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Effect of irrigation method and application of NPK fertilizer on some physical properties of soil, growth of quinoa (Chenopodium quinoa Willd) and distribution of roots in the soil

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Abstract: The current study was conducted at the Agricultural Research Station, College of Agriculture and Marshes, Dhi-Qar University, during the 2020/2021 season. The aim of this work was to determine the best irrigation method (drip, surface) with NPK fertilizer at levels (0, 50, 100 kg do^{-1}) in some physical soil properties and growth indicators of quinoa crop growth and root distribution. The obtained data showed that the application of drip irrigation led to an improvement in the physical properties of the soil, as the bulk density decreased by 58.34%, the total porosity increased by 45.29%, and the saturated water conductivity was 36.71% compared with the irrigation system, which was reflected in the vegetative growth characteristics of the quinoa crop, if the treatment T3 (drip irrigation and 100 kg do^{-1} NPK fertilizer) was superior and gave the highest plant height, leaf area, number of branches and dry weight compared with the rest of the treatments, while the surface irrigation superiority in the distribution of roots in the soil and the treatment of adding manure and 100 kg do^{-1} NPK fertilizer.

Key words: irrigation method, drip irrigation, bulk density, plant height, root distribution.

Introduction:

In southern Iraq, most farmers use traditional irrigation methods instead of drip and sprinkler systems to irrigate their crops. As a result, drip and sprinkler irrigation methods are limited in the region. There are some attempts to introduce and popularize the drip irrigation method as an effective technique to save water in the region. It is known that traditional irrigation methods are less efficient, especially when there is a scarcity of irrigation water (Salim *et al.*, 2016). It is worth noting that surface irrigation methods are usually What farmers practice in most of the southern regions of Iraq, as well as most agricultural areas in southern Iraq suffer from several problems, including salinity and drought, which are common negative environmental factors that affect plant growth and determine the global geographical distribution of vegetation cover and restrict the yield of agricultural crops (Salim *et al.*, 2019). The few studies in the region showed that the use of the drip irrigation system due to the efficiency of salt washing out and their collection at the outer limits of the humidification front Some studies have encouraged the adoption of techniques to support drip irrigation compared to surface irrigation, which has achieved an improvement in the physical properties of the soil and the growth of the crop (Al-Hamad, 2010). Therefore diversification by planting different crops and introducing new varieties that have the ability to withstand stress such as quinoa, a crop that belongs to the Chenopodiaceous, as it is considered a candidate crop for agricultural diversity for its good ability to adapt to different environmental conditions, such as drought resistance and tolerance Frost, saline soil, diseases and pests (Jacobsen *et al.*, 2005). The cultivation of quinoa is preferred in areas with scarce water resources scattered in many areas, As a result of the scarcity of water resources. However, restricting water addition in crop growth stages can significantly increase yield (Garcia *et al.*, 2003).

Increasing the level of NPK fertilizer leads to an increase in the readiness of NPK elements in the soil and thus ease of absorption by the plant, which is reflected in the increase in the activity of vital processes in the plant, such as the increase in the content of chlorophyll affecting the photosynthesis process, which is positively reflected on growth indicators such as plant height, number of leaves and leaf surface area. In order to interest the growth and development of quinoa to grow and reach high yield and high seed quality, it

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requires an adequate amount of essential nutrients in particular nitrogen (N) and potassium (K) (Alvar-Beltrán *et al.*, 2021). Balancing the addition of key nutrients is a major factor in promoting plant growth and yield (Hou *et al.*, 2018). Found that an imbalance between key nutrients especially between nitrogen (N) and potassium (K) may lead to reduced grain growth and yield, however, information regarding the balance of N and K in quinoa was also not clear. While (Abdolahpour *et al.*, 2021) noted that adding NPK fertilizer to quinoa has contributed to increasing and improving the growth of plant height, leaf area and number of branches compared to without adding. As (Minh *et al.*, 2022) showed that adding 150 kg of nitrogen and 105 kg of potassium per hectare^{-1} could be the optimal ratio of nitrogen and potassium for quinoa production.
The study aims to evaluate irrigation methods and the addition of NPK fertilizer to develop the current irrigation in the southern region and increase the productivity of the quinoa crop.

Materials and methods:

A field experiment was conducted in the fields of the College of Agriculture and the Marshes / University of Dhi-Qar, where the experiment was carried out in the 2020 agricultural season on clay-textured soil. Two irrigation methods were used, namely, drip irrigation, which consists of a main line of PVC with a diameter of 53.3 mm and a sub-main pipe of 50 mm and 16 mm for field pipes (lateral) with a length of 5 m, the distance between the drippers is 20 cm, and a drainage of 4 liters hour^{-1} , As for the other irrigation method is the surface. Three additives of the compound fertilizer NPK 20: 20: 20 were used at three levels (0, 50, 100) kg dunum^{-1} (Table 1) and the planting pattern on lines and the process of interaction between them on the growth characteristics and root distribution of the Egyptian quinoa crop. Then plow the soil and soften it well. Then the experimental land was divided into two pieces, the distance between one piece and another 2 m. While each plot was divided into six experimental units with a length of 5 m, the distance between one unit and another was 1 m to control the irrigation water on the one hand and the non-transfer of chemical fertilizers between the units on the other hand, bringing the number of experimental units to 18 experimental units. A split-plot design with three replications was used and the averages were compared with a probability level of (0.05).

Table 1. Treatments setup

code	application fertilizer NPK	Irrigation method
T1	0	drip
T2	50	
T3	100	
T4	0	surface
T5	50	
T6	100	

The experiment was planted at a rate of 2-3 seeds in each hole, with a depth of 5 cm, the area between one hole and another is 20 cm, on lines with a distance of 1 m and a line length of 5 m, at a line rate in each experimental unit. Two weeks after planting, the plants were thinned out to one plant in each hole, and weeding was carried out periodically using hand tools. Add NPK fertilizer all at once before planting. The initial soil properties were measured as in (Table 2).

Table 2: Measurement of the physical and chemical properties of the study soil

Soil depth (cm)		**Properties**	
30 - 15	**15 - 0**		
111.1	162.3	**gm kg^{-1}**	**Sand**
405.3	432.3		**Silt**

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483.6	405.4		**Clay**
Silt clay	Silt clay		**soil texture**
1.361	**1.267**	**Mg m^{-3}**	**bulk density**
2.64	**2.65**		**Real density**
46.80	**47.50**	**%**	**total porosity**
1.51	**2.14**	**mg kg^{-1}**	**organic material**
4.37	**3.21**	**ds m^{-1}**	**ECe**
7.87	**7.81**		**pH**

Measurement of Physical Properties of Soil:

The bulk density and total porosity were estimated according to the method mentioned in (Black *et al.*, 1965), the saturated water conductivity of the soil was measured using the fixed water column method proposed by Klute and described in (Black *et al.*, 1965) by installing a column of water Its height is five cm above the soil column, then calculate the amount of water passing through the soil column for specific periods of time until the values are fixed with time. The values of the saturated water conductivity of the soil were calculated by applying Darcy's law below:

$$Ks = \frac{Q}{At} * \frac{L}{h} \;\ldots\ldots\ldots (1)$$

Since:

Ks = saturated water conductivity of the soil (cm min^{-1}), Q = volume of water passing through the soil column (cm^3). L = length of soil column (cm),

A = surface area of soil section (cm^2), t = time (min). h = length of the soil column + height of the water column above the soil column (cm).

Measurement of growth traits:

1. Plant height (cm): It was measured at the end of the growing season with a ruler from the area of contact of the plant with the soil to the top.
2. Leaf area (cm^2): It was measured by taking ten plants from each line using the Laser Area Meter CL-202 and extracting the average for them.
3. Number of branches (plant branch^{-1}): It was measured by calculating the number of branches for each plant.
4. Dry weight of the plant (ton ha^{-1}): Measurements were taken after the full maturity of the crop, and the total crop (straw + yield) was harvested and dried in an oven at a temperature of 105° C at a rate of 1 m^2 per experimental unit randomly, and then it was calculated and converted to kg ha^{-1}.

Distribution of roots in the soil:

Root length and depth were measured according to the cylinder method proposed by (Al-Kafaf *et al.*, 1977), where the earthen mass of the root was lifted and placed in a water container to separate the soil from the root, and the depths of the roots were measured in this way, and the dry weight of the root was calculated by drying the samples In an electric oven at 70 degrees for 72 hours, then weighed with a sensitive scale.

Statistical analysis:

The obtained data were statistically analyzed using analysis of variance (ANOVA) using Genstat version 10.0. Means were compared using the least significant difference (LSD) test at $p < 0.05$.

Results and discussion

1. Soil Characterization at Harvest:

Table 3 shows the effect of the irrigation method on some physical properties of the soil at the end of the growing season, as we note the success of the drip irrigation method and it gave the highest saturated water conductivity and total porosity at 0.700 m day^{-1}, 54.09% and the lowest apparent density 1.217 g cm^{-3} compared with the tourist irrigation Which gave 0.443 m day^{-1}, 51.64%, 1.288 g cm^{-3}, respectively. Improving the physical properties of the soil using drip irrigation technology is due to the improvement of soil construction and the increase of its aggregates due to the slow movement of water, which was reflected in maintaining the volumetric distribution of the pores by maintaining the pores The large size and not turning into smaller pores, thus reducing the bulk density and increasing the porosity of the soil and the saturated water conductivity (Mclaren and Cameron, 1996). While the flood irrigation led to a reorganization of the soil particles between the pore spaces and an increase in the bulk density, and the first irrigation had the greatest effect on that. It was noticed (Al-Hamad, 2010) that the values of the bulk density increased as a result of the processes of tourist irrigation and the movement of some fine soil particles, which led to an increase in compaction and a decrease in porosity.

Table 3: Effect of irrigation method on some physical properties of soil

irrigation method	saturated water conductivity (m day^{-1})	Porosity (%)	BD (g cm^{-3})
before planting	0.430 b	51.37 b	1.281 b
drip	0.700 a	54.09 a	1.217 a
surface	0.443 b	51.64 b	1.288 c
LSD	0.1518	1.157	0.0300

2. Growth Parameters:

Table 4 shows the effect of the irrigation method and the addition of NPK fertilizer on some growth characteristics of the quinoa crop, as the highest plant height, leaf area, number of branches and dry weight was obtained when using the drip irrigation technique by 71.90 cm, 2327 cm^{2}, 19.23 plant branch^{-1}, 3.79 to do^{-1}, respectively, while the lowest values were when irrigation was 47.84 cm, 1224 cm^{2}, 14.68 plant branch^{-1}, 1.29 to do^{-1}, respectively, and the reason for this is that better moisture provision allowed for an increase in the effectiveness and efficiency of the photosynthesis process and an increase in The production of dry matter, which in turn led to an increase in plant growth rates, which was clearly reflected on the increase in the growth characteristics of the quinoa crop (Hammam and Mansour, 2018). As well as the improvement in the physical properties of soil (Table 3).

We also notice from (Table 4) an increase in plant height by 47.70%, leaf area by 68.23%, number of branches by 45.35%, and dry weight 108.69% when adding NPK fertilizer at a level of 100 kg do^{-1} compared to without adding, and this increase is due to the joint role of the major necessary elements for growth The plant, as the addition of nitrogen leads to an increase in protein synthesis in the cells of the plant, and this led to an increase in cell division and thus an increase in the elongation of the plant, which was reflected on the rest of the growth characteristics of quinoa (Almadini *et al.*, 2019), and this result is consistent with the findings of (Al-asadi and Al-dogagy, 2021, Owji *et al.*, 2020, Fawy *et al.*, 2017), They found that an increase in quinoa growth vocabulary by increasing the levels of nitrogen fertilizer, as well as the role of potassium and phosphorous in improving growth characteristics (Alvar-Beltrán *et al.*, 2021) that the needs of the quinoa crop of N and K are from medium to high, while the need for P is in smaller quantities, and it was suggested to add 12.7, 1.6, 35.5 kg ha^{-1} of N, P and K respectively, To produce one ton of total biomass (including stem, leaves and seeds), as noted (Ibrahim *et al.*, 2020). Increasing plant height, number of branches and dry weight by increasing the levels of NPK fertilizer

Table 4: Effect of irrigation method and the addition of NPK fertilizer on some growth characteristics of quinoa

Application Fertilizer NPK	plant height (cm)			Leaf area (cm^2)		
	Irrigation method			Irrigation method		
	drip	surface	average	drip	surface	average
0	59.00	38.77	48.88	1726	937	1331.5
50	71.43	45.61	58.52	2305	1205	1755.3
100	85.27	59.13	72.20	2950	1530	2240
average	71.90	47.84		2327	1224	
LSD	**I= 3.165**	**F=3.149**	**I*F= 3.879**	**I= 568.233**	**F=193.221**	**I*F= 438.494**
	number of branches			dry weight (to do^{-1})		
0	16.14	11.64	13.89	2.71	0.98	1.84
50	18.91	14.66	16.78	3.65	2.11	2.88
100	22.64	17.74	20.19	5.00	2.68	3.84
average	19.23	14.68		3.79	1.92	
LSD	**I= 2.150**	**F= 1.396**	**I*F= 1.946**	**I= 0.796**	**F= 0.585**	**I*F= 0.776**

** **I=** Irrigation method, **F=** Application Fertilizer NPK

3. Root distribution:

Figures 1, 2 show the effect of the irrigation method and the addition of NPK fertilizer on the distribution of quinoa roots in the soil, as we note the superiority of the surface irrigation factors (T4, T5, T6) over the rest of the drip irrigation factors in increasing the spread and distribution of the roots of the quinoa crop, if the T6 treatment gave higher The root length is 44.67 cm and the dry weight of the root is 20 g, while the lowest value in T1 treatment was 21.33 cm for the length of the root and 10 g for the dry weight of the root, The decrease in root length and root dry weight in the drip irrigation method is due to the fact that the root total is less than that of the surface irrigation system due to the water added in the drip irrigation system is greater compared to the drip irrigation and this is consistent with what was mentioned by (Khalil *et al.*, 2020), that the spread and distribution of the roots under the drip irrigation system is mainly concentrated in the first 0.10 m of the soil mound if it reaches 76% of the total weight of the root.
We also note the superiority of the treatments of adding NPK fertilizer (T3, T6) at a level of 100 kg ha^{-1} in increasing root length and dry weight, as increasing the level of application led to an increase in the spread and distribution of the root inside the soil pot, as mentioned by (Kakabouki *et al.*, 2019) that The density of roots increases by adding nutrients to the soil, especially fertilizers that contain nitrogen, while it decreases in areas where there is a lack of nutrients. Phosphorous, which plays an important role in improving the root system of plants by increasing root branches, especially if the additions are large with nitrogen, and this result is consistent with the findings of (Qi *et al.*, 2019).

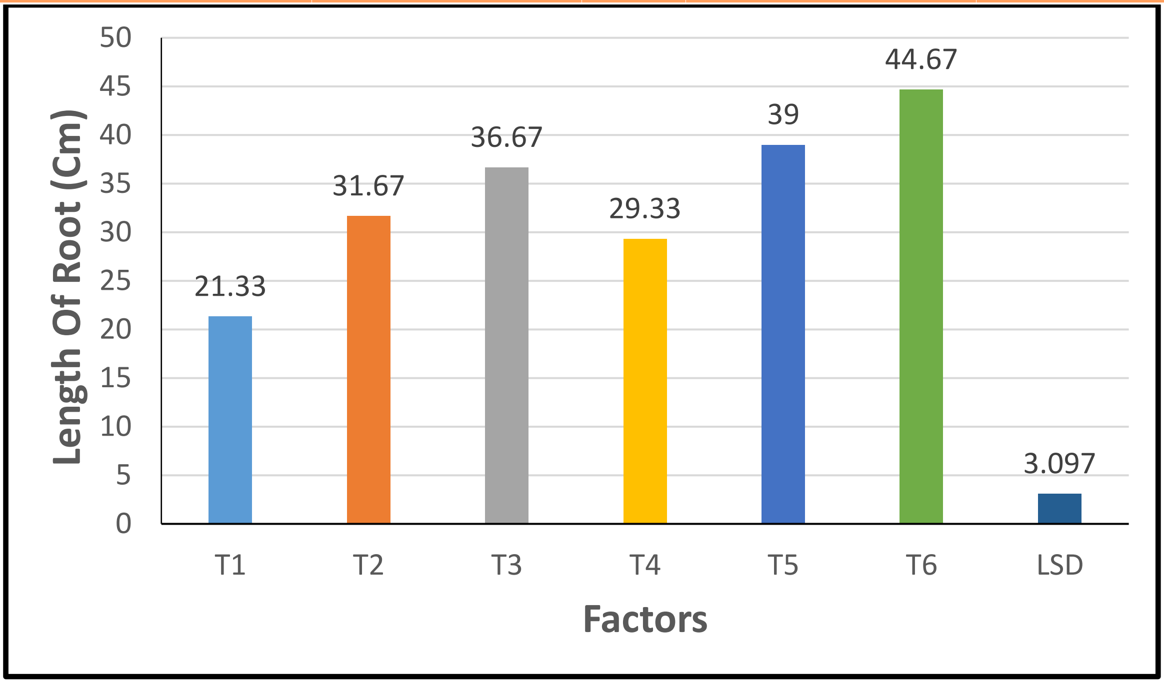

Figure 1: The effect of irrigation method and the application of NPK fertilizer on the root length of quinoa crop (cm)

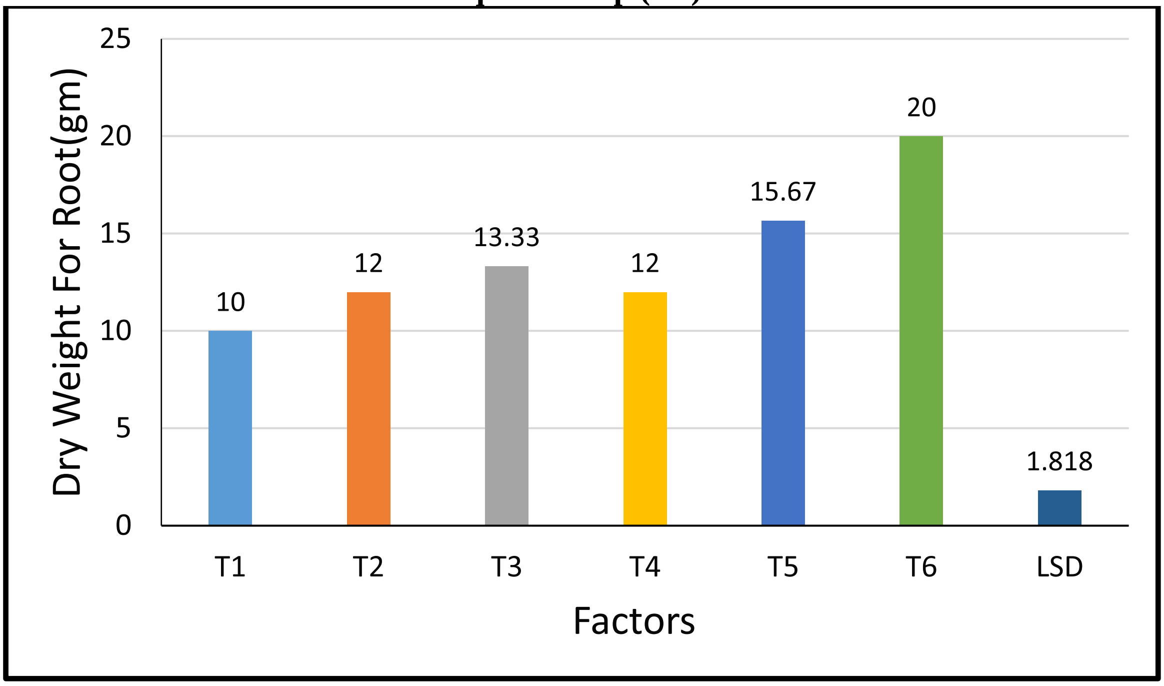

Figure 2: The effect of irrigation method and the application of NPK fertilizer on the dry weight of quinoa roots (g)

Conclusions:

The present results indicated that root growth and quinoa growth characteristics were significantly affected by both irrigation and fertilization methods. As the bulk density decreased, the total porosity and the saturated water conductivity increased when using the drip irrigation method. The effects of irrigation and fertilization method on the growth of quinoa, all vegetative growth characteristics increased by increasing the level of fertilizer and drip irrigation, due to the improvement of soil properties. As for the roots, the fraction of quinoa roots (about 70%) was concentrated in the top soil layer 0-30 cm. Root height density and root mass density increased with increasing fertilizer rates. In addition, the highest density of root mass was

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observed under minimal irrigation. The values obtained with a higher fertilization rate (100 kg NPK do^{-1}). In conclusion, increasing the levels of applied NPK fertilizer up to 100 kg do^{-1} improves plant growth and thus is reflected on root growth of quinoa crop.

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