ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2025, 10 (1): 120-127 doi: 10.28978/nesciences.1642273

Effect of Three Levels Application of NPK Fertilizer and Irrigation Method on Yield and Yield Components of Quinoa (Chenopoduim Quinoa Willd.)

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Abstract

This study was done at a research farm of the faculty of Agriculture and Marshlands of Thi-Qar University, in Silty Clay soils during the growing season 2021-2022 to study the effect of three levels of NPK fertilizer addition on the yield and some components of quinoa plant under surface irrigation and drip irrigation methods, The study was conducted according to the randomized complete block design with three replications. Mineral fertilizer was added at three levels (0%, 50%, and 100%) of the recommended dose (120, 50, and 80 kg K ha^{-1}) of NPK sequentially. The finding indicated that the treatment with the full recommended dose of fertilizer 100% attained the most outcomes in dry substance yield and grain production of quinoa plant, at 8.84 and 2.71 megagrams $hectare^{-1}$, respectively, in contrast to the treatment under control, which showed 3.11 and 0.90 megagrams $hectare^{-1}$, respectively. Additionally, the drip irrigation method was associated with the best results in quinoa yield, the highest average in grain yield was reached 1.95 megagrams $hectare^{-1}$, with a notable distinction of surface irrigation treatment, which showed 1.47 megagrams $hectare^{-1}$.

Keywords:

Irrigation, NPK fertilizer, quinoa, straw, yield.

Article history:

Received: 23/10/2024, Revised: 23/12/2024, Accepted: 11/01/2025, Available online: 31/03/2025

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Introduction

Quinoa is a herbaceous plant native to the Andes Mountains in South America, part of the Amaranthaceae family. It is grown as a food crop in the United States, Ecuador, Bolivia, Peru, and Canada (Hasan et al., 2021). Quinoa seeds are appropriate for human and animal consumption due to their outstanding nutritional value, boasting high protein content along with a range of minerals and vitamins. (Nowak et al., 2016). The past few recent years have seen increased interest in quinoa as a grain crop, as its productivity has increased several times worldwide, not only due to possessing high nutritional content but, it also exhibits remarkable resilience to a range of environmental conditions, such as drought, salt, and coldness, and its ability to thrive in saline soils. (Angeli et al., 2020). Quinoa growth and yield are positively impacted by mineral fertilizer, productivity increases with increased use of nitrogen fertilizer (Papastylianou et al., 2014; Fawy et al., 2017).

To promote plant growth and increase productivity, quinoa plants need soil fertilization with essential nutrients such as nitrogen and phosphorus, which are applied at different times of growth (Geren, 2015). The irrigation needs of plants differ based on the climate and the plant's growth stage. If quinoa is grown as a winter crop, we can depend only on rainfall or provide supplementary irrigation during the seed formation period. However, if it is sown as a summer crop, irrigation must be little and at frequent times, with discontinuation during the maturity stage (Veerasamy & Fredrik, 2023). Care must be taken in irrigating the plant during the initial period to be sure the plant grows properly because of the tiny size of the seeds (Heirish, 2019). The study aims to establish the optimal NPK level using various irrigation systems to identify the appropriate irrigation method under current water scarcity conditions (Thiyagarajan Jayaraman et al., 2024).

Materials and Methods

In the 2021-2022 season, a study was conducted at the research farm of the Agriculture Faculty and Marshlands of Thi-Qar University to investigate the impact of three levels of NPK fertilizer and irrigation method on the yield components of the quinoa plant (Malešević et al., 2023). The field experiment was conducted in Silty Clay soil after performing all standard agricultural operations. The land was divided into two plots, with a distance of 2 meters between each plot. Two irrigation methods were used: drip irrigation for the first plot and surface irrigation for the second plot. Each plot was divided into 9 rows, each 5 meters long, with a distance of 50 cm between rows and one row per experimental unit. Quinoa seeds of an Egyptian variety were planted on 15th December 2021, 4-5 seeds per hole, 1 cm depth, and 20 cm space between each hole (Gladkov & Gladkova, 2021). Three levels of mineral fertilizer were added: 0% of the recommended dose (no addition), 50% of the recommended dose (60, 25, and 40 kg ha^{-1}), and 100% of the recommended dose (120, 50, and 80 kg ha^{-1}) of NPK sequentially. The fertilizer was administered in two doses, one during the vegetative growth phase and the other dose during the flowering phase. The study was conducted according to the randomized complete block design with three replications. Random soil samples were gathered from the study site and mixed to obtain a composite sample to determine various physical and chemical soil characteristics Table 1.

Table 1. Some soil chemical and physical characteristics before sowing

Parameter		Value	Unit
(pH)		7.85	
(ECe)		4.47	dS m^{-1}
(O.M)		2.82	g kg^{-1}
Soil separates	Sand	170	g kg^{-1}
	Silt	423	g kg $^{-1}$
	Clay	407	g kg^{-1}
Soil texture		Silty clay	

Studied Traits

1. **Inflorescence plant^{-1}:** The number of inflorescences per plant was calculated as the average of ten randomly selected plants per experimental unit.
2. **Inflorescence height (cm):** The height of the inflorescences of ten different plants selected for each experimental unit was measured using a tape measure and the average was calculated.
3. **Biological yield (µg ha^{-1}):** The total dry matter weight was calculated based on the plant area per square meter per experimental unit and converted to (µg ha^{-1}).
4. **Grain yield (µg ha-1):** Counted based on the yield of each unit area of the plant of every treatment and converted to (µg ha^{-1}).
5. **Straw yield (µg ha-1):** Based on the plant area per square meter per experimental unit, the grain weight was subtracted from the total dry matter weight to get its value, which was then converted to (µg ha-1).
6. **Harvest index (%):** Counted by dividing grain yield by the dry yield and multiplying it by 100.

Statistical Analysis

Genstat version 10.0 was used to statistically analyze the data using Analysis of Variance (ANOVA). At a significance level of 0.05, the arithmetic means of the treatments were compared using LSD.

Results and Discussion

Number of Inflorescences plant-1

The results showed significant differences between the mean values of the fertilizer treatments and irrigation methods. No significant interaction between the research variables Table 2. Treatment M2 outperformed with the highest inflorescence values of 24.50 inflorescences plant^{-1}, with a notable variation from treatment M1, which recorded a mean of 19.82 inflorescences plant^{-1}, in contrast to the treatment under control M0, which showed the smallest average of 10.83 inflorescences plant^{-1}. This is attributed to the provision of essential nutrients, especially nitrogen and potassium. Nitrogen stimulates stem and leaf growth through photosynthesis, increasing cell numbers and overall growth. Potassium plays a vital role in increasing leaf area and activating enzymes responsible for photosynthesis, causing an increase in the overall growth of the plant, this clearly shows an increase in the number of inflorescences on the plant. This result is consistent with (Shoman, 2018)'s finding.

The results also showed that the irrigation system had a significant impact on the number of inflorescences per plant. Drip irrigation treatment outperformed and provided the highest significant value for the number of inflorescences at 20.43 inflorescences plant^{-1}. This is attributed to the provision of necessary moisture, which contributed to increasing plant growth rates, and caused a noticeable increase in inflorescences number. This is consistent with what (Al-Yasiry, 2022) indicated. However, the interaction between mineral fertilization and irrigation method had no significant impact on the number of inflorescences per plant.

Table 2. Influence of mineral fertilizer and irrigation method on the number of inflorescences per quinoa plant (inflorescence plant^{-1})

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	D	
M_0	8.66	12.99	10.83
M_1	16.99	22.65	19.82
M_2	23.33	25.66	24.50
Mean	16.33	20.43	
LSD 0.05	IR	M	M * IR
	3.708	2.542	NS

Height of Inflorescence (cm)

The results indicated significant variation in the means of treatments for adding mineral fertilizer Table 3, as treatment M2 excels with the highest mean of 66.2 cm, with a notable difference from the M1 treatment, which produced a mean of 46.4 cm compared to the control treatment M0 (28.4 cm). This could be explained by the plant's uptake of the nutrients and their enhanced availability in the soil solution, especially nitrogen, which is essential in the synthesis of chlorophyll molecules, proteins, enzymes, hormones, and amino acids that speed up plant development by facilitating cell division and elongation. This aligns with (Soliman et al., 2019).

The results also appeared a significant influence on the irrigation system, as drip irrigation treatment (D) outperformed and gave the best average of 51.8 cm. This may be because better water supply methods increase nutrient use efficiency by reducing losses, especially of nitrogen, thus increasing its availability in the soil solution, positively affecting plant growth and inflorescence length, as mentioned by (Al–Jutheri & Ali, 2011).

The results revealed a non-significant interaction between mineral fertilization and irrigation method on the length of inflorescence.

Table 3. Influence of irrigation method and mineral fertilizer on height of inflorescences (cm)

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	**D**	
M_0	25.3	31.4	28.4
M_1	43.6	49.2	46.4
M_2	57.8	74.7	66.2
Mean	42.2	51.8	
LSD 0.05	IR	M	M * IR
	8.04	7.20	NS

Biological Yield (µg ha-1)

The results indicate significant differences between fertilization treatments Table 4. Treatment M2 was superior and had the highest biological crop, at 8.84 µg ha^{-1}, having a notable distinction from treatment M1 (4.67 µg ha^{-1}), the control treatment had the lowest average, of 3.11 µg ha^{-1}. A possible increase in biological crop attributed to the absorption of nutrients, which accelerated photosynthesis raised the dry matter weight, and then increased the biological yield (Papastamatiou et al., 2014).

The results indicate that the irrigation method and the biological crop were not significantly affected by the two-way interaction between the irrigation method and mineral fertilization.

Table 4. Influence of irrigation method and mineral fertilizer on Biological Yield (µg ha^{-1})

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	**D**	
M_0	2.67	3.55	3.11
M_1	4.13	5.21	4.67
M_2	7.17	10.50	8.84
Mean	4.66	6.42	
LSD 0.05	IR	M	M * IR
	NS	1.709	NS

Straw yield (µg ha-1)

The results demonstrated that the means of the mineral fertilizer differed significantly from one another Table 5. Treatment M2 was superior with the highest straw yield at 6.13 µg ha^{-1}, with a significant variation from the M1 treatment (3.14 µg ha^{-1}), however the average of comparison treatment reached the lowest level of 2.21 µg ha^{-1}. This can be attributed to some of the above reasons for increasing biological crops. The results show that the irrigation method and the interaction between fertilizer and irrigation method have no significant influence on straw yield.

Table 5. Influence of irrigation method and mineral fertilizer on Straw Yield (µg ha^{-1})

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	**D**	
M_0	1.92	2.49	2.21
M_1	2.93	3.35	3.14
M_2	4.70	7.56	6.13
Mean	3.18	4.47	
LSD 0.05	IR	M	M * IR
	NS	1.104	NS

Grain yield (µg ha-1)

The results clarified the presence of significant variation between the levels of mineral fertilizer treatment Table 6. Treatment M2 excelled in grain yield with the highest rate of 2.71 µg ha^{-1}, this significantly differed from the level of 50% represented by the M1 treatment, which recorded 1.53 µg ha^{-1}, however, the control comparison showed the lowest rate of 0.90 µg ha^{-1}. This can be due to the supply of NPK nutrients and their increased concentration in the plant. Nitrogen is a component of proteins and is involved in most biochemical processes in the protoplasm and enzymatic reactions, thereby increasing photosynthetic efficiency and carbohydrate synthesis. Phosphorus is important for energy compound formation and plays an essential role in the translocation of sugars and manufactured materials from source to sink. Potassium contributes to increased photosynthetic efficiency, activates numerous enzymes, and plays a role in transporting manufactured materials in the leaves to storage sites, leading to increased grain yield. This agrees with what was mentioned by (Almadini et al., 2019)

The results also showed that the irrigation method had a significant impact on grain yield, with drip irrigation treatment D being more effective and having the highest rate of 1.95 µg ha-1, with significant differences from the surface irrigation treatment (1.47 µg ha^{-1}). This may be due to the efficiency and superiority of drip irrigation in providing good and uniform moisture, as well as reducing losses and optimal utilization of added fertilizers, which stimulated quinoa plant growth and gave the highest yield. This is consistent with what was mentioned by (Al–Jutheri & Ali, 2011).

However, the interaction between mineral fertilization and irrigation methods did not have a significant effect on grain productivity.

Table 6. Influence of irrigation method and mineral fertilizer on Grain Yield (µg ha^{-1})

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	**D**	
M_0	0.75	1.05	0.90
M_1	1.20	1.86	1.53
M_2	2.47	2.94	2.71
Mean	1.47	1.95	
LSD 0.05	IR	M	M * IR
	0.091	0.751	NS

Harvest index (%)

The outcomes in Table 7 showed that fertilizer application, irrigation method, and their interaction did not have a significant effect on the harvest index.

Table 7. Influence of irrigation method and mineral fertilizer on harvest index (%)

Fertilizer treatments (M)	**Irrigation method (IR)**		**Mean**
	S	**D**	
M_0	28.2	29.2	28.7
M_1	29.1	36.3	32.7
M_2	34.4	27.9	31.2
Mean	30.6	31.2	
LSD 0.05	IR	M	M * IR
	NS	NS	NS

Conclusion

Mineral fertilization played a crucial role in increasing the total dry matter yield and grain yield of quinoa plants, with the superiority and excellence observed in the third level represented by treatment M2 at 100% of the recommended fertilizer rate. Additionally, the drip irrigation represented by treatment D has shown a significant impact in many studied traits. This underscores that choosing this irrigation method enhances many growth traits of quinoa plants, which is reflected in the yield components.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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