Response of quinoa to different levels of spacing and fertilizer

ABSTRACT

In recent years, quinoa has been considering as extraordinary and promising nutri-rich crop, therefore supplementing or replacing of common cereal grains with quinoa carries high potential benefits to consumers worldwide. This is considered as pseudo-cereal crop, as it is a broad leaf plant with starchy dicotyledonous seed and therefore not a cereal. A field experiment entitled response of quinoa (*Chenopodium quinoa*) to different levels of spacing and fertilizer was conducted during *rabi* season of 2018-19, 2019-20 and 2020-21 at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The result of the experiment indicated Plant height at 30, 60 DAS and at harvest was found significantly the highest in spacing S_3 (22.5 cm X 15 cm). In case of fertilizer levels, F_3 (60-40-40 NPK kg/ha) treatment was found significantly the highest plant height at 30, 60 DAS and at harvest. The Inflorescence length and girth was recorded nonsignificant in different spacing but which was recorded significantly the highest in treatment F_3 (60-40-40 NPK kg/ha) among different fertilizer levels. In Pooled basis of spacing, the grain and straw yield were found significantly higher in treatment S_1 (30 cm X 10 cm) and in case of fertilizer levels, the grain and straw yield were recorded significantly higher in treatment F_3 (60-40-40 NPK kg/ha). In economics, the spacing treatment of S_1 (30 cm X 10 cm) gave maximum net return and BCR. In the different fertilizer levels, treatment F_3 (60-40-40 NPK kg/ha) gave maximum net return and BCR.

Keywords: Quinoa, Chenopodium quinoa, Spacing and fertilizer

Introduction

Quinoa (*Chenopodium quinoa* Willd.) is an herbaceous annual plant in the Amaranthaceae family. It originated in South America's Andean region, where indigenous Inca civilizations in Bolivia, Chile, Ecuador, and Peru cultivated it between 5000 and 750 B.C. (Ruas *et al*., 1999). Quinoa cultivation is one of the main sources of income for Andean farmers in South America, but it is no longer limited to them as it has spread to other areas of the world. Quinoa farming has expanded significantly in North America and Europe in recent years. Because of its wider resilience to varying climatic conditions and abundant nutrient supplies, India has lately joined the list of countries cultivating quinoa[8,9,10]. It is taken in a variety of forms, including grains, flakes, pasta, bread, biscuits, beverages, and meals. North Americans and Europeans discovered it as a healthy snack around 1970, and its popularity has skyrocketed in recent years because to its gluten-free (useful for diabetic patients) and high protein content. According to the United Nations Organisation for Agriculture and Food (UNOAF), quinoa grain is the only vegetable food that delivers all essential amino acids that are important for human health and is nutritionally comparable to milk. It has a high protein level ranging from 14 to 18%, which is substantially higher than that of regularly used cereals and millets. It contains a variety of important amino acids, including lysine, isoleucine, methionine, histidine, cystine, and glycine. It has a high concentration of Ca, Fe, Zn, Cu, and Mn, as well as important fatty acids like linoleate and linolenate. Furthermore, 100 g of seed contains vitamins such as thiamine (0.4 mg), folic acid (78.1 mg), vitamin C (16.4 mg), riboflavin (0.39 mg), and carotene (0.39 mg) (Bhargava *et al*., 2007).

It is a resilient plant that thrives under moisture stress and can even be cultivated in marginal soils. However, sandy loam is the best soil for growing quinoa. It grows natively in the Himalayan area of India, where temperatures range from 0 to 20 degrees Celsius. Sardarkrushinagar Dantiwada Agricultural University in Gujarat has begun evaluating various quinoa germplasms and developing agro-techniques for the semiarid plain region as part of a research effort in the All-India Co-ordinated Research Network on Potential Crops.

One of the most essential components of systematic cultivation that could improve crop productivity is inter and intra row spacing. Plants can obtain sufficient water, sunlight, and nourishment from the soil because of optimal spacing, which can influence healthy seed output and yield qualities. Despite its versatility and nutritional superiority, its commercial potential has mostly gone unfulfilled. There is little literature on the date of planting, optimum density, seed rate, spacing, and other agro-techniques for its production in India. In India, very little research has been conducted on the acceptability and standardization of quinoa packing practices. In view of above facts, the research entitled "Response of quinoa (*Chenopodium quinoa* Willd.) to different level of spacing and fertilizer" was undertaken with an objective to standardize the optimum spacing and fertilizer levels for quinoa crop.

Materials and methods

In the rabi seasons of 2018–19, 2019–20, and 2020–21, a field experiment titled "Response of Quinoa (*Chenopodium quinoa* Wild.) to different level of spacing and fertilizer " was carried out at the Center for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experimental site's soil had a texture of loamy sand, a pH of 7.55, low levels of organic carbon (0.21%) and available nitrogen (137.6 kg/ha), medium levels of available phosphorus (25.67 kg/ha) and available potassium (102.7 kg/ha). Nine treatment combinations, comprising 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, were used in the experiment. The treatments were taken in a randomized block design (using a factorial concept) with three replications. The quinoa cultivar EC 507748 was Sown on December 4, 2018, November 20, 2019, and November 13, 2020. Sowing was done manually in previously opened furrows to a depth of 2 cm. Seeds were thoroughly covered with soil, and each plot received a light irrigation after seeding. Aside from that, the crop mentioned above was grown according to the approved techniques. During the crop growing season, one-hand weeding and interculture were used to achieve successful weed control. The observations were recorded according to normal methods. The data were statistically evaluated for the various characteristics indicated by Panse and Sukhatme (1967).

Results and Discussion

The 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.* (2014) and Yarnia (2010). 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 (2009) and Gunjal (2011) were supported by the aforementioned results. At pooled basis result, interaction effect (S×F) in grain and straw yield was found to be nonsignificant.

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.

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.

Conclusion

After three years of experimentation, it is recommended to sow quinoa at 30 cm × 10 cm spacing and apply 60-40-40 NPK kg/ha of fertilizer during the *rabi* season to increase grain yield and net returns.

References

1. Bhargava, A., Shukla, S. and Deepak, O. (2007). Effect of sowing dates and row spacings on yield and quality components of quinoa (*Chenopodium quinoa* Willd.) leaves. *Indian Journal of Agricultural Sciences*, **77**(11): 748-751.
2. Gunjal, G. K. (2011). Studies on Integrated Nutrient Management in grain amaranth (*Amaranthus hypochondriacus* L.) *Ph.D. thesis* submitted to the University of Agricultural Sciences, Bengaluru (Karnataka).
3. Panse V. G. and Sukhatme P. V. (1967) Statistical methods of agricultural workers. ICAR Publ. New Delhi, 381.
4. Parmar, J. K. and Patel, J. J. (2009). Effect of nitrogen management on growth and yield of grain Amaranthus (*Amaranthus hypochondriacus* L.) grown on loamy sand soil. *Asian Journal of Soil Science*, **4** (1):106-109.

5. Pourfarid, A., Kamkar, B. and Abbas, A. G. (2014). The Effect of density on yield and some Agronomical and physiological traits of Amaranth (*Amaranthus spp*.). *International Journal of Farming and Allied Science*, *3*(12): 1256-1259.
6. Ruas Paulo, M., Alejandro, B., Claudete, F., Daniel, J. F. and Andersen, W. R. (1999). Genetic relationship among 19 accessions of six species of *Chenopodium* L., by Random Amplified Polymorphic DNA fragments (RAPD). *Euphytica*, **105**: 25-32.
7. Yarnia, M. (2010). Sowing dates and density evaluation of Amaranth as a new crop. *Advances in Environment and Biology*, **4**(1): 41-46.

8. Basantes-Morales ER, Alconada MM, Pantoja JL. Quinoa (Chenopodium quinoa Willd) Production in the Andean Region: Challenges and Potentials. J. Exp. Agric. Int. [Internet]. 2019 May 31 [cited 2024 Jun. 14];36(6):1-18. Available from: https://journaljeai.com/index.php/JEAI/article/view/1447

9. Abhishek, Thakral S, Kumar P, Rahul, Bhardwaj S, Pareek A, Saini M. Growth, Yield Attributes and Yield of Barley (Hordeum vulgare L.) under Different Levels of Fertilizer and Vermicompost Grown under Every Furrow and Alternate Furrow Irrigation Methods. Int. J. Plant Soil Sci. [Internet]. 2024 May 13 [cited 2024 Jun. 14];36(6):511-9. Available from: https://journalijpss.com/index.php/IJPSS/article/view/4653

10. Youssef MA, Farag MI. Co-application of organic manure and bio-fertilizer to improve soil fertility and production of quinoa and proceeding Jew's mallow crops. Journal of Soil Science and Plant Nutrition. 2021 Sep;21(3):2472-88.

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		

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)