Growth and Economic Return of Quinoa (*Chenopodium quinoa* Willd.) under Different Plant Spacing and Fertility Conditions

Abstract

Quinoa (*Chenopodium quinoa* Willd.) is a native of the Andes that has sparked a worldwide interest due to its unique nutritional value. Quinoa seed have an orthodox magnificent nutritional food quality and were also called "the mother grain". To achieve optimal crop yield, farmers must meticulously manage various factors, ensuring a balanced approach to fertility levels, irrigation, and pest control. It is crucial for farmers to find a delicate balance in achieving specific nutritional and yield targets. The current investigation was conducted in *kharif* 2022, with genotype "EC507742" at Research and Extension Centre, Gaja, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India. The experiment comprised of two factors *viz*., geometry (S): S1- 20 x10 cm, S2- 30 x 10 cm and S3- 40 x 10 cm in main plot and fertility levels (F): F1- Control, F2- 75% NPKS, F3- 100% NPKS and F4- 125% NPKS in sub plot with total of 12 treatment combinations that were evaluated in split plot design with three replications. The data was analysed using OPSTAT with figures from SAS (proc glm). Among the geometries, S2 (30 x 10 cm) excelled in field conditions and economics relative to others. Among different fertility levels, F3 (100% NPKS) demonstrated the greatest growth, yield characteristics, yield, and higher returns for quinoa compared to other fertility levels. The interactions between geometry and fertility levels were also found significant for growth, yield attributes and yield with higher in S2F3. Thus, it can be concluded that using the recommended fertilizer (100% NPKS) with the ideal spacing of 30 x 10 cm improves growth, yield and profitability of Quinoa.

Key words. Quinoa, fertility, spacing, balance, growth, yield, yield attributes and economic

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1. INTRODUCTION

Quinoa (*Chenopodium quinoa*) is a remarkable and versatile crop with deep historical roots dating back over 5,000 years. Originally cultivated by ancient civilizations in the Andean region of South America, it was revered as the "mother grain" and sustained communities in harsh environments, earning a sacred status. Today, quinoa has transformed from a traditional staple into a sought-after superfood, embraced by health-conscious individuals worldwide. One of quinoa's most compelling attributes is its exceptional nutritional content. It is gluten-free and contains all nine essential amino acids, making it a complete protein vital for human well-being. Additionally, quinoa is rich in dietary fibre, vitamins, minerals, and antioxidants, making it a highly beneficial addition to any diet. Its abundance of nourishing elements has earned it the esteemed title of a superfood, playing a significant role in addressing malnutrition concerns and promoting overall health and vitality

The rising global demand for quinoa has created significant economic opportunities for farmers and exporters in quinoa-cultivating regions. As consumers recognize its nutritional benefits, the crop's market value continues to grow, becoming a vital income source for small-scale farmers. This economic advancement empowers local communities in developing areas. The production of high-quality quinoa seeds with desirable protein content, mineral concentration, and overall seed quality is influenced by various factors, including fertility level, irrigation, fertilization, pest and disease management, and crop rotation. The study by [1] demonstrated that increasing nitrogen levels can enhance seed protein content, while higher fertility levels can increase the concentration of essential minerals. However, excessive fertilization should be avoided, as it may negatively impact seed quality.

To achieve maximum crop yield, farmers should carefully manage all these factors, ensuring a balanced approach to fertility levels, irrigation, and pest control. Proper spacing and fertility levels are crucial for uniform seed size and shape, while adequate nutrient availability contributes to a high germination rate. Moreover, genetic makeup and environmental conditions play significant roles in determining seed quality. A comprehensive understanding of these factors and their interactions can help farmers optimize their quinoa production systems and achieve higher yields. It is essential for farmers to strike a careful balance between improving seed quality and meeting specific nutritional and yield goals. By adopting sustainable and responsible agricultural practices, farmers can ensure the production of high-quality quinoa seeds that are not only beneficial for human nutrition but also contribute to the long-term health of the farming ecosystem. Keeping in view the a for mentioned facts and importance, the present study was conceived and initiated to identify the appropriate cropping different spacing and fertility conditions for enhancing the Growth, Yield, Yield Attributes and Economics of quinoa in Uttarakhand regions of India.

2. MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2022 at Research and Extension Centre, Gaja, College of Forestry, Ranichauri (Tehri Garhwal).

Geographically, it is located in latitude 300 16’17’’ N, longitude 780 25’21’’ E and altitude 1700-1760 m above sea level in the chilly temperature, tropical to subtropical zone of Uttarakhand. Thereafter, the experiment was laid out in spilt plot design with three replications with three different geometry (S1: 20 x 10 cm, S2: 30 x 10 cm and S3: 40 x 10 cm) as main plot and four fertility levels (F1: Control, F2: 75 % NPKS, F3: 100 % NPKS and F4: 125 % NPKS as sub plot under tropical to subtropical zone of Uttarakhand. , the mean maximum and minimum temperature, rainfall, relative humidity at morning and afternoon, wind speed and bright sunshine was24.20C, 13.10C, 7.7 mm, 87.1%, 76.7%, 4.0 kmph and 6.0 hr/day, respectively. The experimental soil was silty clay loam in texture, The soil was characterized by medium amount of available nitrogen (242 kg/ha) and phosphorus (22 kg/ha), high amount of available potassium 404 kg/ha) and organic carbon (0.75 %) with slightly acidic pH (6.1). The crop was supplied with recommended dose of fertilizer i.e., NPKS 40:20:20:20 in the form of urea, NPK (12:32:16) and Bentonite, respectively. Entire dose of NPK and S was

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applied as basal through placement in the furrows made with hand hoes 5 cm away from seed rows and at a depth of 2 cm below the seed zone as per the treatments. One irrigation was provided after sowing to facilitate uniform germination of the crop at 25 days after sowing. Field was cleaned before sowing of the crop. Two hand weeding was done manually at 30 and 60 DAS to keep the crop free from weeds. During the seed formation stage, crop was attacked by sucking pest i.e., Aphids and was controlled by spraying the imidacloprid @ 2 ml lit-1 of water. Anthracnose observed after heavy rainfall in crop that was control by mancozeb. Growth, Yield and Yield Attributes from random selected five plants from each net plot was recorded and the mean value was worked out and yield was recorded from each net plot. The crop was harvested on 2 September 2022. The net returns were calculated by subtracting cost of cultivation from gross returns. The experimental data obtained during the course of investigation was analysed by using split plot design (SPD) for field condition with OPSTAT Programme designed and development by O.P. Sheoran, Computer Programmer at CCS HAU, Hisar, India and figure from SAS (proc glm).

3. RESULTS AND DISCUSSION

3.1 Influenced of different spacing and fertility conditions on crop growth and development of quinoa

The data pertaining that S2F3 recorded significantly higher plant population, plant height, number of branches, number of leaves among the other different spacing and fertility conditions under different crop stages while at harvest plant height was non-significant~~lye~~ presented in Table.1 and Table 2, Fig.1-2.

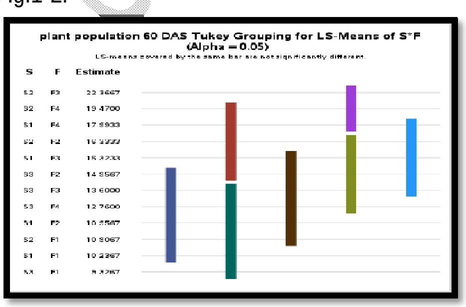

Fig. 1: Plant population at 60 DAS as per Tukey grouping of different spacing and fertility conditions

The wider spacing between plants positively impacted the growth parameters of quinoa due to the reduced competition among plants for vital resources like space, light, moisture, and nutrients, essential for their optimal growth. This observation aligns with the research findings [2].

In contrast, narrow spacing led to diminished plant height, likely caused by increased competition for nutrients and light among plants.On other hand, wider spacing allowed plants to grow taller, as it alleviated this competition. These results are consistent with the study conducted by [3] but they contradict the findings [4]. Furthermore, it was observed that plant height increased progressively with higher NPK levels, with the combination of the highest NPK levels resulting in the tallest plants. This height increase can be attributed to the abundant availability of nitrogen and phosphorus, which promotes improved photosynthesis and overall plant vigor. These observations are in line with the results reported [5,6 and 7]

Regarding the number of branches

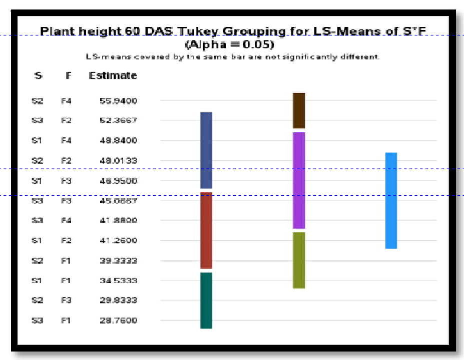

Fig. 2: Plant height at 60 as per Tukey grouping of different spacing andfertility conditions

and leaves, it was found that S2 geometry combined with F3 fertility level significantly influenced these characteristics. The higher level of fertilizer in this combination stimulated chlorophyll synthesis and fostered vegetative growth, leading to an increased number of leaves and branches in the plants.

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Table.1:Interaction of different spacing and fertility conditions under the field condition of quinoa

S.No.	Treatments	Plant Population (60 DAS)	Plant Height (60 DAS)	No.of Leaves (60 DAS)	No.of branchs (60 DAS)	Plant height	Panicle length	Seed yield	Straw yield	COC	Gross Income	Net Profit	B:C
1.	S1F1	10.2	42.9	33.2	25.9	71.3	16.7	290.0	999.6	14795	30999	16204	1.10
2.	S1F2	11.0	41.3	45.9	26.1	73.0	16.8	455.0	1149.5	16511	47799	31288	1.89
3.	S1F3	15.3	47.0	51.0	28.0	75.6	16.9	580.0	1549.4	17248	61099	43851	2.54
4.	S1F4	18.0	48.8	52.8	28.6	78.2	17.3	610.0	1820.7	17891	64641	46751	2.61
5.	S2F1	10.9	43.3	34.6	26.0	73.0	17.7	320.0	1094.8	14795	34190	19395	1.31
6.	S2F2	16.3	48.0	51.3	28.5	76.9	18.0	590.0	1259.0	16511	61518	45007	2.73
7.	S2F3	22.4	29.8	66.8	31.5	63.6	18.1	790.0	1696.9	17248	82394	65146	3.78
8.	S2F4	19.5	55.9	61.7	29.1	83.3	18.2	700.0	1994.1	17891	73988	56098	3.14
9.	S3F1	9.3	42.0	29.9	21.5	68.2	18.3	258.3	961.9	14795	27757	12962	0.88
10.	S3F2	15.0	52.4	49.6	27.3	78.5	19.0	571.7	1282.5	16511	59732	43220	2.62
11.	S3F3	13.6	45.1	46.1	27.6	74.7	19.9	569.4	1261.6	17248	59468	42220	2.45
12	S3F4	12.8	41.9	47.0	26.3	74.6	20.2	505.6	1177.9	17891	52911	35021	1.96
	Mean	14.5	44.8	47.5	27.2	**74.2**	**18.1**	**520.0**	**1354.0**	**16611.3**	**54708.0**	**38097**	**2.3**

Table.2.Effect of different spacing and fertility conditions under the field condition of quinoa

A Geometry (S)	Plant Population (60 DAS)	Plant Height (60 DAS)	No.of Leaves (60 DAS)	No.ofbranchs (60 DAS)	Plant height	Panicle length	Seed yield	Straw yield	COC	Gross Income	Net Profit	B:C
S1(20cm x 10cm)	13.6	42.9	45.7	27.2	74.6	16.9	483.8	1379.8	16611	51135	34523	2.04
S2(30cm x 10cm)	17.3	43.3	53.6	28.7	74.2	18.0	600.0	1511.2	16611	63022	46411	2.74
S3(40cm x 10cm)	12.8	42.0	43.1	25.7	4.1	19.4	600.0	1171.0	16611	49967	33356	1.98
CD (0.05)	1.7	NS	1.3	1.2	NS	9.5	140.2	140.2				
B Fertility level (F)												
F1 Control	10.2	34.2	32.6	24.5	70.8	95.0	289.4	1018.8	14795	30982	16187	1.10
F2 (75 % NPKS)	14.1	47.2	48.9	27.3	76.1	108.7	538.9	1230.3	16511	56350	39838	2.14
F3 (100% NPKS)	17.1	40.6	54.7	29.0	71.3	132.1	646.5	1502.6	17248	67653	50405	2.92
F4 (125% NPKS)	16.4	48.9	53.8	28.0	78.7	117.3	605.2	1664.2	17891	63847	45956	2.57
CD (0.05)	1.6	2.2	2.3	1.4	NS	4.4	59.2	174.6				
To compare means of F at same level of S	3.0	4.4	4.0	2.5	4.4	9.0	105.0	316.6				
To compare means of S at same/different level of F	2.9	5.4	3.6	2.4	5.4	11.5	94.2	295.1				

3.2 Influenced of different spacing and fertility conditions on crop yield and yield attributes of quinoa

The non-significant in panicle length. Significantly higher straw yield was found S2F4 which was statistically at par with S2F3. While, in seed yield the significantly higher seed yield was found S2F3 which was statistically at par with S2F4 among all the interactions between spacing with different fertility conditione presented in Table 1 and Table 2, Fig 3 and 4.This could possibly be attributed to the availability of nutrients to the plants and the improved uptake of elements, especially nitrogen, resulting from the application of fertilizers. Consequently, plants exhibited enhanced nutrient absorption, leading to growth and an increase in the yield attributes and yield. The application of phosphorus may have led to an accumulation of carbohydrates, which were subsequently mobilized to the reproductive parts of the plants.

The significance of potassium, a highly mobile nutrient in plants, should not be overlooked, as

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Comment [H6]: Rewrite the sentence Poorly framed it plays a vital role in the elongation and division of young tissues and contributes to maintaining turgor pressure. Moreover, it improves both the quality and yield of the plants. These findings are consistent with the research conducted in fennel [8 and 9]. Under wider spacing, the plants exhibited broader growth, evidenced by an increased number of branches, panicles, and longer panicle length. These changes can be attributed to the greater access to light, space, and nutrients per plant. These findings align with the research conducted [10], who also observed higher panicle length and spikelet numbers under wider row spacing compared to narrower spacings. This can be explained by the reduced competition among rows for space, nutrients and moisture. However, these all are correlated to each other this might be due to increase availability of growth favouring

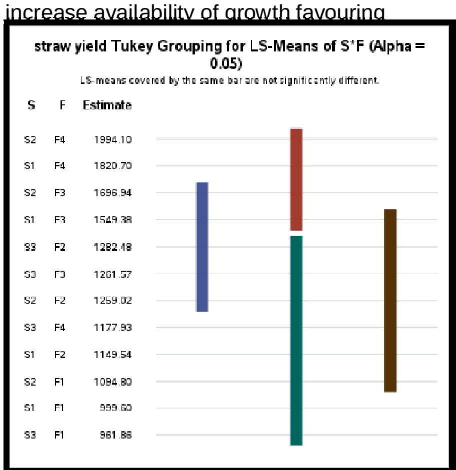

Fig.3. Straw yield of quinoa as per Tukey grouping of different spacing and fertility conditions

parameters were recorded in control with narrower spacing. This might be due to the fact that non-availability of nutrient at early growth period reduced the plant growth significantly. The maximum harvest index obtained in S1 among the geometry and F2 fertility level among all the fertility levels. It could be due to an increased transfer of assimilates from the source to the grains, leading to improved growth and filling [12]

component viz., nutrients, air and moisture at wide geometry. Similar findings having been reported [11] While, test weight of quinoa did

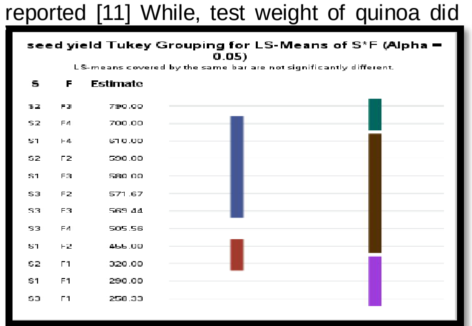

Fig.4. Seed yield of quinoa as per Tukey grouping of different spacing and fertility conditions

not show any significant effect of geometry and fertility level. As quinoa seeds are very minute, the weight did not vary much due to the treatment effects.

The enhanced reproductive growth of cowpea might be attributed to wider spacing, which resulted in reduced congestion and allowed for an expanded gap between plants, facilitating enhanced sun exposure and increased nourishment. These outcomes correspond to the findings of [13] Straw yield exhibited significant variations in response to different spacing treatments. This could be attributed to the increased density of plants in close spacing, resulting in greater plant biomass and subsequent above-ground growth. These outcomes correspond to the findings of [14]. Also, the application of an increased fertilizer dosage resulted in enhanced growth and yield-related traits, leading to seed yield, crop residue and biological yield. These consistent outcomes correspond to the findings of [15]. The lowest values of plant growth

3.4 Influenced of different spacing and fertility conditions on seed economics of quinoa

The variations in interactive effect of gross return, net return and benefit cost ratio were observed among geometry and different fertility levels. The highest gross return, net return and benefit cost ratio was recorded in S2F3 and the lowest recorded in S3F1 presented in Table 1 and Table 2, Fig 5. The

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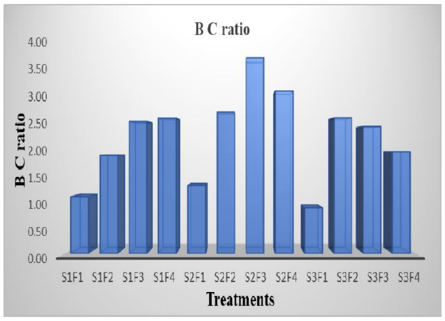

Fig.5: Benefit cost ratio of quinoa as influenced by different spacing and fertility conditions

irrespective of the geometry and it was lower with F1irrespective of fertility levels. The gross and net returns with BC ratio were higher in S2 with application of F3 among all the different spacing and fertility conditions. It was mainly due to higher grain yield on the respective treatments. Quinoa also being a new crop has wide market all over the world, it has gained popularity due to its nutritional value. As it is a new crop in Asian market, it has to be grown in these conditions and benefit the farmers. Central Food Technology Research Institute (CFTRI)has also played at important role in familiarising the crop to consumers and farmers. The high BC ratio might be due to low cost of cultivation and higher net returns fetching more monetary returns.

4. CONCLUSIONS

For getting higher yield optimum different spacing of 30 x 10 cm and for better growth and economic return under the wider spacing of 40 x 10 cm along with recommended fertility condition (100% NPKS) can be preferred.

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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.

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