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# Growth, Yield and Economics of Quinoa as Influenced by Different Dates of Sowing and Varied Crop Geometry

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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 higher plant height was obtained in 16$^{th}$ November date of sowing, total dry matter at harvest was higher at 15$^{th}$ date of sowing ,1$^{st}$ November and 16$^{th}$ November recorded higher number of panicles plant$^{-1}$, maximum seed yield was obtained with 15$^{th}$ October date of sowing. The highest seed yield was obtained with narrow spacing 15×10 cm and was followed by 30×10 cm spacing. The maximum net returns, cost benefit ratio and interaction effect of seed yield was recorded higher on 15$^{th}$ October date of sowing at 15×10 cm spacing.

**Key words:** Quinoa, Geometry, Dry matter, Panicle, Seed, Benefit cost ratio

## INTRODUCTION

Quinoa is discovered as a healthy 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. In India, quinoa was cultivated in an area of 440 hectares with an average yield of 1053 tonnes[9].

It is cultivated in the world with an area of 126 thousand hectares in 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[3]. As per United Nations Organisation for Agriculture and Food, the quinoa grain is the only food that provides all amino acids essential to the life of humans in optimum quantities and is comparable with milk. The protein and oil content ranges from 7.47 to 22.08 per cent and 1.8 to 9.5 per cent respectively. FAO nominated 2013 as International year of Quinoa[1].

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Growing period of quinoa varied between 70 to 200 days over the globe and some entries did not mature in some locations[5]. Quinoa 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. Hence, an experiment was conducted entitled "Evaluation of Quinoa (*Chenopodium quinoa* willd.) at different dates of sowing and varied crop geometry in semi arid regions of Telangana" during *rabi* season, 2015-16.

## MATERIAL AND METHODS

A field experiment was conducted at College farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *rabi* 2015-16. The farm is geographically situated at an altitude of 542.3 m above mean sea level at $17^0$ 19' N latitude, $78^0$ 28' E longitude. The experiment was laid out in split plot design with three replications with three different dates of sowing ($D_1$:15th October, $D_2$:1st November and $D_3$:16th November) as main plots and four crop geometry levels ($S_1$ : 15×10 cm, $S_2$ : 30×10 cm, $S_3$ : 45×10 cm and $S_4$: 60×10 cm) as sub plots under semi arid conditions of Telangana. The variety used was accession line of EC series (Golden yellow colour seed). The weekly mean 31.0°C and 16.1°C (maximum and minimum) temperatures respectively. Weekly mean relative humidity (maximum and minimum) 84.3 per cent and 39.5 per cent, Where as weekly mean sunshine hours, evaporation and wind velocity was 8.1 h $day^{-1}$, 5.5 mm $day^{-1}$ and 1.3 km $h^{-1}$ respectively and rain fall of 18.3 mm received in a single day during the crop growing seaon. The experimental soil was sandy loam in texture, high organic carbon, medium in soil available nitrogen (258 kg $ha^{-1}$), phosphorus (25.3 kg $ha^{-1}$), and potassium (238 kg $ha^{-1}$). 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. One irrigation was provided after sowing to facilitate uniform germination of the crop, and 5-6 irrigations were given at 12-15 days interval. 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. 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. The crop was harvested at 107, 101 and 97 days in three dates of sowing ($D_1$:15th October, $D_2$:1st November and $D_3$:16th November) respectively. The growth parameters *i.e.,* plant height and dry matter accumulation, number of branches $plant^{-1}$, leaf area, were recorded at 60 DAS and yield attributes, yield were recorded at harvest. The data was statistically analyzed by using WINDOSTAT Software Version-7. Significance of the treatments was determined on the basis of F test and critical difference was calculated at 5% level of probability.

## RESULTS AND DISCUSSION

Plant height of quinoa at 90 DAS influenced by sowing dates and varied crop geometry. Among the dates of sowing, tallest plants were observed with 16th November (121.0 cm), 1st November (117.9 cm) that were on par to each other and shortest plants were observed with 15th October (104.3 cm) date of sowing. Similar results are reported by Yarnia (2010) in Amaranth. Among the spacings, wider spacings i.e., 60 cm × 10 cm (121.6), 45 × 10 cm (117.8) and 30 × 10 cm (116.9) showed at par plant height and significantly higher over 15 × 10 cm (101.2). These results are found contradictory to findings of Pourfarid *et al*. (2014) that close spacing increase plant height of quinoa.

Dry matter production and partitioning at harvest (Table1) revealed that 15th October and 1st November dates of sowing produced higher total dry matter (947.7 & 882.3 g $m^{-2}$)

that were at par with each other and significantly higher than 16$^{th}$ November date of sowing. Among different crop geometries, 15 × 10 cm spacing recorded significantly higher total (1199.1 g m$^{-2}$) dry matter production compared to other crop geometries.These findings were supported by Pourfarid *et al*.(2014). Interaction effect of dates of sowing and varied crop geometry was found significant with total dry matter production. Among the combinations, total dry matter production of 15$^{th}$ October and 1$^{st}$ November dates of sowing with 15 × 10 cm spacing (1247.9 & 1270.5 g m$^{-2}$) were at par to each other and significantly higher compared to other combinations. Followed to this 16$^{th}$ November date of sowing with same spacing observed next higher total dry matter (1081.5 g m$^{-2}$).The lowest total dry matter was with 16$^{th}$ November date of sowing and 60 × 10 cm (579.6 g m$^{-2}$) spacing.

1$^{st}$ November (13.8) and 16$^{th}$ November (13.1) dates of sowing were recorded significantly higher number of panicles plant$^{-1}$ as compared to 15$^{th}$ October date of sowing. and they were at par to each other. It may be due to more number of branches recorded in above treatments. and were supported by Yarnia[10] and Hakan Geren *et al*[4]. At different crop geometry levels, number of panicles plant$^{-1}$ 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. Wider spacing (45× 10cm or 60 × 10cm) produced more number of branches plant$^{-1}$ and hence the number of panicles plant$^{-1}$ were found higher at wider spacing as compared to narrow spacing.

The maximum seed yield (2001 kg ha$^{-1}$) was recorded by October 15$^{th}$ date of sowing, which was distinctly superior over other date of sowing. This could be ascribed to higher dry matter partitioning and reproductive parts i.e., number of spikelets, number of grains panicle$^{-1}$,length and weight of panicle. The superiority of October 15$^{th}$ date of sowing with respect to yield attributes and 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 Hakan Geren *et al*.[4] and Sajjad *et al*.[8] in Quinoa and Chaudhari *et al*.[2] in amaranth crop. Sajjad *et al*.[8] reported that late sown crop flowers late and shortened grain filling period due to rise in temperature. Parvin *et al*.[6] also stated that late planting reduces yield because the plant life cycle is limited with temperature and photoperiod. November 1$^{st}$ (1610 kg ha$^{-1}$) was on par with November 16$^{th}$ (1477 kg ha$^{-1}$) date of sowing. Seed yield of Quinoa was decreeased with increased crop geometry from narrow (15 ×10 cm) to wider (60 cm×10 cm) spacing. Highest seed yield was obtained under 15cm ×10 cm (2070 kg ha$^{-1}$) which was significantly higher over other spacings. There was a plastisity in the seed yield of individual plant from 15×10 cm (12.0 g plant$^{-1}$) to 30×10 cm (17.7 g plant$^{-1}$) and 45×10 cm (28.0 g plant$^{-1}$) spacing and thereafter seed yield was constant or slightly decreased. Though seed yield plant$^{-1}$ in wider spacing is high, but the seed yield of narrow spacing (15×10 cm ) over area basis was recorded higher due to higher plant population in narrow row spacing i.e., 15×10 cm (6.0 lakh ha$^{-1}$). Interaction of date of sowing and spacing showed that October 15$^{th}$ date of sowing recorded higher seed yield when grown under 15×10 cm (2392 kg ha$^{-1}$) followed by same date of sowing with 30×10 cm (2083kg ha$^{-1}$) spacing that was at par with 1$^{st}$ November date of sowing with 15×10 cm spacing (2064 kg ha$^{-1}$). The lowest yield was produced by November 16$^{th}$ date of sowing with 60×10 cm (1276 kg ha$^{-1}$) and 45×10 cm (1290 kg ha$^{-1}$) and both were par with each other. This clearly indicated that seed yield was decreased with increase in the inter row plant spacing in all dates of sowing and was supported by Parvin *et al*[6].

Maximum net returns (Rs.159857 ha$^{-1}$) and benefit cost ratio (3.96) were obtained with 15$^{th}$ October date of sowing which was superior to 1$^{st}$ November (Rs.121427 ha$^{-1}$ & 3.04) and 16$^{th}$ November (Rs.1088978 ha$^{-1}$ & 2.80) respectively. Lowest monetary returns were obtained by 16th November date of sowing. Similar results of higher B:C ratio was obtained by Chaudari *et al.*[2] in amaranthus with early sowing. Net returns (Rs.161842 $ha^{-1}$) and benefit cost ratio (3.56) were significantly higher with narrow spacing (15×10 cm) over other spacing.However, B:C ratio was significantly at par with 30×10 cm spacing. The lower net returns (Rs.111841 $ha^{-1}$ & Rs.109853 $ha^{-1}$) and benefit ratio (3.01 & 3.03) was recorded with wider (45×10 cm & 60×10 cm) spacings respectively.

Net returns and B:C ratio of quinoa was significantly influenced due to interaction between dates of sowing and crop geometries. Among the combination treatments, 15th October date of sowing with 15×10cm spacing recorded significantly higher net returns (Rs.192640 $ha^{-1}$) compared to other combinations follwed by 15th October date of sowing with 30×10cm (Rs.168280 $ha^{-1}$) and 1st November with 15×10cm spacing (Rs.161300 $ha^{-1}$) were at par with each other. The lowest net returns were recorded with combination of 16th November date of sowing and 60×10cm (Rs.91708 $ha^{-1}$) spacing. Among the treatment combinations, the B:C ratio of 15th October date of sowing with 30×10cm & 15×10cm spacings (4.20 & 4.13) were at par and significantly higher than other combinations. Lowest B:C ratio was observed with 16th November date of sowing and 60×10cm (2.56) spacing.

Table 1. Growth, yield and economics of quinoa as influenced by different dates of sowing and varied crop geometry

| Treatment | Plant height (cm) at 90 DAS | Total dry matter at Harvest (g $m^{-2}$) | Number of panicles $plant^{-1}$ | Seed yield (kg $ha^{-1}$) | Net returns (Rs. $ha^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|
| **Main: Sowing dates** | | | | | | |
| $D_1$ : October 15 | 104.3 | 947.7 | 12.3 | 2001 | 159857 | 3.96 |
| $D_2$ : November 1 | 117.9 | 882.3 | 13.8 | 1610 | 121427 | 3.04 |
| $D_3$ : November 16 | 121.0 | 780.0 | 13.1 | 1477 | 108978 | 2.80 |
| S Em± | 3.8 | 23.9 | 0.3 | 52 | 5231 | 0.13 |
| CD (P=0.05) | 10.5 | 66.5 | 1.0 | 145 | 14524 | 0.36 |
| **Sub: Spacings** | | | | | | |
| $S_1$: 15×10 cm | 101.2 | 1199.1 | 9.9 | 2070 | 161842 | 3.56 |
| $S_2$: 30×10 cm | 116.9 | 862.2 | 12.0 | 1764 | 136813 | 3.44 |
| $S_3$: 45×10 cm | 117.8 | 777.8 | 14.7 | 1491 | 111841 | 3.01 |
| $S_4$: 60×10 cm | 121.6 | 640.1 | 15.6 | 1460 | 109853 | 3.03 |
| S Em ± | 2.6 | 18.2 | 0.9 | 28 | 2809 | 0.08 |
| CD (P=0.05) | 5.6 | 38.2 | 2.0 | 59 | 5903 | 0.16 |
| CV(%) | 4.9 | 4.4 | 15.6 | 3.5 | 4.5 | 5.2 |
| **Interaction** | | | | | | |
| D×S (main at same level of sub) | | | | | | |
| S Em± | 4.6 | 31.5 | 1.6 | 49 | 4867 | 0.13 |
| CD (P=0.05) | NS | 66.2 | NS | 102 | 10225 | 0.29 |
| S×D(sub at same or different level of main) | | | | | | |
| S Em± | 5.5 | 36.3 | 1.5 | 67 | 6718 | 0.17 |
| CD (P=0.05) | NS | 87.0 | NS | 169 | 16865 | 0.44 |

Table 2. Interaction between sowing dates and varied crop geometry on total dry matter at harvest, Seed yield (kg $ha^{-1}$), net returns and benefit cost ratio of quinoa

**Total dry matter at harvest**

| Treatment | Crop geometry (cm) | | | | |
|---|---|---|---|---|---|
| | $S_1$: 15×10 | $S_2$: 30×10 | $S_3$: 45×10 | $S_4$: 60×10 | Mean |
| **Sowing date** | | | | | |
| $D_1$- October15 | 1247.9 | 964.6 | 844.0 | 734.3 | 947.7 |
| $D_2$ - November1 | 1270.5 | 862.8 | 789.7 | 606.3 | 882.3 |
| $D_3$ -November16 | 1081.5 | 759.2 | 699.9 | 579.6 | 780.0 |
| Mean | 1199.1 | 862.2 | 777.8 | 640.0 | |
| **Interaction** | | | | | |
| D×S | S Em± | 31.5 | CD (P=0.05) | 66.2 | |
| S×D | S Em± | 36.3 | CD (P=0.05) | 87.0 | |

**Seed yield (kg ha$^{-1}$)**

| Treatment | Crop geometry (cm) | | | | |
|---|---|---|---|---|---|
| | $S_1$: 15×10 | $S_2$: 30×10 | $S_3$: 45×10 | $S_4$: 60×10 | Mean |
| **Sowing dates** | | | | | |
| $D_1$- October15 | 2392 | 2083 | 1786 | 1744 | 2001 |
| $D_2$ - November1 | 2064 | 1620 | 1396 | 1361 | 1610 |
| $D_3$ -November16 | 1755 | 1587 | 1290 | 1276 | 1477 |
| Mean | 2070 | 1764 | 1491 | 1460 | |
| **Interaction** | | | | | |
| D×S | S Em± | 49 | CD (P=0.05) | 102 | |
| S×D | S Em± | 67 | CD (P=0.05) | 169 | |

**Net Returns (Rs.)**

| Treatment | Crop geometry (cm) | | | | |
|---|---|---|---|---|---|
| | $S_1$: 15×10 | $S_2$: 30×10 | $S_3$: 45×10 | $S_4$: 60×10 | Mean |
| **Sowing dates** | | | | | |
| $D_1$- October15 | 192640 | 168280 | 140705 | 137802 | 159857 |
| $D_2$ - November1 | 161300 | 122390 | 101968 | 100048 | 121427 |
| $D_3$ -November16 | 131587 | 119770 | 92848.3 | 91708.3 | 108978 |
| Mean | 161842 | 136813 | 111841 | 109852 | |
| **Interaction** | | | | | |
| D×S | S Em± | 4867 | CD (P=0.05) | 10225 | |
| S×D | S Em± | 6718 | CD (P=0.05) | 16865 | |

**Benefit Cost Ratio**

| Treatment | Crop geometry (cm) | | | | |
|---|---|---|---|---|---|
| | $S_1$: 15×10 | $S_2$: 30×10 | $S_3$: 45×10 | $S_4$: 60×10 | Mean |
| **Sowing date** | | | | | |
| $D_1$- October15 | 4.13 | 4.20 | 3.70 | 3.72 | 3.96 |
| $D_2$ - November1 | 3.56 | 3.10 | 2.73 | 2.76 | 3.04 |
| $D_3$ -November16 | 3.00 | 3.03 | 2.60 | 2.56 | 2.85 |
| Mean | 3.56 | 3.46 | 3.00 | 3.06 | |
| **Interaction** | | | | | |
| D×S | S Em± | 0.13 | CD (P=0.05) | 0.29 | |
| S×D | S Em± | 0.17 | CD (P=0.05) | 0.44 | |

## CONCLUSION

The 15$^{th}$ October date of sowing along with 15×10 cm or 30×10cm can be recommended for higher seed yield, net returns and benefit cost ratio of quinoa.

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