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Response of quinoa (*Chenopodium quinoa* Willd.) to different spacing and fertilizer levels under Eastern dry zone of Karnataka

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Abstract
A field experiment was conducted at Main Research Station, University of Agricultural Sciences, Hebbala, Bengaluru during *Rabi* 2018-19 and 2019-20 for two consecutive years. The soil was sandy loam in texture with neutral pH (6.24), low organic carbon (0.25), low in available N (244.14 kg ha^{-1}) and medium in available P_2O_5 (28.32 kg ha^{-1}) and K_2o (186.04 kg ha^{-1}). The experiment was laid out in Split Plot Design with three different spacing (S_1-30x15 cm, S_2-45x15 cm and S_3- 60x15 cm) as main plots and three fertilizer levels (F_1- 20:10:10 NPK kg/ha, F_2- 40:20:20 NPK kg/ha and F_3-60:40:40 NPK kg/ha) in sub plots. Totally there were nine treatment combinations which were replicated thrice in split plot design. The results revealed that among different spacing, significantly higher grain yield was recorded with the spacing of 45 x 15 cm (2022 kg/ha) which was on par with 30 x15 cm (1785 kg/ha) spacing as compared to wider spacing of 60 x 15 cm (1588 kg/ha). Among sub plots, grain yield was significantly higher with the fertilizer level of 60:40:40 NPK kg/ha (1828 kg/ha) but which was on par with fertilizer level of 40:20:20 NPK kg/ha (1710 kg/ha) as compared to the fertilizer level of 20:10:10 NPK kg/ha (1392 kg/ha). Similarly, growth parameters viz., number of branches per plant and panicle length was significantly higher in wider spacing of 60 x15 cm as compared to other spacing. Whereas, plant height significantly higher in narrow spacing of 30 x 15 cm. However, number of branches per plant and panicle length was significantly higher with wider spacing of 60 x15 cm as compared to other spacing. Similarly, maximum net returns and B:C ratio were noticed in fertilizer level of 60:40:40 NPK kg/ha (Rs.153473/ha and 5.23, respectively) which was closely followed by 40:20:20 NKP kg/ha (Rs. 142560/ha and 5.01, respectively).

Keywords: Economics, fertilizers, growth, quinoa, spacing, yield

Introduction
Quinoa (*Chenopodium quinoa* Willd.) is an herbaceous annual plant belongs to family Amaranthaceae. It was originated from the Andean region of South America where it was cultivated by indigenous Inca communities across Bolivia, Chile, Ecuador and Peru between 5000 and 750 B.C. (Ruas *et al*., 1999) [9]. Quinoa cultivation is one of the main livelihoods of Andean farmers in South America but no longer restricted to them as it spread to different parts of the world. In recent years, North America and Europe have taken up quinoa farming in sizeable area. India has recently joined in the list of countries of quinoa cultivation because of its wider adaptability to varied climatic conditions and its rich nutrient sources. It is consumed in varied forms i.e., grains, flakes, pasta, bread, biscuits, beverages, meals etc. It is discovered as a healthy food by North Americans and Europeans in 1970 and its popularity is drastically increased in recent years because of its gluten free (helpful for diabetic patients) and high protein nature. As per United Nations Organization for Agriculture and Food (UNOAF), quinoa grain is the only vegetable food that provides all essential amino acids which are important for human health and is comparable with milk in terms of nutrition. It is rich in protein content ranging from 14 to 18 per cent which is much higher compared to commonly used cereals and millets. It has many essential amino acids like lysine, isoleucine, methionine, histidine, cystine and glycine. It has high amount of Ca, Fe, Zn, Cu and Mn with an oil content of 1.8 to 9.5 per cent and rich in essential fatty acids like linoleate and linolenate. In addition, it is also rich source of vitamins like thiamine (0.4 mg), folic acid (78.1 mg), vitamin C (16.4 mg), riboflavin

(0.39 mg) and carotene (0.39 mg) in 100 g seed (Bhargava *et al.*, 2007).

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. It is a hardy plant which can thrive well under moisture stress and can be grown in marginal soils as well. However, the most suited soil for quinoa forming is sandy loam. In India, it grows naturally in Himalayan region where temperature ranges between 0-20 °C. In Karnataka as a part of research programme in All India Co-ordinated Research Network on Potential crops, Bangalore has initiated evaluation of some quinoa germplasms and development of agro-techniques for semiarid plain region.

Inter and intra row spacing is one of the most important components of systematic cultivation that could enhance productivity of this crop. Due to adequate spacing plants can gain sufficient water, sunlight and nutrition from the soil, which can influence the healthy seed yield and yield attributes. In spite of its wide adaptability and nutritional superiority, its commercial potential has remained untapped. Literature on date of sowing, optimum density, seed rate, spacing and other agro-techniques for its cultivation in India is scanty. Very little research work has been done on the adoptability and standardization of package of practices of quinoa in India. This crop can be grown in varied agro-climatic regions with minimum rainfall and this crop well suited to cropping system because of its short duration. Further, there is a need to develop basic agronomic practices for quinoa crop in order to popularize among farmers. In view of above facts, the research entitled “Response of quinoa (*Chenopodium quinoa* Willd.) to different spacing and fertilizer levels” was undertaken with an objective to standardize the optimum spacing and fertilizer levels for quinoa crop.

Materials and Methods

The field experiment was conducted at the Main Research Station, University of Agricultural Sciences, Hebbal, Bengaluru during *Rabi* 2018-19 and 2019-20 for two consecutive years. The soil was sandy loam in texture with neutral pH (6.24), low organic carbon (0.25), low in available N (244.14 kg ha^{-1}) and medium in available P_2O_5 (28.32 kg ha^{-1}) and K_2o (186.04 kg ha^{-1}). The experiment was laid out in Split Plot Design with three different spacing (S_1-30x15 cm, S_2-45x15 cm and S_3-60x15 cm) as main plots and three fertilizer levels (F_1- 20:10:10 NPK kg/ha, F_2- 40:20:20 NPK kg/ha and F_3-60:40:40 NPK kg/ha) in sub plots. Totally there were nine treatment combinations which were replicated thrice. The experiment site is located in Agro-Climatic Zone V (Eastern Dry Zone) of Karnataka at latitude of 13° 04' North, a longitude 77° 58' East and at an altitude of 904 meters above Mean Sea Level (MSL). The genotype used was EC 507741. The soil was sandy loam in texture with neutral pH (6.24), low organic carbon (0.25), low in available N (244.14 kg ha^{-1}) and medium in available P (28.32 kg ha^{-1}) and potassium (186.04 kg ha^{-1}). The fertilizers were applied as per the treatments in the form of urea, Di-ammonium Phosphate (DAP) and Muriate of Potash (MOP). Entire dose of P, K and half the dose of N was 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. The remaining 50 per cent of N was top dressed during inter cultivation at 30 DAS. Plant protection measures have not been taken as there was no pest and disease incidence during crop growth period. Crop was grown under protective irrigation condition with application of irrigation water as and when needed based on soil moisture condition. Growth parameters *viz*., number of branches per plant and number of leaves per plant were recorded at 60 DAS and remaining data has been recorded at the time of harvest. Data was statistically analyzed by following the analysis of variance as suggested by Panse and Sukhatme (1978) [6].

Results and Discussions

Growth parameters of quinoa as influenced by spacing and fertilizers levels

Pooled data of two years indicated that plant height has influenced significantly by different spacing and fertilizer (Table 1). There was increasing in plant height in closer spacing of 30 x15 cm, while it was decreased in wider spacing 60 x30 cm. The mean data of two years revealed that, among different spacing, plant height was significantly higher with the spacing of 30 x15 cm (127.95 cm) followed by 45x 15 (116.16 cm) and 60 x 15 cm (100.03 cm). This might be due to competition between plants for natural resources in narrow spacing resulted in vertical growth of plants as compared to wider spacing. Whereas, number of branches per plant was significantly higher with wider spacing of 60 x15 cm (19.48) which was on par with 45 x15 cm (18.19) as compared to closer spacing of 30 x 15 cm (15.74). It might be due to wider spacing of the plants that could allow the plants to grow horizontally which may have resulted in increase in number of branches plant^{-1} under wider row spacing than narrow spacing. This could also be due to growing quinoa at wider rows provides plant with more illumination and less underground competition for nutrients and moisture. The above results were line with the findings of Mary *et al*. (2018) [4] who found that spacing of 60 × 45 cm recorded significantly higher number of branches compared to other narrow spacing in Chia crop. The above results were also supported by Oad *et al*. (2002) [5] and Yarnia (2010) [11].

However, among different fertilizer levels, plant height was significantly higher with fertilizer level of 60:40:40 NPK kg/ha (121.07 cm) but which was on par with fertilizer level of 40:20:20 NPK kg/ha (110.97 cm). Similarly, the marked variation in number of branches per plant due to different fertilizer levels was more with the higher fertilizer level. Significantly higher number of branches per plant was observed in higher fertilizer dose of 60:40:40 NPK kg/ha (19.64) which were on par with fertilizer dose of 40:20:20 NPK kg/ha (18.25) as compared to fertilizer level of 20:10:10 NPK kg/ha. The significant increase in number of branches per plant at higher levels of fertilizers is might be due to the better growth and greater uptake of nutrients helped in better cell division, cell elongation and protein synthesis, which ultimately enhanced the rate to produce more number of branches per plant. The above results are in conformity with the findings of Anand *et al* (2020) [1] in grain amaranth. The interaction of spacing and fertilizer levels for number of branches per plant was found non-significant.

Similarly, panicle length (39.14 cm) was significantly higher with the spacing of 60 x 15 cm as compared to other spacing. Among subplots, panicle length was significantly higher with fertilizer level of 60:40:40 NPK kg/ha (37.03 cm) which was at par with the fertilizer levels of 40:20:20 NPK kg/ha (33.99 cm) as compared to 20:10:10 NPK kg/ha (25.09 cm). The increase in the panicle length with increase in fertilizer levels could be due to better availability of major nutrients which may resulted to higher panicle length.

Yield and yield parameters of quinoa as influenced by spacing and fertilizer levels

Grain yield was significantly influenced by spacing and fertilizer levels (Table 2). Among different spacing, significantly higher grain yield was recorded with the spacing of 45x15 cm (2022 kg/ha) which was on par with 30 x15 cm (1785 kg/ha) spacing as compared to wider spacing of 60 x15 cm (1588 kg/ha). This indicates that wider spacing could not compensate in the grain yield mainly due to lesser plant density but more plant density in narrow spacing could compensate with grain yield though lower growth and yield parameters. This could be due to efficient utilization of natural resources (water, light and nutrients) with optimum vegetative growth and higher translocation of photosynthates from source to sink. The above results were in conformity with the findings of Yarnia (2010) [11] and Pourafarid *et al*. (2014) [8]. This indicates that wider spacing could not compensate in the grain yield mainly due to lesser plant density. This indicates that wider spacing could not compensate in the grain yield mainly due to less plant density and more density in narrow spacing could compensate with grain yield obtained in optimum spacing of 45x 15 cm. Hence, 45x 15 cm is found to be optimum for higher grain yield of quinoa crop. Among different fertilizer levels, grain yield was significantly higher in the fertilizer level of 60:40:40 NPK kg/ha (1828 kg/ha) but which was on par with fertilizer level of 40:20:20 NPK kg/ha (1710 kg/ha) as compared to the fertilizer level of 20:10:10 NPK kg/ha (1392 kg/ha).This could be due to adequate availability of major nutrients which are required in larger quantity thus directly help the plants to register higher growth and development and finally grain yield. The above results were in agreement with the findings of Parmar and Patel (2009) [7] and Gunjal (2011) [3].

However, seed yield per plant was significantly higher with the spacing of 60 x15 cm as compared to other spacing. This could be due to better availability of space and illumination results in higher growth parameters and intern seed yield per plant. This could be due to lesser competition for growth resource like light, space, nutrients and also for moisture due to less number of plants in wider spacing. These results were in line with the findings of Mary *et al.* (2018) [4] and Sief *et al.* (2015) [10] who found that wider spacing recorded higher yield per plant compared to narrow spacing in chia and quinoa, respectively. However, among fertilizer levels, application of 60:40:40 NPK kg/ha was found superior by recording higher seed yield per plant (20.76 g/plant) which was closely followed by 40:20:20 NPK kg/ha (19.65 g/plant) as compared to other fertilizer levels. The interaction effect of different spacing and fertilizer levels on yield per plant of quinoa was found significant.

Since, these seeds are very small 10 ml seed weight was recorded instead of 1000 seed weight. Among different crop spacing, higher seed weight was noticed in 60×15 cm (7.01 g) than other spacing and lowest was recorded by 30×15 cm which were statistically non-significant. However, fertilizer level of 60:40:40 NPK kg/ha was noticed higher 10 ml seed weight (6.99 g) as compared to other fertilizer levels. Interaction effect between dates of sowing and different crop geometries was non-significant on 10 ml seed weight of quinoa. Interactions of spacing and fertilizer levels found non-significant with respect to all the yield and yield parameters of quinoa.

Economics

Economic benefit is the most important for farmer's point of view. Though regular market facility is not available in Karnataka for this crop, rates of online market and price fixed by local committee has been taken into consideration for calculating economics. The data revealed that, cost of cultivation is lower in spacing of 45 x 15 cm with application of 40:20:20 NPK kg/ha as compared to same spacing with 60:40:40 NPK kg/ha (Table 3). Similarly, maximum net returns and B:C ratio were noticed in 45x15 cm spacing with fertilizer level of 60:40:40 NPK kg/ha (Rs.153473/ha and 5.23, respectively) which was closely followed by 40:20:20 NKP kg/ha (Rs. 142560/ha and 5.01, respectively).

Table 1: Growth parameters of quinoa as influenced by spacing and fertilizer levels

Treatments	Plant height (cm)			No. of branches per plant			Panicle length (cm)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Main plots : Spacing									
S_1	125.74	130.15	127.95	15.23	16.25	15.74	28.97	33.93	31.45
S_2	114.95	117.37	116.16	17.54	18.83	18.19	35.57	36.41	35.99
S_3	94.27	105.78	100.03	19.56	19.42	19.49	38.06	40.22	39.14
S.Em±	3.04	2.23	2.64	0.65	0.53	0.59	1.38	0.55	0.97
CD (P=0.05)	11.93	6.82	5.97	2.05	1.60	1.83	5.40	2.16	3.78
Sub plots : Fertilizers									
F_1	91.52	105.67	98.60	16.23	17.40	16.82	22.66	27.52	25.09
F_2	108.89	113.04	110.97	17.49	19.01	18.25	35.66	32.26	33.96
F_3	117.55	124.59	121.07	18.85	20.42	19.64	38.28	35.78	37.03
S.Em±	4.56	1.98	3.77	0.62	0.50	0.56	1.54	1.70	1.62
CD (P=0.05)	14.04	6.01	11.53	1.89	1.45	1.67	4.74	5.23	4.99
Interactions									
S.Em±	7.13	2.63	4.88	0.99	0.83	0.91	2.57	2.46	2.52
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: S_1-30x15 cm, S_2-45x15 cm, S_3- 60x15 cm,
F_1- 20:10:10 NPK kg/ha, F_2- 40:20:20 NPK kg/ha, F_3- 60:40:40 NPK kg/ha

Table 2: Yield and yield parameters of quinoa as influenced by spacing and fertilizer levels

Treatments	Grain yield per plant (g/plant)			10 ml seed volume weight (g)			Grain yield (kg/ha)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Main plots : spacing									
S_1	17.21	16.14	16.68	6.05	6.58	6.32	1690	1879	1785
S_2	20.25	18.56	19.41	6.68	6.89	6.79	1924	2120	2022
S_3	23.54	22.55	23.05	6.96	7.05	7.01	1523	1654	1588
S.Em±	0.28	0.32	0.30	0.21	0.23	0.22	75	61	68
CD (P=0.05)	0.89	1.25	1.07	NS	NS	NS	294	185	240
Sub plots : Fertilizers									
F_1	16.25	15.22	15.74	6.15	6.82	6.49	1211	1572	1392
F_2	20.14	19.15	19.65	6.43	6.98	6.71	1611	1809	1710
F_3	21.25	20.26	20.76	6.86	7.05	6.96	1725	1931	1828
S.Em±	0.31	0.35	0.33	0.25	0.28	0.27	0.49	0.82	0.84
CD (P=0.05)	1.02	1.23	1.13	NS	NS	NS	2.50	2.30	2.42
Interactions									
S.Em±	0.38	0.45	0.41	0.29	0.31	0.30	1.01	2.32	2.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: S_1-30x15 cm, S_2-45x15 cm, S_3- 60x15 cm,
F_1- 20:10:10 NPK kg/ha, F_2- 40:20:20 NPK kg/ha, F_3- 60:40:40 NPK kg/ha

Table 3: Economics of quinoa as influenced by spacing and fertilizer levels

Treatments	Cost of cultivation (Rs./ha)			Net returns (Rs./ha)			B:C ratio		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
S1F1	29562	29898	29730	115670	125070	120370	3.89	4.21	4.05
S1F2	31450	31587	31519	129582	147382	138482	4.11	4.68	4.40
S1F3	32658	33785	33222	145679	156579	151129	4.39	4.71	4.55
S2F1	29562	29898	29730	139270	144770	142020	4.68	4.87	4.78
S2F2	31450	31587	31519	152982	167182	160082	4.85	5.30	5.08
S2F3	32658	33785	33222	165479	171279	168379	4.98	5.46	5.22
S3F1	29562	29898	29730	82770	94770	88770	2.78	3.19	2.99
S3F2	31450	31587	31519	103882	114082	108982	3.30	3.62	3.46
S3F3	32658	33785	33222	121279	132179	126729	3.65	3.98	3.82

Note: S_1-30x15 cm, S_2-45x15 cm, S_3- 60x15 cm, F_1- 20:10:10 NPK kg/ha,
F_2- 40:20:20 NPK kg/ha, F_3- 60:40:40 NPK kg/ha

Conclusion

It can be concluded that spacing of 45 x 15 cm was found to be optimum as evidenced in higher grain yield and economics. As there was no much difference between grain yield and monetary benefits in fertilizer level of 60:40:40 and 40:20:20 NPK kg/ha, the fertilizer level of 40:20:20 NPK kg/ha would be optimum for better growth and development of quinoa crop under red sandy loamy soils of Eastern Dry Zone of Karnataka.

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