Research Article

Biological Response of Quinoa Plants to Various Nitrogen Levels and Priming Techniques

Asma Hassan*, Zuhair Hasnain, Muhmmad Asadullah, Syed Saqlain Hussain and Muhammad Abbas Anees

Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan.

Abstract | Quinoa (*Chenopodium quinoa* Wild) is a pseudo cereal, drought-resistant, and medicinally value able with a superior nutritional profile as compared to common cereals. It's obligatory to obtain the maximum yield of quinoa under rain-fed conditions with a well-adjusted quantity of nutrients. To evaluate nitrogen (N) levels viz 55 kg ha^{-1}, 65 kg ha^{-1}, 75 kg ha^{-1}, 85 kg ha^{-1}, and 95 kg ha^{-1} and seed priming techniques water soaking, $K2HPO_4$, $K2SO_4$, and CaSO4 (2%) seeds for half-day used to find out effects on yield of quinoa. The maximum plant height (66.133cm) and the number of branches (5.667) were with N 95 kg ha-1. Leaf area $plant^{t-1}$ from 0 to N85 kg ha^{-1} was increased gradually but later on, decreased. Gradually the Dry matter formation increase with an increase in N level, but above 85 kg ha^{-1} dry matter formation was regressively declined. The highest dry matter accumulation and harvest index 66.6g plant-1 17.31% respectively were calculated with N 85 kg ha^{-1}. The highest crop growth rate (13.7 gm^{-2} day^{-1}) was achieved with N 85 kg ha^{-1}. The highest 1000-grain weight (5.6 g) was measured with 85 kg ha^{-1}. The maximum grain yield (9.43g $plant^{-1}$) was also recorded in N 85 kg ha^{-1}. Total biomass increased with N 85 kg ha^{-1} but decreased up to 85 kg ha^{-1}. Seed priming with K_2SO_4, 2% have harvest index (%), crop growth rate (g m^{-2} day^{-1}), 1000 grain weight, and grain yield were relatively closer to the results of seeds primed with K_2HPO_4, 2% solution soaking of seed for 12 hours. Nitrogen 85 kg ha^{-1} and priming of seeds with $CaSO_4$, were best for the growth and yield parameters in rain-fed agro ecological conditions.

Received | January 31, 2022; **Accepted** | June 27, 2022; **Published** | October 19, 2022
***Correspondence** | Asma Hassan, Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan; **Email:** asmahassan@uaar.edu.pk
Citation | Hassan, A., Z. Hasnain, M. Asadullah, S.S. Hussain and M.A. Anees. 2022. Biological response of quinoa plants to various nitrogen levels and priming techniques. *Sarhad Journal of Agriculture,* 38(4): 1510-1518.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.4.1510.1518
Keywords | Quinoa, Nitrogen, Priming, Growth, Yield

Introduction

Classified selection of crops leads to food security issue, especially in the rained area due to unavailability of quality inputs and environmental constraints. Quinoa (Chenopodium quinoa Wild) plant species, which is found in the Andean zone where its seeds were cultivated in Peru is hospitable to various types of soil and climates (Angeli *et al*., 2020). Quinoa, known to be a good example of a functional food designed has an increased quantity of health-promoting photochemical also gave physiological properties to make a strong contribution to human nutrition (Navrus *et al.*, 2016). Quinoa contains phytohormones, which have human nutrition advantages over other plant foods (Filho *et al.*, 2017).

Quinoa is considered to have significant resistance to drought and different climatic factors that influence crop yields under severe conditions. Quinoa escaping from drought mainly through early maturation is an important feature of drought risk that may be close to the end of the terminal drought (Dua *et al.*, 2021). In region of Bolivian Altiplano, regular quinoa yield was 0.6 Mg ha^{-1} with highly stubby production because of narrow assets of water in that zone. Nitrogen with different levels also grants a certain degree of drought tolerance (Luo and Luo, 2017; Alvar *et al.*, 2019). The N level of 75 kg N per hectare has been proved as the best level of nitrogen supplement for its growth and development to maximize economical yield (Garcia *et al.*, 2020). However, (Cadenas *et al.*, 2021) quinoa has a strong response to the application of nitrogen fertilizer, and the grain yield will not decline with the increase in rate of nitrogen fertilizer. Seed yield and protein content of the seeds can be increased by nitrogen application. Soil treatment with N at the rate of 75 kg N per hectare increased levels, promoting both growth and yield parameters. An increase in biomass, harvest index, and economic yield was observed (Kakabouki *et al.*, 2021).

Priming technique is an emerging technology adopted for prompt, vigorous and undeviating growth to attain better quality and yield. Seed kept hydrated under hygienic condition until emergence of seed started. It is effective and low hydration technique local farmer can adopt easily without investment to gain good crop yield. Priming technique helpful to develop healthy seeding in different crops which lead to good crop yield. According to the nature of crop seed different priming techniques used.

Soluble content of protein can be restored by priming, disregarding their germination capability. In addition, the seed vigor and protein solubility increase through pre-germination by priming (Derbali *et al.*, 2010). When the incubation temperature rises to 35°C, the seed moisture content and germination rate are faster than 25 °C. As the temperature is reduced to 15 °C, the germination rate of the seed-priming technology is significantly reduced. At these temperatures, primer seeds absorb more quickly than unprimed seeds Exposure of plants to salt levels of 10 dSm^{-1} results in a slight reduction in nitrate reductase activity. This may be because the steps of nitrogen metabolism are disturbed in the presence of salt, which leads to a decline in the growth rate of the plant (Meloni *et al.*, 2004). Seed priming with salicylic acid reduces the adverse effects of salt and increases nitrate reductase activity (Kaur *et al.*, 2022). Quinoa lies in the minor grown crop in the zone, characteristically cultivated in the few rainfed region. Rainfed areas are currently under focused in production for improvement of pseudocereals. Yet, it has not been explored which degree N fertilization and seed priming enhance quinoa plant production. The experiment was designed to hypothesize that priming and nitrogen treatment will promote the growth and yield of quinoa in the arid region of Pakistan is to establish the optimum nitrogen level and to establish the best seed priming techniques for obtaining a maximum yield of quinoa under rained regions.

Materials and Methods

Seed priming technique was carried out in the laboratory of Agronomy, department of PMAS Arid Agriculture University Rawalpindi (33°38N, 73°05E) 2017-18. Seed pre-treatment was followed according (Afzal *et al.*, 2006). Quinoa seed was procured from Soil Salinity Research Institute (SSRI), Pindi Bhattian. Ten seeds of quinoa per pot were sown on first fortnight of October 2018. Soil was collected from fields in PMAS-Arid Agriculture University, Rawalpindi, by random sampling. Soil texture was loam (20 % clay, 35 % silt and 70 % sand) and soil pH was 7.78 determined by pH meter (Model 3505, Jenway UK) (Thomas, 1996). Weather record also taken (Figure 1). Seeds were soaked in water solutions of dipotassium phosphate (K_2HPO_4), potassium sulphate (K_2SO_4), calcium sulphate ($CaSO_4$) were also used with concentration of 2% for 12 hours. Twenty-four pots size of (height 22.5cm, base diameter 274cm and 28cm top diameter) have soil weighted of 12 kg were organised. Phosphorus (P_2O_5) and potassium (k_2SO_4) were applied at the rate of 60 and 50 Kg ha^{-1}. The treatments were as no nitrogen (control), nitrogen 55 kg ha^{-1}, nitrogen 65 kg ha^{-1}, nitrogen 75 kg ha^{-1}, nitrogen 85 kg ha^{-1}, nitrogen 95 kg ha^{-1}. In the first week of April quinoa was harvested. The crop was tangled into bundles and was kept under sun to remove moisture. The dried bundles were weighted with the help of digital balance. The crop was threshed manually with the help of sticks. The produce of each pot was weighted. Different parameters data regularly taken during experiment including plant height, number of branches per plant, leaf area per plant, dry matter accumulation (g plant^{-1}), harvest index, growth rate, 1000 grain weight (g), Grain yield (g pot^{-1}), total biomass (g pot^{-1}), grain yield (kg ha^{-1}).

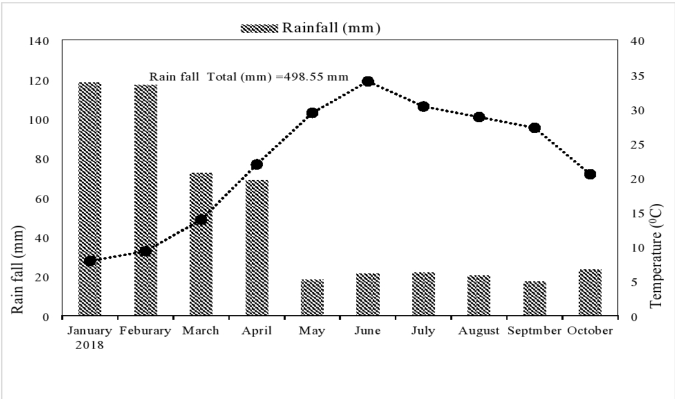

Figure 1: *Weather data research station Rawalpindi (2018).*

Statistical analyses

Analyses of variance tested by Complete Randomized Design (CRD) with by using replicated data. The software statistics ver. 8.1 used and LSD (Least Significant Difference) applied to compare the means of all the parameters to evaluate the significance at 5% level of significance).

Results and Discussion

Plant height (cm)

The maximum plant height 66.133 cm was obtained from nitrogen 95 kg/ha followed by N 85kg ha^{-1} attain 60.083cm plant height. However, N 75kg ha^{-1} was significantly different from N 65kg ha^{-1}and N 55kg ha^{-1} (Table 1). While the lowest plant height 36.1cm was observed in control. In present study, quinoa plant height significantly increased through enhancing the nitrogen rate up to 95 kg ha^{-1}. The mean $CaSO_4$, 2% solution soaking of seed for 12 hours treatment was found to be highest 61.837cm in seed priming techniques. While K_2HPO_4, 2% solution soaking of seed for 12 hours produced comparatively lower results 54.052 cm than P3T3. Water soaking of seeds for 12 hours produced non-significant results (42.497 cm) followed by K_2SO_4, 2% Solution soaking of seed for 12 hours which produced the plants heights of 47.693.

Quinoa plant height increased with increasing nitrogen content, due to the role of nitrogen in stimulating metabolic activity, contributing to an increase in metabolite content, leading to internode elongation and increased plant height, while nitrogen level increased (Ebrahimikia *et al*., 2020).

Number of branches plant^{-1}

Maximum number of branches 5.66cm were observed with N 95 kgha^{-1} followed by N 85 kgha^{-1}. While N 75 kgha^{-1}, (4.33) was statistically at par with N 65 kgha^{-1} and significantly different from N 55 kgha^{-1} (Table 2). Seeds primed with $CaSO_4$ 2% Solution soaking of seed for 12 hours produced significantly higher results with 9.698 branches per plant. No significant differences were found in water soaking of seeds for 12 hours and K2SO4, 2% solution soaking of seed for 12 hours as 3.316 and 4.777, respectively among branches per plant followed by K_2HPO_4, 2% Solution soaking of seed for 12 hours which produced 6.543 number of branches per plant.

Lowest number of branches was produced by the plants treated without nitrogen. Number of branches increased within the increase of nitrogen dose. These results are in agreement with the findings of (Biswas *et al*., 2021).

Table 1: *Plant Height (cm) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Plant height (cm)				
Nitrogen (Control)	30.00 a	38.26cde	33.521 ab	42.61def	36.10 F
Nitrogen 55 kg ha^{-1}	33.76abc	42.67def	36.211 c	50.67 g	40.83 E
Nitrogen 65 kg ha^{-1}	40.76 de	53.67ghi	46.761fg	60.67 lm	50.47 D
Nitrogen 75kg ha^{-1}	44.80 ef	58.50 kl	50.700 g	67.98 o	55.50 C
Nitrogen 85kg ha^{-1}	51.29 gh	61.48lmn	56.454jk	71.10opq	60.08 B
Nitrogen 95kg ha^{-1}	54.36 ij	69.69 op	62.51mn	77.98 r	66.13 A
Mean	42.49 D	54.05 B	47.69 C	61.83 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 2: *Number of Branches Plant^{-1} as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Number of branches plant^{-1}				
Nitrogen (Control)	0.256 a	0.753 fg	0.445 c	1.213 hij	2.666 D
Nitrogen 55 kg ha^{-1}	0.340 b	0.851 fgh	0.505 cd	1.304 hij	3.000 D
Nitrogen 65 kg ha^{-1}	0.394 bc	1.053 hi	0.589 cde	1.631 jk	3.666 CD
Nitrogen 75kg ha^{-1}	0.676 def	0.976 ghi	0.965 ghi	1.716 jk	4.333 BC
Nitrogen 85kg ha^{-1}	0.741 def	1.385 ij	1.050 hi	1.824 jkl	5.000 AB
Nitrogen 95kg ha^{-1}	0.909 gh	1.525 ijk	1.223 hij	2.010 kl	5.666 A
Mean	3.316 CD	6.543 B	4.777 C	9.698 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 3: *Leaf areaPlant^{-1}(cm^2) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Leaf area plant^{-1}(cm^2)				
Nitrogen (Control)	4.496 a	8.183 de	5.652 abc	9.879 fg	7.053 D
Nitrogen 55 kg ha^{-1}	5.934 bc	8.855 ef	6.585 bcd	10.384 fgh	7.940 C
Nitrogen 65 kg ha^{-1}	6.364 bcd	10.586 fgh	7.953 cde	12.563 hi	9.367 B
Nitrogen 75kg ha^{-1}	8.673 def	13.811 ij	10.935 fgh	14.713 jk	12.033 A
Nitrogen 85kg ha^{-1}	8.545 def	14.333 ijk	11.640 ghi	15.082 jkl	12.400 A
Nitrogen 95kg ha^{-1}	5.279 ab	8.925 ef	7.276 cd	11.010 gh	8.123 C
Mean	6.549 D	10.782 AB	8.340 C	12.272 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Leaf area plant^{-1}(cm^2)

Maximum leaf area plant^{-1}(12.400 cm^2) was measured with N 85 kgha^{-1} followed by N 75kgha^{-1}, (12.033 cm^2). While N 65 kgha^{-1} was significantly different from N 55 kgha^{-1}. Smallest leaf area plant^{-1} 7.0533cm^2 was observed in control followed by N 95 kgha^{-1}. Present study shows that there is significant increase in leaf area plant^{-1}(cm^2) from control to N85kgha^{-1} but later on decreased (Table 3).

Results of seeds primed with K_2HPO_4, 2% Solution soaking of seed for 12 hours and $CaSO_4$, were found to be non-significant among them by giving the leaf area plant^{-1}10.782 and 12.272 cm^2, respectively. Non primed seeds water soaked seeds for 12 hours produced lowest leaf area plant^{-1}followed by K_2SO_4, 2% solution soaking of seed for 12 hours and showed the results of 6.549 and 8.340 cm^2, respectively.

Dry matter accumulation (g plant^{-1})

Analyzed data of dry matter accumulation showed the significant effect on different treatment. Highest dry matter accumulation (66.6 g plant^{-1}) was with N 85 kgha^{-1} followed by N 75 kgha^{-1}, (61.033 g plant^{-1}) with N 75 kgha^{-1}. While 65 kgha^{-1}, (55.367 g plant^{-1}) with N 65 kgha^{-1}was significantly different from N 55kgha^{-1}. However lowest dry matter accumulation (44.1 g plant^{-1}) was observed with control followed by N 95 kgha^{-1} (Table 4). Gradually increase in dry matter with increase of nitrogen level up to 85 kg ha^{-1} but above this limit decreases the dry matter accumulation 95 kg ha^{-1}. Due to significant role of dry matter a significantly highest results were found in $CaSO_4$, 2% Solution soaking of seed for 12 hours and showed 59.859 g dry matter accumulation per plant while priming with K_2HPO_4, and K_2SO_4, 2% produced subsequently decreasing results as 56.141, 52.102 and 48.256 g in respect to dray matter accumulation, respectively.

Ali *et al*. (2020) found that increased in dry matter accumulation at 80 to 120 kg ha^{-1}. Nitrogen application on quinoa increased the crop growth rate and quality of the plants ultimately accumulation of dry matter.

Harvest index (%)

Different nitrogen level significantly affected the harvest index (Table 5). The highest harvest index (17.317%) was found with nitrogen 85 kgha^{-1}, followed by its different combinations. The lowest HI (12.420%) was recorded in control which was at par with nitrogen 95 kgha^{-1}. The production of any crop

Table 4: *Dry matter accumulation (g plant^{-1}) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Dry matter accumulation (g plant^{-1})				
Nitrogen (Control)	39.496 a	45.183 cd	41.842 abc	49.879 ef	44.100 F
Nitrogen 55 kg ha^{-1}	43.595 bc	53.795 g	46.855 d	57.104 i	50.337 D
Nitrogen 65 kg ha^{-1}	48.953 e	57.586 i	53.364 g	61.563 kl	55.367 C
Nitrogen 75 kg ha^{-1}	55.673 h	62.713 l	59.935 j	65.811 m	61.033 B
Nitrogen 85 kg ha^{-1}	61.545 kl	67.723 n	65.345 m	71.785 o	66.600 A
Nitrogen 95 kg ha^{-1}	40.273 ab	49.848 ef	45.270 cd	53.010 g	47.100 E
48.256 D	56.141 B	52.102 C	59.859 A		

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 5: *Harvest index (%) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Harvest index (%)				
Nitrogen (Control)	8.595 a	14.363 ef	11.640 c	15.082 fg	12.420 E
Nitrogen 55 kg ha^{-1}	9.695 b	15.465 fg	12.631 cd	17.570 i	13.840 D
Nitrogen 65 kg ha^{-1}	10.405 bc	16.240 h	13.313 de	18.533 ij	14.623 C
Nitrogen 75kg ha^{-1}	12.795 d	17.854 ij	14.776 f	20.586 k	16.503 B
Nitrogen 85kg ha^{-1}	13.459 de	15.574 fg	17.703 i	22.533 l	17.317 A
Nitrogen 95kg ha^{-1}	11.640 c	9.597 b	14.500 f	15.062 fg	12.700 E
Mean	11.098 C	14.849 B	14.094 B	18.228 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

not only determined by its photosynthesis rate also on the segregating of assimilates into seeds, measured through harvest index. With respect to harvesting index primed seed with K_2HPO_4 and K_2SO_4, 2% solution soaking of seed for 12 hours produced statistically non-significant with each other and produced 14.849 and 14.094 % harvesting index. While seed primed with $CaSO_4$, 2% Solution soaking of seed for 12 hours) had significantly highest HI as 18.228 % and controlled was found to be non-significant with 11.098 % harvest index.

Akram *et al*. (2021) harvest index enhanced through increasing nitrogen from 0 to 100 kg N ha^{-1} but it start to decreased at 120 kg N ha^{-1}. The increases in harvest index with increasing nitrogen levels on quinoa are because of the N role in motivating metabolic activity which finally increased yield and its components.

Crop growth rate (g m^{-2} day^{-1})

Application of different nitrogen levels significantly affected the crop growth rate (Table 6). Highest value for crop growth rate (13.7 g m^{-2} day^{-1}) was N 85 kgha^{-1}) followed by, N 75 kgha^{-1} with 12.2 g m^{-2} day^{-1} CGR value. While treatment N2, (10.3 g m^{-2} day^{-1}) with N 65 kgha^{-1} was significantly different from N 55 kgha^{-1}). The lowest CGR (8.133 gm^{-2}day^{-1}) was with control, was statistically at par with N 95kgha^{-1}, (8.4333g m^{-2} day^{-1}) treated with nitrogen 95 kgha^{-1}. Crop growth rate determines the crop strength. Plants primed with K_2HPO_4, and K_2SO_4, 2% Solution soaking of seed for 12 hours were found to be statistically nonsignificant by producing 10.751 and 9.494g m^{-2} day^{-1}. While $CaSO_4$, 2% Solution soaking of seed for 12 hours was highly significant with crop growth rate of 14.098g m^{-2} day^{-1}. As in control seed was soaked only in water for 12 hours so results were found with lowest crop growth rate of 7.056 m^{-2} day^{-1}.

CGR is directly linked to the daily crop performance, and the nutrients use efficiency (Wang *et al*., 2020).

1000 grain weight (g)

Analyzed data regarding to 100-garin weight (g) showed significant influence of different treatments (Table 7). The highest 1000-grain weight (5.6 g) was measured with N 85 kgha^{-1}), followed by 75kgha^{-1}, (5.1333g) with nitrogen 75 kgha^{-1}. While N2, (4.5333 g) with nitrogen 65 kgha^{-1} was significantly different from N1, N 55kgha^{-1}). The lowest 1000-grain weight (2.9667g) was calculated control followed by N 95kgha^{-1}). Results of our present study show that different nitrogen has effect 1000 grain weight (g). Similar results were reported by Basra *et al*. (2014) who stated that 1000 grain weight of quinoa crop was not affected through N application from 0 to 120 kg ha^{-1}.

Seed priming did not produce significant results with respect to 1000 grain weight water soaked of seeds for a day, K_2HPO_4, 2% solution soaking of seed for a day and P2T2 (K_2SO_4, 2% solution soaking of seed for a day were found statistically nonsignificant with 2.545, 4.729 and 3.305 g demonstration of results, respectively. Only $CaSO_4$, 2% solution soaking of seed for a day highest results toward 1000 grain weight with 6.398 g.

Grain yield (g $plant^{-1}$)

Data regarding grain yield was presented in (Table 8). Maximum grain yield (9.4333 g $plant^{-1}$) was recorded in N4, treated with nitrogen 85 $kgha^{-1}$followed by N3(8.4667g $plant^{-1}$) applied with nitrogen 75 $kgha^{-1}$ which was statistically significantly from N2, (7.3667 g $plant^{-1}$) and N1, (6.636g $plant^{-1}$). While the lowest grain yield, (5.9333 g $plant^{-1}$) was produced with control. These results are in agreement with Almadini *et al*. (2019) who reported that with increasing the nitrogen rate increased the grain yield. Afrin (2018) also reported that grain yield $plant^{-1}$ in quinoa improved gradually (1 g to 10 g $plant^{-1}$) with increasing N rate up to 360 kg N ha^{-1}. Reasons might be the difference in quinoa genotypes regarding maturation period and agro-ecological situations.

Table 6: *Crop Growth Rate (g m^{-2} day^{-1}) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Crop growth rate (g m^{-2} day^{-1})				
Nitrogen (Control)	5.207 a	9.205 def	6.610 bc	11.510 efg	8.133 E
Nitrogen 55 kg ha^{-1}	6.706 bc	10.915 ef	7.161 cd	12.549 fg	9.333 D
Nitrogen 65 kg ha^{-1}	6.811 bcd	12.331 fg	8.049 cd	14.010 ghi	10.300 C
Nitrogen 75 kg ha^{-1}	8.545 de	13.533 gh	11.640 efg	15.082 hi	12.200 B
Nitrogen 85 kg ha^{-1}	9.405 def	12.181 fg	15.131 hi	18.082 j	13.700 A
Nitrogen 95 kg ha^{-1}	5.659 ab	6.341 b	8.375 cde	13.357 gh	8.433 E
Mean	7.056 C	10.751 B	9.494 BC	14.098 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 7: *1000 grain weight (g)as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	1000 grain weight (g)				
No Nitrogen (Control)	1.206 a	3.314 bc	2.048 ab	5.301 ef	2.9667 CD
Nitrogen 55 kg ha^{-1}	2.340 ab	4.251 de	3.371 bc	6.304 fg	4.0667 B
Nitrogen 65 kg ha^{-1}	2.840 bc	4.953 ef	3.731 cd	6.607 gh	4.5333 B
Nitrogen 75 kg ha^{-1}	3.236 bc	5.946 fg	4.005 de	7.344 h	5.1333 A
Nitrogen 85 kg ha^{-1}	3.741 cd	6.385 fg	4.450 de	7.824 hi	5.6000 A
Nitrogen 95 kg ha^{-1}	1.909 a	3.525 cd	2.223 ab	5.010 ef	3.1667 C
Mean	2.545 CD	4.729 BC	3.305 BCD	6.398 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD Test.

Table 8: *Grain yield (g $plant^{-1}$) as influenced by the different N level and seed priming techniques on Quinoa crop.*

Nitrogen levels	Grain yield (g $plant^{-1}$)				
No Nitrogen (Control)	3.788 ab	6.435 de	4.685 bc	8.824 fg	5.933 E
Nitrogen 55 kg ha^{-1}	3.836 ab	7.183 ef	5.650 cd	9.879 gh	6.637 D
Nitrogen 65 kg ha^{-1}	4.334 abc	8.055 fg	6.535 de	10.544 hi	7.367 C
Nitrogen 75 kg ha^{-1}	5.651 cd	6.341 de	8.545 fg	13.329 kl	8.467 B
Nitrogen 85 kg ha^{-1}	6.586 de	11.015 ij	7.161 ef	12.969 k	9.433 A
Nitrogen 95 kg ha^{-1}	3.149 a	7.225 ef	5.553 cd	9.006 gh	6.233 DE
Mean	4.557 D	7.709 B	6.355 BC	10.759 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 9: *Total biomass (g pot^{-1})as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Total biomass (g pot^{-1})				
No Nitrogen (Control)	44.401 a	54.423 de	49.181 b	60.796 gh	52.200 E
Nitrogen 55 kg ha^{-1}	51.184 c	62.295 hi	56.855 f	68.655 lm	59.747 D
Nitrogen 65 kg ha^{-1}	58.953 fg	67.586 kl	63.264 ij	71.569 n	65.343 C
Nitrogen 75 kg ha^{-1}	64.673 ijk	72.679 no	69.135 lm	75.111 p	70.400 B
Nitrogen 85 kg ha^{-1}	61.545 h	67.723 kl	65.345 jk	71.785 n	74.433 A
Nitrogen 95 kg ha^{-1}	53.873 d	61.788 h	57.276 fg	66.010 jk	59.737 D
Mean	55.772 D	64.416 B	60.176 C	68.988 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Table 10: *Grain yield (kg ha^{-1}) as influenced by the different N level and seed priming techniques on Quinoa crops.*

Nitrogen levels	Grain yield (kg ha^{-1})				
Nitrogen (Control)	784.05 a	990.36 bc	931.65 b	1242.39d	987.11 F
Nitrogen 55 kg ha^{-1}	1273.71 d	1995.46 fg	1691.26 e	2460.38hi	1855.20 E
Nitrogen 65 kg ha^{-1}	1726.48 e	2635.34 ij	2131.33 fg	3019.98 k	2378. 28 C
Nitrogen 75 kg ha^{-1}	2034.87 fg	2721.47 j	2425.61 hi	3215.28 lm	2599. 31 B
Nitrogen 85 kg ha^{-1}	2101.69 fg	2770.85 j	2416.04 hi	3412.462m	2675. 26 A
Nitrogen 95 kg ha^{-1}	1248.71 d	2575.58 ij	2259.75 g	3362.92 lm	2361.74 CD
Mean	1528.25 D	2281.51BC	1975.94C	2785.57 A	

Means with different letters indicate significant difference at P< 0.05 according to Tukey HSD test.

Seeds primed with K_2HPO_4, 2% Solution soaking of seed for a day and K_2SO_4, 2% Solution soaking of seed for 12 hours were found non-significant as the results showed 7.709 and 6.355 g grain yield per plant, respectively. While seeds primed with P3T3 ($CaSO_4$, 2% Solution soaking of seed for a day produced highest weight of grain yield per plant with 10.759 g. In water soaked seeds for 12 hours was found statistically at par from by producing grain yield of 4.557 g grain per plant.

Total biomass (g pot^{-1})

Results indicated that N 85 kgha^{-1}produced maximum biomass (74.433 g pot^{-1}). It was significantly different from N5with nitrogen 95 kgha^{-1} (59.737g pot^{-1}). While nitrogen 75 kgha^{-1} (70.400 g pot$^{-1)}$ with was statistically different from N 65 kgha^{-1} and N 55 kgha^{-1}. However, the lowest biomass (52.2 g pot^{-1}) was measured with N_0, (control). Total biomass is a yield component in quinoa and significant variation in this parameter might be involved significant yield decrease in quinoa (Table 9).

Lowest total biomass was found when seed was primed by water for 12 hours control showed 55.772 g biomass per pot. Results of K_2HPO_4, 2% Solution soaking of seed for 12 hours showed that 64.416 g biomass was produced and K_2SO_4, 2% Solution soaking of seed for 12 hours produced 60.176 g total biomass which is lowest from. Total biomass was found to be highly significant in $CaSO_4$, 2% Solution soaking of seed for 12 hours which weighed 68.988 g biomass per pot.

Shoman (2018) reported that increasing the nitrogen level values sharing the same letters don't have significant difference increased the total biomass of quinoa crop from 7% to 27% under diverse tillage oprations.

Grain yield (kg ha^{-1})

Maximum grain yield (2675.266 kg ha^{-1}) was recorded in 95 kgha^{-1}, treated with nitrogen 85 kgha^{-1}followed by N3 (2599. 312kg ha^{-1}) applied with nitrogen 75 kgha^{-1}which was statistically significantly from N2, (2378. 285kg ha^{-1}) and N5, (2361.741kg ha^{-1}). While the lowest grain yield, (987. 117kg ha^{-1}) was produced with control these results agree with Schulte *et al.* (2005) increasing the nitrogen rate increased the grain yield. Seeds primed with K_2HPO_4, K_2SO_4, 2% solution soaking of seed for a day were found non-significant as the results showed 2281.514 and 1975.94 5kg grain per hectare, respectively. While seeds primed with $CaSO_4$, 2% Solution soaking of seed for a day) produced highest weight of grain yield with 2785 kg ha^{-1}. Water soaking of seeds for a day was found statistically at par from $CaSO_4$ by producing grain yield of 1528 kg ha^{-1}.

Grain yield plant^{-1} in quinoa improved gradually with increasing N rate up to 360 kg N ha^{-1} Shoman (2018). Reasons might be the difference in quinoa genotypes regarding maturation period and agro-ecological situations.

Conclusions and Recommendations

Nitrogen application of 85 kg N ha^{-1} supplementation and priming of seeds with $CaSO_4$ was proved to be best level for quinoa growth and development under agro ecological conditions of dry land.

Novelty Statement

Need of time scale to explore which degree nitrogen fertilization and seed priming enhance quinoa plant production in dry land.

Author's Contribution

Asma Hassan: Prepared research plan and worked for overall management.
Zuhair Hasnain: Prepared first draft.
Muhmmad Asadullah: Provided technical input.
Syed Saqlain Hussain: Applied statistical analyses.
Muhammad Abbas Anees: Improved the language.

Conflict of interest
The authors have declared no conflict of interest.

References

Afrin, S., 2018. Influence of fertilizer levels on growth and yield of quinoa (Chenopodium quinoa) (Doctoral dissertation, Department of Agronomy, Sher-E-Bangla Agricultural University).

Afzal, I., S.M. Basra, N. Ahmad, M.A. Cheema, E.A. Warraich and A. Khaliq. 2002. Effect of priming and growth regulator treatments on emergence and seedling growth of hybrid maize (*Zea mays* L.). Int. J. Agric. Biol., 4: 303-306.

Afzal, I., S.M.A. Basra, A. Hameed and M. Farooq. 2006. Physiological enhancements for alleviation of salt stress in wheat. Pak. J. Bot., 38(5): 1649-1659.

Akram, M.Z., S.M.A. Basra, M.B. Hafeez, S. Khan, S. Nazeer, S. Iqbal and N. Zahra, 2021. Adaptability and yield potential of new quinoa lines under agro-ecological conditions of Faisalabad, Pakistan. Asian J. Agric. Biol., 2: 202005301. https://doi.org/10.35495/ajab.2020.05.301

Ali, S., M.U. Chattha, M.U. Hassan, I. Khan, M.B. Chattha, B. Iqbal and M.Z. Amin. 2020. Growth, biomass production, and yield potential of quinoa (*Chenopodium quinoa* Willd.) as affected by planting techniques under irrigated conditions. Int. J. Plant Prod., 14(3): 427-441. https://doi.org/10.1007/s42106-020-00094-5

Almadini, A.M., A.E. Badran and A.M. Algosaibi. 2019. Evaluation of efficiency and response of quinoa plant to nitrogen fertilization levels. Middle East J. Appl. Sci., 9: 839-849.

Alvar-Beltrán, J., A. Dao, M.A. Dalla, C. Saturnin, P. Casini, J. Sanou and S. Orlandini. 2019. Effect of drought, nitrogen fertilization, temperature and photoperiodicity on quinoa plant growth and development in the Sahel. Agronomy, 9(10): 607. https://doi.org/10.3390/agronomy9100607

Angeli, V., S.P. Miguel, M.D. Crispim, M.W. Khan, A. Hamar, F. Khajehei and C. Piatti. 2020. Quinoa (Chenopodium quinoa Willd.): An overview of the potentials of the golden grain and socio-economic and environmental aspects of its cultivation and marketization. Foods, 9(2): 216. https://doi.org/10.3390/foods9020216

Basra, S.M.A., D.S Iqbal and D.I. Afzal. 2014. Evaluating the response of nitrogen application on growth, development and yield of quinoa genotypes, Int.J. Agri. Biol., 16(5):886-892.

Biswas, P.K., K. Fateman and A. Rahman. 2021. Influence of planting method and nitrogen dose on growth and yield of quinoa (*Chenopodium Quinoa* Willd.). Bangladesh Agron. J., 24(1): 83-92. https://doi.org/10.3329/baj.v24i1.55548

Cadenas-Castillo, J.E., J.H. Delatorre, Godoy, L. Bascuñán and J.P. Rodriguez. 2021. Quinoa (Chenopodium quinoa Wild.) seed yield and efficiency in soils deficient of nitrogen in the bolivian altiplano: An analytical review. Plants, 10(11): 2479. https://doi.org/10.3390/plants10112479

Derbali, W., A. Manaa, R. Goussi, I. Derbali, C. Abdelly and H.W. Koyro. 2021. Post-stress restorative response of two quinoa genotypes differing in their salt resistance after salinity release. Plant Physiol. Biochem., 164: 222-236. https://doi.org/10.1016/j.plaphy.2021.04.024

Dua-e-Zainab, A.H.G., A. Zafar, S. Sohail, H. Zafar, A.B. Ijaz, Q. Farooq and M.M.U. Husnain. 2021. A brief study of quinoa role and its adaptation towards salinity and drought stress. https://doi.org/10.18782/2582-7146.143

Ebrahimi, R., A. Ahmadian, A. Ferdousi, S. Zandi, B. Shahmoradi, R. Ghanbari *et al.*, K. Yetilmezsoy. 2020. Effect of washing and cooking on nitrate content of potatoes (cv. Diamant) and implications for mitigating human health risk in Iran. Potato Res., 63(3): 449-462.

Ebrahimikia, M., M.M. Jami, H. Marvi, Y. Hasheminejhad and G.M. Ghasemzadeh. 2021. Agro-physiological response of quinoa (Chenopodium quinoa Willd.) to the nitrogen application rate and split application method. J. Soil Sci. Plant Nutr., 21(4): 3437-3450. https://doi.org/10.1007/s42729-021-00618-6

Farooq, M., S. Basra, H. Rehman and B. Saleem. 2008. Seed priming enhances the performance of late sown wheat (Triticum aestivum L.) by improving chilling tolerance. J. Agron. Crop Sci., 194(1): 55-60. https://doi.org/10.1111/j.1439-037X.2007.00287.x

Filho, A.M.M., M.R. Pirozi, J.T.D.S. Borges, H.M.P. Sant-Ana, J.B.P. Chaves and J.S.D.R. Coimbra. 2017. Quinoa: Nutritional, functional, and antinutritional aspects. Crit. Rev. Food Sci. Nutr., 57(8): 1618-1630. https://doi.org/10.1080/10408398.2014.1001811

Garcia-Parra, M., R.R. Stechauner, R.A.D. Gonzalez, R.C. Ortiz, J.N. Plazas and C.A. Colmenares. 2020. Chlorophyll fluorescence and its relationship with physiological stress in Chenopodium quinoa Willd. Notulae Bot. Hortic. Agrobotanici Cluj-Napoca, 48(4): 1742-1755. https://doi.org/10.15835/nbha48412059

Iqbal, S.M.B.S. and I. Afzal. 2014. Evaluating the response of nitrogen application on growth development and yield of quinoa genotypes. Int. J. Agric. Biol., 16(5).

Jacobsen, S.E., 2003. The worldwide potential for quinoa (Chenopodium quinoa Willd.). Food Rev. Int., 19(1-2): 167-177. https://doi.org/10.1081/FRI-120018883

Kakabouki, I.P., D. Hela, I. Roussis, P. Papastylianou, A.F. Sestras and D.J. Bilalis. 2018. Influence of fertilization and soil tillage on nitrogen uptake and utilization efficiency of quinoa crop (Chenopodium quinoa Willd.). J. Soil Sci. Plant Nutr., 18(1): 220-235. https://doi.org/10.4067/S0718-95162018005000901

Kakabouki, I., A. Mavroeidis, A. Tataridas, I. Roussis, N. Katsenios, A. Efthimiadou and Bilalis, D. 2021. Reintroducing Flax (*Linum usitatissimum* L.) to the Mediterranean Basin: The Importance of Nitrogen Fertilization. Plants, 10(9): 1758.

Kaur, H., S.J. Hussain, G. Kaur, P. Poor, S. Alamri, M.H. Siddiqui and M.I.R. Khan. 2022. Salicylic acid improves nitrogen fixation, growth, yield and antioxidant defence mechanisms in chickpea genotypes under salt stress. J. Plant Growth Regul., pp. 1-14. https://doi.org/10.1007/s00344-022-10592-7

Luo, Z.B. and J. Luo. 2017. Uncovering the physiological mechanisms that allow nitrogen availability to affect drought acclimation in Catalpa bungei. Tree Physiol., 37(11): 1453-1456. https://doi.org/10.1093/treephys/tpx115

Meloni, D.A., M.R. Gulotta, C.A. Martínez and M.A. Oliva. 2004. The effects of salt stress on growth, nitrate reduction and proline and glycinebetaine accumulation in Prosopis alba. Braz. J. Plant Physiol., 16(1): 39-46. https://doi.org/10.1590/S1677-04202004000100006

Naik, S., R. Paramesh, R. Siddaraju and P.R. Shankar. 2020. Studies on growth parameters in quinoa (Chenopodium quinoa Willd.). Int. J. Chem. Stud., 8(1): 393-397. https://doi.org/10.22271/chemi.2020.v8.i1f.8278

Navruz, V.S. and N. Sanlier. 2016. Nutritional and health benefits of quinoa (*Chenopodium quinoa* Willd.). J. Cereal Sci., 69(1):371-376.

Schulte, H.O., C. Nassenstein, M. Lommatzsch, D. Quarcoo, H. Renz and A. Braun. 2005. Tumor necrosis factor-α and interleukin-6 regulate secretion of brain-derived neurotrophic factor in human monocytes. J. Neuro Imm., 160(1-2): 204-209.

Shoman, A., 2018. Effect of sowing dates and nitrogen on productivity of quinoa (Chenopodium quinoa Willd.) at desert areas. J. Plant Prod., 9(4): 327-332. https://doi.org/10.21608/jpp.2018.35702

Thomas, G.W., 1996. Soil pH and soil acidity. In: Page, D.L. Sparks. Methods of Soil Analysis Part 3. Soil Sci. Soc. Am. No. 5 Madison, Wisconsin, USA. pp. 475-490. https://doi.org/10.2136/sssabookser5.3.c16

Wang, N., F. Wang, C.C. Shock, C. Meng and L. Qiao. 2020. Effects of management practices on quinoa growth, seed yield, and quality. Agronomy, 10(3): 445. https://doi.org/10.3390/agronomy10030445