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Studies on growth parameters in quinoa (*Chenopodium quinoa* Willd.)

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Abstract
Quinoa (*Chenopodium quinoa* willd.) is a pseudo cereal, which belongs to family amaranthaceae. Application of chemical fertilizers improves the nutrient availability in soil and high plant growth condition is seen, thus augment the seed yield. Keeping these views, the present investigation was undertaken at ZARS, UAS, GKVK, Bengaluru during *Rabi* 2018. The treatment combinations were arranged in factorial randomised block design with two replications which includes two factors, spacing and nutrient application, with 4 levels of spacing and 4 levels of nutrient application. The results revealed that, the treatment with spacing of 45x10 cm and high amounts of nutrient 150:75:75 kg NPK ha^{-1} recorded the highest growth parameters like plant height at 30 DAS (25.91 cm), 60 DAS (119 cm) and at harvest (122.28 cm), total number of branches plant^{-1} (17.70), total number of panicles plant^{-1} (17.63), length of glomerule (16.55 cm), where as in spacing with 55x10 cm and nutrient 150:75:75 kg NPK ha^{-1} recorded the highest values in days to 50 per cent flowering (51.97 %), days to maturity (89.32 days), field emergence (89.17 %) respectively.

Keywords: Quinoa, growth, glomerule and field emergence

1. Introduction

Quinoa (*Chenopodium quinoa* willd.) is an annual herbaceous plant belonging to family *Amaranthaceae* and having its origin in the Pacific slopes of the Andes in South America. It has been cultivated in the Andean region for more than 7000 years (Pearsall, 1992) [9]. The seeds may be utilised for human food, in flour purpose and in animal feed stock also (Repo-carrasco *et al*., 2003) [12]. It has good nutritive value. It is a pseudo cereal botanically related to amaranthus (*Amaranthus spp*) which has the potential to grow with less inputs, water and tolerate to a variety of biotic and abiotic stresses (Rea *et al*., 1979) [11]. Quinoa is a fast-growing plant and grows up to 2 metres tall with different types of leaves like ovate and rhombhoidal in same plant and is similar in the appearance to common weed (*Chenopodium album* called as goosefoot or lambs quarter). Each inflorescence has many small achenes which are around 2 mm in diameter. It is an achene (seed like fruit with a thick seed coat) with different colours ranging from white, pale yellow, orange, red, black and brown. Quinoa has greater capacity of adaptation to soil pH, photoperiod, altitude etc. Quinoa can be grown from sea level to an altitude 3,900 meters above mean sea level and pH range of 6 to 8.5 and temperature from sub-tropical to tropical and humid areas. Quinoa can be succesfully grown on marginal soils showing its low nutrient requirements (Jacobson, 2003) [7]. It is assumed to be a quantitative short day species where the length of the vegetative phase not only depends on latitude of the origin and also depends on the day length (Rishi and Galwey, 1984) [13]. Thus the global intrest generated following the declaration of 2013 as the “International year of quinoa”.The highest production of quinoa in world is Peru with 79,269 tonnes per yer followed by Bolivia with 65,548 tonnes, and Eucador with 3903 tonnes per year (FAOSTAT of United nations 2013) [5]. Quinoa was cultivated in an area of 440 hectares with an average yield of 1.053 tonnes hectare^{-1} (Srinivasa Rao, 2015) [17] in India.

Andhra Pradesh Academy of Rural Development (APARD), Hyderabad has initiated the project called “Project Anantha”. This project had been initiated to search to substitute for ground nut crop with quinoa and thus improved the economic status of farmers in anathapur district and getting more net profit for the farmers.

They reported that quinoa (yellow colour entry) had taken 90-120 days and produced average seed yield of 760 kg ha^{-1} (APARD, 2013-14). Data from 2013-14 is not yet documented. The growing period in Greece was 110-160 days and the yield was 2000 kg ha^{-1} (Jacobsen, 2003) [7]

During green revolution many hybrids and varieties were released, but indias ranking in hunger index was more, it could be compensated by one of the super grain crop called quinoa. Due to scanty availability of information and lack of standardisation procedures in seed production, this research need to be adressed.

The quinoa crop is usually grown on poor fertility soil and moisture is the limiting factor for growth and development. Under these conditions, optimum nutrient supplement is necessary to minimize the effects of soil nutrient status and to promote good plant growth. However quinoa is highly responsive to soil nitrogen (Erley *et al*., 2005) [4]. Therefore, it becomes more important to find out the variations with respect to different plant density and nutrient management in relation to its growth and productivity.

2. Material and methods

Field experiments were carried out in quinoa (*Chenopodium quinoa* Willd.) during *Rabi*, 2018 at ZARS, UAS, GKVK, Bengaluru. Quinoa cv. EC 507740 was raised during *Rabi*, 2018 at ZARS, University of Agricultural Sciences, Bangalore, which is situated between 13° 15' N latitude and 77° 32' East longitudes, at 930 m altitude above Mean Sea Level (MSL). The experiment was laid out in Fatorial randomized complete block design and replicated in two times with sixteen treatments, with four dfferent spacings and nutrient levels. Five tagged plants were used for getting results on growth parameters.

2.1. Plant height (cm)

The plant height was measured from the base of the plant at ground level to the growing tip of the plant (base of the top leaf) at 30 DAS, 60 DAS and at harvesting stage. After emergence of the panicle, the height was taken up to the base of the panicle on the main shoot. The average plant height was worked out and expressed in centimetres.

2.2. Total number of panicles $plant^{-1}$

From randomly selected five plants, total number of panicles $plant^{-1}$ was calculated at 30 DAS, 60 DAS and at harvesting stage. Data was pooled and average total number of panicles was determined.

2.3. Total number of branches $plant^{-1}$

From randomly selected five plants, total number of branches were counted at 30 DAS, 60 DAS and at harvesting stage. Data was pooled and average total number of branches were determined.

2.4. Length of glomerule

From randomly selected five plants, length of glomerule of panicle were measured at harvest. Recorded data was pooled and average length of glomerule was determined.

2.5. Days taken to 50 per cent flowering

Daily counts were made in each plot to know the days taken to 50 per cent flowering after vegetative stage. The date on which 50 per cent of the total plants were flowered in each plot was recorded. The number of days taken to 50 per cent maturity was computed from the date of sowing and mean was expressed as whole number.

2.6. Days taken to maturity

Daily counts were made in each plot to know the days taken to maturity after vegetative stage. The date on which 100 per cent of total plants were matured in each plot was recorded. The number of days taken to 100 per cent maturity was computed from the date of sowing and mean was expressed as whole number.

2.7. Field emergence (%)

Field emergence was calculated by sowing 100 seeds in 4 replications with 5 cm spacing between the seeds. Then number of seeds germinated and seedlings emerged with in the field were counted on 10^{th} day after sowing. The field emergence was calculated by using following formula suggested by Saha and Basu (1981) [15].

$$\text{Field emergence (\%)} = \frac{\text{Number of seedlings emerged}}{\text{Total number of seeds sown}} \times 100$$

2.8. Statistical analysis

The experimental data collected on various growth and yield components of plant were subjected to Fisher’s method of Analysis of Variance technique (Gomez and Gomez,1984) [6]. The level of significance used in ‘F’ test was at P=0.05. Whenever F-test was significant for comparison amongst the treatments an appropriate value of critical difference (CD) was worked out. Otherwise against CD values abbreviation NS (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 0.05 per cent.

3. Results

The results of growth parameters of quinoa *viz*., plant height at 30, 60 DAS and at harvest, number of branches $plant^{-1}$, total number of panicles $plant^{-1}$, days to 50 per cent flowering, length of gomerule, days to maturity, field emergence are represented in Table 1.

3.1. Plant height (cm)

Among the different nutrient levels and spacings significant difference was observed for plant height. At 30 DAS plant height was significantly influenced by different spacing and varied amounts of nutrients at 30 DAS. Among spacing, the highest plant height (22.57 cm) was attained in spacing S_4 (55 x 10 cm). Among different amounts of nutrients N_4 gave higher plant height 22.39 cm followed by N_3 (21.33 cm) and lower plant height was observed in N_1 (16.80 cm). Interaction of both different spacing and nutrient levels gave higher plant height in T_{12} (S_3N_4) was (25.91) cm, whereas lower plant height was seen in T_1 (S_1N_1) was (12.16) cm. At 60 DAS, the maximum plant height was observed in wider spacing in S_3 (45 x10 cm) (110.62 cm) and least was noticed in narrow spacing S_1 (25 x 10 cm) is 95.18 cm.There was non significant difference in plant height at 60 days after sowing due to difference nutrient levels. Highest plant height was observed in N_3 (125:62.5:62.5 NPK ha^{-1}) is (108.84 cm) where as lower plant height is observed in N_1 (75:37.5:37.5 NPK ha^{-1}) is 98.50 cm. Interaction of both spacing and nutriets showed a non significant difference in plant height, highest was observed in T_{12} (S_3N_4) is (119 cm) followed by S_3N_3 T_{11} (117.19 cm) where as lower plant height was observed in T_1 (S_1N_1) is 92.36 cm. At harvest stage showed significant difference due to spacing levels. Highest was observed in S_3 (45 x 10 cm) is (117.93 cm) and least was observed in S_1 (25 x 10 cm) is 100.10 cm. There was no significant difference in plant height at harvest due to difference nutrient levels. Highest was observed in N_4 (125:62.5:62.5 Kg NPK ha^{-1}) is (112.03 cm) whereas lower plant height was observed in N_1 (75:37.5:37.5 Kg NPK ha^{-1}) is 102.41 cm. The plant height showed non significantly difference by interaction of both spacing and nutrients. Higher plant height was observed in T_{12} (S_3N_4) is 122.28 cm followed by T_{16} (S_4N_4) is 113.82 cm and lowest was observed in S_1N_1 (97.90 cm).

3.2. Total number of branches plant^{-1}
The total number of branches plant^{-1} were significantly different as influenced by different levels of spacing. The highest total number of branches was observed in S_4 (55 x 10 cm) was 15.59 whereas lower number of branches was observed in S_1 (25 x 10 cm) was 8.90.The total number of branches were significantly different as influenced by different levels of nutrients. The highest total number of branches was observed in N_4 (150:75:75 Kg NPK ha^{-1}) was 14.57, where as lower was observed in N_1 (75:37.5:37.5 Kg NPK ha^{-1}) was 11.24. Interaction effect of both nutrients and spacing levels has a Non significant difference in total number of branches. The highest was observed in T_{12} (S_3N_4) is 17.70 followed by T_{16} (S_4N_4) was 15.88 whereas lower number of branches was observed in T_1 (S_1N_1) was 6.05.This results conveyed that total number of branches were more in higher spacing of 45x10 cm and nutrient level of 150:75:75 kg NPK ha^{-1} because of higher nutrient supply to individual plant and it absorbs more and good plant growth is seen, so more number of branches were seen. These results are in accordance to Ramesh (2016) [10] in quinoa.

3.3. Total number of panicles plant^{-1}
Total number of panicles plant^{-1} were significantly differed with different levels of spacing. Highest number of panicles plant^{-1} was observed in S_3 (45 x 10 cm) is 15.22 whereas lower number of panicles were observed in S_1 (25 x 10 cm) is 8.47. Total number of panicles plant^{-1} differed significantly with different levels of nutrients. Highest number of panicles was observed in N_4 (150:75:75 Kg NPK ha^{-1}) is 14.74 whereas lower in N_1 (75:37.5:37.5 Kg NPK ha^{-1}) is 11.51.
Interaction effect of both spacing and nutrients on the total number of panicles plant^{-1} differed significantly. Highest total number of panicles plant^{-1} was observed in T_{12} (S_3N_4) is 17.63 followed by T_{16} (S_4N_4) is 15.76 and lower was observed in T_1 S_1N_1 (5.19).

3.4. Length of glomerule
The length of glomerule was observed with different levels of spacing and it was found highest in case of S_3 (15.78 cm) and lowest length of glomerule is observed in S_1 (9.07 cm). The length of glomerule was observed with different levels of nutrient application. It showed that highest length of gloerule was observed in N_4 (16.12 cm) where as lowest length of glomerule was observed in N_1 (9.41 cm). Interaction levels of different spacing and nutrient showed significant difference in length of glomerule. Highest was observed in S_3N_4 (16.55 cm) followed by S_3N_3 (16.10 cm), where as lower length of glomerule is seen in S_1N_1 (2.60 cm).
The results conveyed that length of glomerule was higher in wider spacing 45x10 cm and with application of higher nutrients 150:75:75 kg NPK ha^{-1}.

3.5. Days to 50 per cent flwering
Days to 50 per cent flowering with different spacing levels show significant difference. Wider spacing S_4 (51.97) took more number of days and narrow spacing S_1 (44.99) took less number of days for 50 per cent flowering. Days to 50 per cent flowering with different nutrient levels shown non significant difference. However application of more amount of nutrients. Nutrient levels N_4 took more number of days (49.53) and lower nutrient level N_1 took less number of days (48.07) for 50 per cent flowering.
Interaction of spacing and nutrients showed non significant difference for days to 50 per cent of flowering. However higher number of days were taken in S_4N_4 (52.45) and lower number of days for 50 per cent flowering is taken in S_1N_1 (43.65).

3.6. Days to maturity
Days taken to maturity showed non significant difference among the spacing treatments. Wider spacing (S_4) took 89.32 days and narrow spacing (S_1) took 88.02 days to complete maturity stage. Days taken to maturity differed non significantly among the nutrient levels. N_4 nutrient level took more number of days (91.22) to complete maturity. Whereas, N_1 nutrient level took less number of days (86.88). The interaction of spacing levels and nutrient levels for days taken to maturity was found to be non significant for days taken to maturity. Highest number of days (93.45) was taken in S_4N_4 to complete maturity followed by S_3N_4 (93.45) and least number of days (86.50) taken in S_1N_1.

3.7. Field emergence
Statistically significant difference was found for the field emergence among the spacing treatments. However, field emergence ranges from 85.75 to 89.17 %. Field emergence was significantly affected by nutrient levels. However field emergence varies from 85.84 to 89.23 %. Field emergence showed non-significant differences due to interaction effects of spacing and nutrition. However, highest field emergence was recorded in S_4N_4 (91.47 %) and lowest was observed in S_1N_1 (84.76 %).

Table 1: Influence of spacing and nutrients on growth parameters in quinoa

Treatments	Plant height			Total number of branches plant^{-1}	Total number of panicles plant^{-1}	Length of glomerule	Days to 50 % flowering	Days taken to maturity	Field emergence (%)
	30 DAS	60 DAS	At harvest						
Spacings (cm)									
S_1 : 25 x 10	15.71	95.18	100.10	08.90	08.47	09.07	44.99	88.02	85.75
S_2 : 35 x 10	19.51	104.2	104.88	12.41	14.53	13.59	48.27	89.09	86.76
S_3 : 45 x 10	21.52	110.2	111.93	15.22	15.22	15.78	49.88	89.31	88.12
S_4 : 55 x 10	22.57	108.4	110.70	15.59	14.78	13.03	51.97	89.32	89.17
S.Em ±	1.11	3.32	5.44	0.482	0.48	0.305	1.31	2.578	0.393
CD (P = 0.05)	3.36	10.03	NS	1.45	1.46	0.919	3.94	NS	1.18

Nutrient levels kg ha^{-1}									
N_1 : 75:37.5:37.5	16.80	98.50	102.41	11.24	11.51	09.41	48.07	86.88	85.84
N_2 : 100:50:50	18.79	104.2	105.09	12.67	12.91	12.70	48.49	88.24	86.88
N_3 : 125:62.5:62.5	21.33	108.8	108.07	13.64	13.85	13.25	49.03	89.40	87.85
N_4 : 150:75:75	22.39	107.4	112.03	14.57	14.74	16.12	49.53	91.22	89.23
S.Em ±	1.11	3.32	5.44	0.482	0.48	0.305	1.31	2.578	0.393
CD (P = 0.05)	3.36	NS	NS	1.45	1.46	0.919	NS	NS	1.18
Interactions (S x N)									
S_1N_1	12.16	92.36	97.90	06.05	05.19	02.60	43.65	86.50	84.76
S_1N_2	14.94	95.50	99.09	08.65	07.63	09.60	44.51	87.99	85.38
S_1N_3	18.21	95.43	100.63	10.30	10.37	09.85	45.35	88.55	86.09
S_1N_4	17.56	97.44	102.79	10.60	10.72	14.24	46.46	89.06	86.82
S_2N_1	15.07	96.05	99.34	09.84	13.74	08.31	47.76	87.12	85.76
S_2N_2	18.50	110.69	103.87	11.95	13.99	12.70	48.00	88.38	86.19
S_2N_3	21.69	108.68	107.04	13.75	14.55	14.00	48.52	89.83	86.91
S_2N_4	22.79	103.49	109.26	14.11	14.87	19.35	48.82	91.05	88.20
S_3N_1	18.89	101.30	105.39	13.80	13.70	14.70	49.40	87.80	86.18
S_3N_2	19.42	105.00	108.12	14.62	14.39	15.80	49.70	88.64	87.43
S_3N_3	21.87	117.19	117.95	14.78	15.18	16.10	50.05	89.48	88.46
S_3N_4	25.91	119.00	122.28	17.70	17.63	16.55	50.40	91.34	90.44
S_4N_1	21.08	104.30	107.04	15.29	13.44	12.05	51.50	86.10	86.70
S_4N_2	22.33	105.63	109.29	15.49	14.64	12.70	51.75	87.98	88.56
S_4N_3	23.56	112.26	112.68	15.74	15.33	13.05	52.20	89.78	89.99
S_4N_4	23.31	111.52	113.82	15.88	15.76	14.35	52.45	93.45	91.47
S.Em ±	2.23	6.65	10.88	0.965	0.96	0.610	2.62	5.157	0.787
CD (P = 0.05)	NS	NS	NS	NS	2.92	1.839	NS	NS	NS
CV (%)	15.94	8.99	14.39	10.48	10.34	6.70	7.60	8.20	1.27

4. Discussion

Plant height is more in high nutrient applied and more spacing treatments, this might be due to the plants getting more area for absorption and more light inception for photosynthesis, more water and air for better development of growth characters. This results are in accordance with Shazhad. M.A. Basra *et al*. (2014) [16] in quinoa, Ramesh. k (2016) [10] in quinoa, Rishi and Galwey (1991) [14] in quinoa, Karnam Navya Jyothi *et al.* (2016) [8] in foxtail millet and Bhomte *et al.* (2016) [2] in little millet.

In case of number of branches and number of panicles the results revealed that higher number of panicles plant^{-1} were reported in the wider spacing of 45 x 10 cm and highest level of nutrients 150:75:75 kg NPK ha^{-1}, which might lead to increased vegetative growth with increase in nutrient level and wider spacing may helped in good interception of solar light, nutrients and increased photosynthesis. These results were in accordance with the findings of Karnam Navya Jyothi *et al.* (2016) [8] in foxtail millet.

Length of glomerule was higher in case of spacing with 45x10 cm and nutrient application of 150:75:75 kg NPK ha^{-1} because individual plant got good solar light interception and more nutrients to absorb, so plant growth was good and length of glomerule was increased.

The results showed that days taken to 50 per cent flowering and days to maturity significantly differed. This might be due to prolonged vegetative growth with increased available nitrogen in soil due to wider spacing and high nitrogen level treatments. The similar results were also reported by Chouhan *et al.* (2015) [3] in pearl millet.

Field emergence was higher because of wider spacing and high nutrient availability.

5. Conclusion

Plant height, total number of branches plant^{-1}, total number of panicles plant^{-1}, length of glomerule was more in spacing with 45x10 cm spacing and with higher nutrient levels 150:75:75 kg NPK ha^{-1}, whereas days to maturity, days to flowering and field emergence were higher in spacing of 55x10 cm and nutrient levels of 150:75:75 kg NPK ha^{-1}.

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