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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 2538-2541

www.thepharmajournal.com
Received: 15-03-2022
Accepted: 22-06-2022

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Effect of different nitrogen levels and different spacing on the different growth attributes of Quinoa (*Chenopodium quinoa* Willd.)

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Abstract
Quinoa (*Chenopodium quinoa* Willd.), is a pseudo-cereal crop and as a field crop it has a great potential in the improvement of food for humans and animals even under the conditions of marginal lands. For getting high crop yields, nutrients in balanced amount are a basic requirement. The experiment was laid out in Split Plot Design with four replications and there were 3 spacing parameters i.e. 30 cm, 45 cm and 60 cm and 3 nitrogen scheduling *i.e.* 40 kg, 80 kg and 120 kg. Data on growth parameters *viz.* plant height, leaf area index, dry matter content, crop growth rate and net assimilation rate were studied at three growth stages from 30 days after sowing (DAS), 60 DAS and at harvest. At harvest, S3 - 60 cm (150.52 g) had the highest dry matter content and Maximum dry matter content was obtained with N3-120kg (150.69g). At 30 DAS, the best crop growth rates were obtained under S3-60 cm (2.71) and maximum crop growth rate was computed using N3-120 kg (2.89). S3-60cm (5.33) had the greatest net assimilation rate at harvest. Under nitrogen scheduling, the greatest net assimilation rate was determined using N3 - 120 kg (5.32). At harvest maximum leaf area index under spacing was recorded with S3 - 60 cm (3.78) and under nitrogen scheduling maximum leaf area index recorded with N3 - 120 kg (3.53). S3 - 60 cm (114.72 cm) observed maximum plant height at harvest and under nitrogen scheduling maximum plant height depicted with N3 - 120 kg (113.38 cm).

Keywords: Pseudo-cereal, growth, scheduling, grain and plant height

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) [4]. The Quinoa has broad-leaves, annual crop. It is tolerant to frost, salinity and drought and has the ability to grow on normal soil condition. Quinoa is most renowned for being one of the only food plants which is the tremendous source of essential amino acids, micronutrients, vitamins, phenolic compounds and minerals and having the high total antioxidant capacity. The protein and oil content ranges from 7.47 to 22.08 per cent and 1.8 to 9.5 per cent respectively (Choudhary *et al.* 2020) [2]. Quinoa can be cultivated in low fertile soils of rainfed areas with low inputs not only to overcome hunger and malnutrition of small and marginal farmers but also to gain good market price through practicing above scientific practices (Prajapati *et al.* 2022) [8].

Material and Method

Location of Experiment

The experiment was conducted at the Research Farm (Agronomy), SOAS, Career Point University, Kota, Rajasthan situated in Southeast part of Rajasthan at an altitude of 579.5 meter above mean sea level and at 24º35’ N latitude and 73º42’ E longitude. The region falls under agro- climatic zone V (humid Southeastern Plain) of Rajasthan.

Field application and experimental design

White quinoa cultivar of quinoa (*Chenopodium quinoa* Wild.) was used as crop material. The experiment was carried out with a split plot design with four replicates at three different nitrogen levels (40, 80 and 120 kg ha-1) and three spacing factors (30 cm, 45 cm and 60 cm). Seeds were sown uniformly in rows 10 cm apart and at a depth of 4-5cm in all the plots at the rate of 15 kg ha^{-1} after proper field preparation. Hand weeding is done at 20 and 40 DAS manually as per treatments. To maintain adequate soil moisture, field was irrigated at different critical stages, taking rainfall into consideration. The crop was harvested manually by serrated edged sickles at physiological maturity when leaves and stems turned brownish yellow and grains become hard enough. The moisture percentage in the grains was less than 14%. The bundle of harvested produce of each net plot was weighed after sun drying for recording biological yield. Threshing of each bundle of individual plot was done manually by wooden sticks.

Statistical Analysis
Analysis of the data obtained on different traits of experiment was subjected to statistical analysis as suggested by Panse and Sukhatme (1985) [6] and results were evaluated at 5% level of significance.

Result and Discussion
Growth attributes
Data on growth parameters *viz.* plant height, leaf area index, dry matter content, crop growth rate and net assimilation rate were studied at three growth stages at 30 days after sowing (DAS), 60 DAS and at harvest.

Plant height (cm.)
The data related to plant height is placed in the Table. The effect of different spaces and nitrogen scheduling on increasing plant height at 30 DAS, 60 DAS and at harvest was found significant. Under spacing, maximum plant height was recorded with S3 - 60 cm (9.91 cm) whereas N3 - 120 kg (11.80 cm) was found maximum under nitrogen scheduling during 2020. At 60 DAS, maximum plant height was recorded with S3 - 60 cm (53.71 cm), and it was significantly superior over S1 - 30 cm (49.58 cm) while statistically at par with S2 - 45 cm (52.51 cm). Hence, Treatment S1 and S2 are not significantly different.

Table 1: Plant height (cm) as influenced by various treatments at different stages of growth

Treatments	Plant height at 30 DAS (cm)			Plant height at 60 DAS (cm)			Plant height at harvest (cm)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S1 - 30 cm	9.07	10.27	9.67	49.10	50.06	49.58	109.21	110.17	109.69
S2 - 45 cm	8.17	9.05	8.61	51.03	53.99	52.51	112.25	112.21	112.23
S3 - 60 cm	9.87	9.94	9.91	52.93	54.49	53.71	114.34	115.10	114.72
S.Em ±	0.17	0.18	0.43	1.11	1.20	1.07	1.46	1.38	1.20
CD at 5%	0.48	0.51	0.81	3.08	3.12	3.70	4.90	4.35	4.63
Nitrogen Scheduling									
N1 - 40 kg	10.47	11.04	10.76	50.43	51.39	50.91	109.94	110.90	110.42
N2 - 80 kg	10.90	10.97	10.94	51.90	52.38	51.38	110.96	111.92	111.44
N3 - 120 kg	11.57	12.01	11.80	53.13	53.96	53.55	112.90	113.86	113.38
S.Em ±	0.17	0.14	0.18	0.80	0.76	0.74	0.86	0.88	0.87
CD at 5%	0.43	0.37	0.49	2.60	2.40	2.52	2.75	2.81	2.80

Nitrogen scheduling showed maximum plant height with N3 - 120 kg (53.55 cm) which was statistically at par with N2 - 80 kg (51.38 cm) but significantly superior over N1 - 40 kg (50.91 cm). Hence Treatment N3 and N2 are not statistically different likewise N1 and N2 are also not statistically different (at par). S3 - 60 cm (114.72 cm) observed maximum plant height at harvest which was statistically at par with S2 - 45 cm (112.23 cm) but significantly superior over S1 - 30 cm (109.69 cm). Similar results are reported by Yarnia (2010) [10] in Amaranth. Under nitrogen scheduling maximum plant height depicted with N3 - 120 kg (113.38 cm) which was statistically at par with N2 - 80 kg (111.44 cm) but significantly superior over N1 - 40 kg (110.42 cm). Jacobsen *et al.* (1994) [3] expressed that plant height of quinoa increased with increasing N fertilization rate from 40 to 160 kg N ha^{-1}. Our findings are in accordance with those researcher's results.

Leaf Area Index (LAI)
Observations of leaf area index influenced by different treatments presented in the table 2

The effect of various treatments on leaf area index were found significant at 30, 60 DAS and significant at harvest.

Table 2: Leaf area index (LAI) influenced by various treatments at different stages of growth

Treatments	LAI at 30 DAS			LAI at 60 DAS			LAI at harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S1 - 30 cm	1.14	1.41	1.28	2.41	2.59	2.51	2.57	3.05	2.91
S2 - 45 cm	2.01	2.31	1.46	2.44	2.57	2.50	2.98	3.72	3.12
S3 - 60 cm	1.17	2.01	1.59	2.97	3.02	2.99	3.57	3.98	3.78
S.Em ±	0.09	0.11	0.14	0.19	0.21	0.19	0.26	0.25	0.25
CD at 5%	0.21	0.24	0.30	0.53	0.56	0.54	0.84	0.86	0.85
Nitrogen Scheduling									
N1 - 40 kg	1.80	1.97	1.89	2.10	2.18	2.15	2.78	2.89	2.83
N2 - 80 kg	2.63	2.52	2.57	2.59	2.57	1.73	2.94	3.02	2.98
N3 - 120 kg	2.56	2.65	2.61	2.44	2.49	2.47	3.50	3.56	3.53
S.Em ±	0.13	0.15	0.14	0.17	0.19	0.17	0.19	0.20	0.20
CD at 5%	0.34	0.37	0.39	0.49	0.42	0.51	0.68	0.69	0.69

At 30 DAS, maximum leaf area index was observed with S3 - 60 cm (1.59) and N3 - 120 kg (2.60) under treatment spacing and nitrogen scheduling respectively. At 60 DAS, maximum leaf area index was recorded with S3 - 60 cm (2.99) and N3 - 120 kg (2.47) under treatment spacing and nitrogen scheduling respectively. At harvest, maximum leaf area index under spacing was recorded with S3 - 60 cm (3.78) and it was significantly superior over S1 - 30 cm (2.83) while statistically at par with S2 - 45 cm (3.12). under nitrogen scheduling maximum leaf area index recorded with N3 - 120 kg (3.53) which was statistically at par with N2 - 80 kg (2.98) but significantly superior over N1 - 40 kg (2.83). An increasing trend of LAI was recorded with increasing application of N level according to Basra *et al*., 2014 [1].

Dry matter content (DMC)

Data pertaining to dry matter content as affected by different treatments are presented in the table. Each period of experiment *viz*., 30 DAS, 60 DAS and time of harvest was found significant. Further, maximum dry matter content was observed with S1 - 30 cm (9.51 g) and N1 – 40 kg (9.57 g) under treatment spacing and nitrogen scheduling respectively.

Table 3: Dry matter content (DMC) (g) as influenced by various treatments at different stages of growth

Treatments	DMC 30 DAS (g)			DMC at 60 DAS (g)			DMC at harvest (g)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S1 - 30 cm	9.47	9.53	9.51	77.72	77.64	77.68	147.67	147.63	147.65
S2 - 45 cm	9.36	9.29	9.33	78.70	79.62	79.16	148.87	149.83	149.35
S3 - 60 cm	9.18	9.22	9.21	79.95	80.27	80.11	150.54	150.50	150.52
S.Em ±	0.14	0.12	0.11	0.61	0.81	0.71	0.85	0.82	0.83
CD at 5%	0.37	0.34	0.29	2.10	2.63	2.37	2.80	2.65	2.71
Nitrogen Scheduling									
N1 - 40 kg	9.51	9.63	9.57	78.35	77.27	77.81	148.87	149.83	149.35
N2 - 80 kg	9.32	9.22	9.27	79.42	78.34	78.88	149.00	150.96	149.98
N3 - 120 kg	9.47	9.42	9.46	80.00	80.12	80.06	150.21	151.17	150.69
S.Em ±	0.09	0.11	0.10	0.45	0.61	0.53	0.41	0.38	0.39
CD at 5%	0.21	0.27	0.24	1.58	1.96	1.77	1.30	1.32	1.31

At 60 DAS, maximum dry matter content was recorded with S3 - 60 cm (80.11 g) and it was significantly superior over S1 - 30 cm (77.68 g) while statistically at par with S2 - 45 cm (79.16 g). Hence both treatment was not significantly different. Under nitrogen scheduling maximum dry matter content recorded with N3 - 120 kg (80.06 g) which was statistically at par with N2 - 80 kg (78.88 g) but significantly superior over N1 - 40 kg (77.81 g). At harvest, maximum dry matter content was recorded with S3 - 60 cm (150.52 g) and it was significantly superior over S1 - 30 cm (147.65 g) while statistically on par with S2 - 45 cm (149.35 g). These findings were supported by Pourfarid *et al*. (2014) [7]. Under nitrogen scheduling maximum dry matter content recorded with N3 - 120 kg (150.69 g) which was statistically on par with N2 - 80 kg (149.98 g) but significantly superior over N1 - 40 kg (149.35 g).

Crop Growth Rate (CGR)

Data showing crop growth rate affected by different treatments are presented in the table. Data showed significant effect for each of the given period *viz*., 30 DAS, 60 DAS and plant at harvest and results was depicted. At 30 DAS maximum crop growth rate observed with S2 - 60 cm (2.83) and lowest with S1 - 30 cm (2.69).

Table 4: Crop growth rate (CGR) as affected by different treatments at different stages of growth

Treatments	CGR 30 DAS			CGR at 60 DAS			CGR at harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S1 - 30 cm	2.71	2.67	2.69	1.52	2.31	1.92	1.51	2.23	1.87
S2 - 45 cm	2.87	2.79	2.83	1.64	2.53	2.08	1.85	2.65	2.25
S3 - 60 cm	2.68	2.73	2.71	1.85	2.79	2.32	2.10	2.71	2.41
S.Em ±	0.09	0.07	0.13	0.06	0.12	0.09	0.17	0.13	0.15
CD at 5%	0.21	0.19	0.34	0.29	0.40	0.31	0.55	0.45	0.50
Nitrogen Scheduling									
N1 - 40 kg	2.64	2.67	2.66	1.59	2.38	1.98	1.60	2.40	2.00
N2 - 80 kg	2.81	2.76	2.79	1.67	2.56	2.11	1.88	2.68	2.28
N3 - 120 kg	2.87	2.89	2.89	1.70	2.74	2.22	1.91	2.81	2.36
S.Em ±	0.11	0.13	0.10	0.04	0.09	0.07	0.09	0.12	0.11
CD at 5%	0.31	0.36	0.34	0.10	0.32	0.21	0.30	0.40	0.32

At 60 DAS, highest values of crop growth rate was recorded maximum under S3- 60 cm (2.32) and it was significantly superior over S1 - 30 cm (1.92) while statistically at par with S2 - 45 cm (2.08). Under nitrogen scheduling maximum crop growth rate was observed maximum with N3 - 120 kg (2.22) which was statistically at par with N2 - 80 kg (2.11) but significantly superior over N1 - 40 kg (1.98). Crop growth rate was recorded maximum with S3 - 60 cm (2.41) at harvest time and it was significantly superior over S1 - 30 cm (1.87) while statistically at par with S2 - 45 cm (2.25). Hence treatment S1 and S2 was not statistically different. Under nitrogen scheduling, maximum crop growth rate recorded with N3 - 120 kg (2.36) which was statistically at par with N2 - 80 kg (2.28) but significantly superior over N1 - 40 kg

(2.00). Our findings were supported by Basra *et al*., 2014 [1] that CGR was also improved with increasing levels of nitrogen (100 and 135 kg N ha^{-1}).

Net Assimilation Rate (NAR)
Data related to net assimilation rate affected by different treatments are presented in the table.

Table 5: Net Assimilation rate (NAR) influenced by various treatments at different stages of growth

Treatments	NAR 30 DAS			NAR at 60 DAS			NAR at harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S1 - 30 cm	3.47	3.52	3.49	3.90	4.52	2.26	4.26	5.20	4.73
S2 - 45 cm	4.21	4.23	4.22	4.32	5.14	4.73	4.89	5.68	5.28
S3 - 60 cm	3.45	3.47	3.46	4.86	5.88	5.77	4.94	5.73	5.33
S.Em ±	0.07	0.11	0.13	0.21	0.30	0.25	0.18	0.16	0.17
CD at 5%	0.19	0.32	0.36	0.92	1.01	0.96	0.62	0.51	0.57
Nitrogen Scheduling									
N1 - 40 kg	3.67	3.71	3.69	3.86	4.93	4.39	4.33	5.17	4.75
N2 - 80 kg	4.71	4.74	4.73	4.11	5.42	4.76	4.60	5.44	5.02
N3 - 120 kg	3.14	3.19	3.17	4.60	6.08	5.34	5.05	5.59	5.32
S.Em ±	0.21	0.19	0.18	0.19	0.27	0.23	0.17	0.12	0.15
CD at 5%	0.57	0.53	0.49	0.71	0.98	0.85	0.58	0.40	0.49

At 30 DAS, maximum net assimilation rate under spacing observed with S2 –45 cm (4.22) and lowest with S1 - 60 cm (3.46). Under nitrogen scheduling maximum net assimilation rate was recorded with N2 - 80 kg (4.73) and lowest with N3 - 120 kg (3.17). At 60 DAS, highest values of net assimilation rate were observed under S3 - 60 cm (5.77) and it was remarkably superior over S1 - 30 cm (2.26) while statistically at par with S2 - 45 cm (4.73). Under nitrogen scheduling maximum net assimilation rate was found with N3 - 120 kg (5.34) which was statistically at par with N2 - 80 kg (4.76) but significantly superior over N1 - 40 kg (4.39). At harvest, highest values of net assimilation rate was calculated under S3 - 60 cm (5.33) and it was significantly superior over S1 - 30 cm (4.73) while statistically at par with S2 - 45 cm (5.28). Similar results were shown in Ramesh *et al.* 2017 *i.e.* maximum net gain of assimilates was observed under wider spacing between 60-90 DAS which was significantly higher compared to closer spacing. While minimum NAR shown at all stages of crop growth with closer spacing. Under nitrogen scheduling maximum net assimilation rate was calculated with N3 - 120 kg (5.32) which was statistically at par with N2 - 80 kg (5.02) but significantly superior over N1 - 40 kg (4.75).

Conclusion
The spacing and nitrogen level effects were the main sources of variation in all characters tested. At harvest, S3 - 60 cm (150.52 g) had the highest dry matter content and Maximum dry matter content was obtained with N3-120kg (150.69g). At 30 DAS, the best crop growth rates were obtained under S3-60 cm (2.71) and maximum crop growth rate was computed using N3-120 kg (2.89). At 60 DAS, the maximum net assimilation rate was computed under S3-60cm (5.77) and greatest net assimilation rate was computed with N3 - 120 kg (5.34). S3-60cm (5.33) had the greatest net assimilation rate at harvest. Under nitrogen scheduling, the greatest net assimilation rate was determined using N3 - 120 kg (5.32). The highest assimilation is due to more number of leaves per plant and efficient uptake of nutrients and water which ultimately improved leaf expansion. At harvest maximum leaf area index under spacing was recorded with S3 - 60 cm (3.78) and under nitrogen scheduling maximum leaf area index recorded with N3 - 120 kg (3.53). S3 - 60 cm (114.72 cm) observed maximum plant height at harvest and under nitrogen scheduling maximum plant height depicted with N3 - 120 kg (113.38 cm).

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