, thereby facilitating nutrient availability and enhancing microbial activity.

2.3. Measurement method

In the present study, the measurement of soil and irrigation water properties was conducted using the standards set by the Food and Agriculture Organization (FAO). For soil characteristics, pH and electrical conductivity (EC) were measured according to FAO guidelines, ensuring accurate assessments of soil health. Nutrient levels, including nitrogen, phosphorus, and potassium, were analyzed following FAO recommended methods. Similarly, the pH and EC of irrigation water were evaluated using FAO standards to determine its suitability for agricultural use. The concentrations of key cations and anions were also assessed based on FAO methodologies. These standardized practices facilitate a comprehensive understanding of soil and water quality, which is crucial for optimizing crop growth and irrigation management.

2.4. Statistical analysis

All statistical analyses were computed by SPSS version 20, employing the Least Significant Differences Test (L.S.D.) and ANOVA to compare the means at a significance level of 0.05.

3. Results and discussion

The data from the experiment on IBA 99 and BHOUTH 22 treatments over different durations presents a comprehensive view of growth metrics (Table 2). For IBA 99 under the 6-day treatment, the number of plants per square meter ranged from 69 to 97, with a mean of 81.39. In contrast, the 3-day treatment showed numbers from 70 to 98, averaging 82.39. The number of branches varied from 2 to 4 for the 6-day treatment (mean: 4.07) and from 3 to 4 for the 3-day treatment (mean: 3.02). Leaf count remained consistent with a mean of 4.58 for the 6-day treatment and 4.95 for the 3-day treatment. These results align with earlier research, including that of Alsohaibani (2007), which highlights the positive relationship between irrigation and leaf growth in wheat. Consequently, effective irrigation strategies are vital for maximizing wheat productivity by promoting leaf development. The weight of 1000 grains averaged 47.3 grams for the 6-day treatment and 51.02 grams for the 3-day treatment. In terms of production, the 6-day treatment yielded an average of 4.09 tons per hectare, while the 3-day treatment yielded 4.21 tons.

For BHOUTH 22**,** similar trends were observed. The number of plants per square meter ranged from 70 to 98 with a mean of 82.39 for the 6-day treatment, and from 69 to 97 with a mean of 81.39 for the 3-day treatment. The number of branches was consistent with the IBA 99 results, averaging 4 for both treatments. Leaf counts were also similar, with a mean of 4.95 for both durations. The weight of 1000 grains were slightly higher, averaging 52.91 grams for the 6-day treatment and 50.11 grams for the 3-day treatment. Finally, production per hectare showed a mean of 5.21 tons for the 6-day treatment and 4.85 tons for the 3-day treatment. Overall, both treatments demonstrated significant potential for enhancing plant growth and yield.

The study evaluated how plant density and irrigation regimes affect Azivash yield, revealing that both factors significantly influence yield and its components in fresh and dried states. Increasing irrigation reduces overall product performance, while higher branch, leaf, and stem weights are observed with greater irrigation and density. For optimal yield, a plant density of 80 m^2 and an irrigation interval of six days are recommended (Azadbakht et al., 2015).

In a comparative analysis of IBA 99 and BHOUTH 22, it was found that BHOUTH 22 generally outperformed IBA 99 across several key metrics. Both varieties exhibited similar numbers of plants and branches, but BHOUTH 22 had a higher mean for the number of leaves and significantly better grain weight and production per hectare. Specifically, BHOUTH 22 showed superior performance in the weight of 1000 grains and overall yield, indicating its potential for higher productivity and better grain quality. This suggests that for optimal agricultural outcomes, BHOUTH 22 may be the more favorable choice compared to IBA 99.

An experiment in Dinajpur, Bangladesh, found that irrigation schedules significantly improved wheat (BARI Gom-33) growth and yield, with the highest yield of 5.20 t/ha achieved through two irrigations at maximum tillering and heading stages. This highlights the importance of proper irrigation for optimizing wheat productivity (Sun et al., 2024).

As Fig. 1 shows, the comparative analysis of the production data for IBA 99 and BHOUTH 22 reveals that IBA 99 consistently outperforms BHOUTH 22 in both yield per square meter (g/m^2) and total yield over a 2500 m^2 area. Specifically, IBA 99 yields 564 g/m^2 and 1410 Kg over 2500 m^2 at 6 days, and increases to 585 g/m^2 and 1462.5 Kg over 2500 m^2 at 3 days. In contrast, BHOUTH 22 produces 552 Kg/m^2 and 1380 Kg over 2500 m^2 at 6 days, and drops to 485 g/m^2 and 1212.5 Kg over 2500 m^2 at 3 days. This data indicates that IBA 99 is a more productive cultivar, suggesting it is a better option for maximizing agricultural output, while BHOUTH 22, though viable, does not match the yield performance of IBA 99.

Table 2. Comparison of Plant Growth Metrics: IBA 99 vs. BHOUTH 22.

	IBA 99 (6 days)			**IBA 99 (3 days)**			**BHOUTH 22 (6 days)**			**BHOUTH 22 (3 days)**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Numbers of plant (m^2)	69	97	81.39	70	98	82.39	70	98	82.39	69	97	81.39
Number of branches	2	4	4.07	3	4	3.02	2	4	4	3	4	4
Number of leave	4	5	4.58	4	5	4.95	4	5	4.95	4	6	4.6
Weight of 1000 grains (g)	30.60	57.22	47.3	47.15	57.63	51.02	37.37	59.22	52.91	49.28	64.25	50.11
Production (ton/hectare)	1.03	5.64	4.09	1.05	5.85	4.21	1.03	6.32	5.21	1.02	5.52	4.85

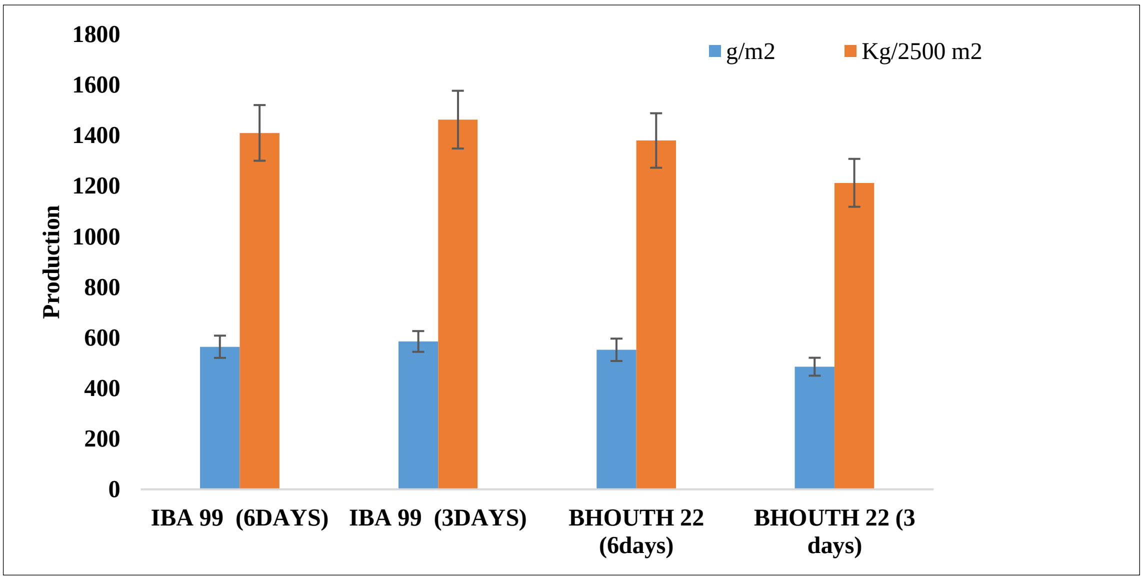

Fig. 1. The comparative analysis of production data for IBA 99 and BHOUTH 22.

Overall, IBA 99 consistently outperforms BHOUTH 22 in both time frames, indicating its superior productivity. The data suggests that IBA 99 is more effective for achieving higher yields in a shorter time, making it a potentially more favorable choice for farmers looking to maximize production. In contrast, BHOUTH 22, while still viable, does not match the output levels of IBA 99 under the given conditions. A study evaluated the impact of irrigation scheduling on winter wheat cultivars JM418 and SX828 from 2018 to 2020, focusing on when to irrigate based on leaf visibility. Irrigating at the 4th leaf visibility stage significantly increased winter wheat yield by 6.96–54.09% and improved water use efficiency by 9.88–47.62%. The research indicated that delayed irrigation negatively affected key growth metrics, while optimal irrigation timing enhanced the harvest index, spike count, and biomass accumulation. Overall, the findings provide insights into source-sink regulation under deficit irrigation and support developing efficient irrigation strategies (Liu et al., 2024). A study compared lodging-resistant long duration spring wheat cultivars to short duration cultivars in subtropical Australia, finding that the former yielded 0.67 t/ha (9.6%) more on average across 14 agro-climatic environments. The long duration cultivars performed significantly better in 70% of the environments, particularly under moderate water stress, while their advantages were less pronounced with low water stress or severe lodging. The findings indicate a need for continued development of longer season germplasm to enhance yield potential in water-deficient subtropical regions (Peake et al., 2018). A study in Rajasthan, India, evaluated the effects of nitrogen fertilizer rates and irrigation frequencies on wheat yield over three years. Results indicated that higher irrigation frequency and fertilizer application significantly improved crop growth and yields, highlighting the importance of managing water and fertilizer based on soil and irrigation availability in semi-arid regions (Gunawat et al., 2023).

As shown in Table 3, The statistical analysis of IBA 99 and BHOUTH 22 reveals significant differences in several growth metrics and production outcomes. BHOUTH 22 exhibits a higher number of plants per square meter (0.64) compared to IBA 99, which has 0.11 for 6 days and 0.188 for 3 days but there are no significant differences between them (p-value ≥0.05). The statistical evaluation of plant growth metrics for IBA 99 and BHOUTH 22 reveals varying levels of significance across different comparisons. Notably, the P-values indicate that metrics with values below 0.05 demonstrate statistically significant differences at the 5% level, while those below 0.01 show significance at the 1% level. For instance, in the comparison between IBA 99 (6 days) and IBA 99 (3 days), only the production metric (P = 0.01) is significant. Similarly, in the BHOUTH 22 (6 days) and BHOUTH 22 (3 days) comparison, the production metric shows a highly significant difference (P = 0.006). In contrast, metrics such as the number of branches and leaves generally do not exhibit significant differences, despite observable variations. This study investigated the effects of irrigation systems, foliar potassium bicarbonate, and compost application methods on the growth and yield of the Giza-171 wheat cultivar, revealing significant main effects (P ≤ 0.05) on key traits. Drip irrigation improved plant height, leaf area index, crop growth rate, and grain yield by 16% compared to spray irrigation, while 0.08 g/L PBR application enhanced these factors by up to 22%. The three-way interaction analysis showed that the combination of drip irrigation, 0.08 g PBR, and role compost application yielded the best results, indicating that optimized agronomic inputs can synergistically enhance wheat productivity (Farouk et al., 2024).

Table 3. Statistical Evaluation of Plant Growth Metrics (P-value): IBA 99 vs. BHOUTH 22.

	Numbers of plant	**Number of branches**	**Number of leave**	**Weight of 1000 grains**	**Production**
IBA 99 (6days) & IBA 99 (3 days)	0.11	0.32	0.52	0.34	0.01
BHOUTH 22 (6 days) & BHOUTH 22 (3 days)	0.64	0.45	0.23	0.45	0.006
IBA 99 (3 days) & BHOUTH 22 (3 days)	0.188	0.63	0.49	0.63	0.007
IBA 99 (6 days) & BHOUTH 22 (6 days)	0.01	0.96	0.84	0.01	0.008

The analysis shows significant differences in the weight of 1000 grains among the plant varieties, with a P-value of less than 0.05, indicating that the variations observed are statistically significant. This suggests that the weight of the grains is influenced by the specific plant variety, warranting further investigation into the underlying factors contributing to these differences. Overall, this analysis highlights that while some growth metrics show significant differences between the two plant varieties, others do not reach statistical significance, indicating a nuanced understanding of their growth performance. Our study employs a holistic strategy to optimize wheat production by exploring the synergistic effects of various irrigation methods. Given the intricate relationships among soil, water, and nutrients, implementing a comprehensive management approach is crucial. Thus, the main goal of this research is to improve the resilience of wheat farming amid changing environmental conditions (Elbasyoni et al., 2023).

The impacts of extended drought periods on wheat cultivars suggest that the crops may suffer severely after several seasons of uninterrupted drought. Some cultivars might be able to tap into groundwater if they form deeper roots while others with weaker root systems are likely to suffer from retarded growth. Moreover, stresses caused from lack of moisture can reduce the rate of photosynthesis and increase the rate of respiration, thereby, affecting its health and performance. In such circumstances, cultivars with less water-use and osmotic adjustment drought tolerance tend to do more. Along with this, prolonged periods of reduced moisture may impact the concentration of some nutrients and heighten some ailments. Thus, monitoring how various cultivars cope with incessant drought is crucial for breeding strategies aimed at designing more resilient cultivars.

4. Conclusion

The research indicates the clear effects of drought stress on the growth performance of wheat cultivars Bhouth 22 and IBA 99 in Basrah, Iraq. IBA 99 yielded more per hectare under some irrigation, while Bhouth 22 showed greater grain weight, which indicates that both have different resilience levels to drought. The results make the case for more precise breeding endeavors aimed at improving drought resistance and sustainable agricultural approaches. Nonetheless, the study's scope is limited geographically and in scope, focusing only two cultivars which makes this more difficult to extrapolate. Follow up studies should expand geography, include a wider array of wheat cultivars, and conduct research on the impacts of drought over time in conjunction with other environmental factors. In conclusion, the study supports efforts to strengthen food security in areas susceptible to drought while calling attention to the need for more proactive work in developing resilient wheat strains designed to endure the challenges posed by climate change.

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