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Response of Quinoa (*Chenopodium quinoa* Willd.) to Different Dates of Sowing and Crop Geometry under Protective Irrigation

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ABSTARCT

The experiment was carried out during *kharif* 2019 at Main Research Station, Hebbal, University of Agriculture Sciences, GKVK, Bengaluru to find out the optimum date of sowing and spacing for quinoa crop. The experiment was laid out in split plot design with three replications with four dates of sowing (D_1: July second fortnight, D_2: August first fortnight, D_3: August second fortnight and D_4: September first fortnight) and four crop geometry (S_1: 30 × 15 cm, S_2: 45 × 15 cm, S_3: 60 × 15 cm and S_4: 75 × 15 cm). The results revealed that, significantly higher grain and stover yield (2051 and 2439 kg ha^{-1}, respectively) were recorded in July second fortnight sowing. Among crop geometry, grain and stover yield were significantly higher with the spacing of 45 × 15 cm (1941 kg ha^{-1} and 2346 kg ha^{-1}, respectively) as compare to other spacings. Similarly, July second fortnight date of sowing was recorded significantly higher number of panicles plant^{-1} (16.20), panicle length (36.89 cm) and yield plant^{-1} (25.18 g plant^{-1}). Maximum gross returns (Rs.205100 ha^{-1}), net returns (Rs.176537 ha^{-1}) and benefit cost ratio (6.18) were noticed in second fortnight of July sowing. However, maximum gross returns (Rs.194125 ha^{-1}), net returns (Rs.164869 ha^{-1}) and benefit cost ratio (5.64) were obtained with the spacing of 45 × 15 cm.

Keywords : Date of sowing, Economics, Growth, Plant geometry, Quinoa, Response, Yield

QUINOA (*Chenopodium quinoa* Willd.) is a potential nutri-rich pseudo-cereal native to Andean region of South America. It is an annual herbaceous plant belongs to the family Amaranthaceae. It is cultivated in the world wide with an area of 126 thousand hectares with a production of 103 thousand tonnes. Bolivia in South America is the biggest producer of quinoa with 46 per cent of world production followed by Peru with 42 per cent and United States of America with 6.3 per cent (FAOSTAT, 2013). In India, it grows naturally in Himalayan region. Though statistics of exact area and production is not available, it is mentioned in one of the report that quinoa in India is cultivated in an area of 440 hectares with a production of 1053 tonnes (Srinivasa Rao, 2015). In 2013, Uttarakhand state reportedly signed a research agreement with Peru to grow quinoa in the state and research institutes in Andhra Pradesh. Rajasthan State Seeds Corporation engaged some farmers to grow this crop on experimental basis and managed to produce more than 20,000 quintals of seed. Few farmers in Fazilka district of Panjab, adjoining Rajasthan border also cultivated this crop for first time during 2017-18.

In Karnataka as a part of research programme in all India Co-ordinated Research Network on Potential Crops, Bengaluru who initiated compatibility studies and evaluation of some quinoa germplasms. In recent years, few farmers showing interest to grow this crop because of its nutrient content and climate resilience. Hence, there is a need to develop agronomic practices for further popularization of this crop which can play a major role in future diversification of agriculture system in India. Inspite of its wide adaptability, nutritional superiority, its commercial potential has remained untapped. Literature on optimum density, seed rate, spacing and other agro techniques for its cultivation in India is scanty. Optimum planting time is first step and considered as a base that leads to development of proper production technology especially for a new crop in a particular region (Sajjad *et al*., 2014). Inter and intra row spacing is one of the most important components of systematic cultivation that could enhance productivity of this crop. Therefore, there is a need to understand the relationship between sowing time and plant density to identify the optimum date of sowing. Hence, the experiment has been planned.

Material and Methods

The field experiment was conducted at the Main Research Station, University of Agricultural Sciences, Hebbal, Bengaluru during *kharif* 2019. The experiment was laid out in Split plot design with four different sowing windows as main plots and four crop geometries as sub-plots. Totally, there were 16 treatments combinations with three replications. This site is located in Agro-climatic Zone V (Eastern Dry Zone) of Karnataka at a latitude of 13° 04' North, a longitude 77° 58' East and at an altitude of 904 meters above mean sea level. The variety used was EC 507744. The monthly mean temperature (maximum and minimum) during crop growth period was 27.7 °C, 16.1 °C with an average of 91.4 and 58.3 per cent relative humidity and total Rainfall of 786.4 mm was received during crop growth period of July- December. The experimental soil was sandy loam in texture with acidic pH, low organic carbon (0.25), available N (254.14 kg ha^{-1}) and medium in available P (28.32 kg ha^{-1}) and potassium (186.04 kg ha^{-1}). The crop was supplied with recommended dose of fertilizer *i.e.,* 60 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} in the form of urea, Di-ammonium phosphate (DAP) and Muriate of Potash (MOP), respectively. 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. Protective irrigations were given when there was no rainfall for more than 8-10 days, only two irrigations were given during the month of July and August especially during germination stage to ensure good germination. Data on growth and yield attributes from randomly selected five plants from each net plot was recorded and the mean value was worked out and yield was recorded from each net plot. July 26th, August 9th, August 26th and September 16th sown crop were harvested at 97, 95, 93 and 90 DAS, respectively. Data was statistically analyzed by following the analysis of variance as suggested by Panse and Sukhatme (1978). Critical difference was calculated wherever F test was found significant at 5 per cent probability level and the values were furnished.

Results and Discussion

Yield and Yield Attributes of Quinoa

Yield and yield parameters were significantly influenced by dates of sowing, spacing and their interaction. Among different sowing dates, significantly higher grain yield, stover yield (2051 and 2439 kg ha^{-1}, respectively), higher number of panicles $plant^{-1}$ (16.20), panicle length (36.89 cm), 10 ml seed weight (7.15 g 10 ml^{-1}) and yield per plant (25.18 g $plant^{-1}$) were recorded in July second fortnight sowing. Nevertheless, sowing during August first fortnight (1688 and 2098 kg ha^{-1}, respectively) and August second fortnights (1517 and 1916 kg ha^{-1}, respectively) were found on par with each other. This could be due to efficient utilization of natural resources (water and nutrients) with optimum vegetative growth and higher translocation of photosynthates from source to sink. The above results were in line with the findings of Hakan *et al*. (2014), Sajjad *et al*. (2014) in amaranth crop. The above results were also supported by Parvin *et al*. (2013) who stated that late planting reduces yield because the plant life cycle is limited with temperature and photoperiod (Table 1).

Among varied crop geometry, grain yield (1941 kg ha^{-1}), stover yield (2346 kg ha^{-1}), higher number of panicles $plant^{-1}$ (15.70), panicle length (34.35 cm), 10 ml seed weight (7.07 g 10 ml^{-1}) and yield per plant (23.88 g $plant^{-1}$) obtained with the spacing of 45 × 15 cm were significantly higher as compared to narrow spacing of 30 × 15 cm and wider spacing of 60 × 15 cm (1647 and 2049 kg ha^{-1}, respectively) spacing. The grain and stover yield with the spacing of 30 × 15 cm and 60 × 15 cm were on par with each other and both were superior over the wider spacing of 75 × 15 cm. This could be due to better growth and development of crop and better photosynthetic activities in early sown crop. The above results were in conformity with

TABLE 1

Yield and yield parameters of quinoa as influenced by different sowing dates and crop geometry

Treatments	Number of panicles plant^{-1}	Panicle length (cm)	10 ml seed weight (g)	Yield per plant (g plant^{-1})	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Main : Sowing windows						
D_1 : Second fortnight of July (July 26)	16.20	36.89	7.15	25.18	2051	2439
D_2 : First fortnight of August (August 09)	15.34	33.39	7.08	23.83	1688	2098
D_3 : Second fortnight of August (August 26)	13.98	31.52	7.03	22.31	1517	1916
D_4 : First fortnight of September (September 16)	13.18	28.96	6.86	20.03	1398	1799
F - test	*	*	NS	*	*	*
S.Em.±	0.34	0.71	0.14	0.44	31.34	45.22
CD (p=0.05)	1.17	2.46	NS	1.52	108.46	156.49
Sub: Crop geometry						
S_1 : 30 × 15 cm (2,22,222 plants ha^{-1})	12.70	30.21	6.97	20.56	1695	2065
S_2 : 45 × 15 cm (1,48,000 plants ha^{-1})	14.95	32.43	7.03	23.31	1941	2346
S_3 : 60 × 15 cm (1,11,111 plants ha^{-1})	15.34	33.76	7.05	23.60	1647	2049
S_4 : 75 × 15 cm (88,888 plants ha^{-1})	15.70	34.35	7.07	23.88	1371	1791
F - test	*	*	NS	*	*	*
S.Em.±	0.26	0.80	0.12	0.27	19.18	38.64
CD (p=0.05)	0.76	2.34	NS	0.78	55.99	112.79
Interaction (D × S)						
S.Em.±	0.52	1.60	0.24	0.53	38.36	77.28
CD (p = 0.05)	NS	NS	NS	1.55	111.97	NS

the findings of Yarnia (2010) and Pourafarid *et al.* (2014). This indicates that wider spacing could not compensate in the grain yield mainly due to less plant density. Hence, 45 x 15 cm is found to be optimum for higher grain yield of quinoa crop. Several workers studied the effect of row spacings on grain yield and defined optimum row spacing as influenced by environmental factor and the variety used by Malligawadit and Patil (2015). Interaction of date of sowing and spacing showed that July second fortnight date of sowing with the spacing of 45×15 cm recorded significantly higher grain yield (2392 kg ha^{-1}) followed by July second fortnight date of sowing with 30×15 cm spacing (2083 kg ha^{-1}). This is clearly indicated that seed yield was decreased as increase in the inter row plant spacing in all the dates of sowing. Similar results were also supported by Parvin *et al.* (2013).

The interaction effect of different sowing windows and varied crop geometry on yield parameters of quinoa were found non significant.

Growth Attributes of Quinoa

July second fortnight sowing was recorded significantly higher plant height (175.33 cm), number of branches per plant (22.22), higher number of leaves per plant (648), leaf area per plant (551.88 cm^2 plant^{-1}), leaf area index (0.78) and dry matter production per plant (22. 95 g plant^{-1}) which were on par with August first fortnight sowing and superior over other sowing dates (Table 2). The variation in plant growth within dates of sowing of quinoa might be due to efficient utilization of available resources such as nutrients, water and sunlight and adaptability of crop to the given set of climatic conditions. Plant height reduction in delayed

TABLE 2

Growth parameters of quinoa as influenced by different sowing dates and crop geometry at harvest

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area plant^{-1} (cm^2 plant^{-1})	Leaf area index	Dry matter (g plant^{-1})
Main: Sowing windows						
D_1 : Second fortnight of July (July 26)	175.33	22.22	648	551.88	0.78	22.95
D_2 : First fortnight of August (August 09)	165.73	19.79	619	538.00	0.76	21.88
D_3 : Second fortnight of August (August 26)	156.06	17.97	533	519.84	0.73	19.97
D_4 : First fortnight of September (September 16)	150.04	17.10	468	481.37	0.68	17.45
F - test	*	*	*	*	*	*
S. Em.±	1.60	0.67	13.27	6.22	0.02	0.50
CD (p=0.05)	5.54	2.32	45.91	21.51	0.06	1.72
Sub : Crop geometry						
S_1 : 30 × 15 cm (2,22,222 plants ha^{-1})	167.24	17.40	539	504.04	1.12	16.35
S_2 : 45 × 15 cm (1,48,000 plants ha^{-1})	159.37	19.01	570	525.84	0.78	20.90
S_3 : 60 × 15 cm (1,11,111 plants ha^{-1})	158.93	19.88	577	529.30	0.59	21.33
S_4 : 75 × 15 cm (88,888 plants ha^{-1})	157.64	20.35	582	531.91	0.47	21.67
F - test	*	*	*	*	*	*
S.Em.±	1.09	0.50	8.68	4.72	0.02	0.35
CD (p=0.05)	3.18	1.45	25.34	13.77	0.06	1.02
Interaction (D × S)						
S.Em. ±	2.18	0.99	17.36	9.43	0.04	0.73
CD (p=0.05)	6.36	NS	NS	NS	NS	NS

planting was related to changes in temperature and day length during growth season. The similar results were reported by Hakan *et al*. (2014) and Fernando *et al.* (2012). The higher leaves per plant resulted in more leaf area per plant and also dry matter production. The above results were in conformity with the findings of Ramesh *et al.* (2017) and Yarnia (2010). The above results were also supported by Hirich *et al*. (2014), Lizica and Bjarne (2014).

Among varied crop geometry, 75 × 15 cm spacing recorded significantly higher number of branches per plant (20.35), number of leaves per plant (582), leaf area (531.91 cm^2 plant^{-1}), dry matter production per plant (21.67 g plant^{-1}) which were on par with 60 × 15 cm, 45 × 15 cm as compared to 30 × 15 cm spacing. This could be due to growing quinoa in wider rows provides plant with more illumination and less underground competition for nutrients and moisture. Whereas, significantly higher plant height (167.24 cm) and leaf area index (1.12) was recorded with 30 × 15 cm as compared to other spacings. This could be due to the fact that only vertical growth occurs due to competition for all the resources in closure spacing.

The above results were in agreement with the findings of Sief *et al*. (2015). The above results were also supported by Henderson *et al.* (2000), Malligawadit and Patil (2015) and Olofintoye *et al*. (2015). The interaction was found non significant.

Economics

Among sowing windows, maximum gross returns (Rs.205100 ha^{-1}), net returns (176537 ha^{-1}) and benefit cost ratio (6.18) were obtained in second fortnight of July sowing which was superior over other dates of sowing. This could be attributed to selection of suitable date of sowing is non-monetary input that influences the seed yield and gross returns. Similar results of higher B : C ratio was obtained by Chaudhari *et al.* (2009) in amaranth crop with early sowing (Table 3). Among crop geometry, maximum gross returns (Rs.194125 ha^{-1}), net returns (Rs.164869 ha^{-1}) and benefit cost ratio (5.64) were obtained with spacing of 45 × 15 cm which was superior over other crop geometries. The cost of cultivation in 30 × 15 cm spacing was higher due to more cost on inter cultivation and higher seed rate (as it was narrow spacing) and other agronomic practices. The gross returns, net returns and B: C ratio are higher due to more grain yield kg ha^{-1} is obtained because of favorable climatic conditions for better of crop and also due to optimum plant population under the spacing of 45 × 15 cm and better availability of growth resources *viz.*, moisture, space, light and nutrients under optimum plant population. These results were supported by Chaudhari *et al.* (2009) and Ramesh *et al.* (2017). Net returns and B : C ratio of quinoa was significantly influenced due to interaction between dates of sowing and crop geometries (Table 3). Among the treatment combinations, July second fortnight with spacing of 45 × 15 cm recorded significantly higher net return and B: C ratio (Rs.209944/ha and 7.18) which was superior over other spacings.

Based on the results obtained, it was found that July second fortnight sowing with the spacing of 45 × 15 cm is ideal for higher grain yield of quinoa during *kharif* season under eastern dry zone of Karnataka. Growth parameters *viz.*, number of branches per plant, number of panicles per plant and panicle length were

TABLE 3

Economics of quinoa as influenced by different sowing windows and crop geometry

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:Cratio
Main: Sowing windows				
D_1: Second fortnight of July (July 26)	28562	205100	176537	6.18
D_2: First fortnight of August (August 09)	28562	168875	140312	4.92
D_3: Second fortnight of August (August 26)	28562	151750	123187	4.31
D_4: First fortnight of September (September 16)	28562	139850	111287	3.89
Sub: Crop geometry				
S_1: 30 × 15 cm (2,22,222 plants ha^{-1})	31800	169550	137750	4.33
S_2: 45 × 15 cm (1,48,000 plants ha^{-1})	29256	194125	164869	5.64
S_3: 60 × 15 cm (1,11,111 plants ha^{-1})	27342	164775	137433	5.03
S_4: 75 × 15 cm (88,888 plants ha^{-1})	25851	137125	111274	4.30
Interaction (D × S)				
D_1S_1	31800	208300	176500	5.55
D_1S_2	29256	239200	209944	7.18
D_1S_3	27342	198500	171158	6.26
D_1S_4	25851	174400	148549	5.75
D_2S_1	31800	162000	130200	4.09
D_2S_2	29256	206400	177144	6.05
D_2S_3	27342	171000	143658	5.25
D_2S_4	25851	136100	110249	4.26
D_3S_1	31800	158700	126900	3.99
D_3S_2	29256	175500	146244	5.00
D_3S_3	27342	149800	122458	4.48
D_3S_4	25851	123000	97149	3.76
D_4S_1	31800	149200	117400	3.69
D_4S_2	29256	155400	126144	4.31
D_4S_3	27342	139800	112458	4.11
D_4S_4	25851	115000	89149	3.45

higher in wider spacing of 75 x 15 cm. Net returns and B : C Ratio were higher with July second fortnight sowing with 45 x 15 cm spacing.

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