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MICRONUTRIENTS AND ETHEPHON EFFECTS ON WHEAT WATER STATUS, PRODUCTIVITY, AND DROUGHT INDICES UNDER WATER STRESS IN A GREENHOUSE ENVIRONMENT

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ABSTRACT

Water scarcity is a major constraint to wheat production in semi-arid regions, necessitating agronomic strategies that enhance drought tolerance and water-use efficiency. This study evaluated the interactive effects of water regimes, foliar-applied micronutrients (Zn, Mn, B, and Fe), and ethephon on wheat water status, water productivity, and drought tolerance indices of three bread wheat (Triticum aestivum L.) varieties (Hawler 4, IBA 99, and Jehan) under semi-controlled greenhouse conditions in Erbil, Iraq, during the 2024–2025 growing season. A randomized complete block design with three replications compared two irrigation regimes (40–60% and 80–100% field capacity) and nine foliar treatments applied at tillering (ZS25). Water stress (40–60% FC) reduced of the relative water content (RWC), plant water content, and water productivity in all varieties. Ethephon in combination with micronutrients, especially 1 g l⁻¹ of (Zn, Mn, B, and Fe), with 500 mg l⁻¹ ethephon, markedly improved RWC, water productivity, and overall physiological performance. Varietal responses differed; Hawler 4 showed a (water-saver) strategy with higher RWC and water productivity under stress, while Jehan exhibited superior drought tolerance based on indices (SSI, STI, YSI, TOL). These results demonstrate that drought stress adversely affects wheat physiology, but integrated foliar application of micronutrients and ethephon, particularly micronutrients at 1 g l⁻¹ with ethephon at 500 mg l⁻¹, offers an effective strategy for wheat cultivation in water-limited environments.

KEYWORDS: Micronutrient, Ethephon, Wheat, Water Status, Water Stress and Drought Indices.

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1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and a primary source of food security in arid and semi-arid regions, however, as a primary global food staple, wheat ranks among the most extensively cultivated, consumed, and stockpiled crops worldwide (Marcek et al. 2019). However, shifting rainfall patterns driven by climate change are expected to increase the frequency of droughts, leading to significant declines in crop output. Consequently, water scarcity has emerged as a critical barrier to wheat production, posing a severe threat to global food security (Hussain et al. 2019). Reduction in leaf water potential has a direct effect on gaseous exchange through stomata leads to the decrease in stomatal conductance and transpiration, relative water content under drought stress is decreases by 43% that closes stomata leads to lower supply of CO2 for photosynthesis and decrease in photosynthetic rate (Nyaupane et al., 2023). Plants bolster their resilience to drought through osmotic adjustment, a process involving the accumulation of various organic and inorganic solutes to sustain cell turgor. Maintaining this internal pressure is crucial for continued cell expansion, growth, and development during periods of water stress. Furthermore, the buildup of these osmolytes enables stomata to remain open, ensuring ongoing CO2 fixation even when water is scarce (Paudel et al., 2020). Although drought severely compromises physical and physiological plant traits—such as relative water content and leaf water potential—using specific biochemical and physiological markers offers a rapid and efficient method for screening drought resilience. Consequently, evaluating different cultivars under controlled environments serves as a highly effective strategy for identifying the most robust drought-tolerant varieties (Salim et al., 2021).

Drought indices, which measure drought severity based on yield loss under drought conditions relative to normal conditions, have been used to screen drought-tolerant genotypes (Mitra, 2001). According to the results of Ghanem and Farouk (2024) found that different wheat cultivars respond to water scarcity uniquely, as measured by a range of physiological and yield stability indicators. These insights provide a valuable foundation for plant breeders looking to design programs that yield genetically superior, drought-tolerant wheat varieties suited for dry climates. Stomata are essential for managing water loss and carbon uptake, especially when plants face environmental stress (Yang et al., 2023). While plants naturally respond to drought and salinity by closing their stomata, gathering osmolytes, and producing antioxidants, these defenses become inadequate under combined stresses because the critical communication between the plant's roots and shoots gets disrupted (Hussain et al., 2021; Angon et al., 2022).

A plant's nutrient uptake behavior during environmental stress acts as a dual indicator, highlighting both the immediate physiological impacts and the plant's inherent capacity for adaptation and tolerance (Khan, 2025). Micronutrient combination (Zn, Fe, and B) application influence on photosynthesis and stomatal conductance has been shown to increase stomatal conductance, relative leaf water content, and photosynthetic rate under heat and moisture stress (Venugopalan et al., 2022). The results of Mustafa, (2025) showed that using a combination of micronutrients (Zn, Mn, B, Cu and Fe) at a concentration of 1 g l^{-1} by spray application significantly affected on water productivity, reaching (0.793) kg/m^3 compared to the control (0.543) kg/m^3. Ethylene, a gaseous plant hormone, influences the adaptive measures adopted by plants subjected to drought stress by regulating the drought stress-mediated signal transduction-associated responses (Nazir et al., 2024). Ethylene-focused studies point out that, depending on the species and degree of stress, exogenous ethylene or ACC can alter drought-induced stomatal responses and water relations, sometimes encouraging closure and water conservation and other times preserving conductivity (Hussain et al., 2020). Applying ethephon during periods of environmental stress significantly influences various vital physiological processes in agricultural crops. Research indicates that the exogenous application of ethylene boosts overall photosynthetic capacity by increasing stomatal conductance and enhancing Rubisco activity (Fatma et al., 2021). The aim of this study is effects of micronutrients and ethephon foliar application on water status, water productivity and drought tolerance indices of bread wheat varieties under water-stress in a greenhouse environment.

2. RESEARCH AND METHODOLOGY

This study was conducted under semi-controlled greenhouse conditions at the Gerdarasha research station in Erbil (36° 11′ 3″ N, 44° 1′ 48″ E; 415 m a.s.l.), affiliated with the Ministry of Agriculture and Water Resources, Kurdistan Region, Iraq. The experimental period spanned from December 1, 2024, to May 15, 2025. The experiment employed a Randomized Complete Block Design (RCBD) with three replicates, incorporating two water regimes (40–60% and 80–

100% field capacity). The study evaluated two primary factors: first, three bread wheat varieties (Hawler 4, IBA 99, and Jehan); and second, nine chemical treatments involving micronutrients (Zn, Mn, B, and Fe) and ethephon. These treatments included a control, individual applications of micronutrients (M1=1 g l^{-1} and M2=2 g l^{-1}) and ethephon (E1=500 mg l^{-1} and E2=1000 mg l^{-1}), and their respective combinations (M1E1, M1E2, M2E1, and M2E2). On December 1, 2024, seeds were sown in plastic pots (20 cm diameter, 24 cm depth) filled with 10 kg of dry sandy loam soil. Ten seeds were initially planted per pot and subsequently thinned to six plants following germination. The plants were allowed a 51-day establishment period, reaching the seedling stage (ZS15), before the initiation of water treatments. Two water regimes were imposed: 40–60% and 80–100% field capacity. Irrigation volumes were calculated using the gravimetric method as detailed in Table 1. Foliar applications of micronutrients and ethephon were administered as a single dose at the tillering stage (ZS25), with plants sprayed until runoff. Soil physicochemical properties are presented in Table 2. Analysis of the irrigation water indicated a pH of 7.73 and an electrical conductivity is 0.85 ds/m.

Table (1): Explains information about added water to two levels of field capacity of water in the pots.

Field capacity	**Weight of pot (kg)**	**Weight of soil (kg)**	**Water added liter**	**Total pot weight (kg)**	**Amount of water added per time/liter**	**Number of irrigation to flowering stage**	**Total weight of water added/ liter to the flowering stage**	**Number of irrigation to maturity stage**	**Total weigh t of water added/liter to the maturity stage**
40%	0.110	10	1.16	11.27	0.58	22	12.76	33	18.56
60%	0.110	10	1.7	11.85					
80%	0.110	10	2.32	12.43	0.58	33	19.14	48	28.71
100%	0.110	10	2.90	13.01					

Table (2): Some of soil physiochemical properties for Gerdarasha-Erbil locations.

Soil sample	**EC ds/m**	**pH**	**N %**	**P ppm**	**K ppm**	**O.M%**	**Classification USDA**			**So4%**	**$CaCO_3$**	**Zn%**	**Mn%**	**B%**	**Fe%**
							Clay	**silt**	**sand**						
Grdarasha field	0.73	7.7	0.0029	4.79	220	2.10	30.95	25.5	43.55	0.0318	14	0.000966	0.000224	0.0000702	0.0000173
							Clay loam								

Water Content Status:

Based on the method by Barrs (1968), cut leaves were first weighed to obtain their fresh weight (FW). After soaking in water for three hours, their fully saturated, or turgid, weight (TW) was recorded. The leaves were then oven-dried at 80°C for 24 hours to establish their dry weight (DW). Finally, in accordance with Lonbani and Arzani (2011), these FW, TW, and DW measurements were used to calculate three specific parameters:

Relative water content = (FW - DW)/(TW - DW) x 100

Initial water content = (FW - DW)/DW

Plant water content = FW - DW

Water productivity (WP):

Is a measure of crop yield in kilograms divided by the amount of water used or consumed in crop production in cubic meters (Heydari, 2014), according to the following equation:

Water productivity = $\frac{\text{Grain yield}}{\text{Water used}}$ (kg/m^3) .... (Chawla et al., 2023)

Drought Indicators:

These indicators were calculated according to the following equation:

1. Stress Susceptibility Index (SSI): [1 - (YS/YP)] / [1 - (Ys − Yp)] (Fischer & Maurer, 1978) where:

YS is the yield of the variety under stress at 40–60% of field capacity.

YP is the yield of the variety under irrigation at 80–100% of field capacity.

Ys is the average yield of all varieties under stress at 40–60% of field capacity.

Yp is the average yield of all varieties under irrigation at 80–100% of field capacity.

(YS/YP) is the severity of the stress.

The relative yield under water stress was calculated by dividing the yield of a specific genotype under stress by the yield of the highest-yielding genotype in the group.

2. Stress Susceptibility Index (SSI) = [1 - (YS / YP)] / [1 - (Ys / Yp)] (Fischer & Maurer, 1978)
3. Mean Productivity (MP) = YP + YS / 2 (Hussain et al., 1990)
4. Tolerance (TOL) = YP - YS (Hussain et al., 1990)

5. Yield Stability Index (YSI) = YS / YP (Bouslama & Chabaough, 1984)

6. Stress Tolerance Index (STI) = (YS) (YP) / $(Yp)^2$ (Fernandez, 1992)

7. Drought Sensitivity Index (SDI) = Yp - Ys / Yp (Farshadfar & Javadinia, 2011)

8. Drought Resistance Index (DRI) = Ys x (Ys/Yp) / $\bar{Y}$s (Lan, 1998)

3. DATA STATISTICAL ANALYSIS

According to Duncan's multiple range test (DMRT), differences in the application groups were analyzed with a significance value of $p \leq 0.01$. Statistical analyses were performed with Statistical Analysis System (SAS Institute, 2016) SAS v9 Standard Version package program and differences between control and application groups were analyzed by one-way ANOVA (AL-Rawi et al., 2011).

4. RESULTS AND DISCUSSIONS

The results showed that Relative Water Content (RWC) response differed depending on the situation. Under stress, Jehan's RWC decreased as usual (78.061% compared. 89.384%). Even though under stress, Hawler 4 and IBA 99 maintained high RWC values (82.173% and 80.070%, respectively), indicating effective osmotic adjustment or stomatal control mechanisms. Under stress, figure (1), both Plant Water Content and Initial Water Content were continuously decreased. IWC dropped from 7.506 g (80-100% FC) to 6.192 g (40-60% FC) for the Hawler 4 variety, figure (2 and 3). The combination of micronutrients 1 g l^{-1} with ethephon foliar applications 500 mg l^{-1} proved to be quite successful. Jehan variety showed a high plant water content response of micronutrient (Zn, Mn, B and Fe) at 2 g l^{-1} with ethephon foliar applications 500 mg l^{-1} under normal conditions (80-100% FC) (160.11 g) likely an outlier or fresh weight anomaly, but noting high water status. Under stress, Jehan variety with micronutrient (Zn, Mn, B and Fe) at 1 g l^{-1} and ethephon foliar applications 500 mg l^{-1} recorded a plant water content of 1.630 g, the highest among its stress treatments table (3).

The results confirm that water stress (40-60% FC) negatively impacts wheat physiology, reducing tissue water content and overall water productivity. However, the variety Hawler 4 exhibited a distinct (water-saver) strategy, effectively maintaining high relative water content and water productivity under drought. The adverse effects of stress were significantly mitigated by the application of growth enhancers and fertilizers, with the micronutrient (Zn, Mn, B and Fe) at 1 g l^{-1} and ethephon foliar applications 500 mg l^{-1} combination proving particularly effective. This treatment is presumed to enhance root efficiency or osmotic adjustment, thereby supporting higher turgor pressure and more efficient biomass production per unit of water used. The superior performance of Hawler 4 under the micronutrient at 1 g l^{-1} and ethephon 500 mg l^{-1} regime identifies this combination as an optimal strategy for cultivation in water-limited environments. The superior performance of combined micronutrient and ethephon treatments indicates synergistic interactions that help plants sustain higher tissue hydration and water-use efficiency under drought. These results align with prior studies showing enhanced relative water content and water-use efficiency in wheat treated with micronutrients and growth regulators during water limitation.

Water productivity is defined as a measure used to relate the yield to the amount of water used, whether rainwater or irrigation. It is a crucial indicator in sustainable agriculture and water resource management, especially in arid and semi-arid regions (Heydari, 2014). Spraying wheat leaves with ethephon at a concentration of 500 mg l^{-1} significantly improved water productivity at field capacity (40-60%), achieving 1.320 kg/m^3. The lowest significant rate was observed in the control group (without micronutrients and ethephon), at 1.145 kg/m^3. The Jihan variety significantly outperformed others, recording the highest average at 1.414 kg/m^3, while the lowest significant average was obtained by the IBA 99 variety (1.076 kg/m^3). This indicates that the Jihan variety is the most efficient in water utilization under stress conditions (drought-resistant) at field capacity level 40-60%. At 80-100% field capacity, the Hawler 4 variety significantly outperformed the Hawler 4 variety, recording the highest yield of 1.381 kg/m^3, while the IBA 99 variety recorded the lowest yield (1.265 kg/m^3). This indicates that Hawler 4 responds better to full irrigation for optimal yield, figure (4). This aligns with the findings of Mustafa (2025), who confirmed that water productivity varies among varieties. The most significant interaction was the application of micronutrient foliar spray (1 g l^{-1}) with Ethephon (500 mg l^{-1}) to the Jihan variety under stress conditions (40-60%), resulting in the highest water productivity value of 1.630 kg/m^3. Under optimal conditions (80-100%) of field capacity, the Ethephon (500 mg l^{-1}) treatment applied to the Hawler 4 variety resulted in the highest yield value of 1.507 kg/m^3. kg/m^3 table (3). The high-water productivity under field capacity (40-60%) in the Jihan variety indicates that it has a better ability to convert the limited amount of water into dry matter compared to other varieties, while the Hawler 4 variety benefits more from increased moisture in achieving higher production per unit of water.

Table (3): Effects of Micronutrients and Ethephon on Water Status, and productivity in Bread Wheat Varieties

Varieties x Fertilizer		Relative water content (%)	Initial water content (g)	Plant water content (g)	Water productivity ($kg.m^3$)	Relative water content (%)	Initial water content (g)	Plant water content (g)	Water productivity ($kg.m^3$)
		Field Capacity 40-60%				Field Capacity 80-100%			
Hawler 4	**Control**	79.560 e-g	6.036 c-e	0.846 c	1.050 g-j	79.70 c	7.311 c-e	1.826 ab	1.343 a-d
	M 1	75.787 ij	6.223 a-d	1.090 ab	1.130 f-j	82.70 c	7.537 a-d	1.900 a	1.417 a-d
	M 2	73.147 jk	6.373 abc	1.120 ab	1.037 h-j	72.18 c	7.719 abc	1.810 ab	1.326 a-d
	E 1	90.643 a	5.956 d-f	1.130 ab	1.203 c-j	76.64 c	7.210 d-f	1.960 a	1.507 a
	E 2	86.653 b	6.166 b-d	1.150 ab	1.249 c-i	72.83 c	7.465 b-e	1.870 ab	1.453 abc
	M 1 E 1	91.063 a	6.213 a-d	1.230 a	1.259 c-i	73.40 c	7.523 a-d	1.653 bc	1.420 a-d
	M 1 E 2	76.93 g-i	6.453 ab	1.210 a	1.134 e-j	71.80 c	7.812 ab	1.540 cd	1.394 abc
	M 2 E 1	90.510 a	5.810 e-g	1.100 ab	1.189 c-j	82.34 c	7.036 e-g	2.016 a	1.306 a-d
	M 2 E 2	75.287 ij	6.560 a	1.040 b	1.045 g-j	79.48 c	7.941 a	1.926 a	1.264 a-d
IBA 99	**Control**	71.080 k	5.233 i-k	0.440 d	1.066 g-j	65.28 c	6.337 i-k	1.310 de	1.239 a-d
	M 1	75.787 ij	5.120 i-k	0.460 d	1.125 f-j	61.63 c	6.201 i-k	1.280 e	1.416 a-d
	M 2	80.350 def	5.020 jk	0.430 d	1.022 h-j	68.04 c	6.075 jk	1.270 e	1.203 a-d
	E 1	81.330 c-f	5.210 i-k	0.510 d	1.445 e-j	81.506 c	6.312 ij	1.310 de	1.331 a-d
	E 2	76.217 hi	5.396 h-j	0.490 d	1.010 ij	76.91 c	6.539 h-j	1.320 de	1.097 d
	M 1 E 1	81.897 c-e	5.393 h-j	0.560 d	0.985 j	72.93 c	6.531 h-j	1.310 de	1.226 a-d
	M 1 E 2	86.730 b	5.030 jk	0.500 d	1.055 g-j	77.77 c	6.092 jk	1.350 de	1.226 a-d
	M 2 E 1	80.880 c-f	5.040 jk	0.470 d	1.105 f-j	72.50 c	6.103 jk	1.233 e	1.285 a-d
	M 2 E 2	86.363 b	4.976 k	0.460 d	1.171d-j	76.91 c	6.024 k	1.320 de	1.361 a-d
Jehan	**Control**	76.637 hi	5.476 g-i	0.520 d	1.320 c-f	78.05 c	6.635 g-i	1.300 de	1.221 a-d
	M 1	73.080 jk	5.663 f-h	0.550 d	1.290 c-g	82.05 c	6.859 f-h	1.280 e	1.159 b-d
	M 2	78.787 f-h	5.373 h-j	0.520 d	1.404 bcd	78.18 c	6.507 h-j	1.290 de	1.129 cd
	E 1	83.440 c	5.216 i-k	0.530 d	1.613 ab	75.14 c	6.317 i-k	1.300 de	1.321 a-d
	E 2	76.970 g-i	5.233 i-k	0.490 d	1.398 b-d	72.25 c	6.336 i-k	1.300 de	1.437 abc
	M 1 E 1	77.640 g-i	5.133 i-k	0.470 d	1.630 a	120.17 b	6.216 i-k	1.303 de	1.465 ab
	M 1 E 2	77.087 g-i	5.146 i-k	0.460 d	1.377 c-e	66.98 c	6.232 i-k	1.210 e	1.350 a-d
	M 2 E 1	75.93 i	5.256 i-k	0.480 d	1.423 abc	160.11 a	6.368 i-k	1.293 de	1.351 a-d
	M 2 E 2	83.007 cd	5.110 i-k	0.490 d	1.270 c-h	71.51 c	6.188 i-k	1.230 e	1.215 a-d

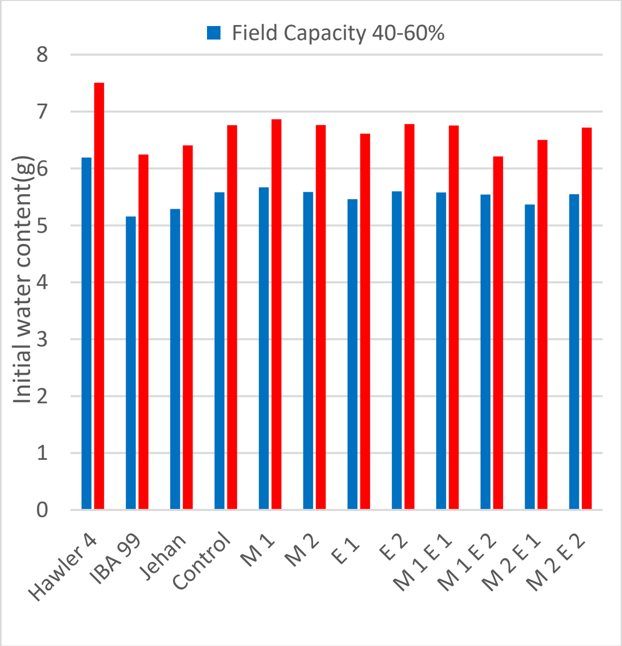

Figure 1: Effect of micronutrient, ethephon applications and bread wheat varieties on relative water content (%) under water stress.

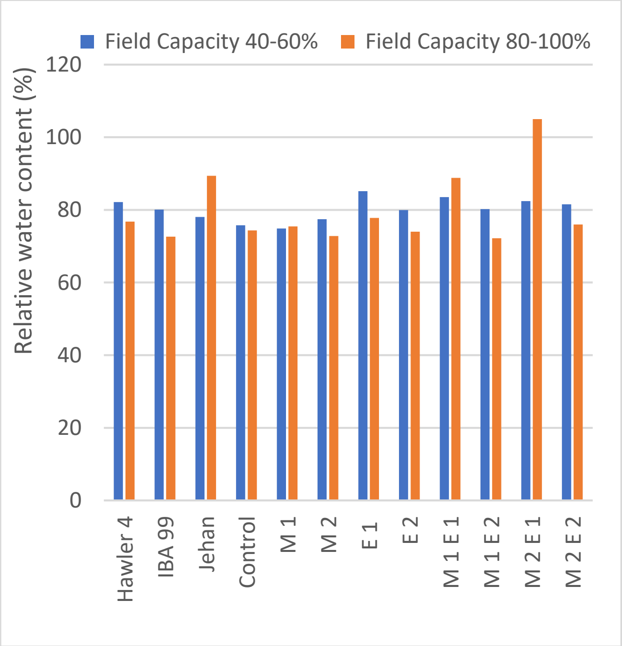

Figure 2: Effect of micronutrient, ethephon applications and bread wheat varieties on initial water content(g) under water stress.

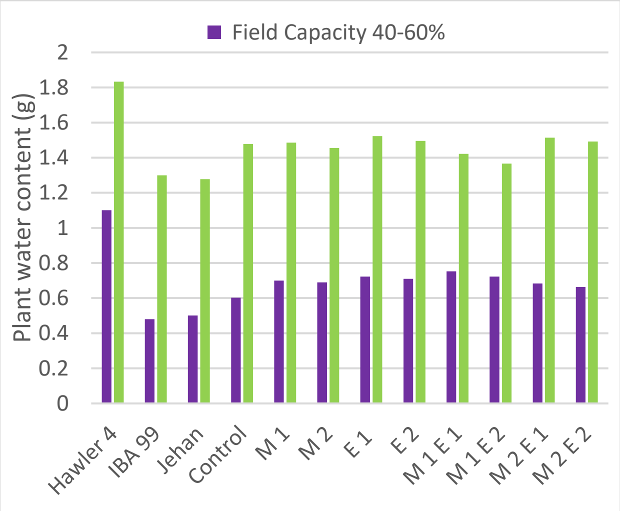

Figure 3: Effect of micronutrient, ethephon applications and bread wheat varieties on plant water content (g) under water stress.

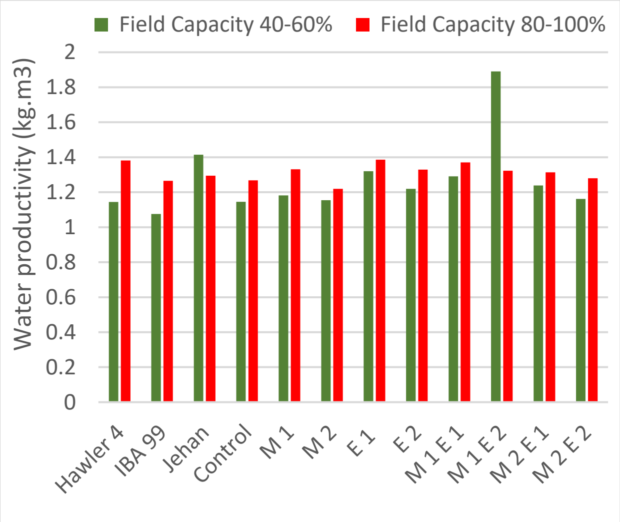

Figure 4: Effect of micronutrient, ethephon applications and bread wheat varieties on water productivity (kg.m3) under water stress.

Drought indices are an effective tool for screening resistant genotypes, as their evaluation relies on calculating the reduction in yield under stress conditions compared to normal conditions (Mitra 2001). The data in table (4) showed significant differences between the cultivated wheat varieties (Hawler 4, IBA 99, and Jihan) in their response to drought stress, based on various tolerance and resistance indices at a probability level of 5%. The results showed that the Jihan variety significantly outperformed the other varieties in all positive efficiency and tolerance indices (MP, YSI, DRI, and STI). Regarding the productivity rate (MP), the Jehan variety achieved the highest productivity rate of 7.496, significantly outperforming the IBA 99 variety, which had the lowest productivity rate of (6.558). The Jehan variety also recorded the highest in (STI) Stress Tolerance Index (0.747), (DRI) Drought Resistance Index (1.52), and Production Stability Index (YSI) (0.901), reflecting its high ability to maintain high productivity under stress conditions compared to other varieties. These results are consistent with those of Farshadfar (2000), Golabadi et al., (2006), and Mehraban et al. (2018), who found that varieties with the highest values of MP, YSI, DRI, and STI exhibited high productivity under drought conditions, while those with lower values showed lower productivity. As noted in the table, other indicators such as the Drought Sensitivity Index (SDI) and the Stress Susceptibility Index (SSI) were also observed. The Jehan variety exhibited the lowest values in both drought sensitivity (0.098) and stress susceptibility (0.330), confirming its low resistance to water scarcity. Conversely, the IBA 99 variety showed the highest sensitivity and stress susceptibility (0.316 and 1.066, respectively), indicating its vulnerability to drought. These findings align with Drikvand et al. (2012), who asserted that varieties with lower SSI values can be relied upon for cultivation in rain-dependent regions due to their tolerance. For drought.

Regarding the indicators where lower values are indicative of efficiency (the lower the value, the greater the resistance), the Jehan variety exhibited outstanding behavior. Similarly, for tolerance to stress (TOL), the lowest value (the most stable) was for the Jehan variety (0.773), while this value increased significantly for the IBA 99 variety, reaching (2.660). This indicates a substantial yield gap for this variety when subjected to stress compared to normal irrigation conditions. These results are consistent with those of Golabadi et al. (2006), who found that selecting genotypes based on TOL values enhances yield in stress-free environments but negatively impacts yield under moisture-deficient conditions.

Table (4): Drought Indices for studied wheat varieties.

Varieties	Stress Susceptibility Index	Tolerance	Stress Tolerance Index	Drought Sensitivity Index	Mean Productivity	Yield Stability Index	Drought Resistance Index
Hawler 4	1.003 b	2.295 b	0.645 b	0.298 b	7.082 b	0.702 b	0.646 b
IBA 99	1.066 a	2.660 a	0.557 c	0.316 a	6.558 c	0.684 c	0.623 b
Jehan	0.330 c	0.773 c	0.747 a	0.098 c	7.496 a	0.901 a	1.52 a

Table (5) shows the simple correlation coefficients between drought tolerance and resistance indicators and productivity rate. The results showed highly significant correlations (negative and positive) between the studied indicators, reflecting the nature of the relationship between productivity and plant behavior under stress. The correlation between yield rate (MP) and tolerance indices showed a strong, positive correlation between MP and the stress tolerance index (STI), with a correlation coefficient of (r = 0.993**). This is consistent with Farshadfar and Sutka (2002) and Ahmed (2015), who found a strong relationship between MP and STI when using the correlation coefficient for drought indices in maize. Furthermore, yield rate (MP) was positively correlated with the drought resistance index (DRI) at a value of (r = 0.776*), confirming that high-yielding varieties possess good resistance mechanisms. Similarly, the relationship between sensitivity indices (SSI, SDI) and stability indices (YSI) was also examined. A positive correlation (r = 1.000**) was recorded between the drought sensitivity index (SDI) and the stress exposure index (SSI), indicating that both indices. They give the same classification for varieties in terms of sensitivity. In contrast, these two indices (SSI and SDI) were negatively correlated with the Yield Stability Index (YSI) at a value of (-1.000**). This confirms the inverse relationship: the higher the stress index, the lower the variety's stability and yield consistency. There is also an inverse and negative relationship between the Stress Susceptibility Index (SSI) and the Stress Tolerance Index (STI), with a negative correlation (r = -0.729**). This result is consistent with the findings of Boussen et al. (2010).

As for the Tolerance Index (TOL), although it is used to measure yield variation, the results showed a highly significant positive correlation between it and the Stress Susceptibility Index (SSI) at a value of (r = 0.989**). This result clearly indicates that selection to reduce the TOL value may not serve high productivity, because TOL was also strongly and positively correlated with MP (r = 0.989**), meaning that high-yielding varieties It tends to show a greater difference in yield when exposed to stress compared to irrigated conditions. Therefore, it is preferable not to rely solely on TOL as a selection criterion in breeding programs for drought tolerance. Nasir ud-Din et al. (1992) confirmed that a negative correlation coefficient between MP and TOL indicates high productivity, while a positive correlation does not favor productivity under drought conditions.

Similarly, the Drought Resistance Index (DRI) exhibits highly significant negative correlations with sensitivity indices; it correlated with the SSI at (-0.983**) and with the SDI at (-0.984**). This confirms the effectiveness of the DRI in distinguishing between resistant and sensitive varieties, as higher DRI values are associated with lower stress sensitivity.

Table (5): Correlation coefficient for drought indices.

	Stress Susceptibility Index	Tolerance	Stress Tolerance Index	Drought Sensitivity Index	Mean Productivity	Yield Stability Index	Drought Resistance Index
Stress Susceptibility Index	1						
Tolerance	0.989 **	1					
Stress Tolerance Index	- 0.729 *	- 0.626	1				
Drought Sensitivity Index	1.000 **	0.989 **	- 0.731 *	1			
Mean Productivity	- 0.649	- 0.534	0.993 **	- 0.651	1		
Yield Stability Index	- 1.000 **	- 0.989 **	0.731 *	- 1.000 **	0.651	1	
Yield Stability Index	- 0.983**	- 0.948**	0.841 **	- 0.984 **	0.776 *	0.984 **	1

5. CONCLUSIONS

Water stress (40–60% field capacity) significantly impaired wheat physiological traits, reducing relative water content, plant water status, and water productivity across all tested varieties. Foliar application of micronutrients (Zn, Mn, B, and Fe), particularly at 1 g l^{-1}, effectively alleviated these negative effects by improving stomatal characteristics and tissue hydration under drought conditions. Ethephon combined application with micronutrients, especially micronutrients at 1 g l^{-1} with ethephon at 500 mg l^{-1}, markedly enhanced relative water content and water productivity under water stress. Varietal differences were evident, with Hawler 4 exhibiting a pronounced water-saving strategy by maintaining higher water status and productivity under stress, while Jehan showed superior drought tolerance based on drought indices (SSI, STI, YSI, and TOL).

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