Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(4): 1204-1206
Received: 07-05-2020
Accepted: 09-06-2020

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Consequence of fertility levels and row spacing on growth, yield and economics of quinoa (*Chenopodium quinoa*) under saline- sodic soil conditions of Southern Rajasthan

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Abstract

The experiment was carried out on Quinoa during 2016-17 and 2017-18 at Agricultural Research Sub Station, Vallabhnagar, MPUAT, Udaipur (Rajasthan) to evaluate the performance of new emerging crop quinoa under different fertility levels and row spacing under saline- sodic soil conditions. The experiment was frame out in split plot design and it was replicated three times. Date of sowing for experiment was 17th November, 2016 and 15th, November, 2017. The treatments consisted of four fertility levels *viz*., control, 75% RDF (90+ 37.5 kg ha^{-1} NP), 100% RDF (120+ 50 kg ha^{-1} NP), 125% RDF (150+ 62.5 kg ha^{-1} NP) and three row spacings *i.e* 12.5, 25.0, 50.0 cm. The results revealed that among fertility levels; the maximum plant height (69.26 cm), minimum days (59.83) required for flowering and the minimum days to maturity (115.67); yield attributes *viz*., maximum seed yield (1351.7 kg ha^{-1}), maximum biological yield (2788.6 kg ha^{-1}) and maximum straw yield (1436.9 kg ha^{-1}) and maximum net return (Rs. 29074.6 ha^{-1}) and B-C ratio (2.04) were recorded under treatment F_4 *i.e*. 125 per cent recommended dose of fertilizer. Amongst row spacings maximum plant height (55.02 cm), seed yield (1232.9 kg ha^{-1}), net return (Rs. 25495.8 ha^{-1}) and benefit- cost ratio (1.97) was obtained under 25.0 cm row spacing.

Keywords: Amino acids, biological yield, economics, net return, gross return

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a native plant of the Andean region of South America and has been used as a staple food crop for thousands of years (Martinez *et al*., 2015) [5]. This annual crop has broad-leaves and height ranges from 100 to 150 cm in normal soil conditions. Deep penetrating root system in this crop will helps in quick and optimum water absorption, essential for metabolic process and it can be cultivated from sea level up to an altitude of 3800 metre. Plants of quinoa crop also show tolerance to frost, salinity and drought and has the ability to grow on marginal soils. Quinoa is most renowned for being one of the only food plants that are an tremendous source of essential amino acids, micronutrients, vitamins, phenolic compounds and minerals and having the high total antioxidant capacity (FAO, 2013) [3]. The protein and oil content ranges from 7.47 to 22.08 per cent and 1.8 to 9.5 per cent respectively (Bhargava *et al*., 2006) [1]. Growing period of quinoa varied between 70 to 200 days over the globe and some entries did not mature in some locations (Jacobsen, 2003) [4]. Due to its important role in food security at the event of focusing global attention on nutrition and poverty eradication (FAO, 2013) [3]. Because of its nutritive values, United Nations has declared the year 2013, as an international year of quinoa (Bhargava *et al*., 2006) [1]. Quinoa crop has spacious adaptability, nutritional supremacy and commercial potential keeping all facts in mind we can say that this crop can play a major role in crop diversification of India agriculture system in near future.

2. Materials and Methods

An experiment was conducted on Quinoa during *Rabi* season of 2016-17 and 2017-18 at Agricultural Research Sub Station, Vallabhnagar, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The soil was saline- sodic in nature, having pH 9.81, electrical conductivity 3.6, organic carbon 0.27 per cent, HCO_3 1.5 me l^{-1}, Cl^- 3.5 me l^{-1}, Ca^{2++} + Mg^{++} 2.0 me l^{-1}, SO_4 35.96 me l^{-1}, RSC 3.9 me l^{-1} Na^+ 110.5 ppm, K^+ 33.1 ppm and available N 191, P 32.15 and K 302 kg ha^{-1}, respectively. The treatments consisted of four fertility levels *viz*., Control, 75% RDF (90: 37.5 kg ha^{-1} NP), 100% RDF (120: 50 kg ha^{-1} NP), 125% RDF (150: 62.5 kg ha^{-1} NP) and three row spacing (cm) *i.e*. 12.5 (24 rows), 25.0 (12 rows), 50.0

(06 rows). For sowing seed was drilled into lines as per treatment (row spacing). For fulfil of different fertility levels as per treatment supply through commercial fertilizers *i.e.* urea and DAP. Full dose of phosphorus and half dose of nitrogen were applied at the time of sowing (basal dose) by drilling and remaining nitrogen dose was splited twice; first applied at 20 and second one at 40 DAS in standing crop as top dressing. One light irrigation was given just after the sowing to facilitate uniform germination of the crop, over all 7 irrigations were given at 15 days interval. 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. Then crops were harvested from each net plot area individually, tagged and weighed.

3. Results and Discussion

3.1 Fertility Levels

On the basis of pooled data, studies on fertility levels indicated that application of 125 per cent recommended dose of fertilizer recorded the maximum plant height (67.99 cm), the minimum days required for flowering (59.56) and the minimum days to maturity (114.44) as compare to control, 75 and 100% RDF. Data further indicated that maximum plant height was recorded under 125% RDF which was statistically higher over rest of the treatments, same trend was observed in days to maturing but in days to flowering it was statistically at par with 75 and 100% RDF but superior over control (Table 1).

The variation in plant height 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 climate conditions. Similar results are reported by Yarnia (2010) [11] in Amaranth. The maximum seed yield (1351.7 kg ha^{-1}), biological yield (2788.6 kg ha^{-1}) and straw yield (1436.9 kg ha^{-1}) were obtained under treatment F_4 *i.e* 125% RDF which was statistically superior rest of treatments in seed yield, at par with 100% RDF in biological yield and at par with 75 and 100% RDF in straw yield. The highest harvest index (56.22) was obtained with 100per cent recommended dose of fertilizer which was statistically higher over rest of the treatments. The higher yield may be due to efficient utilization of natural resources (water and nutrients) with optimum vegetative growth and higher translocatation of photosynthates from source to sink. Similar results were reported by Parvin *et al.* (2013) [6] and Sajjad *et al.* (2014) [9]. The maximum gross return (Rs.56942.6 ha^{-1}), net return (Rs. 29074.6 ha^{-1}) and B-C ratio (2.04) were obtained under 125 per cent RDF which was statistically at par with 100 per centre commended dose of fertilizer but higher over 75% RDF and control (Table 3).

3.2 Row spacing

The row spacing also affects the growth characteristics and yield of quinoa. The maximum plant height (55.02 cm), minimum days required for flowering (59.25) days and minimum days required for maturity 115.46 days, were recorded under row spacing of 25.0 cm, which was statistically at par with 50.0 cm row spacing but statistically higher over 12.5 cm row spacing (Table 1). It might be due the number and broader leaves per plant at wider spacing. This was supported by Smitha *et al.* (2011) [10] in Amaranth. The maximum seed yield (1232.9 kg ha^{-1}) was obtained under 25.0 cm row spacing which was statistically higher over rest of the row spacings. However, biological yield and straw yield were statistically non significant in both the years of investigation as well as pooled basis. On pooled data basis, the highest harvest index (57.26%) were obtained at 25.0 cm row spacing, which was statistically at par with 50.0 cm row spacing but higher over 12.5 cm (Table 2). This might be due to the higher number of plants per unit area in case of narrow spacing as compared to wider spacing. Whereas, in extreme narrower row spacing *i.e.* 12.5 cm competition for sun light, space, nutrient and moisture between plants were much more therefore plants were very week and thin. These results are in close conformity with findings of Prommarak (2014). Data from Table 3 shows that the maximum gross return (Rs. 51417.0 ha^{-1}), net return (Rs. 25495.8 ha^{-1}) and B-C ratio (1.97) were obtained under 25.0 cm row spacing, which was statistically higher over rest of the row spacing (50 and 12.5 cm). Similar results have been reported earlier by of Chaudhari *et al.*, 2009 [2].

Table 1: Effect of fertility levels and row spacings on growth characters of quinoa

Treatments	Plant height (cm)			Days to flowering			Days to maturity		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Fertility levels									
F_1 (Control)	42.47	43.26	42.87	61.44	61.33	61.39	116.22	119.00	117.61
F_2 (75% RDF)	49.12	49.70	49.41	59.89	61.00	60.44	115.33	118.00	116.67
F_3 (100% RDF)	50.94	52.10	51.52	60.89	60.89	60.89	115.56	118.33	116.94
F_4 (125% RDF)	67.99	70.53	69.26	59.56	60.11	59.83	114.44	116.89	115.67
SEm±	1.84	1.80	1.29	0.51	0.57	0.38	0.44	0.51	0.34
CD(p=0.05)	6.36	6.23	3.97	1.77	1.98	1.18	1.53	1.75	1.04
Row spacings (cm)									
S_1 (12.5)	49.99	51.76	50.87	61.00	61.33	61.17	116.00	118.58	117.29
S_2 (25.0)	54.41	55.62	55.02	59.17	59.33	59.25	114.00	116.92	115.46
S_3 (50.0)	53.50	54.31	53.90	61.17	61.83	61.50	116.17	118.67	117.42
SEm±	1.84	1.57	1.05	0.44	0.36	0.25	0.48	0.44	0.28
CD(p=0.05)	5.51	4.72	3.02	1.33	1.07	0.71	1.43	1.32	0.81

Table 2: Effect of fertility levels and row spacings on yield and harvest index of quinoa

Treatment	Seed yield (kg ha^{-1})			Biological yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Fertility levels												
F_1 (Control)	820.5	852.5	836.5	1595.4	1635.4	1615.4	774.9	782.9	778.9	53.82	54.05	53.94
F_2 (75% RDF)	990.7	1044.6	1017.7	2252.6	2292.6	2272.6	1261.9	1247.9	1254.9	48.50	49.75	49.12
F_3 (100% RDF)	1241.4	1250.3	1245.9	2332.7	2372.7	2352.7	1091.3	1122.3	1106.8	56.59	55.85	56.22

F_4 (125% RDF)	1345.8	1357.6	1351.7	2773.6	2803.6	2788.6	1427.8	1446.0	1436.9	48.79	48.47	48.63
SEm±	64.2	86.1	53.7	236.0	236.0	166.9	246.7	232.2	169.4	6.23	5.81	4.26
CD(p=0.05)	222.2	297.8	165.4	816.7	816.5	514.2	853.6	803.6	522.0	NS	NS	NS
Row spacings (cm)												
S_1 (12.5)	1003.1	1068.1	1035.6	2284.6	2324.6	2304.6	1281.6	1256.6	1269.1	45.35	47.46	46.40
S_2 (25.0)	1221.1	1244.7	1232.9	2267.1	2299.6	2283.3	1046.0	1054.8	1050.4	57.71	56.80	57.26
S_3 (50.0)	1074.7	1066.0	1070.4	2164.0	2204.0	2184.0	1089.3	1137.9	1113.6	52.72	51.82	52.27
SEm±	65.2	59.8	38.3	166.1	165.8	101.6	180.8	182.7	111.3	5.12	5.23	3.17
CD(p=0.05)	195.5	179.3	110.4	NS	NS	NS	NS	NS	NS	15.36	15.69	9.14

Table 2.1 Interaction seed yield (kg ha^{-1})

Fertility levels x Row spacing	12.5 cm	25.0 cm	50.0 cm
Control	688.31	957.75	863.46
90: 37.5 kg ha^{-1} NP	995.84	1075.56	981.59
120: 50 kg ha^{-1} NP	1162.85	1385.15	1189.62
150: 62.5 kg ha^{-1} NP	1295.23	1513.16	1246.77
SEm±	76.42		
CD(p=0.05)	220.78		

Table 3: Effect of fertility levels and row spacings on economics of quinoa

Treatment	Gross return (Rs ha^{-1})			Net return (Rs ha^{-1})			B-C ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Fertility levels									
F_1 (Control)	34369.8	35666.2	35018.0	11369.8	12666.2	12018.0	1.49	1.55	1.52
F_2 (75% RDF)	42151.4	44281.3	43216.4	16229.4	18359.3	17294.4	1.63	1.71	1.67
F_3 (100% RDF)	51838.7	52258.2	52048.5	24943.7	25363.2	25153.5	1.93	1.94	1.94
F_4 (125% RDF)	56688.9	57196.2	56942.6	28820.9	29328.2	29074.6	2.03	2.05	2.04
SEm±	2469.5	3407.9	2104.3	2469.5	3407.9	2104.3	0.09	0.13	0.08
CD(p=0.05)	8545.7	11792.9	6484.0	8545.7	11792.9	6484.0	0.33	0.45	0.25
Row spacings (cm)									
S_1 (12.5)	42685.5	45235.5	43960.5	16764.2	19314.2	18039.2	1.63	1.73	1.68
S_2 (25.0)	50934.8	51899.2	51417.0	25013.5	25978.0	25495.8	1.95	1.99	1.97
S_3 (50.0)	45166.4	44916.7	45041.6	19245.1	18995.5	19120.3	1.73	1.73	1.73
SEm±	2487.7	2258.3	1454.8	2487.7	2258.3	1454.8	0.09	0.09	0.05
CD(p=0.05)	7458.1	6770.3	4190.9	7458.1	6770.3	4190.9	0.27	0.26	0.16

Table 3.1: Interaction B-C ratio

Fertility levels x Row spacing	12.5 cm	25.0 cm	50.0 cm
Control	1.30	1.71	1.56
90: 37.5 kg ha^{-1} NP	1.64	1.73	1.63
120: 50 kg ha^{-1} NP	1.82	2.15	1.84
150: 62.5 kg ha^{-1} NP	1.96	2.28	1.89
SEm±	0.108		
CD(p=0.05)	0.312		

4. Conclusion
Considering the interaction between different fertility levels and row spacing it is recommended that 150 kg nitrogen + 62.5 kg phosphorus ha^{-1} along with 25.0 cm row spacing to derive maximum benefit from quinoa under saline- sodic soil conditions of Southern Rajasthan.

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