International Journal of Plant & Soil Science

Volume 36, Issue 8, Page 302-308, 2024; Article no.IJPSS.119107
ISSN: 2320-7035

Response of Quinoa to Different Levels of Spacing and Fertilizer

Ashok. N. Chaudhary [a++*], N.N. Prajapati [a++] and Jigar Desai [a]

[a] Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar-385 506, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i84858

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119107

Original Research Article

Received: 22/05/2024
Accepted: 24/07/2024
Published: 27/07/2024

ABSTRACT

The field experiment conducted at the Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, evaluated the response of quinoa (Chenopodium quinoa) to different spacing and fertilizer levels across multiple seasons (2018-19, 2019-20, and 2020-21). The result of the experiment indicated plant height at 30, 60 days after sowing (DAS), and at harvest was significantly highest in the S3 spacing treatment (22.5 cm x 15 cm). Similarly, the F3 fertilizer treatment (60-40-40 NPK kg/ha) resulted in significantly taller plants at these stages compared to other fertilizer levels. While spacing did not significantly affect inflorescence length and girth, treatment with F3 fertilizer (60-40-40 NPK kg/ha) notably increased these parameters compared to other fertilizer treatments. On a pooled basis, spacing treatment S1 (30 cm x 10 cm) significantly increased grain and straw yield. Likewise, fertilizer treatment F3 (60-40-40 NPK kg/ha) resulted in significantly higher grain and straw yield compared to other fertilizer levels. Spacing treatment S1

[++] Assistant research scientist;
**Corresponding author: E-mail: drashok_agro@sdau.edu.in; ashokjegoda@gmail.com;*

Cite as: *Chaudhary, Ashok. N., N.N. Prajapati, and Jigar Desai. 2024. "Response of Quinoa to Different Levels of Spacing and Fertilizer". International Journal of Plant & Soil Science 36 (8):302-8. https://doi.org/10.9734/ijpss/2024/v36i84858.*

(30 cm x 10 cm) demonstrated the highest net return and Benefit Cost Ratio (BCR) in economic terms. Similarly, fertilizer treatment F3 (60-40-40 NPK kg/ha) showed the highest net return and BCR among the different fertilizer treatments. In conclusion, the experiment highlights that spacing S3 (22.5 cm x 15 cm) and fertilizer F3 (60-40-40 NPK kg/ha) are optimal for achieving maximum plant height, inflorescence development, grain and straw yield, as well as economic profitability in quinoa cultivation. These findings provide valuable insights for enhancing productivity and economic viability in the cultivation of this promising pseudo-cereal crop.

Keywords: Quinoa; chenopodium quinoa; spacing; fertilizer.

1. INTRODUCTION

Quinoa (*Chenopodium quinoa* Wild.) is an annual herbaceous plant belonging to the Amaranthaceae family. Originally cultivated by ancient Inca civilizations in the Andean regions of Bolivia, Chile, Ecuador, and Peru around 5000 to 750 B.C., quinoa has historically been a vital crop for Andean farmers. Over time, its cultivation has expanded beyond South America, gaining popularity in regions like North America, Europe, and increasingly, India. Quinoa is versatile and consumed in various forms such as grains, flakes, pasta, bread, biscuits, beverages, and as a meal ingredient. Its introduction to North Americans and Europeans as a healthy snack around the 1970s has contributed to its global popularity. This surge is largely due to its gluten-free nature, which is beneficial for individuals with dietary restrictions like diabetes, and its high protein content, ranging from 14% to 18%. This protein content surpasses that of commonly used cereals and millets.

According to the United Nations Organization for Agriculture and Food (UNOAF), quinoa stands out as a complete vegetable food source, containing all essential amino acids necessary for human health. It is nutritionally comparable to milk in terms of its amino acid profile. Quinoa is notably rich in amino acids such as lysine, isoleucine, methionine, histidine, cystine, and glycine. Additionally, it boasts significant concentrations of essential minerals like calcium, iron, zinc, copper, and manganese, as well as essential fatty acids like linoleic acid and alpha-linolenic acid. Moreover, quinoa seeds are a good source of vitamins including thiamine (vitamin B1), folic acid (vitamin B9), vitamin C, riboflavin (vitamin B2), and carotene (provitamin A) [1]. These nutrients collectively contribute to its reputation as a highly nutritious food option.

Quinoa (*Chenopodium quinoa* Wild.) is known for its resilience to moisture stress and its ability to thrive in marginal soils, although it prefers sandy loam soil for optimal growth. Native to the Himalayan region of India, quinoa is adapted to temperatures ranging from 0 to 20 degrees Celsius. Recognizing its potential, Sardarkrushinagar Dantiwada Agricultural University in Gujarat has initiated research to evaluate various quinoa germplasms and develop suitable agricultural techniques for the semi-arid plains, as part of the All-India Co-ordinated Research Network on Potential Crops.

One crucial aspect of systematic quinoa cultivation that significantly impacts crop productivity is the management of inter and intra-row spacing. Proper spacing ensures that plants receive adequate water, sunlight, and nutrients from the soil, thereby influencing seed yield and overall crop quality. Despite its nutritional benefits and versatility, the commercial potential of quinoa remains largely untapped in India. There is a notable lack of comprehensive literature regarding optimal planting dates, seed rates, spacing, and other agricultural practices essential for successful quinoa production in the country.

Furthermore, research on the acceptability and standardization of quinoa processing and packing practices in India is limited. Given these gaps, the study titled "Response of quinoa (*Chenopodium quinoa* Wild.) to different levels of spacing and fertilizer" was undertaken. The primary objective of this research is to establish standardized recommendations for optimal spacing and fertilizer application in quinoa cultivation. By addressing these fundamental agricultural parameters, the aim is to enhance quinoa productivity and facilitate its adoption as a viable crop option in diverse agro-climatic regions of India. This research initiative is crucial not only for maximizing the yield and quality of quinoa but also for promoting its economic viability and sustainability in Indian agriculture. It underscores the importance of systematic scientific inquiry to unlock the full potential of quinoa as a nutritious and resilient crop choice for farmers in India and beyond.

2. MATERIALS AND METHODS

The field experiment conducted at the Center for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, spanned the rabi seasons of 2018–19, 2019–20, and 2020–21. The experimental site featured loamy sand soil with a pH of 7.55, low organic carbon content (0.21%), and medium levels of available nitrogen (137.6 kg/ha), phosphorus (25.67 kg/ha), and potassium (102.7 kg/ha). The experiment employed a randomized block design with a factorial concept, comprising nine treatment combinations. These treatments included three levels of spacing: S_1 (30 cm x 10 cm), S_2 (30 cm x 15 cm), and S_3 (22.5 cm x 15 cm), and three levels of fertilizers. The quinoa cultivar EC 507748 was sown on December 4, 2018, November 20, 2019, and November 13, 2020. Seeding was performed manually in previously prepared furrows at a depth of 2 cm, followed by light irrigation and soil coverage. The entire crop management process adhered to recommended agricultural practices, including hand weeding and interculture for effective weed control throughout the growing season. Observations and measurements of various parameters were conducted following standard protocols, and the collected data were statistically analyzed using methods described by Panse and Sukhatme [2] to assess the treatment effects on quinoa growth and yield characteristics**.**

3. RESULTS AND DISCUSSION

he plant stand was recorded as non-significant in different spacings on a pooled basis (Table 1), and the similar pattern was observed in fertilizer levels. Plant height at 30, 60 DAS, and harvest was considerably higher in S_3 spacing (22.5 cm X 15 cm). In terms of fertilizer levels, the F_3 (60-40-40 NPK/ha) treatment produced the highest plant height at 30, 60 DAS, and harvest. The interaction effect was found to be non-significant in both plant stand and plant height. This could be due to competition between plants for natural resources in narrow spacing, which resulted in vertical growth of plants as opposed to wide spacing. In the pooled basis (Table 2), Among the various fertilizer levels, treatment F_3 (60-40-40 NPK/ha) had the maximum recorded inflorescence length and girth, whereas the other spacing results were not statistically significant. There was no significant difference identified in the cases of spacing, test weight, days to 50% flowering, and HI. Fertilizer levels were shown to have no significant effects on test weight or days to 50% flowering; however, treatment F_3 (60-40-40 NPK/ha) had a substantially higher HI value across the different fertilizer levels. When it came to inflorescence length, the interaction effect was found to be statistically recorded, but it was non-significant for inflorescence girth, test weight, days to 50% flowering, and HI (Table 3). S_2F_3 was observed to have a much longer inflorescence than S_3F_3 and S_1F_3, with similar results under other interaction circumstances.

Grain and straw yield in treatment S_1 (30 cm X 10 cm) was found to be significantly higher in Pooled basis (Table 4) of spacing, and was comparable to treatment S_3 (22.5 cm X 15 cm). As a result, all yield characteristics character were recorded higher in this spacing compared to other treatment. This suggests that lower plant density in wider spacing would not be able to make up for it in terms of grain production, whereas higher plant density in narrower spacing would be able to do so through decreased growth and yield parameters. A higher transfer of photosynthates from source to sink and optimal vegetative development could be the result of this efficient use of natural resources (light, water, and nutrients). The aforementioned outcomes agreed with the conclusions stated by Pourafarid et al. [3] and Yarnia [4]. This suggests that lower plant density was the primary reason why greater spacing was unable to offset the loss in grain yield. Regarding fertilizer levels, treatment F_3 (60-40-40 NPK/ha) yielded the highest grain and straw yields when compared to other treatments, since all yield attribute values were reported higher in this treatment.

Quinoa yields showed a notable increase with increasing fertilizer frequencies. This may be because the major nutrients that are needed in greater quantities are readily available. This helps the plants grow and develop more, which in turn increases grain yield. The findings of Parmar and Patel [5] and Gunjal [6] were supported by the aforementioned results. At pooled basis result, interaction effect (S×F) in grain and straw yield was found to be nonsignificant [7].

The spacing treatment of S_1 (30 cm X 10 cm) in economics produced a maximum net return of 73,571 Rs/ha and a BCR of 3.08 compared to the remaining spacing. Treatment F_3, which consisted of 60-40-40 kg NPK/ha, yielded the highest net return and BCR among all fertilizer levels.

Table 1. Effect on plant stand and height of quinoa under different levels of spacing and fertilizer

Treatments	Plant stands at harvest	Plant Height at 30 DAS (cm)	Plant Height at 60 DAS (cm)	Plant Height at Harvest (cm)
Spacing (S)				
S1	220	18.68	81.88	121.14
S2	170	18.75	77.27	113.7
S3	245	19.83	87.61	124.15
S. Em	16.00	0.308	1.462	1.868
CD (5 %)	NS	0.876	4.153	5.304
Fertilizer levels (F)				
F1	206	12.51	70.33	106.38
F2	213	20.48	82.79	120.43
F3	216	24.28	93.64	132.19
S. Em	3.60	0.978	1.382	3.366
CD (5 %)	NS	3.839	3.925	13.215
Interaction (S×F)				
S. Em	10.770	0.517	2.357	3.162
CD (5 %)	NS	NS	NS	NS
C.V %	8.81	8.63	8.77	8.27

Table 2. Effect on Yield attributes and HI of quinoa to different levels of spacing and fertilizer

Treatments	Inflorescence length (cm)	Inflorescence girth (cm)	Test weight (g/10ml)	Days to 50% Flowering	Harvest index (%)
Spacing (S)					
S1	25.16	39.5	7.29	47.0	46.31
S2	24.05	39.9	7.32	46.6	46.51
S3	25.34	39.6	7.22	47.6	45.97
S. Em	0.446	0.61	0.555	0.379	0.333
CD (5 %)	NS	NS	NS	NS	NS
Fertilizer levels (F)					
F1	21.05	33.6	7.22	47.18	45.68
F2	25.43	40.8	7.29	46.89	46.2
F3	28.07	44.6	7.32	47.17	46.91
S. Em	1.307	1.05	0.555	0.391	0.141
CD (5 %)	5.131	4.124	NS	NS	0.401
Interaction (S×F)					
S. Em.	0.775	1.018	0.1	0.633	0.234
CD (5 %)	2.197	NS	NS	NS	NS
C.V %	9.27	8.31	4.09	4.28	1.52

Table 3. Interaction effect of spacing and fertilizer levels on inflorescence length (cm) of quinoa

Treatment	Fertilizer Levels		
Spacing	**F1**	**F2**	**F3**
S1	21.56	25.65	28.26
S2	18.50	25.17	28.50
S3	23.11	25.47	27.45
S.Em	0.775		
CD (5 %)	2.197		
C.V %	9.27		

Nitrogen content in seed and straw was found to be insignificant due to differences in spacing, fertilizer levels, and their interaction (Table 5). Phosphorous content in seed and straw was found to be non-significant across different spacings and interactions. Fertilizer level F_1 was significantly higher than F_2 for phosphorus content in seed, and F_1 was significantly higher for phosphorus content in straw (Table 5). Potassium content in seed was found to be non-significant under different fertilizer levels and interactions, whereas in spacing, S_3 was significantly higher and on par with S_2. Potassium content in straw was found to be non-significant due to variations in spacing, fertilizer levels, and their interaction (Table 5).

After quinoa was harvested, the data (Table 6) on available nitrogen (kg/ha) in the soil was determined to be non-significant for a variety of spacing, fertilizer levels, and interaction effects. After quinoa was harvested, the data (Table 6) on the amount of phosphorus that was still available in the soil (kg/ha) was determined to be non-significant for a variety of spacing, fertilizer levels, and interaction effects. After quinoa was harvested, the data (Table 6) on available potassium (kg/ha) in the soil was determined to be non-significant for a variety of spacing, fertilizer levels, and their interaction effects.

Table 4. Effect on Grain, Straw Yield and economics of quinoa to different levels of spacing and fertilizer

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Gross Income (Rs/ha)	Cost of cultivation (Rs/ha)	Net Income (Rs/ha)	BCR
Spacing (S)						
S1	20.8	24.0	93735	30339	63397	3.09
S2	18.8	21.5	84645	30339	54307	2.79
S3	20.0	23.4	90000	30339	59662	2.97
S. Em	0.392	0.395	-	-	-	-
CD (5 %)	1.11	1.12	-	-	-	-
Fertilizer levels (F)						
F1	14.9	17.67	67230	30339	36892	2.22
F2	20.5	23.86	92295	32002	60293	2.88
F3	24.2	27.28	108900	35329	73571	3.08
S. Em	0.393	0.404	-	-	-	-
CD (5 %)	1.12	1.15	-	-	-	-
Interaction (S×F)						
S. Em	0.694	0.68	-	-	-	-
CD (5 %)	NS	NS	-	-	-	-
C.V %	10.31	8.86	-	-	-	-

Quinoa selling Price: 45 Rs/kg

Table 5. N, P & K Content in seed & straw of quinoa under different levels of spacing and fertilizer

Treatments	Nutrients content (%) in seed			Nutrients content (%) in straw		
	N	P	K	N	P	K
Spacing (S)						
S1	13.86	0.38	1.03	1.68	0.37	4.07
S2	16.42	0.40	1.23	1.27	0.39	4.02
S3	0.85	0.34	1.33	1.45	0.33	3.84
S. Em	0.147	0.0232	0.074	0.15	0.026	0.22
CD (5 %)	NS	NS	0.222	NS	NS	NS
Fertilizer levels (F)						
F1	0.17	0.43	1.23	1.57	0.46	4.18
F2	0.05	0.36	1.15	1.42	0.33	4.07
F3	0.46	0.33	1.21	1.40	0.30	3.68
S. Em	0.147	0.0232	0.074	0.15	0.026	0.22
CD (5 %)	NS	0.069	NS	NS	0.08	NS
Interaction (S×F)						
S. Em	0.255	0.04	0.128	0.26	0.046	0.381
CD (5 %)	NS	NS	NS	NS	NS	NS
C.V %	18.61	18.69	18.62	30.8	22.17	16.62

Table 6. Available N, P & K status of soil after harvest of quinoa

Treatments	Available nutrient status (kg/ha) in soil		
	Available N	Available P_2O_5	Available K_2O
Spacing (S)			
S1	140.8	20.1	102.3
S2	124.8	21.9	91.7
S3	147.7	25.4	108.7
S. Em	7.692	3.094	5.42
CD (5 %)	NS	NS	NS
Fertilizer levels (F)			
F1	139.4	22.1	108.0
F2	142.9	20.4	97.5
F3	131.0	24.8	97.2
S. Em	7.692	3.094	5.42
CD (5 %)	NS	NS	NS
Interaction (S×F)			
S. Em	13.324	5.36	9.388
CD (5 %)	NS	NS	NS
C.V %	16.75	41.38	16.11

Fig. 1. Field view of experiment at harvest time

Fig. 2. Treatment S1F3 (30 cm X 10 cm) X (60-40-40 N, P & K)

4. CONCLUSION

Based on a rigorous three-year experiment, it is recommended to sow quinoa seeds with a spacing of 30 cm × 10 cm and apply 60-40-40 kg/ha of NPK fertilizer during the rabi season. These practices have shown substantial benefits by significantly increasing both grain yield and net returns. This optimal combination of spacing and fertilizer application optimizes plant growth, ensuring efficient utilization of essential resources such as water and nutrients. As a result, it enhances the overall economic viability of quinoa cultivation in the experimental area.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhargava A, Shukla S, Deepak O. Effect of sowing dates and row spacings on yield and quality components of quinoa (*Chenopodium quinoa* Willd.) leaves. Indian Journal of Agricultural Sciences. 2007;77(11):748-751.
2. Panse VG, Sukhatme PV. Statistical methods of agricultural workers. ICAR Publ. New Delhi. 1967;381.
3. Pourfarid A, Kamkar B, Abbas AG. The effect of density on yield and some agronomical and physiological traits of amaranth (*Amaranthus spp*.). International Journal of Farming and Allied Science. 2014;3(12):1256-1259.
4. Yarnia M. Sowing dates and density evaluation of Amaranth as a new crop. Advances in Environment and Biology. 2010;4(1):41-46.
5. Parmar JK, Patel JJ. Effect of nitrogen management on growth and yield of grain amaranthus (*Amaranthus hypochondriacus* L.) grown on loamy sand soil. Asian Journal of Soil Science. 2009;4(1):106-109.
6. Gunjal GK. Studies on integrated nutrient management in grain amaranth (*Amaranthus hypochondriacus* L.) Ph.D. thesis submitted to the University of Agricultural Sciences, Bengaluru (Karnataka); 2011.
7. Ruas Paulo M, Alejandro B, Claudete F, Daniel JF, Andersen WR. Genetic relationship among 19 accessions of six species of *Chenopodium* L., by Random Amplified Polymorphic DNA fragments (RAPD). Euphytica. 1999;105:25-32.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/119107