Synergistic Impact of Micronutrient and Ethephon Applications on Physiological and Biochemical Traits of Bread Wheat Varieties under Water Stress

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Abstract

The experiment was conducted during the winter season 2024-2025 in a greenhouse (Semi-closed or semi-controlled) in the field of (Gerdarasha-Erbil), to study the synergistic impact of micronutrient and ethephon application on physio-chemical traits of bread wheat varieties under water stress. Using a randomized complete block design (RCBD) with three replicates. The first factor represented (9) nine combinations of micronutrients (Zn, Mn, B, and Fe) and ethephon (480 g/liter), and the second factor represented three bread wheat Varieties (Hawler 4, IBA 99, and Jehan). Micronutrient combination and ethephon applications have a significant effect on physiological and biochemical traits of three bread wheat varieties under two field capacity 40-60% and 80-100%. From field capacity 80-100%, the highest leaf area, dry matter and crop growth rate recorded in Hawler4 variety with micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1}, and Jehan variety given the highest contents of total chlorophyll and carotene when applied combination of micronutrient 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1}, despite of the maximum amount of (APX) and (SOD) was recorded from Hawler4 variety with ethephon foliar applications by (500 mg L^{-1}). But from field capacity 40-60%, micronutrient combined 1 g L^{-1} with ethephon 500 mg L^{-1} and Jihan variety recorded the highest leaf area, crop growth rate, dry matter, total chlorophyll, carotene content, and catalase (CAT), but the highest value of SOD and APX was given with ethephon (1000 mg L^{-1}).

Keywords: Micronutrient, ethephon, wheat, varieties and water stress.

Introduction

Wheat is one of the most important cereal crops and a staple food worldwide, and increasing its productivity requires balanced nutrient management. There are various methods for applying these nutrients, such as seed treatment and soil application, but foliar application is considered the most effective. Micronutrients have significantly improved a variety of wheat growth indicators, including the leaf area index (LAI), leaf area duration, crop growth rate (CGR), chlorophyll content. The use of micronutrients has also enhanced wheat productivity and quality, contributing to improved nutritional value, positively impacting human and animal health, and helping address challenges related to global food security [26]. Microelements play essential roles in biochemical, physiological, chemical, metabolic, and cellular functions, as well as enzymatic processes. Zinc (Zn) contributes to nitrogen metabolism in plants, accumulating amino acids and amides and promoting protein synthesis in plants [29]. As a constituent of numerous enzymes and proteins, iron (Fe) is fundamental to plant growth. Its functions are multifaceted, including facilitating energy transfer, supporting the structural formation of root cells, and enabling nitrogen fixation. Critically, iron also activates enzymatic reactions essential for photosynthesis and respiration [4]. A key function of the micronutrient manganese (Mn) is to enable the splitting of water molecules (photolysis) in photosystem II. This provides the necessary electrons to start the electron transport system and is a critical step in releasing oxygen during photosynthesis [15]. [30] found that applying micronutrients enhanced wheat plant growth by boosting photosynthesis and other physiological functions. A boron application rate of 2 kg ha^{-1} specifically increased the crop growth rate (CGR). The highest CGR values resulted from either the combined application of several micronutrients (Zn, Cu, Fe, Mn, and B) or the sole application of zinc. The authors attribute this improvement to boron's role in facilitating more efficient nutrient utilization, which leads to greater leaf area, enhanced photosynthetic activity, and increased accumulation of dry matter. The researcher [3] found in a study the effect of spraying microelements (Fe, Zn, Mn, Cu, B) on two varieties of bread wheat (Jihan - Adana) using different concentrations (zero, 500, 1000, 1500 mg L^{-1}), significant differences as the concentration (1500 mg L^{-1}) exceeded in the characteristics of vegetative growth as a leaf area.

Research indicates that plant growth regulators offer a method for reducing crop water consumption by suppressing the leaf area index and crop growth rate in the early growing season. This conservation of water can decrease the potential for drought impact during later, more vulnerable phases such as flowering and seed development [18]. The significance of this lies in the role of chlorophyll, a vital photosynthetic pigment. Chlorophyll is fundamental to photosynthesis and yield, as it is responsible for absorbing light energy and governs the plant's photosynthetic potential. [12]. Under conditions of limited water availability and drought stress, ethephon-treated drought-resistant plants demonstrated significantly lower water and osmotic potentials compared to untreated counterparts. Despite ethephon also increases plant tolerance to salinity and reduces heavy metal toxicity by increasing photosynthetic efficiency, increasing the activity of antioxidant enzymes, increasing proline production, regulating water balance within the plant, improving root volume, and increasing the ability of leaves to retain water. It also improves water use efficiency, especially during the flowering stage [24, 21, 40]. Researchers [8] conducted spraying of ethephon on the growth and productivity of wheat at four concentrations of ethephon (0, 0.300, 0.600 and 0.900 kg ha^{-1}) the results showed that the 0.900 kg ha^{-1} level was superior in the number of tillers m^2 and flag leaf area, compared to the control treatment, while the highest plant height and the highest lodging index percentage were recorded when no ethephon concentration was used (the control). Ethephon treatment affects ethylene synthesis, initiates drought defense reactions, and causes changes in

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antioxidant enzyme activity, which is also associated with the development of drought tolerance in plants. Foreign studies have shown that treatment with ethephon solution in spinach, but at low concentrations (1 mM), can increase enzyme activity. These changes are expected to be regulated by CAT enzyme activity [32]. The capacity for drought tolerance is a multifaceted attribute determined by a confluence of genetic, physiological, and environmental factors. Studies reveal that bread wheat genotypes exhibit substantial genetic variability in their adaptation to drought stress, underscoring the potential for targeted breeding programs to develop more resilient varieties [2]. In arid and semi-arid regions with limited water availability, abiotic stresses are the primary constraints on crop yield [10]. Among these, drought is a major stressor that significantly limits agricultural production. To cope with drought conditions, crops activate a range of adaptive morpho-physiological, biochemical, and molecular responses. [1]. The aim of this study is synergistic impact of micronutrient and ethephon applications on physiological traits of bread wheat varieties under water stress.

Material and Methods

The experiment was conducted during the period between the 1st of December 2024 to 15th of May 2025 in a greenhouse (Semi-closed or semi-controlled) in the field of (Gerdarasha-Erbil) (36° 11’ 3" N and 44° 1’ 48" Elevation 415m above sea level) affiliated with the Ministry of Agriculture and Water Resources - Kurdistan Region of Iraq. There were two water regimes: 40-60% and 80-100% field capacity. Treatments were arranged in a randomized complete block design (RCBD) with three replicates. The first factor represented (9) nine combination of micronutrients (Zn, Mn, B and Fe) and ethephon (480 g L); Control, M1=(Zn, Mn, B and Fe) 1 g L^{-1}, M2= (Zn, Mn, B and Fe) 2 g L^{-1}, E1= ethephon 500 mg L^{-1}, E2= ethephon 1000 mg L^{-1}, M1E1= (Zn, Mn, B and Fe) 1 g L^{-1} with E1= ethephon 500 mg L^{-1}, M1E2= (Zn, Mn, B and Fe) 1 g L^{-1} with E2= ethephon 1000 mg L^{-1}, M2E1= (Zn, Mn, B and Fe) 2 g L^{-1} with E1= ethephon 500 mg L^{-1} and M2E2= (Zn, Mn, B and Fe) 2 g L^{-1} with E2= ethephon 1000 mg L^{-1}, the second factor represented the use of three bread wheat cultivars (Hawler 4, IBA 99 and Jehan). Seeds were sown at the date (1/12/2024) in plastic pots of uniform size (20 cm diameter and 24 cm depth) containing 10 kg dry sandy loam soil. In each pot, 10 seeds were sown. After germination, the plants were thinned to maintain 6 plants per pot, the plants were allowed to establish for 51 days in the seedling stage ZGS:15 before the onset of various water regimes 40-60% and 80-100% field capacity. The gravimetric method was used to determine the amount of water required to be added to pots based on the field capacity used in the experiment, 40-60% and 80-100% as shown in Table (1). Wheat leaves were sprayed by micronutrient and ethephon with a single dose at the tillering stage (ZGS:25) until completely wet, according to the treatments and combinations used in the experiment. Some soil physiochemical properties for soil elucidated in table (2). Physiochemical properties for irrigation water for

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Gerdarasha-Erbil location the pH is 7.73 and the electrical conductivity is 0.85 dsm.

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

100	80	60	40	Field capacity
0.11	0.11	0.11	0.11	Weight of pot (kg)
10	10	10	10	Weight of soil (kg)
2.9	2.32	1.7	1.16	Water added liter
13.01	12.43	11.85	11.27	Total pot weight (kg)
0.58		0.58		Amount of water added per time/liter
33		22		Number of irrigations to flowering stage
19.14		12.76		Total weight of water added/liter to the flowering stage
48		33		Number of irrigations to maturity stage
28.71		18.56		Total weight of water added/liter to the maturity stage

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

Value	Physiochemical Property
0.73	EC ds/m
7.7	pH
0.0029	N %
4.79	P ppm
220	K ppm
2.1	O.M%
30.95	Clay %
25.5	Silt %
43.55	Sand %
Clay loam	Texture Class
0.0318	So4%
14	$CaCO_3$
0.000966	Zn%
0.000224	Mn%
0.0000702	B%
0.0000173	Fe%

Physiological parameters:

At the flowering stage, three plants were randomly selected from each pot to evaluate some physiological parameters; leaf area (cm^2) using the Viticanopy computer application [13], and dry matter (g plant) refers to the dry mass of the plant after 48 hours of drying at 80°C. Crop growth rate (g plant day^{-1}) is determined by dividing dry matter yield (g plant) at the

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flowering stage by the number of days from sowing to the flowering stage [27].

Crop Growth Rate: (CGR) = 1 /GA × (W2-W1)/ (T2- T 1)

DW (g): dry matter, T: time, W: weight, GA: ground area

Chlorophyll pigment (Mg g^{-1} Fw):

To determent chlorophyll pigment using (99% ethanol) at flowering (ZGS:65) stage, flag leaf was selected from each plant (Total chlorophyll, and Carotenoids) were measured by weight 0.5 g of fresh leaves being put in a dark bottle glass, then 10 ml of 99% ethanol were added to the dark bottle. Next, after 24 hours, 10 ml of 99% ethanol were added, while, after 48 hours, 10 ml of 99% ethanol were added. Finally, after 72 hours, the chlorophyll a, b, total, and carotene were calculated by spectrophotometer [11 and 25]

Total Chlorophyll = Chlorophyll a + Chlorophyll b

Carotenoids =4.2 E 452.5- 0.0264 Chl .a + 0.426 Chl .b

Were E equal optical density at the given wave length.

Antioxidant enzyme activities:

This assay employs a Sandwich ELISA methodology. The provided microplate is pre-coated with a capture antibody specific for Ascorbate Peroxidase (APX), Superoxide Dismutase (SOD), and Catalase (CAT). Standards or samples are added to the wells, allowing the target antigens to bind to the immobilized antibodies. Subsequently, a Horseradish Peroxidase (HRP)-conjugated detection antibody, specific for each enzyme, is added to form a complex. Any unbound components are then removed through a washing step. Following the wash step, TMB substrate solution is added to each well. A blue color will develop only in wells containing the target enzyme (APX, SOD, or CAT) bound to the HRP-conjugated antibody. The addition of a stop solution then changes the color from blue to yellow. The optical density (OD) of this yellow product is measured spectrophotometrically at 450 nm. Since the OD value is directly proportional to the concentration of the target enzyme, the concentrations of APX, SOD, and CAT in the samples can be determined by plotting their OD values against a standard curve [35, 36 and 37].

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 [34] SAS v9 Standard Version package program and differences between control and application groups were analyzed by one-way ANOVA [5].

Results

The effect of micronutrient combined (Zn, Mn, B and Fe) with ethephon foliar applications and bread wheat varieties on some physiological traits under water stress are shown in table (3), the highest leaf area (585.269 cm^2), dry matter (10.896 g $plant^{-1}$), and crop growth rate (0.072 g $plant^{-1}$ day^{-1}), recorded in Hawler4 variety from field capacity 80-100%, whereas the highest leaf area (416.060 cm^2), dry matter (7.285 g $plant^{-1}$), and crop growth rate (0.048 g $plant^{-1}$ day^{-1}), recorded in Jehan variety from field

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capacity 40-60%. From the combination of micronutrient (Zn, Mn, B and Fe) with ethephon foliar applications, the results are shows the highest leaf area (647.09 cm^2), dry matter (12.618 g $plant^{-1}$), and crop growth rate (0.084 g $plant^{-1}$ day^{-1}), recorded in micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1} when the planted at field capacity 80-100%, whereas the, but the highest leaf area (440.30 cm^2), dry matter (8.113 g $plant^{-1}$), and crop growth rate (0.054 g $plant^{-1}$ day^{-1}), recorded when applied ethephon by 500 mg L^{-1} from field capacity 40-60%. Despite the highest total chlorophyll (23.017 Mg g^{-1} Fwt) retrieved from IBA99 variety, but the highest carotene content (6.170 Mg g^{-1} Fwt) retrieved from Jehan variety from field capacity 80-100%, and total chlorophyll and carotene content (19.360 and 7.411 Mg g^{-1} Fwt) respectively recorded in Jehan variety from field capacity 40-60%. The highest total chlorophyll content (25.337 Mg g^{-1} Fwt) recorded in micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} , and the carotene content (6.655 and 7.993 Mg g^{-1} Fwt) recorded in micronutrient combined (Zn, Mn, B and Fe) 2 g L^{-1} with ethephon foliar applications 1000 mg L^{-1} at both field capacities 80-100% and 40-60% respectively.

Table (4) displayed a wide variation between treatments from the interaction between micronutrient combined (Zn, Mn, B and Fe) with ethephon foliar applications and bread wheat varieties on some physiological traits under field capacities 40-60% and 80-100%; highest leaf area, dry matter, crop growth rate (748.53 cm^2), (14.710 g $plant^{-1}$), (0.097 g $plant^{-1}$ day^{-1}), respectively, recorded in Hawler4 variety with micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1} when the planted at field capacity 80-100%, whereas the highest leaf area (8.050 cm^2), was recorded from interaction between micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} and Jehan variety, while the highest dry matter (9.233 g $plant^{-1}$), and crop growth rate (0.061 g $plant^{-1}$ day^{-1}) was obtained from interaction between micronutrient combined (Zn, Mn, B and Fe) 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} when the planted IBA 99 variety at field capacity 40-60%. From the interaction Jehan variety given the highest contents of total chlorophyll and carotene (26.038 and 7.333 Mg g^{-1} Fwt), respectively, when applied combination of micronutrient 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1}, However, Jehan variety outperformed the other varieties at field capacity 40-60% in total chlorophyll and carotene content (22.090 and 8.808 Mg g^{-1} Fwt), respectively, when applying a micronutrient combination 1 g L^{-1} with foliar applications of 500 mg L^{-1} ethephon.

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Table (3): Effect of micronutrient and ethephon application on some biochemical traits, chlorophyll and carotene pigment of bread wheat varieties under water stress

Table (4): Effect of interaction between micronutrient and ethephon application on some

C G R g plant^{-1} day^{-1}	Dry matter g plant^{-1}	Leaf area (cm^2)	Carotene (mg.g^{-1} F.wt)	T. Chl. (mg.g^{-1} F.wt)	C G R g plant^{-1} day^{-1}	Dry matter g plant^{-1}	Leaf area (cm^2)	Carotene (mg.g^{-1} F.wt)	T. Chl. (mg.g^{-1} F.wt)	Treatment
Field Capacity 80-100%					**Field Capacity 40-60%**					**Varieties**
0.072 a	10.896 a	585.269 a	5.421 b	21.834 c	0.040 b	6.041 b	369.865 b	6.512 b	17.771 c	**Hawler 4**
0.070 a	10.597 a	532.224 b	5.451 b	23.017 a	0.045 a	6.835 a	366.010 b	5.563 b	18.525 b	**IBA 99**
0.060 b	9.086 b	453.105 c	6.170 a	22.302 b	0.048 a	7.285 a	416.060 a	7.411 a	19.360 a	**Jehan**
										Fertilizer
0.067 b	10.063 b	496.97 ed	4.688 g	17.759 f	0.041 de	6.160 de	324.77 d	5.631 g	14.784 f	**Control**
0.084 a	12.618 a	647.09 a	4.644 g	19.831 e	0.047 bc	7.104 bc	373.80 c	5.578 g	16.408 e	**M 1**
0.069 b	10.377 b	515.59 cd	5.077 f	21.256 d	0.044 cd	6.682 cd	303.43 d	6.098 f	17.230 cd	**M 2**
0.066 b	9.987 b	939.43 c	5.411 e	22.225 c	0.054 a	8.113 a	440.30 a	6.499 e	19.285 bc	**E 1**
0.060 cd	9.037 cd	462.48 f	5.833 d	23.820 b	0.050 ab	7.63 ab	406.31 b	7.006 d	19.237 bc	**E 2**
0.084 a	12.633 a	595.30 b	6.441 b	25.337 a	0.052 a	7.922 a	445.12 a	7.736 b	20.410 a	**M 1 E 1**
0.065 bc	9.787 bc	507.66 d	6.044 c	24.521 a	0.039 def	5.94 def	399.49 b	7.306 c	20.950 a	**M 1 E 2**
0.058 d	8.757 d	477.86 ef	6.335 b	23.620 b	0.037 ef	5.655 ef	374.88 c	7.609 b	19.770 b	**M 2 E 1**
0.056 d	8.476 d	469.42 f	6.655 a	22.691 c	0.035 f	5.263 f	387.70 bc	7.993 a	18.896 c	**M 2 E 2**

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biochemical traits, chlorophyll and carotene pigment of bread wheat varieties under water stress

C G R g plant^{-1} day^{-1}	Dry matter g plant^{-1}	Leaf area (cm^{2})	Carotene (mg.g^{-1} F.wt)	T. Chl. (mg.g^{-1} F.wt)	C G R g plant^{-1} day^{-1}	Dry matter g plant^{-1}	Leaf area (cm^{2})	Carotene (mg.g^{-1} F.wt)	T. Chl. (mg.g^{-1} F.wt)	Varieties x Fertilizer	
Field Capacity 80-100%					Field Capacity 40-60%						
0.077 bc	11.546 bc	538.28 ef	4.466 kl	17.637 ij	0.038 f-k	5.760 f-j	286.45 k	5.365 kl	14.596 op	**Control**	**Hawler 4**
0.097 a	14.710 a	748.53 a	4.333 l	20.027 gh	0.041 d-k	6.226 d-j	365.01 g-i	5.205 l	16.576 k-m	**M 1**	
0.071 c-f	10.653 c-g	585.18 c-e	4.733 jk	21.301 fg	0.041 d-k	6.166 d-j	301.01 i-k	5.685 jk	16.200 l-n	**M 2**	
0.072 b-e	10.913 b-f	579.58 c-e	5.400 gh	20.588 gh	0.049 cde	7.433 c-e	416.07 c-e	6.486 gh	18.470 gh	**E 1**	
0.061 e-k	9.180 f-k	554.62 d-f	5.666 fg	23.194 de	0.050 b-d	7.633 b-d	411.47 d-f	6.806 fg	18.223 g-i	**E 2**	
0.075 b-d	11.283 b-d	621.21 bc	6.223 e	24.299 b-d	0.043 d-i	6.483 d-h	408.54 d-g	7.475 e	19.093 fg	**M 1 E 1**	
0.072 b-e	10.890 b-f	539.59 ef	6.666 e	25.636 ab	0.032 jk	4.906 ij	392.58 e-h	7.647 de	20.216 c-e	**M 1 E 2**	
0.065 c-h	9.840 c-i	530.58 fg	5.340 g-i	23.326 de	0.032 jk	4.913 ij	391.59 e-h	6.414 g-i	19.303 e-g	**M 2 E 1**	
0.060 f-k	9.050 g-k	569.84 d-f	6.266 e	20.500 g	0.032 k	4.853 j	356.06 hi	7.527 e	17.263 i-l	**M 2 E 2**	
0.061 e-k	9.260 f-k	526.25 fg	4.600 kl	18.462 ij	0.037 h-k	5.555 g-j	348.58 hi	5.525 kl	15.273 n-o	**Control**	**IBA 99**
0.083 b	12.426 b	645.60 b	4.433 kl	20.608 fg	0.046 c-h	6.953 c-g	373.19 e-i	5.325 l	17.050 j-l	**M 1**	
0.076 bc	11.403 b-d	489.70 gh	5.133 hi	22.146 ef	0.046 c-h	6.930 c-g	267.31 k	6.166 hi	17.573 h-k	**M 2**	
0.065 c-i	9.750 d-i	571.48 d-f	5.200 hi	23.050 de	0.053 a-c	8.056 a-c	439.98 b-d	6.246 hi	19.011 e-g	**E 1**	

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0.063 d-i	9.473 e-j	478.17 hi	5.600 fg	23.730 c-e	0.047 c-h	7.90 c-f	369.71 f-i	6.726 fg	18.640 f-h	**E 2**	
0.103 a	15.403 a	600.22 cd	5.766 f	25.676 ab	0.061 a	9.233 a	416.21 c-e	6.926 f	20.596 b-d	**M 1 E 1**	
0.069 c-g	10.413 c-g	545.03 ef	5.233 hi	25.211 a-c	0.042 d-j	6.386 d-i	344.05 i	6.426 g-i	20.543 b-d	**M 1 E 2**	
0.057 h-k	8.523 i-k	493.16 gh	6.400 ed	23.778 c-e	0.040 e-k	6.040 e-j	384.49 e-i	7.678 de	19.700 d-f	**M 2 E 1**	
0.058 g-k	8.723 h-k	440.40 i-k	6.700 cd	24.453 a-d	0.035 i-k	5.283 h-j	350.57 hi	8.047 cd	18.243 g-i	**M 2 E 2**	
0.062 f-k	9.383 f-k	426.38 jk	5.000 ij	17.176 j	0.047 c-f	7.170 c-f	339.28 ij	6.005 ij	14.483 p	**Control**	
0.071 b-f	10.720 c-g	547.12 ef	5.166 hi	18.858 hi	0.054 a-c	8.133 a-c	383.20 e-i	6.206 hi	15.600 m-o	**M 1**	
0.060 f-k	9.076 g-k	471.89 h-j	5.666 gh	20.323 gh	0.046 c-h	6.95 c-g	341.97 ij	6.446 gh	17.916 g-i	**M 2**	
0.062 f-k	9.30 f-k	467.22 h-j	5.633 fg	23.036 de	0.059 ab	8.903 ab	464.85 b	6.766 fg	20.273 c-e	**E 1**	
0.056 h-k	8.460 i-k	354.65 l	6.233 e	24.536 a-d	0.054 a-c	8.166 a-c	437.75 b-d	7.486 e	20.850 bc	**E 2**	**Jehan**
0.074 b-d	11.2013 be	564.46 d-f	7.333 a	26.038 a	0.053 a-c	8.050 a-c	510.62 a	8.808 a	21.540 ab	**M 1 E 1**	
0.053 i-k	8.060 i-k	438.26 i-k	6.533 ed	23.916 cd	0.043 d-i	6.526 d-h	461.85 b	7.847 de	22.090 a	**M 1 E 2**	
0.052 jk	7.910 jk	409.85 k	7.266 ab	23.757 c-e	0.040 f-k	6.013 e-j	348.55 hi	8.728 ab	20.306 c-e	**M 2 E 1**	
0.051 k	7.656 k	398.02 k	7.000 bc	23.079 de	0.037 g-k	5.653 f-j	456.48 bc	8.407 bc	21.183 a-c	**M 2 E 2**	

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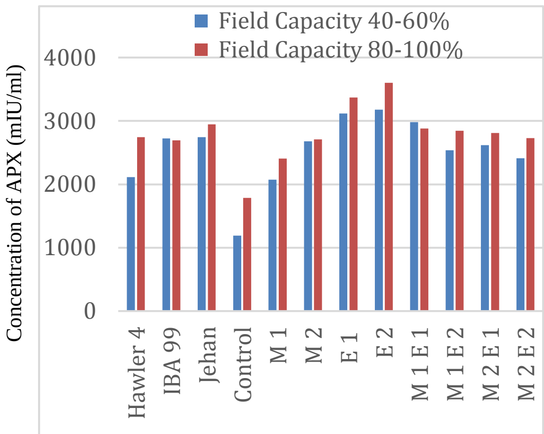
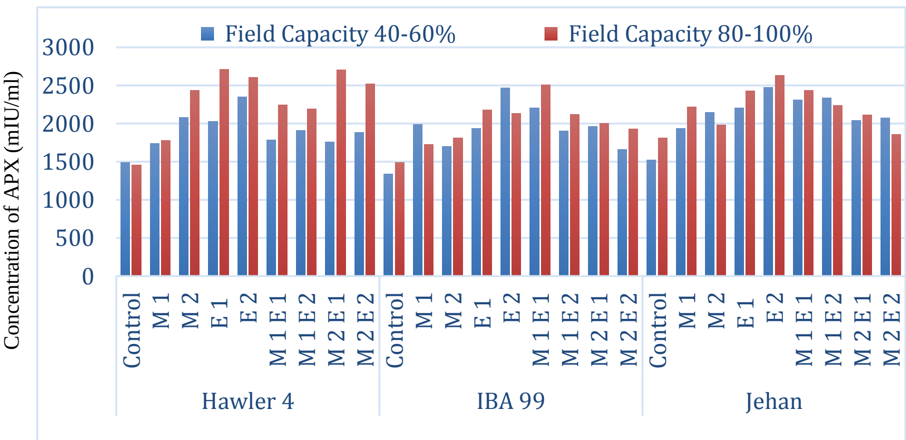
From Figures (1, 3 and 5); The combination of micronutrient (Zn, Mn, B and Fe) and ethephon foliar applications has significant affected on antioxidant enzyme activities as Ascorbate Peroxidase (APX) (mIU ml), Superoxide Dismutase (SOD) (pg ml) and Catalase (CAT) (ng ml) of bread wheat varieties under water stress, according on the table (6), the results demonstrated that Hawler4 variety superiority of other varieties on APX content (2297.182 mIU ml), but Jehan variety recorded the highest amount of SOD (2944.34 pg ml) and CAT (19.733 ng ml) at field capacity 80-100%. However, Jehan variety superiority of other varieties on APXm SOD and CAT content (2117.676 mIU ml, 2742.511 pg ml and 19.683 ng ml) respectively, when planted at 40-60% of field capacity.

Both antioxidants' enzyme activities, APX (mIU ml) and SOD (pg ml) achieved highest amount from applied ethephon foliar applications by (1000 mg L^{-1}) contain APX (2457.73 mIU ml) and (SOD) (3603.69 pg ml) at field capacity 80-100%, however APX (2432.316 mIU/ml) and (SOD) (3178.280 pg/ml) at field capacity 40-60%, while Catalase (CAT) (ng ml) given the highest amount when applied combination of micronutrient 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} reached (21.178 and 20.567 ng ml) at both field capacities 80-100% and 40-60% respectively, figures (1, 3 and 5).

The maximum amount of antioxidants' enzyme activities, ascorbate peroxidase (APX) (2711.26 mIU ml) and superoxide dismutase (SOD) (3816.92 pg ml) was recorded from flag leaf at flowering stage, when using interaction between Hawler4 variety with ethephon foliar applications by (500 mg L^{-1}) in the field capacity 80-100%, but catalase (CAT) antioxidant characterized by highest value from both field capacities 80-100% and 40-60% when applied interaction between micronutrient combined by 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} reached (23.993 and 23.733 ng/ml) respectively. As for field capacity 40-60%, the highest value of antioxidants' enzyme SOD and APX, was obtained when planting the Jihan variety in interaction with ethephon foliar applications by (1000 mg L^{-1}) contain APX 2473.180 mIU ml) and (SOD) (3484.473 pg ml), figures (2, 4 and 6)





Concentration of SOD (pg/ml)

Figure 1: APX enzyme activities contain

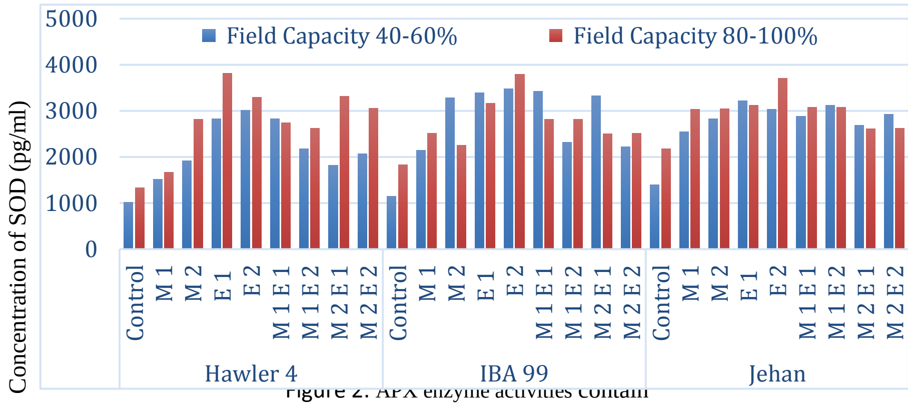


Figure 2: APX enzyme activities contain

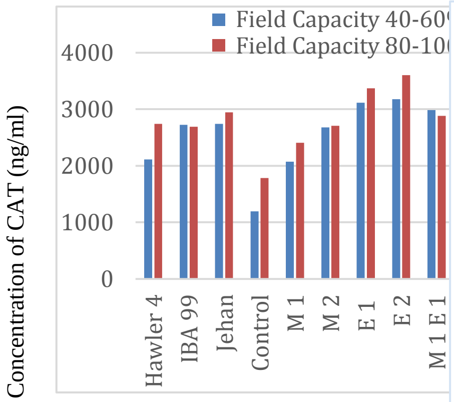


Figure 5: CAT enzyme activitie

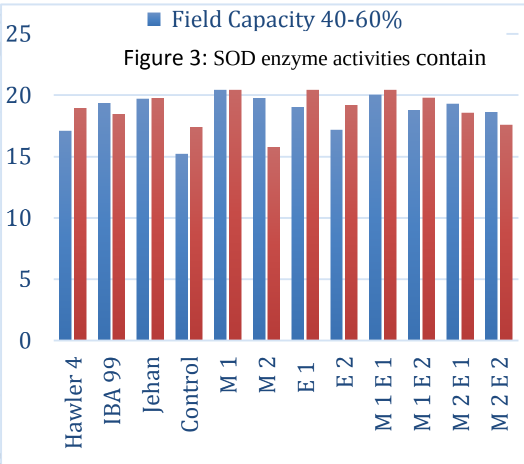


Figure 3: SOD enzyme activities contain

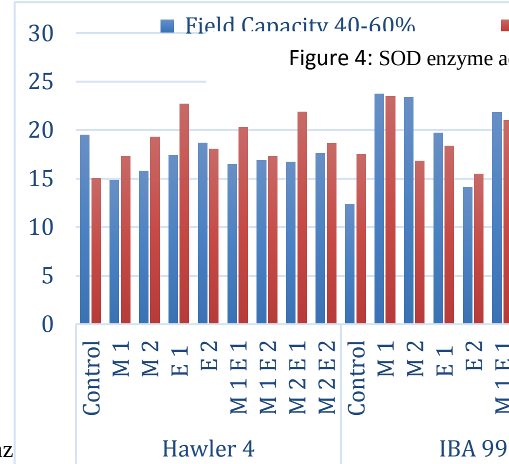


Figure 4: SOD enzyme a

Figure 5: CAT enzyme activities contain

Figure 6: CAT enzyme activities contain

Discussion:

The growth and development of crops are significantly impaired by drought stress, which triggers numerous abnormalities across morphological, physiological, biochemical, and molecular levels. The degree of impairment depends on the water stress's duration, the plant's growth stage, and its intensity [31]. From a physiological perspective, the application of micronutrient combinations has been shown to positively affect Crop Growth Rate (CGR) This is achieved by increasing the efficiency of photosynthesis and optimizing the distribution of biomass, even when plants are under stress.

Drought stress reduced the chlorophyll content, there were significant increases in chlorophyll content in drought tolerant genotypes compared to the non-tolerant genotypes when compared to the drought-sensitive wheat variety [33]. According to [16], the micronutrients zinc (Zn), boron (B), and manganese (Mn) are indispensable for the metabolism of rice and wheat, they contribute to several essential physiological functions, including the synthesis of chlorophyll, the process of photosynthesis, the activation of various enzymes, and the preservation of membrane integrity. The results indicate that the enzyme's activity in wheat is significantly enhanced by the addition of potassium (K), iron (Fe), zinc (Zn), and manganese (Mn), whether applied to the soil or as a foliar treatment, the underlying mechanism for this enhancement is the role these nutrients play in

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protein synthesis and enzyme activation, they function as carrier elements and induce structural changes to the enzyme's active site, thereby improving the binding affinity for its [7]. Studies show that combined applications of Zn and Fe can significantly enhance Total chlorophyll and total carotenoid content in wheat leaves indicated that Zinc and Iron play important role in improvement of quality, regulation of enzymatic process and the chlorophyll content [23]. Adequate hormonal balance confers a competitive edge for survival under diverse stress conditions. Zinc supplementation contributes to drought tolerance through a distinct pathway: it inhibits membrane-bound NADPH oxidase activity. This inhibition results in reduced synthesis of reactive oxygen species (ROS) and lessens photoxidation. Furthermore, the observed enhancement in SOD, POD, and CAT activities confirms that zinc plays a dual role in diminishing ROS generation and strengthening the plant's antioxidant defense system against oxidative damage during water stress [38].

The application of ethephon on various vegetable crops significantly decreased plant height while promoting the growth of lateral branches, this reduction in height occurs because ethephon releases ethylene, which exhibits anti-gibberellin properties. By suppressing gibberellin activity, ethylene inhibits cell elongation, leading to shorter plants [39]. Studies indicate that ethephon often reduces plant height by inhibiting cell elongation and internode growth, which may help divert resources toward stress defense mechanisms [22]. Ethephon application by 200 Mg L^{-1}under water stress maintains leaf moisture by improving root volume and dry weight of wheat crop [20]. Ethephon typically leads to a temporary decline in CGR (Crop Growth Rate) immediately after application, reflecting its growth-retardant properties, all of the measured traits (flag leaf area, chlorophyll content,) were significantly higher in the ethephon treatment, the efficacy of ethephon is due to the suppression of excessive stem growth, induction of carbohydrate accumulation, and improvement of partitioning of photosynthates to the grains [14]. The advantageous impact of ethephon can be attributed to its optimization of source-sink dynamics by expanding the flag leaf area and elevating chlorophyll concentration, ethephon augments photosynthetic efficiency and improves the transport of assimilates. consequently, this results in greater grain weight and enhanced wheat yield [6]. The observed improvement in photosynthesis following ethephon treatment is likely due to its positive effects on both carbohydrate metabolism and the antioxidant defense system, the role of chlorophyll pigments is critical to this process, as they are the primary molecules that absorb photons from light, thereby enabling the photosynthetic reactions to occur [17]. Ethephon has been shown to influence both photosynthetic pigments and photosynthetic rate under normal as well as under stress conditions, furthermore application of ethephon under stress condition is also known to improve photosynthesis and antioxidant defense system [28]. Foliar application of ethephon significantly enhances the antioxidant defense system in bread wheat under water stress. Ethephon, as an ethylene-releasing compound, acts as a priming agent that upregulates key antioxidant enzymes including SOD, CAT, POD and APX this coordinated response improves the plant's capacity to scavenge reactive oxygen species, thereby reducing oxidative damage and

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maintaining cellular integrity under drought conditions [22 and 9].The effect is dose- and genotype-dependent, with optimal concentrations enhancing enzyme activities, drought-tolerant varieties typically show a more pronounced beneficial response due to their inherently robust antioxidant systems [19].

Conclusions:

The study showed that combination of micronutrient with ethephon foliar application and bread wheat varieties had significant difference analysis under two field capacities 80-100% and 40-60%, for all trats measured of physiological parameters, chlorophyll pigment and antioxidant enzyme activities. Hawler4 variety response the highest plant height, leaf area, dry matter, crop growth rate, relative growth rate, net assimilation rate, (APX) and (SOD), and Jehan variety given the highest contents of chlorophyll -a, total chlorophyll and carotene when applied combination of micronutrient 1 g L^{-1} with ethephon foliar applications 500 mg L^{-1} from field capacity 80-100%. But from field capacity 40-60%, the highest leaf area, dry matter, CGR chlorophyll-a, total chlorophyll, carotene content, and catalase (CAT), was recorded in Jihan variety at micronutrient combined 1 g L^{-1} with ethephon 500 mg L^{-1}, however chlorophyll-b, SOD and APX was given with ethephon (1000 mg L^{-1}).

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