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# Effect of Depletion Levels of Available Water and Phosphate Fertilization on Water Consumption and Yield of Lettuce

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**ABSTRACT**

A field experiment was conducted with the aim of knowing the effect of different depletion levels of ready water and different levels of phosphate fertilization on the water consumption of lettuce crop, yield coefficient and some characteristics of lettuce plant. The results showed that the highest water consumption was 386.8 mm at the 30% depletion level, and the lowest water consumption at the 80% depletion, reaching 292.8 mm. As for the phosphate fertilization, it had a very small effect on the water consumption. The beginning of growth and then increased in the average age of the plant to decline in the stage of maturity. It is also noted from the results that the different levels of depletion clearly affected the characteristics of the studied plant, as it reached the highest yield at the depletion level of 30% at 36.9 ton·h$^{-1}$, while the lowest yield was at the depletion rate of 80% at 27.1 ton·h$^{-1}$. As for the phosphate fertilization, it was huh. The other as a factor influencing significantly on the yield traits, as it gave the phosphate fertilization to zero level 32.8 ton·h$^{-1}$ for the traits in a row, and the values were higher than them for the level of fertilization, while the phosphate fertilization level gave the highest value for the plant yield.

**Keywords**: water consumption, phosphate fertilizer, lettuce, kc

## INTRODUCTION

Deficient irrigation is one of the practices that are used to improve water use and thus save costs. This is done by allowing crops to withstand water stress to an allowable limit that does not normally affect yield reduction (Capra et al, 2008; yazgan et al, 2008; Geerts et al, 2009; Hassan et al., 2021a). The crop is exposed to water stress by reducing the amount of irrigation water, and the strategy of deliberately reducing irrigation water is used to maintain what is commensurate with the water needs of the crop (Kirnak et al, 2016; Hassan et al., 2022).

Lettuce occupies an important place in the global economy, with a production of up to 26 million tons per year (FAO, 2019). Lettuce has been cultivated in the world for many years, especially in soils rich in organic matter, which accelerate the growth of lettuce and reduce the duration of the harvest. However, nitrogenous chemical fertilizers are used, and it is grown in greenhouses all year round, and the time of harvest varies according to variety and environmental factors (Sarıbaş and Uzun, 2019; Hassan et al. 2021; Mohammed, 2018; Ali et al., 2021). Drip irrigation is a type of irrigation system Microorganisms that are on the surface of the soil or buried within the soil surface and have the ability to deliver water and other nutrients by entering the water into the main roots of plants and other plant parts gradually, the main objective of drip irrigation is to put water directly into the main root zone and reduce evaporation. This study was carried out in order to determine the water consumption of lettuce under different irrigation systems.

## MATERIALS AND METHODS

A field experiment was carried out for the fall season 2021, in one of the fields located in Babylon governorate, to study the effect of phosphate fertilization and different irrigation levels on some characteristics of lettuce, lettuce productivity and water consumption. The split plot system was used according to a complete randomized sector design (RCBD), which included three replications with two factors, where the levels of phosphate fertilization were the main factor in three levels: 0, 100 and 200 kg·ha$^{-1}$, while the second factor included three irrigation levels of available water was: 30, 60 and 80%.

**Table 1.** Some chemical and physical properties of the experimental soil before planting

| Specification | | Value | Unit |
|---|---|---|---|
| PH | | 7.33 | ----- |
| EC | | 2.43 | dS·m$^{-1}$ |
| OM | | 0.75 | % |
| N | | 41 | ppm |
| P | | 5.1 | ppm |
| K | | 41 | ppm |
| Bulk density | | 1.37 | g·cm |
| Soil texture | Sand | 731 | g·kg |
| | Silt | 283 | g·kg |
| | Clay | 85 | g·kg |
| Soil class | | Sandy loam | |
| Water content at F.C. | | 0.29 | cm·cm |
| Water content at P.W.P | | 0.14 | cm·cm |
| Available water | | 0.15 | cm·cm |

## Irrigation scheduling and depletion level monitoring

The gravimetric method was used to measure soil moisture and to follow the change in soil moisture content and to determine the irrigation date according to the depletion levels of the irrigation treatments Soil samples were taken from a depth of 0–15 cm at the beginning of vegetative growth and then changed the depth during the different stages of growth from a depth of 0–30 cm to 0–40 until the time of harvest. Soil moisture content was estimated for each irrigation by drying the samples in the microwave at a temperature of 105°C for 12 minutes after the temperature and drying time were adjusted with the electric oven. Soil samples were placed in cans made of aluminum and weighed while wet, and after drying, they were weighed again and the moisture content was estimated according to the method proposed

The depth of irrigation water to be added at each irrigation according to the equation (2) mentioned by Kovda et al. (1973):

$$d = (\Theta_{f.c} - \Theta_w) \cdot D \quad (1)$$

where: $d$ – water depth (cm),
$\Theta_{fc}$ – volumetric field capacity (cm$^3$·cm$^{-3}$),
$\Theta_w$ – volumetric water content before irrigation (cm$^3$·cm$^{-3}$),
$D$ – soil depth (cm).

The actual water consumption of wheat was calculated by using the water balance equation (Allen et al., 1998):

$$(I+P+C) - (ET_a+D+R) = \Delta S \quad (2)$$

where: $I$ – depth of added irrigation water (mm),
$P$ – rainwater depth (mm),
$C$ – height of water in capillary property (mm), assuming it was zero, because groundwater is deep,
$ET_a$ – actual transpiration evaporation (mm),
$D$ – the puncture water depth (mm), assuming zero because the losses for deep leaching were 0,
$R$ – runoff (mm) assumed equal to 0,
$\Delta S$ – change in soil moisture storage between beginning and end of season.

The modified Penman-Monteith equation adopted from FAO-56 to estimate the evapotranspiration reference transpiration ETo (Allen et al., 1998) using the AquaCrop Model.

$$ETo = \frac{\left(0.408 * \Delta(Rn-G)+\gamma\left(\frac{900}{T+273}U_2(ea-ed)\right)\right)}{\Delta+\gamma(1+0.34\,U_2)} \quad (3)$$

where: $ETo$ – evaporation transpiration reference (mm·day$^{-1}$).
$Rn$ – net irradiance at the crop surface (MJ·m $^{-2}$·day$^{-1}$).
$G$ – heat flux at the soil surface (MJ·m $^{-2}$ ·day$^{-1}$).
$T$ – average daily air temperature at an altitude of 1.5 – 2.5 m (º m).
$U_2$ – wind speed measured at a height of 2 m (m·s$^{-1}$).
$ea$ – saturated vapour pressure at 1.5–2 m (kPa) altitude.
$ed$ – true vapour pressure at 1.5–2 m (kPa) altitude.
$ea–ed$ – decrease in vapour pressure (kPa).
$\Delta$ – slope of the vapour pressure curve (kPa/º m).
$\gamma$ – psychometric constant (kPa/º m),
900 – conversion constant,

The yield factor of wheat during the growth stages was calculated using the following equation (Allen et al., 1998):

$$Kc = \frac{\text{ETa}}{\text{ETo}} \tag{4}$$

where: *Kc* – yield factor (without units),
*ETa* – actual transpiration evaporation (mm),
*ETo* – refractory transpiration evaporation (mm).

Water productivity was calculated according to the equation mentioned in Allen et al. (1998).

### Statistical analysis

The data were analyzed according to the nested design and with three replications. The data were analyzed using the (2012) Gen Stat Discovery Filition 4 program, according to the mathematical model below and the coefficients are distributed randomly, and the significant differences between the means were compared with the Least Significant Difference-LSD test.

## RESULTS AND DISCUSSION

### Water balance

The results in Table 2 show the water balance equation factors for irrigation treatment for different depletion levels and different levels of phosphate fertilization. *ETa* values differed according to the different depletion levels. The highest water consumption was 386.8 mm·season$^{-1}$ at the depletion level of 30% and the level of 200 kg·ha$^{-1}$ of phosphorous, which 20 irrigated and 381.8 mm·season$^{-1}$ were taken at when treating a depletion level of 30% and a level of 100 kg·ha$^{-1}$ of phosphorous that was taken 20 irrigated, and 374.8 mm·season$^{-1}$ when treating a depletion level of 30% and a level of 0 kg·ha$^{-1}$ of phosphorous which were taken 19 irrigated. The results in the table also show that the highest water consumption is 349.8 mm·season$^{-1}$ at a depletion level of 60% and at a level of 200 kg·ha$^{-1}$ of phosphorous, which was taken 16 irrigated and 348.8 mm·season$^{-1}$ at a depletion level of 60% and a level of 100 kg·ha$^{-1}$ of phosphorous, which 16 irrigated, and 343.8 mm·season$^{-1}$ were taken at a 60% depletion treatment and a level of 0 kg·ha$^{-1}$ of phosphorous was taken, which was taken 15 irrigated. The results in the table also show that the highest water consumption is 300.8 mm·season$^{-1}$ at a depletion level of 80% and at a level of 200 kg·ha$^{-1}$ of phosphorous, which was taken 12 irrigated and 292.8 mm·season$^{-1}$ at a depletion level of 80% and a level of 100 kg·ha$^{-1}$ of phosphorous, which 12 irrigated, and 284.8 mm·season$^{-1}$ were taken at 80% depletion treatment and a level of 0 kg·ha$^{-1}$ of phosphorous was taken, which was taken 11 irrigated.

The reason for this is due to the decrease in the water consumption of the treatments as a result of the different levels of the added irrigation water, as the depth of the added irrigation water decreases for the irrigation treatments when the level of depletion is increased from 30% and 60% to 80%. These results were consistent with what was found (Al-Asbahi, 2003; Garg et al., 2022).

### Crop coefficient

Figures 1–3 shows the different values of the crop coefficient for the different growth stages of the lettuce plant, which depended on the reference

**Table 2.** The total water consumption, rain and the amount of water added under the effect of different depletion rates and different phosphate levels

| Water level, % | Level of P | No. of irrigation | Water added, mm | Rain, mm | Storage | Eta, mm |
|---|---|---|---|---|---|---|
| 30 | 0 | 19 | 300 | 61.8 | 13 | 374.8 |
| | 100 | 20 | 305 | 61.8 | 15 | 381.8 |
| | 200 | 20 | 308 | 61.8 | 17 | 386.8 |
| 60 | 0 | 15 | 258 | 61.8 | 24 | 343.8 |
| | 100 | 16 | 260 | 61.8 | 27 | 348.8 |
| | 200 | 16 | 262 | 61.8 | 26 | 349.8 |
| 80 | 0 | 11 | 198 | 61.8 | 25 | 284.8 |
| | 100 | 12 | 202 | 61.8 | 29 | 292.8 |
| | 200 | 12 | 208 | 61.8 | 31 | 300.8 |

evapotranspiration values (ETo) depending on the climatic data and the actual evapotranspiration values (ETa). The values of the crop coefficient in the vegetative growth stage ranged between 0.68 to 0.85 for all level 30%, 60%, and 80%, respectively. This indicates that the 30% treatment was the ratio of the actual water consumption (ETa) to the reference evapotranspiration (ETo) higher than the rest of the treatments, and the reason for this is due to the fact that the value of *Kc* is the product of dividing the actual water consumption (ETa) by the evapotranspiration – transpiration Reference (ETo). Where the treatment showed a 30% relative decrease in the amount of added water with a higher value of the actual water consumption (ETa), while the values of the crop coefficient Kc were between 0.68 to -1.68 for all irrigation treatments (Fig. 1, 2 and 3). It is noticeable that the values of the crop coefficient increased in the tuber final stage, as it reached 1.10 to 1.68 for all levels. The reason for this is due to the high values of actual evaporation – transpiration in the final stage due to the large growth of the potato plant when quantities of moisture are available close to the field capacity and the plant's need for water and food to meet the requirements of this important stage of the plant growth period, as the actual water consumption increases The penetration of the roots into the soil and the increase in the area of the soil volume that stores water and then prepares it for the roots of the completed plant in its vegetative growth, so the actual water consumption increased, which was reflected in the value of the crop factor. It indicated that there are differences in the actual water consumption of the transactions during the first stages, which coincides with different amounts of evaporation from the evaporation basin at the different stages of growth, which affected the final rate of the calculated crop factor during the entire stage.

As for the tuber completion stage, the values of the yield coefficient decreased from mid stag and amounted to 0.75 to 0.91 for all levels of calculated evaporation. The reason for this is due to the low values of the crop coefficient at the stage of completion of the tuber growth, to the decrease in the value of the actual water consumption of the plant due to the low need of the plant for water at this stage and the high temperatures and consequently the high values of evapotranspiration – reference transpiration (Lynch, 1995 and Zrust, 1995). In general, it is noted that the values of the crop coefficient gradually increase with the stages of growth until it reaches its highest value at the stage of filling the tubers and then begins to decline at the stage of completion of the growth of the tubers (Doorenbos and Kassm, 1979). It is noted that the values of the crop coefficient calculated depending on the evaporation basin were less than the values proposed globally, and the reason for this may be due to the different climatic conditions, soil and varieties, as well as the impact of irrigation levels (Ojala et al., 1990; Al Dhair and Hussein, 2008; Hassan et al., 2019; Abd Elrahmam et al., 2022).

## Effect of water level and p-level on plant

### *Plant height*

Table (3) shows the effect of using three levels of phosphate fertilizer under different irrigation levels on the height of lettuce plant. It was found that increasing the levels of added phosphate fertilizer had a significant effect in increasing plant height, while the effect of a significant decrease in the amount of added water was in reducing this trait. The effect of the interaction was significant in increasing the plant height. The highest average was 36.66 (cm·plant$^{-1}$) at a phosphate fertilization level of 200 kg·h$^{-1}$, While the lowest average was when phosphate fertilizer was not added, which amounted to 31.5 (cm·plant$^{-1}$). As for water stress, it led to a decrease in plant height at levels 80% and 60%, which amounted to 30.33 and 34.5 (cm·plant$^{-1}$) respectively, compared to 30% level of water stress, which amounted to 37.33 (cm·plant$^{-1}$).

As for the effect of the interaction between the levels of phosphate fertilization and water stress, the highest values in this trait were 40 (cm·plant$^{-1}$) and the lowest value was 28 (cm·plant$^{-1}$).

### *Total yield*

Table 3 shows the effect of using three levels of phosphate fertilizer under different irrigation levels on the total yield of lettuce plant. It was found that increasing the levels of added phosphate fertilizer had a significant effect in increasing total yield, while the effect of a significant decrease in the amount of added water was in reducing this trait. The effect of the interaction was significant in increasing the total yield. The total yield average was 34.3 µg·ha$^{-1}$ at a phosphate fertilization level of 200 kg·h$^{-1}$, While the lowest average was when phosphate fertilizer was not added, which amounted to 30.13 µg·ha$^{-1}$. As for water stress, it

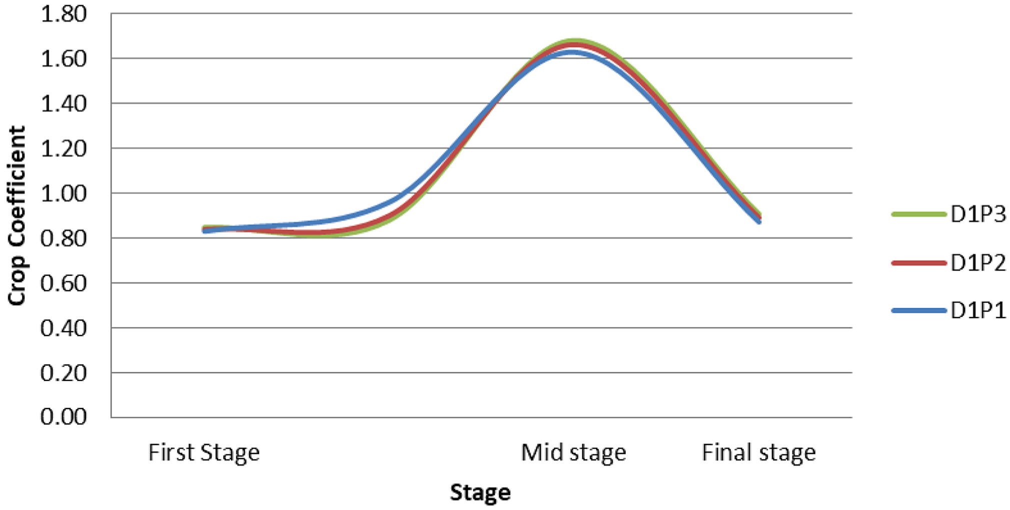


**Fig. 1.** The different values of the crop coefficient for the different growth stages of the lettuce plant at 30% depletion

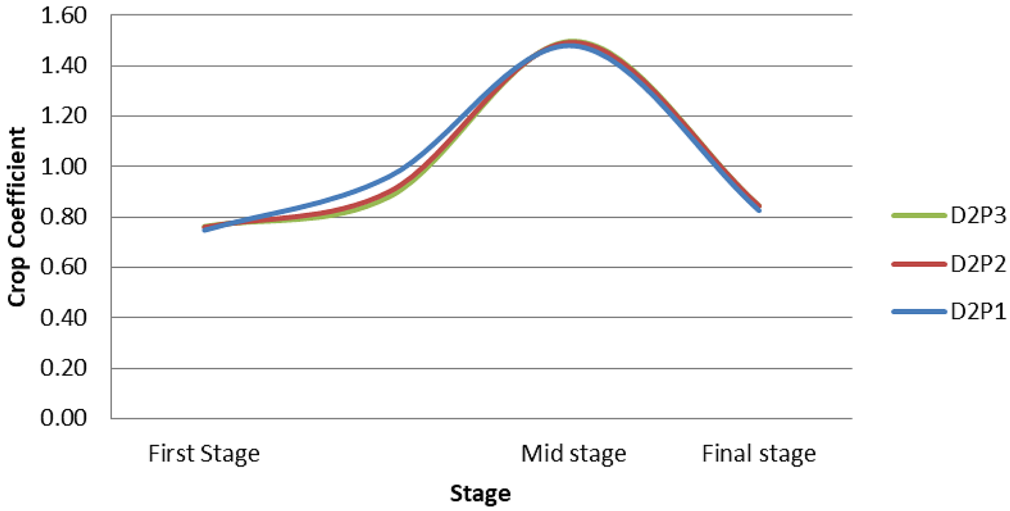


**Fig. 2.** The different values of the crop coefficient for the different growth stages of the lettuce plant at 60% depletion

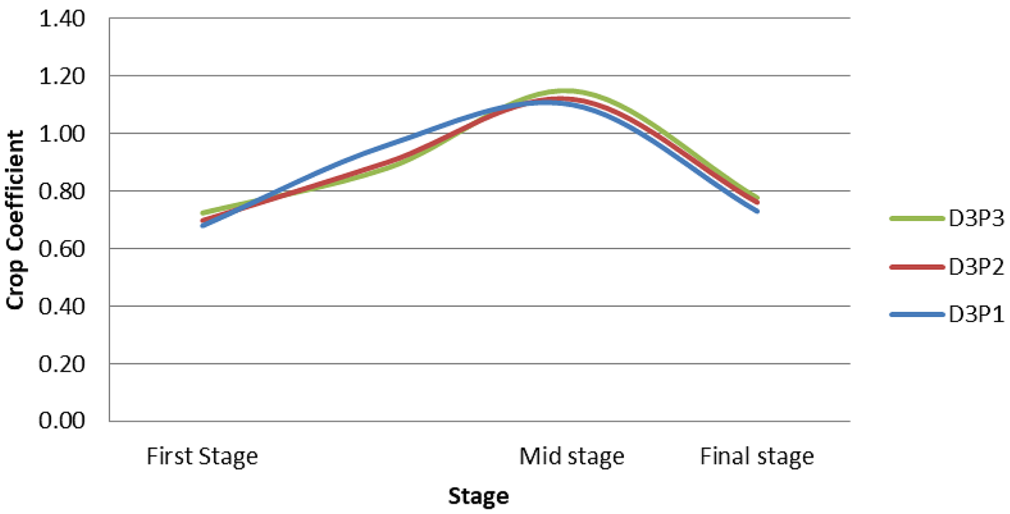


**Fig. 3.** The different values of the crop coefficient for the different growth stages of the lettuce plant at 80% depletion

**Table 3.** Effect of phosphate level with different irrigation levels on some properties of lettuce

| Water level, % | Phosphate level, kg·ha$^{-1}$ | Total yield, µg·ha$^{-1}$ | Average head weight, gm | Plant hight, cm | Head perimeter, cm |
|---|---|---|---|---|---|
| 30 | 0 | 32.8 | 595 | 35 | 55 |
| | 100 | 35.4 | 623 | 37 | 57 |
| | 200 | 36.9 | 664 | 40 | 59 |
| 60 | 0 | 30.5 | 532 | 31.5 | 48 |
| | 100 | 33.2 | 586 | 35 | 54 |
| | 200 | 34.9 | 609 | 37 | 56 |
| 80 | 0 | 27.1 | 480 | 28 | 45 |
| | 100 | 28.9 | 522 | 30 | 49 |
| | 200 | 31.1 | 538 | 33 | 52 |

led to a decrease in total yield at levels 80% and 60%, which amounted to 29.03 and 22.86 µg·ha$^{-1}$ respectively, compared to 30% level of water stress, which amounted to 35.05 µg·ha$^{-1}$.

As for the effect of the interaction between the levels of phosphate fertilization and water stress, the total yield values in this trait were 36.9 µg·ha$^{-1}$ and the lowest value was 27.1 µg·ha$^{-1}$.

*Average head weight*

Table 3 shows the effect of using three levels of phosphate fertilizer under different irrigation levels on the average head weight of lettuce plant. It was found that increasing the levels of added phosphate fertilizer had a significant effect in increasing average head weight, while the effect of a significant decrease in the amount of added water was in reducing this trait. The effect of the interaction was significant in increasing the average head weight. The average head weight average was 603.66 gm at a phosphate fertilization level of 200 kg·h$^{-1}$, While the lowest average was when phosphate fertilizer was not added, which amounted to 535.66 gm. As for water stress, it led to a decrease in Average head weight at levels 80% and 60%, which amounted to 513.33 and 575.66 gm respectively, compared to 30% level of water stress, which amounted to 627.33 gm.

As for the effect of the interaction between the levels of phosphate fertilization and water stress, the Average head weight values in this trait were 664 gm and the lowest value was 480 gm.

*Head perimeter*

Table 3 shows the effect of using three levels of phosphate fertilizer under different irrigation levels on the head perimeter of lettuce plant. It was found that increasing the levels of added phosphate fertilizer had a significant effect in increasing head perimeter, while the effect of a significant decrease in the amount of added water was in reducing this trait. The effect of the interaction was significant in increasing the head perimeter. The Head perimeter average was 55.66 cm at a phosphate fertilization level of 200 kg·h$^{-1}$, While the lowest average was when phosphate fertilizer was not added, which amounted to 49.33 cm. As for water stress, it led to a decrease in head perimeter at levels 80% and 60%, which amounted to 48.66 and 52.66 cm respectively, compared to 30% level of water stress, which amounted to 57 cm.

As for the effect of the interaction between the levels of phosphate fertilization and water stress, the Head perimeter values in this trait were 59 (cm) and the lowest value was 45 cm.

It is clear from the above that the increase in plant height, total yield, Head perimeter and Average head weight to the important role of phosphate fertilizer in increasing the level of nutrients and thus the formation of many cytochromes and ferredoxin of great importance in the process of photosynthesis, which increases growth rates, and chlorophyll increases By increasing the level of phosphate fertilizer (Saudi, 2017; Waheed et al., 2021).

The negative effect of increasing water stress can also be observed by increasing the level of depletion of prepared water, as the effect of water stress on plants and soil led to a decrease in the values of both plant height, total yield, Head perimeter and Average head weight, due to damages to cell membranes and imbalance. Ionic and anhydrous, changes in the levels of plant hormones and inhibition of enzymatic activity that lead to a disturbance in the photosynthesis process, which negatively affects the characteristics of the plant, as well as the water stress that the plant was exposed to during the growth stages, especially the stage of growth and fullness of the bean, led to a decrease in the products of photosynthesis and metabolism Carboniferous as a result of a decrease in plant height (Tarraf et al., 2015; Güner and Yavaşoğlu, 2018).

## CONCLUSION

Based to results obtained it was concluded that increasing the level of depletion of prepared water reduces the volume of consumed water. Consequently, increasing the level of depletion of the prepared water reduces the production and characteristics of the plant. And finally, the presence of phosphate levels increased the ability of the soil to retain moisture.

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