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# Effect of Water Stress and NPK Fertilization on Growth, Yield of Wheat and Water Use Efficiency

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***Abstract:*** *Water is the most important factor for plant growth while NPK fertilization plays an important role under deficit irrigation or under stress condition in arid and semi-arid regions. A field experiment in Randomize Complete Block Design with three replicates were carried out at two different locations in Iraq, the first was in Al – Qadisiya province and the second in Wasit province during winter season of 2015-2016 in clay loam and loam to study the effect of irrigation treatments (main plots): irrigation at 40% depletion of available water ($I_1$), irrigation at 60% depletion of available water ($I_2$), and irrigation at 80% depletion of available water ($I_3$), and NPK fertilizers treatments (as sub plot): 100kg N/ha+ 40 kg P/ha+ 80 kg K/ha ($F_1$), 150kg N/ha+ 60 kg P/ha+ 80 kg K/ha ($F_2$) and 200kg N/ha+ 80 kg P/ha+ 80 kg K/ha ($F_3$) on wheat plant growth, total yield and water use efficiency.* The water content of depletion water for 0-0.2m layer was calculated from planting to growth stage and increasing of irrigation water depth to include 0-0.4m during flowering and grain formation stages. All agricultural processes for crop management were used according to recommendation. Actual evapotranspiration was estimate using water balance equation. *The obtained results could be due irrigation at 40% depletion of available water and/or irrigation at 60% depletion of available water supplied sufficient soil moisture in the root zone which increased the capacity of wheat plant in photosynthesis and consequently increased flag leaf area, number of spikes $m^{-2}$ and plant height (cm). The results also showed that the application of NPK fertilizers significantly improved the all parameter growth, yield, water use efficiency of wheat, and the lowest yields and highest were associated with the 100kg N/ha+ 40 kg P/ha+ 80 kg K/ha ($F_1$) and 200kg N/ha+ 80 kg P/ha+ 80 kg K/ha ($F_3$), respectively while the level of fertilizers $F_3$ did not significant with $F_2$. The total amount of ETa was 471, 423 and 349 mm at 40, 60 and 80% depletion of available water, respectively in Al – Qadisiya location and 485, 435 and 333 mm at 40, 60 and 80% depletion of available water, respectively in Wasit location. Also the result shows high value of $WUE_f$ and $WUE_c$ at 60% depletion of available water ($I_2$) recorder 1.74 and 1.38 kg $m^{-3}$ in Al – Qadisiya location and 1.56 and 1.26 kg $m^{-3}$ in Wasit location,*

***Keywords:*** *water stress, wheat, NPK fertilizers, yield, water use efficiency*

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## I. Introduction

Water is a basic necessity for life and is fast becoming an economically scarce resource in many areas of the world especially in arid and semiarid regions. In plants, functions of water are manifold, such as maintenance of turgidity, uptake and translocation of nutrients and metabolites, sequestration of excessive salts and toxic material into vacuoles or out of tissue and serving as medium for all biochemical and bio-energy reactions [1]. Drought stress is one of the most important and effective factors in agricultural practices in arid and semi-arid regions of the worlds.

Water deficit affects every aspect of plant growth by modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of a crop [2], Moisture stress during spike emergence and an thesis has been reported to reduce grain yield up to 20% mainly through reduction of individual grain weight [3]. The meaning of WUE, as a comparative measure of plant productivity per unit of water used, depends on the unit with which productivity (photosynthesis or biomass accumulation) and WU (transpiration, evapotranspiration or precipitation/ irrigation) are expressed, at leaf, plant or canopy level [4].

Water use efficiency (WUE) is a physiological parameter of key importance, expressing the ability of the crop to preserve the water reserves of the soil, thus combining drought tolerance and high yield potential [5]. Numerous authors from various parts of the world have demonstrated substantial differences between the WUE values of individual winter wheat cultivars [6], but have also emphasised the fact that WUE values change if the water supplies to the crop are limited [7].

N and P fertilization is a common practice to increase grain production, but its performance depends on soil water status. The importance of increasing crop yield and improving soil quality through fertilization has been confirmed. The increasing use of N fertilizer could significantly increase wheat production**.** The increasing use of N and P fertilizer could significantly increase wheat production, and already affects a large proportion of the world's food production [8 and 9].

Wheat is planted on about 100 million hectares in the developing world, excluding the countries of Central Asia and the Caucasus. Wheat (*Triticum aestivum* L.) is a staple food for more than 35% of the world's population [10] and it is also one of the most important cereal crops in Iraq. However, few experiments have been done on evapotranspiration (ET) and WUE under circumstances with only N or / and P fertilizer and with water stress and Iraq conditions, The objectives were (1) to investigate impacts of traditional N and P fertilization on growth and yields of wheat and (2) to establish relationships among crop yield, WUE and ET and determine optimum N, P and K fertilizer rates in semi arid of Iraq.

## II. Material and Methods

Field experiments were carried out at two different locations in Iraq, the first was in Al – Qadisiya province and the second in Wasit province during winter season of 2015-2016 in clay loam and loam soil classified as *Typic Torriflovent* (as subgroup classification) at both locations, respectively. Soil samples were air dried ground and then sieved through 2 mm sieve. Soil samples then analyzed according to methods described in [11 and 12] for physical and chemical soil properties respectively. Results of analyses are shown in (Table 1). This study included following treatments:

1. Irrigation treatments (as main plot):

a. Irrigation at 40% depletion of available water ($I_1$).
b. Irrigation at 60% depletion of available water ($I_2$).
c. Irrigation at 80% depletion of available water ($I_3$).

2. NPK fertilizers treatments (as sub plot):

a. 100kg N/ha+ 40 kg P/ha+ 80 kg K/ha ($F_1$).
b. 150kg N/ha+ 60 kg P/ha+ 80 kg K/ha ($F_2$).
c. 200kg N/ha+ 80 kg P/ha+ 80 kg K/ha ($F_3$).

Planting took place on 22/12/2015 IPA 99 cultivar and 27/12/2015 Abu-Ghraib 3 cultivar for Al – Qadisiya and Wasit locations, respectively, in 0.25 m spaced rows with net plot size of 3 m × 5 m, in a randomized complete block design with three replicates. Each experimental unit included of 6 rows. All plots were irrigated with river water (ECi = 0.9 and 0.80 $dS.m^{-1}$ for Al–Qadisiya and the Wasit locations, respectively). Irrigation was scheduled when soil water content in the root zone was depleted by the crop to specific levels of available water. The soil depth of the effective root zone increased from 0.20 m at planting to 0.40 m in flowering and grain formation stages. Weeds were frequently controlled manually during crop growth and development stages. The amount of water consumed from the root zone between two successive irrigations as a water depth in cm, was calculated from the following equation [13]:

$$d = D \times P_b \times \frac{(Q_2 - Q_1)}{100} \dots\dots (1)$$

Where:
d = Depth of water added
D = irrigation root zone depth (cm)
$P_b$ = Bulk density of soil ($g.\ cm^{-3}$)
$Q_2$ = The percentage of soil moisture at field capacity
$Q_1$ = The percentage of soil moisture before irrigation

**Table 1:** Some chemical and physical soil properties

| Properties | Unit | Al – Qadisiya | Wasit |
|---|---|---|---|
| pH | --- | 7.21 | 7.22 |
| EC(1:1) | $dS\ m^{-1}$ | 4.3 | 3.3 |
| Organic matter | $gm\ kg^{-1}$ | 7.5 | 5.4 |
| $CaCO_3$ | | 210 | 221 |
| Available N | $mg\ kg^{-1}$ | 42 | 47 |
| Available P | | 25 | 28 |
| Available K | | 251 | 286 |
| Sand | $mg\ kg^{-1}$ | 404 | 350 |
| Silt | | 268 | 440 |
| Clay | | 328 | 210 |
| Texture | | Clay loam | Loam |
| Bulk density | $Mg\ m^{-3}$ | 1.41 | 1.30 |
| Water content at FC | $cm^3\ cm^{-3}$ | 0.35 | 0.39 |

| | | | |
|---|---|---|---|
| Water content at WP | | 0.13 | 0.123 |
| Available water | | 0.22 | 0.267 |

The amount of water consumed in each irrigation interval was obtained from the difference between soil content before the following irrigation and field capacity. Actual evapotranspiration was estimated according to the [13]:
ETa = R + I – D ± ΔW……. (2)
Where:
ETa= Evapotranspiration (mm) R = Rainfall (mm) I = Depth of irrigation (mm)
D = Depth of drainage (mm) ΔW = the change of soil water storage in the measured soil depth
Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored. Water use efficiency (crop and field) were calculated according to the following equation [13]:

$$WUE_c = \frac{Yield}{ET_a} \dots\dots..(3)$$

$$WUE_f = \frac{Yield}{Water\ applied} \dots\dots\dots(4)$$

Plant samples of one square meter from each plot were harvested and ten plants were taken randomly to determine yield attributes: flag leaf area, plant height, spike $m^{-2}$ and the grain yields calculated from one square meter then converted to kg $h^{-1}$. Harvest was done on May 15 and 18 / 2016 in Al – Qadisiya and the Wasit locations, respectively Data were analyzed using SAS [14] and differences among treatments tested according to LSD $_{0.05}$.

## III. Result and Discussion

Results presented in Table 2, 3 and 4 show that, irrigation of wheat plants at 40% depletion of available water (10 and 12 irrigations till harvest for Al – Qadisiya and Wasit locations, respectively) and at 60% depletion of available water (6 and 7 irrigations till harvest for Al – Qadisiya and Wasit locations, respectively) led to not significant between the treatments $I_1$ and $I_2$ but increase when compare with $I_3$ treatment, and gave the highest values of plant height (cm), number of spike $m^{-2}$ and flag leaf area ($cm^2$). The results also showed the application of NPK fertilizers significantly improved the plant height, number of spike and flag leaf area, recorders 96, 99 and 100 cm for Al – Qadisiya location and 97, 99 and 101 cm for Wasit location; 528, 546 and 560 spike $m^{-2}$ for Al – Qadisiya location and 552, 583 and 592 spike $m^{-2}$ for Wasit location; and 51.40, 54.05 and 56.70 $cm^2$ for Al – Qadisiya location and 45.23, 48.41 and 51.19 $cm^2$ for Wasit location. As shown in the combined analysis**,** the interaction effects between irrigation treatments and application of NPK fertilizers on plant height, number of spike and flag leaf area in Table 2, 3 and 4 were significant. As for interaction, the tallest plant height 106 and 104 cm for Al – Qadisiya location in $I_1F_3$ and $I_2F_3$, respectively; 107 and 104 cm for Wasit location in $I_1F_3$ and $I_2F_3$, respectively and 605 and 602 spike $m^{-2}$ for Al – Qadisiya location in $I_1F_3$ and $I_2F_3$, respectively and 638 and 635 spike $m^{-2}$ for Wasit location in $I_1F_3$ and $I_2F_3$, respectively, while flag leaf area recorder 60.22 and 60.73 $cm^2$ in Al – Qadisiya location and 54.45 and 55.34 $cm^2$ in Wasit location for $I_1F_3$ and $I_2F_3$, respectively.

**Table 2:** Wheat plant height (cm) as affected by the irrigation and NPK fertilizers treatments

| Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fertilizers treatment | Al – Qadisiya | | | | Wasit | | | |
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | Mean | $I_1$ | $I_2$ | $I_3$ | Mean |
| $F_1$ | 101 | 100 | 88 | 96 | 103 | 101 | 88 | 97 |
| $F_2$ | 104 | 102 | 91 | 99 | 106 | 103 | 90 | 100 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $F_3$ | 106 | 104 | 91 | 100 | 107 | 104 | 92 | 101 |
| LSD 0.05 Interaction | 2.96 | | | LSD 0.05 Fertilizers Treatments 2.93 | 2.98 | | | LSD 0.05 Fertilizers Treatments 2.91 |
| Mean Irrigation | 104 | 102 | 90 | | 106 | 103 | 90 | |
| LSD 0.05 Irrigation | 2.81 | | | | 3.3 | | | |

**Table 3:** Number of wheat spike $m^{-2}$ as affected by the irrigation and NPK fertilizers treatments

| Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fertilizers treatment | Al – Qadisiya | | | | Wasit | | | |
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | Mean | $I_1$ | $I_2$ | $I_3$ | Mean |
| $F_1$ | 590 | 586 | 408 | 528 | 623 | 620 | 413 | 552 |
| $F_2$ | 598 | 593 | 446 | 546 | 632 | 633 | 485 | 583 |
| $F_3$ | 605 | 602 | 473 | 560 | 638 | 635 | 504 | 592 |
| LSD 0.05 Interaction | 40.76 | | | LSD 0.05 Fertilizers Treatments 24.82 | 42.56 | | | LSD 0.05 Fertilizers Treatments 17.67 |
| Mean Irrigation | 598 | 594 | 442 | | 631 | 629 | 467 | |
| LSD 0.05 Irrigation | 33.54 | | | | 31.29 | | | |

**Table 4:** Flag leaf area ($cm^2$) of wheat as affected by the irrigation and NPK fertilizers treatments

| Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fertilizers treatment | Al – Qadisiya | | | | Wasit | | | |
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | Mean | $I_1$ | $I_2$ | $I_3$ | Mean |
| $F_1$ | 54.21 | 53.67 | 46.33 | 51.40 | 49.67 | 47.80 | 40.33 | 45.23 |
| $F_2$ | 57.56 | 57.31 | 47.28 | 54.05 | 51.29 | 51.15 | 42.80 | 48.41 |
| $F_3$ | 60.22 | 60.73 | 49.16 | 56.70 | 54.45 | 55.34 | 43.78 | 51.19 |
| LSD 0.05 Interaction | 3.24 | | | LSD 0.05 Fertilizers Treatments 2.81 | 4.64 | | | LSD 0.05 Fertilizers Treatments 2.84 |
| Mean Irrigation | 57.33 | 57.24 | 47.59 | | 51.80 | 51.76 | 42.30 | |
| LSD 0.05 Irrigation | 1.94 | | | | 1.35 | | | |

The obtained results could be due to irrigation of wheat plants at 40% depletion of available water ($I_1$) and/or 60% depletion of available water ($I_2$) supplied sufficient soil moisture in the root zone which increased the capacity of wheat plant in photosynthesis and consequently increased flag leaf area, plant height (cm) and number of spike $m^{-2}$. The previous results are in full agreement with those reported by [15] and [16]. Plant growth parameter promoting NPK fertilizers improved photosynthesis may be by increasing water and nutrients absorption leading to produce more assimilation and improve plant growth. Rainfall in this season was enough to bear plants to irrigation at 60% depletion of available.

Addition to the shortage of water may affect the division and elongation stem cells, as well as lower the density of the vegetation in $I_3$ treatment as a result of the small number of spike and lower leaf area. Also note a difference in number of spike $m^{-2}$ in both locations, Abu Ghraib cultivar gave the highest number of spike $m^{-2}$, and is due cultivars variation in the number of spike to genetic differ, since it is one of properties associated with the genetic composition [17].

Data illustrated in Table 5 showed the effect of irrigation treatments and the application of NPK fertilizers on the wheat grain yield (Ton $ha^{-1}$). The irrigation treatment at 40% depletion of available water ($I_1$) produced highest average grain yield 5.72 and 5.34 Ton $ha^{-1}$ for Al – Qadisiya and Wasit locations, respectively and didn't differ significantly from irrigation treatment at 60% depletion of available water ($I_2$) 5.52 and 5.28 Ton $ha^{-1}$ for Al – Qadisiya and Wasit locations, respectively. While the percentage reduced grain yield for the irrigation treatment at 80% depletion of available water ($I_3$) by 45.95, 41.34 % and 44.10, 40.69%, as compared to irrigation at 40% and 60% depletion of available water for Al – Qadisiya and Wasit locations, respectively.

**Table 5:** Wheat Grain yield (Ton $ha^{-1}$) as affected by the irrigation and NPK fertilizers treatments

| Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fertilizers treatment | Al – Qadisiya | | | | Wasit | | | |
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | Mean | $I_1$ | $I_2$ | $I_3$ | Mean |
| $F_1$ | 4.34 | 4.26 | 2.78 | 3.79 | 4.15 | 4.17 | 2.34 | 3.55 |
| $F_2$ | 5.99 | 5.86 | 3.22 | 5.02 | 5.54 | 5.56 | 3.46 | 4.85 |
| $F_3$ | 6.83 | 6.44 | 3.81 | 5.69 | 6.32 | 6.11 | 3.96 | 5.46 |
| LSD 0.05 Interaction | 0.84 | | | LSD 0.05 Fertilizers Treatments 0.69 | 0.86 | | | LSD 0.05 Fertilizers Treatments 0.77 |
| Mean Irrigation | 5.72 | 5.52 | 3.27 | | 5.34 | 5.28 | 3.25 | |
| LSD 0.05 Irrigation | 0.36 | | | | 0.32 | | | |

Grain yields ranged from 2.78 to 6.83 Ton $ha^{-1}$ in Al – Qadisiya location, and from 2.34 to 6.32 Ton $ha^{-1}$ in Wasit location. Generally, the lowest yields and highest were associated with the 100kg N/ha+ 40 kg P/ha+

80 kg K/ha ($F_1$) and 200kg N/ha+ 80 kg P/ha+ 80 kg K/ha ($F_3$), respectively and the level of fertilizers $F_3$ not significant with $F_2$. The Grain yields increased with increasing N and P fertilizer treatment. Thus, N and P application significantly increased yields of wheat, previous research has shown similar results with N fertilizer application significantly increasing maize and wheat yield compared to unfertilized treatments [18]. [19] Reported that inorganic (N) and phosphorus (P) fertilization increased grain yields by 50–60% in China, and reports from Europe showed that N fertilizers can increase crop yield significantly [20].

These findings suggest that the implementation of a strategically applied N fertilizer program is more complicated than defining a yield goal and measuring N credits. In addition to the impacts it can also increase the yield response per unit of N applied.

Mineral nutrients play an important role in increasing plant resistance to drought stress. Under regulated deficit irrigation, potassium fertilization increase crop tolerance to water stress by utilizing the soil moisture more efficiently than in K deficient plants. The increase in the stress tolerance by K fertilization may be due to promotion of root growth associated with more nutrient and water uptake [21] and through the reduction of water loss. It also maintain the osmotic and turgor of the cell and regulate the stomatal functioning under water stress condition [22].

Table 6 presents the informative data about amounts of irrigation water applied. Total amount of irrigation water applied varied from 263 mm to 385 mm in Al – Qadisiya location, and from 250mm to 402mm in Wasit location, depending on the water depletion. The total amount of $ETa$ was 471, 423 and 349 mm at 40, 60 and 80% depletion of available water, respectively in Al – Qadisiya location and 485, 435 and 333 mm at 40, 60 and 80% depletion of available water, respectively in Wasit location. These values were quite nearly than results for the same crop under different climatic and environmental conditions in Iraq.

Table 6 also shows high value of $WUE_f$ and $WUE_c$ at 60% depletion of available water ($I_2$) recorder 1.74 and 1.38 kg $m^{-3}$ in Al – Qadisiya location and 1.56 and 1.26 kg $m^{-3}$ in Wasit location, compared to 40 and 80% depletion of available water ($I_1$ and I3). The reason for the high value of $WUE_f$ and $WUE_c$ at 60% to lower amounts water added formed greater proportion of and have good yield didn't differ significantly compare to 40% as well as the availability of rain and low temperatures help the formation the plant dry matter contributed to mainly in grain filling during the period of interruption rain. These result indicted the role of rainfall, increased wetted soil volume inside root zone and this mean increasing in water volume which was stored in root zone.

**Table 6:** Amounts of irrigation water applied**,** Actual Evapotranspiration and Water use efficiency crop and field of wheat as affected by the irrigation and NPK fertilizers treatments

| Location | Treatment | number of irrigation | water applied depth (mm) | Rain depth (mm) | Actual Evapotranspiration (mm) | WUEc | WUEf |
|---|---|---|---|---|---|---|---|
| Qadisiya | $I_1$ | 9 | 385 | 86 | 471 | 1.28 | 1.57 |
| | $I_2$ | 7 | 337 | 86 | 423 | 1.38 | 1.74 |
| | $I_3$ | 4 | 263 | 86 | 349 | 0.94 | 1.24 |
| Mean | | | 332 | 86 | 414 | 1.20 | 1.52 |
| Wasit | $I_1$ | 10 | 402 | 83 | 485 | 1.14 | 1.38 |
| | $I_2$ | 6 | 352 | 83 | 435 | 1.26 | 1.56 |
| | $I_3$ | 4 | 250 | 83 | 333 | 0.98 | 1.30 |
| Mean | | | 335 | 83 | 418 | 1.13 | 1.41 |

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