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Geographical adaptation of quinoa in India and agrotechniques for higher productivity of quinoa

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Abstract
The field experiment was conducted at college farm, college of Agriculture, Hyderabad during Rabi 2015-16 to evaluate Quinoa (Chenopodium quinoa Willd.) at different dates of sowing and varied crop geometry in semi-arid regions of Telangana. The 15th October date of sowing, 15 cm × 10 cm spacing, dibbling method of sowing, RDF:100 kg N, 50 kg P_2O_5, 50 kg K_2O ha^{-1}, recorded the higher growth, yield and yield attributes of quinoa. The drip method of irrigation recorded the higher yield and yield attributes than the surface method of irrigation. The field should be kept weed free up to 30 days after sowing.

Keywords: Quinoa, dibbling, irrigation, weed, RDF

Introduction
Quinoa (*Chenopodium quinoa* Willd.) is an annual herbaceous plant belongs to Amaranthaceae family, but formerly placed in Chenopodiaceae family that originated in the Pacific slopes of the Andes in South America. It was cultivated and used by the *Inca* (ruling class) people since 5,000 B.C. It is cultivated in the world 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) [2]. In India, quinoa was cultivated in an area of 440 hectares with an average yield of 1053 tonnes (Srinivasa Rao, 2015) [7]. Quinoa ***is*** discovered as a health food by North Americans and Europeans in the 1970's and its popularity is dramatically increased in recent years because it is gluten-free (helpful for diabetic patients) and high in protein.

As per United Nations Organisation for Agriculture and Food, the quinoa grain is the only vegetable food that provides all amino acids essential to the life of humans in optimum quantities and is comparable with milk. The protein content ranges from 7.47 to 22.08 per cent. The oil content is 1.8 to 9.5 per cent and rich in essential fatty acids. The digest ability of quinoa protein is more than 80 percent. Quinoa also contain natural anti-oxidants like α-tocopheral (5.3 mg), γ-tocopheral (2.6mg) in 100 g seed and phytoestrogens that prevent chronic diseases such as osteoporosis, breast cancer, heart diseases and other feminine problems caused by lack of oestrogen during the menopause. Hence FAO nominated 2013 as International year of Quinoa (Bhargava *et al*., 2006) [1].

Growing period of quinoa varied between 70 to 200 days and some entries did not mature in some locations. The experiment conducted to evaluate quinoa entries in America, Europe and Africa and reported that growing period of quinoa in Kenya was 65-98 days and all cultivars matured with seed yield of 4000 kg ha^{-1}. In Denmark and Sweden, growing period was 120-160 days but yields were low and few varieties only matured. The growing period in Greece was 110-160 days and the yield was 2000 kg ha^{-1}(Jacobsen, 2003) [3].

Reasons for Quinoa acceptance in India
In India 65% population was dependent on agriculture, though more than 50% population practiced it was very difficult to feed the rapidly growing population, hence India used to import some of the food grains from other countries, but during 1966-67 green revolution played an important role on the Indian agriculture sector especially rice and wheat, the dwarf gene varieties of rice and wheat were introduced from Mexico to India for the higher cereal production. Pulses and oil seed crops, soybean for proteins and sunflower for oil seeds introduced from China and America respectively in to India though the traditional varieties were cultivated but their yields were recorded low due to higher pest and diseases incidence.

In the similar way it is the right time to introduce the crop like quinoa in India to check the some of the health problems facing by Indian population.

Since, India tops in malnutrition with over 45 per cent among children and 70 per cent pregnant woman and nearly 52 per cent population ***are***suffering with diabetes due to over dependence on few cereal foods (rice or wheat) (Srinivasa Rao, 2014) [6].

Agro techniques for higher productivity of quinoa

1. Dates of sowing and seed rate

Very little research work has been done on the adoptability and standardisation of package of practices of quinoa in India. Bhargava *et al.*(2006) [7] studied about genetic variability and adaptation in North India and reported that entries originated from inter- Andean valleys of Bolivia that are white or yellow in colour with small size are more adoptable than other entries. 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) [5]. Hence, an experiment is proposed entitled "Evaluation of Quinoa (*Chen**o**podium quinoa* Willd.) at different dates of sowing and varied crop geometry in semi-arid regions of Telangana". In this, 3 dates of sowing viz. i.e. D_1: 15th October, D_2: 1st November, D_3: 16th November and 4 spacings (S_1:15 cm × 10 cm, S_2: 30 cm × 10 cm, S_3: 45 cm × 10 cm, S_1: 60cm × 10 cm). The seed rate (5.00, 2.50, 1.67, 1.25 kg ha^{-1} respectively) were tried at college of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana.

2. Method of sowing

Healthy, matured and vigorous seeds were used for sowing and seeds were treated with Pseudomonas flourescence @ 10 g kg-1 seed and sowing was done by mixing seeds with sand and placed 3-4 seeds at intra row spacing of 10 cm on three different dates at varied crop geometry. The 20 days old seedlings can be transplanted.

Among the dates of sowing (Table 2), tallest plants were observed with 16th November (123.1 cm), 1st November (120.7 cm) that were on par to each other and shortest plants were observed with 15th October (110.1cm) date of sowing at harvest. The variation in plant height 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 climate conditioins. Similar results are reported by Yarnia (2010) [8] in Amaranth. The 1st November (13.8) and 16th November (13.1) dates of sowing were recorded significantly higher number of panicles per plant as compared to 15th October date of sowing and they were at par to each other. The panicle length was significantly higher at 15th October date of sowing (25.3 cm). It might be due to the favourable climatic conditions like temperature, photoperiod and taken more growing degree days and days for flowering (22 days) and grain filling (25days) which led to the increase in the panicle size. The protein content of quinoa seed was found non-significant with date of sowing and crop geometry. Among the dates of sowing,1st November date of sowing (14.1 %) recorded higher seed protein, but it was on par with 15thOctober (13.6%) and 16th November (14.0%). Panicle weight of 15th October (487.5 g m-2) date of sowing was significantly higher than 16th November (430.2 g m-2) date of sowing. The maximum seed yield (2001 kg ha-1) was recorded by October 15th date of sowing, which was distinctly superior over other date of sowing. The stalk yield obtained by 15thOctober date of sowing was significantly higher (2293 kg ha-1) over the rest of the date of sowing. Maximum benefit cost ratio (3.96) were obtained with 15thOctober date of sowing which was superior to 1st November (3.04) and 16th November (2.80).

wider spacings i.e.,60cm × 10 cm (124.7 cm), 45 × 10 cm (123.0 cm) and 30 × 10 cm (119.7 cm) showed at par plant height and significantly higher over 15 × 10 cm (104.5 cm). These results are found contradictory to findings of Pourfarid *et al*. (2014). At different crop geometry levels, number of panicles per plant recorded at 60 cm × 10 cm (15.6) and 45 cm × 10 cm (14.7) were at par to each other and significantly higher than 15 cm × 10 cm (9.9) and 30 cm × 10 cm (12.0) crop geometries. Panicle length at 45 cm × 10 cm (23.5 cm) and 60 cm × 10 cm (23.3 cm) were at par with each other and significantly higher than 15 cm × 10 cm (19.0 cm) and 30 cm × 10 cm (22.1cm) crop geometries. The protein content was non significant with the spacings. However 30×10cm (14.0%) recorded higher higher protein content (14.0%) but it was on par with 15×10cm (13.8%), 45×10cm (13.9%), 60cm×10cm (13.8%) spacings. The spacing of 15cm × 10 cm recorded significantly higher panicle weight (677.9 g m-2) compared to other spacings. It might be due to higher panicle length and higher number of plants per unit area. Seed yield of Quinoa was decreeased with increased crop geometry from narrow (15 ×10cm) to wider (60cm×10 cm) spacing. Highest seed yield was obtained under 15cm ×10cm (2070 kg ha-1) which was significantly higher over other spacings. There was a plastisity in the seed yield of individual plant from 15×10cm (12.0 g plant-1), 30×10cm (17.7 g plant-1) and 45×10cm (28.0 g plant-1) spacing and thereafter seed yield was constant or slightly decreased. Spacing of 15×10cm recorded highest stalk yield (2417 kg ha-1) which was significantly superior over other spacings and was attributed to higher vegetative growth due to higher plant population per unit area. Maximum benefit cost ratio (3.56) was obtained with narrow spacing (15×10 cm) over other spacing. However, B:C ratio was significantly at par with 30×10 cm spacing.

3. Fertilizer application

The crop was supplied with recommended dose of fertilizer *i. e.,* 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} in the form of urea, single super phosphate and muriate of potash, respectively, Entire dose of P, K and ½ 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 ½ dose of N was applied in two more equal splits at 25 and 50 days after sowing. Same trend of fertilizer application was followed for all the three dates of sowing treatments.

4. Irrigation

Water management is very important for quinoa cultivation in the initial 20-30 days the of crop. If irrigation is not provided the crop will show wilting symptom and results in lower yields. it is better to give irrigation by drip method if possible. The research was conducted on irrigation with different treatments and concluded that drip method of irrigation recorded the higher yield and yield attributes compared to other irrigation methods.

5. Weed management & Plant protection

One hand weeding was done with manual labour at 30 DAS to keep the crop free from weeds. research is going on for the chemical weed management in quiona.

During the seedling stage, the crop was affected by leaf eating caterpillars and leaf miners that was controlled by spraying Quinolphos @ 2ml lit^{-1} of water along with stickers for

vegetative weed control. Stickers are used as the quinoa leaf is shiny with waxy like coating rich in calcium oxalates. During the seed formation stage, crop was attacked by sucking pest i.e., Aphids and was controlled by spraying the Dimethoate @ 2ml lit^{-1} of water.

Table 1: Influence of irrigation treatments on plant height (cm), panicle length (cm), Number of panicle plant^{-1} and yield (kg ha^{-1}) of quinoa

	Treatments	Plant height (cm)	Panicle length (cm)	Number of Panicle plant^{-1}	Yield (kg ha^{-1})
T_1	0.5 E throughout cropping period	120.7	32.5	5.3	1736
T_2	1.0 E throughout cropping period	133.0	35.8	8.1	2912
T_3	Irrigation with 0.5 E at vegetative and1.0 E at both flowering and at grain filling stage	134.3	35.3	6.1	2332
T_4	Irrigation with 0.5 E at vegetative, 1.0 E at flowering and 0.5 E at grain filling stage	135.3	34.6	5.3	1823
T_5	Irrigation with 0.5 E at vegetative, 0.5 at flowering and 1.0 at grain filling stage	128.3	32.7	5.7	1962
T_6	Irrigation with 1.0 E at vegetative, 0.50 E at flowering and 0.5 E at grain filling stages	132.8	33.5	4.7	1869
T_7	Irrigation with 1.0 E at vegetative, 1.0 E at flowering and 0.5 at grain filling stages	123.7	32.3	5.1	1885
T_8	Irrigation with 1.0 E at vegetative, 0.5 E at flowering and 1.0 E at grain filling stages30.66.5	130.8	36.2	5.3	2482
T_9	Irrigation with 0.5 IW: CPE throughout crop growth by flatbed surface method	115.9	30.6	6.7	1555
T_{10}	Irrigation with 1.0 IW: CPE throughout crop growth by flatbed surface method	118.3	33.4	8.4	2089
	SEm ±	4.05	3.25	0.4	114.6
	CD (P=0.05)	12.1	3.7	1.2	340.4

Table 2: Effect of dates of sowing and spacing on plant height (cm), yield attributes and yield of Quinoa.

Treatment	Plant height (cm) at harvest	Number of panicles plant^{-1}	Panicle length (cm)	Protein (%)	Panicle weight (g m^{-2})	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	B:C ratio
Main: Sowing dates								
$_1$D : October15	110.1	12.3	25.3	13.6	487.5	2001	2293	3.96
$_2$D : Novembe r1	120.7	13.8	22.7	14.1	470.1	1610	2036	3.04
$_3$D : November16	123.1	13.1	17.8	14.0	430.2	1477	1877	2.80
S Em±	1.3	0.3	0.4	0.2	18.0	52	85	0.13
CD (P=0.05)	3.7	1.0	1.2	NS	52.2	145	236	0.36
CV(%)	2.7	7.0	5.0	4.1	9.5	7.5	10.7	7.3
Sub: Spacings								
$_1$S : 15× 10cm	104.5	9.9	19.0	13.8	677.9	2070	2417	3.56
$_2$S : 30× 10cm	119.7	12.0	22.1	14.0	448.3	1764	2186	3.44
$_3$S : 45× 10cm	123.0	14.7	23.5	13.9	394.5	1491	1895	3.01
$_4$S : 60× 10cm	124.7	15.6	23.3	13.8	329.6	1460	1777	3.03
S Em ±	1.1	0.9	0.6	0.3	15.2	28	61	0.08
CD (P=0.05)	2.3	2.0	1.3	NS	32.0	59	128	0.16
CV(%)	2.0	15.6	6.2	4.6	6.9	3.5	6.2	5.2
Interaction								
D×S (main at same level of sub)								
S Em±	1.9	1.6	1.1	0.3	26.3	49	105	0.13
CD (P=0.05)	4.0	NS	2.3	NS	55.4	102	NS	0.29
S×D (sub at same or different level of main)								
S Em±	2.1	1.5	1.0	0.3	29.1	67	125	0.17
CD(P=0.05)	5.0	NS	2.3	NS	68.8	169	NS	0.44

Conclusion

Among the different dates October 15th and among spacings 15×10cm recorded better results. The proper management practices for quinoa cultivation can record 6-8 q/acre average yield.

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