EVALUATION OF THE EFFECT OF SEED RATE AND NITROGEN FERTILIZER MANAGEMENT ON AGRONOMIC CHARACTERISTICS AND GRAIN YIELD COMPONENTS IN QUINOA SUMMER CULTIVATION IN FARS PROVINCE

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Abstract

In order to investigate the effect of seed rate and nitrogen fertilizer management on quinoa trait, a two-year factorial experiment based on randomized complete block design was done during the summer of 2017 and 2018 in Kharameh region. Experimental factors included seed rate at five levels of 6, 7, 8, 9 and 10 kg ha^{-1} and nitrogen at six levels of 120, 150 and 180 kg ha^{-1} nitrogen divided into 2 (two leaf, Budding) and 3 times (two leaf, budding and pollination initiation), respectively. With increasing seed rate, grain yield increased from 1716.33 to 3622.92 kgha^{-1} and increasing nitrogen from 120 to 180 kg ha^{-1} increased the grain yield in the 2 and 3-time split treatments by 17.2% and 17.1%, respectively. Regarding the interaction between seed rate and nitrogen on grain yield, the highest yield was obtained at 10 kg ha^{-1} seed with 180 kg ha^{-1} N per hectare divided at 3 times with average yield of 3740 kg ha $^{-1}$ and the lowest grain yield was obtained from interaction of 6 kg ha^{-1} seed with 120 kg ha-1 of nitrogen split at two times with average yield of 1305 kg ha^{-1} . With increasing seed rate, number of sub panicles per plant significantly increased from 6.95 to 14.6. Among nitrogen levels, the highest 1000-seed weight was obtained by treatment with 180 kg using three times (2.8 g). Whit increasing the number of nitrogen application times at each application level significantly increased grain yield and other measured indices.

Keywords; Nitrogen Spilit, Quinoa, Seed Amount.

Introduction

Given the growing population growth in the country, there is an obvious need to increase crop production. Also, the limited water resources in Iran and the fact that a vast area of the country are climatically among arid and semiarid zones, it is of paramount importance to properly manage water exploitation along with accurate use of agronomic practices, particularly under limited available inputs (Foster, 1999; Chevallier, 2005). The industry of new plants is mainly facing with new species and varieties, new areas and technologies for a crop production, new markets or a combination of these factors. One of these plants that produces crop under drought and water deficit conditions is Quinoa, *Chenopodium quinoa*, a member of the Amaranthaceae family and the Chenopodiaceae subfamily, which is endemic to the Andean regions of the Americas (Bhargava and Srivastava, 2013). This plant is cultivated from areas of sea level up to 4000 m above sea level and has several drought tolerance mechanisms and high water use efficiency (Alvarez-Juete et al., 2010 and Brady et al., 2007). Earliness is an important factor to produce sufficient biomass during the growing season, when adequate moisture is available, and additionally it reduces the risk of frost and high cold mostly occurring in arid areas (Jacobsen, 2003). Density is also an important and influential factor in achieving optimal yield. Determination of an optimal plant density in turn plays an important role in the use of production resources in agroecosystems (Kafi et al. 2011). An optimal number of plants per unit area is the density by which all environmental factors are fully utilized by the plant, thereby minimizing intra- and inter-plant competitions, which results in a maximum possible yield with the desired quality (Khajehpour, 2001). The number of plants per unit area depends on germination ability, percentage of emergence and establishment, competition level, and survival of seedlings. The amount of seed affects grain production per unit area by affecting single-plant grain yield. If grain yield is low due to competition, a large number of plants at high density can compensate for the lack of plant yield and consequently grain production per unit area (Koutroubas et al., 2000). In a study on four plant distances of 5, 10, 15, and 20 cm with a fixed row spacing of 50 cm, it was observed that grain amounts in safflower head increased significantly with increasing plant distance (a reduction on grain level) (Fathi and Majdi Nasab, 2002). Decreased 1000-seed weight of rapeseed was observed by increasing grain numbers (Vincence and Belan, 1988).

Nitrogen contributes to the formation of amino acids, vitamins, and chlorophyll. If nitrogen is sufficiently provided to the plant, it can to increase plant growth rate and protein storage of grain s (Siadat et al. 2013). Erley et al. (2005) reported that quinoa strongly reacts to nitrogen fertilizer use. Breti et al. (2000) obtained that the highest yield of quinoa grain s with the highest level of nitrogen consumption (225 kg/ha). Excessive amounts of nitrogen reduce grain yield as it decelerates grain ripening and improves plant vegetative growth. Consumption of nitrogen fertilizer increases both grain yield and protein content (Brenner and Williams 1995). Goma (2013) reported that nitrogen fertilization increased the vegetative growth, metabolism rate, and dry matter accumulation in quinoa. An experimental study was conducted at Izmir University in Turkey to investigate the effect of nitrogen fertilizer levels (zero, 50, 75, 100, 125, 125, 150, and 175 kg/ha) on quinoa grain yield in Mediterranean climatic conditions. It was found that nitrogen use at 150 kg/ha was the best amount for the production of maximum grain yield, harvest index and 1000-seed weight (Geren, 2015). In the United Arab Emirates, it was reported that nitrogen use at 120 kg/ha was the best level for quinoa cultivation (Mosseddaq et al., 2016). Based on experimental results in Mollasani, Ahvaz, an increase in the amount of nitrogen fertilizer led to increased yield and yield components as well as grain and plant nitrogen content in some varieties of quinoa. There were significant differences between levels of nitrogen fertilizer and varieties of quinoa in terms of the number of sub-branches, plant height, stem diameter, number and weight of inflorescence in the plant, number of grain s in the inflorescence, 1000-seed weight and grain yield, dry matter yield, and harvest index (Shahmansouri 2015). Other studies also indicated an increase in quinoa grain yield because of increased nitrogen use (Eisa and Abdel-Ati, 2014; Schulte et al., 2005).

In another study, the effects of planting date, nitrogen fertilizer levels, and their interaction were significant on all measured agronomic traits of quinoa. A comparison of mean values showed decreases in nitrogen use efficiency indices with increasing nitrogen consumption from 80 to 320 kg/ha. It was also observed that a planting date of October 20 and using 320 kg/ha of nitrogen were more suitable for obtaining the maximum yield of quinoa grain s in Ahvaz region (Saeidi et al., 2020). Given that appropriate number of grain s and optimum amount and time of nitrogen fertilizer use affect the plant growth and yield, this study aimed to evaluate the effect of seed amounts and nitrogen fertilizer levels on the growth and yield of quinoa grain in climatic conditions of Kharameh city in Fars province.

Materials and Methods

The interaction of grain number and nitrogen fertilizer management on agronomic traits, yield, and yield components of quinoa were investigate in salt soils of Fars province (Kharameh), located at 29° 32′ N and 53° 11′ E with an altitude of 1597 m above sea level. A factorial experiment in a complete randomized block design with three replications was started on 31 August 2018 until 2019 for two consecutive years. Experimental factors were the amount of grain s consumed at five levels (6, 7, 8, 9, and 10 kg/ha) and nitrogen split application at six levels (120, 150, and 180 kg/ha) in two and three split applications of two-leaf and budding stages and two-leaf, budding, and pollination onset. Each block consisted of 30 plots with totally 90 plots for the whole experiment. The blocks were 2 m apart and each plot measured 2 × 3 m^2. The water salinity was12 dS/m. The TITICACA cultivar obtained from Yazd Salt Research Center was used in this research.

The examined agronomic traits were plant height, leaf area, leaf dry weight, plant dry weight, grain yield, grain yield components (panicle length, panicle diameter, and number of sub-panicles), and 1000-seed weight. One m^2 of each plot and an average of 15 plants per plot were harvested to calculate grain yield and yield components, respectively. The 1000-seed weight was obtained by calculating 100-seed weight with a moisture content of 14% by a digital scale. To investigate and analyze the growth rate, four destructive sampling was performed four weeks after emergence once a week to obtain plant height, plant and leaf dry weights, and leaf area. After completion of data collection in the above experiments, data were analyzed by analysis of variance (ANOVA) using SAS. Mean values were compared with Duncan's multiple range test at significance levels of 1 and 5%.

Results and Discussion

The results of physicochemical analysis of the studied farm soil during the experimental years (Table 1) indicate that the soil has high salinity, alkaline acidity, low organic carbon, moderate to good phosphorus and potassium, and appropriate microelements of iron, zinc, manganese, and copper, with a loamy texture. Due to the high tolerance of quinoa to soil salinity, there was no need to wash the soil to reduce salinity. Based on these results, potash and phosphorus fertilizers and foliar application of microelements were not applied due to the appropriate levels of these elements.

Table 1. Results of physical and chemical analysis of experimental farm soil before testing

Year	EC	pH	OC	N	P	K	Fe	Zn	Mn	Cu	SAND	SILT	CLAY
	$dS.m^{-1}$		%		PPM						%		
2018	10.6	7.52	0.44	0.02	15.4	449	7.2	1.53	19.75	1.52	31.6	45.1	23.3
2019	9.8	7.38	0.57	0.03	12	351	8.2	0.9	15.2	1.8	26.2	38.7	25.1

Table 2 summarizes the meteorological statistics of the surveyed period from 2018 to 2019. Accordingly, the maximum average temperature in the studied months belongs to August with 31.7 °C in the first year and 31.6 °C within the two years of the experiment. The minimum average temperatures in both experimental years belong to December with 8.12 and 7.7 °C, respectively, for the growing seasons of 2017-18 and 2018-19, respectively. Total amounts of rainfall were respectively 20 and 53.3 mm during the experimental period in 2018 and 2019.

Table 2. Mean values of monthly minimum and maximum temperatures and precipitation during quinoa growth in Kherameh within growing seasons of 2018 and 2019

Month	Mean of Min. Temperature (°C)		Mean of Max. Temperature (°C)		Precipitation (mm)	
	2018	2019	2018	2019	2018	2019
July	30.8	30.7	31.7	31.6	0	0
Aug.	27.9	28.5	28.8	28.1	0	0
Sep.	21.4	22.7	22.3	23.5	0	0.3
Oct.	12.8	13.4	13.4	13.0	0	24
Nov.	8.12	7.7	8.8	8.3	20	29

Based on the results of compound ANOVA (Table 3), the effect of year was significant at 1% level on plant height, plant dry weight, panicle length and diameter, number of sub-panicles, and 1000-seed weight, but it had no significant effects on the other traits. According to the ANOVA results, the independent effect of seed amounts and N levels and their interaction were significant on all the examined traits at a level of 1%. The interaction of year × seed amounts was significant on the leaf and plant dry weights and panicle diameter at a level of 1%, but it was not significant on the other traits. The interaction of year × N was significant on leaf and plant dry weights at 1% and on panicle diameter at 5%, but it did not affected the other traits significantly.

Table3. Summary of a two-year compound ANOVA for Plant height (P.H.), Leaf area (L.A), Leaf dry weight (L.D.W.), Plant dry weigh (P.D.W.) [after 4^{th} week], panicle length (Pan. L.), panicle diameter (Pan. D), Sub-panicles no. (S. Pan. no.), 1000-grain weight (T.G.W), and Grain yield (G.Y.) with different seed amounts and nitrogen levels

S.O.V.	df	P.H.	L.A.	L.D. W	P.D.W.	Pan. L.	Pan. D	S.Pan. no	TG W	G.Y.
Year (Y)	1	80.0**	0.01 ^{ns}	0.01 ns	231.20**	7.13**	0.89**	33.54**	0.28 **	10904.45 ns
Year Error	4	3.24	0.03	0.01	4.83	0.55	0.01	1.04 ^{ns}	0.01	1666.67
Seed amount(D)	4	204.81 **	359.14 **	47.10 **	209332.5 0**	204.73 **	27.61 **	323.45 **	8.05 **	17567680. 30**
Y× D	4	0.88 ^{ns}	0.01 ^{ns}	0.03**	12.20**	0.09 ^{ns}	0.02**	0.08 ^{ns}	0.01 ns	561.95 ^{ns}
Nitrogen (N)	5	209.66 **	25.80* *	1.45**	6518.72**	108.74 **	15.50 **	411.51 **	2.33 **	1182925**
Y×N	5	0.97 ^{ns}	0.01 ^{ns}	0.02**	10.13**	0.17 ^{ns}	0.01*	0.05 ^{ns}	0.00 ns	675.05 ^{ns}
D×N	20	93.12* *	4.38**	0.10**	375.32**	1.81**	0.16**	8.63**	0.11 **	298307.54 **
Y× D× N	20	0.65 ^{ns}	0.01 ^{ns}	0.01**	6.48**	0.09 ^{ns}	0.02**	0.08 ^{ns}	0.01 ns	209.60 ^{ns}
Error	11 6	1.88	0.02	0.01	2.61	0.48	0.00	0.49	0.00	790.80
C.V.%		15.2	12.3	9.6	11.80	14.10	11.30	12.20	15.8	14.1

* and **: Significant at 5% and 1% probability levels, respectively.
ns: Non-significant

A comparison of mean values for the effects of seed numbers on the studied traits (Table 4) reveals that the 1000-seed weight increased from 1.83 to 3.06 g by increasing the seed level from 6 to 10 kg/ha. Arif et al. (2010) reported an increase in 1000-seed weight with increasing corn plant density. The 1000-seed weight increased significantly with increasing N consumption from 120 to 180 kg/ha. An increase in the N use intervals at each level also led to a significant increase in the 1000-seed weight (5, 3, 4, and 12% for 120, 150, and 180 kg/ha of N, respectively). The highest and lowest values of the 1000-seed weight were respectively recorded in treatments with 180 kg/ha of N at three stages (2.8 g) and 120 kg/ha of N at two intervals (2 g), which were placed at the highest and lowest statistical groups with a significant difference.

Table 4. Comparison of the average simple effects of plant density and different levels of on yield, yield components, and some agronomic traits of quinoa nitrogen in two years

Nitrogen levels*	P.H. (cm)	L.A. (cm^2 /plant)	L.D.W (gram/m^2)	P.D.W. (gram/m^2)	Pan.L. (cm)	Pan. D (cm)	S. Pan no. (per plant)	TGW (gram)	G.Y (Kg ha^{-1})
N1	55.9^{f}	19.0^{f}	2.58^{f}	155.5^{f}	10.9^{f}	2.8^{f}	4.85^{f}	2.0^{f}	2393.4^{f}
N2	61.5^{e}	19.3^{e}	2.7^{e}	162.5^{e}	12.5^{e}	3.3^{e}	7.10^{e}	2.1^{e}	2474.1^{e}
N3	64.6^{d}	19.7^{d}	2.8^{d}	170.0^{d}	13.2^{d}	3.66 d	10.05 d	2.3^{d}	2525.1^{d}
N4	70.1^{c}	20.4^{c}	3.0^{c}	177.3^{c}	14.0^{c}	3.95^{c}	11.80 c	2.4^{c}	2563.1^{c}
N5	72.8^{b}	20.9^{b}	3.1^{b}	184.5^{b}	15.0^{b}	4.33 b	13.40 b	2.5^{b}	2806.2^{b}
N6	79.1^{a}	21.4^{a}	3.1^{a}	195.8^{a}	16.3^{a}	4.83^{a}	14.39 a	2.8^{a}	2899.6^{a}

مقدار بذر Seed amount**									
D1	63.83 D	16.31 E	1.27 E	97.08 E	10.94 E	3.01 E	6.95 E	1.83 E	1716.33 E
D2	58.33 E	18.15 D	2.19 D	121.75 D	12.25 D	3.17 D	8.38 D	2.04 D	2409.33 D
D3	66.08 C	20.01 C	3.13 C	154.92 C	13.22 C	3.54 C	9.75 C	2.33 C	2446.83 C
D4	69.92 B	21.48 B	3.57 B	209.67 B	14.69 B	4.21 B	11.58 B	2.49 B	2855.83 B
D5	78.56 A	24.55 A	4.16 A	287.92 A	17.14 A	5.15 A	14.67 A	3.06 A	3622.92 A

Averages with at least one common letter in each column do not have a statistically significant difference (Duncan 5%).

N1 and N2: 120 Kg ha^{-1} two times (two leaves and flora initiation) and three times (two leaves, floral initiation and beginning of flowering stages), N3, N4: 150 Kg ha^{-1} two times (two leaves and flora initiation) and three times (two leaves, floral initiation and beginning of flowering stages), N5 and N6: 180 Kg ha^{-1} two times (two leaves and flora initiation) and three times (two leaves, floral initiation and beginning of flowering stages), and ** D1, D2, D3, D4, and D5 are 6, 7, 8, 9 and 10 Kg ha^{-1} with plant distances of 2,4,6, 8, and 10, respectively, on the row.

Increased N consumption likely reduced the competition between seeds for nutrient uptake, and consequently more photosynthates were allocated to each plant, thereby increasing the 1000-seed weight. A research also confirmed that average weight of corn grain decreased by 9-25% due to N defficiency in various N consumption treatments (Ghadiri and Majidian, 2003). An increase in the amount of consumed seed from 6 to 10 kg/ha resulted in a significant elevation of the plant and leaf dry weights. The highest plant dry weight belonged to a seed density of 10 kg/ha (287.92 g/m^2), which increased significantly compared with the lowest density with an average of 97.08 g/m^2. Leaf dry weight also increased significantly from 1.27 to 4.16 g/ m^2 due to an increase in seed density (Table 4). Increased N content led to elevated plant and leaf dry weights per unit area. An increase in N use from 120 to 180 kg/ha in the two- and three-stage split applications resulted in increased leaf dry weight by 20.2 and 14.8%, and plant dry weight by 18.6 and 20.5%, respectively. The plant dry weight increased by the consumption of each N level in the three-stage compared to the two-stage split applications (4.5, 4.6, and 6.12% at N levels of 120, 150 and 180 kg/ha, respectively).

Nitrogen is one of the key environmental factors in the control of biomass and yield through affecting leaf area index (radiation absorption) and photosynthetic capacity per unit area of leaf area (Tuil and Van, 1965). Research has shown that plant growth rate can be controlled by the plant nutrient content (Tesar, 1984). Nitrogen allocation to leaves increases nitrogen use efficiency, thus, increasing CO_2 absorption and dry matter production per unit of nitrogen (Kim and Chol, 1991). Dry matter yield was reported to increase with increasing nitrogen fertilizer (Caks, 2001).

The interaction of N × seed amount on the plant and leaf dry weights indicated that the highest amount of this parameter (180 kg/ha) was obtained in the three-stage split application and a seed amount of 10 kg/ha (4.45 and 323.5 g/m^2 of the leaf and plant dry weights, respectively). All these indices increased with increasing the seed amount, the area, and the stage of nitrogen fertilizer use (Table 5).

An increase in the amount of seeds from 6 to 10 kg resulted in significant increases in the panicle length from 10.94 to 17.14 cm (56.6%), panicle diameter (71.09%), and the number of sub-panicles from 6.95 to 14.67. The results also showed significant elevations in the panicle length and diameter and the number of sub-panicles with increasing use of nitrogen. The findings showed that, the abovementioned indices increased at each nitrogen level with increasing times N fertilizer application. Due to the interaction of nitrogen (180 kg) at three stages with 10 kg/ha of seeds, the panicle length, diameter, and number of sub-panicles alone were placed in the highest statistical group (21.5 cm, 5.91 cm, and 19.5 panicles/m^2, respectively) (Table 5).

Plant height increased by 23.7% with increasing nitrogen levels and seed density from 6 to 10 kg. The maximum average plant height (78.56 cm) among the treatments was found in a seed amount of 10 kg/ha, which was placed in the highest statistical group with a significant difference compared to the other treatments. An increase in nitrogen level and consumption stage led to elevated height of the plant. When the nitrogen consumption stage increased from two to three stages, the plant height rose by 10.01, 8.5, and 8.7% at 120, 150, and 180 kg/ha of N levels, respectively. It seems that an increase in nitrogen consumption provided better conditions for the use of sunlight and the production of photosynthates through increasing the durability and the LAI, ultimately leading a significant increase in plant height (Mousavi et al., 2015). Nitrogen deficiency in cereals reduces plant height (Kamkar et al., 2011). It was also stated that increased amount of nitrogen fertilizer resulted in elevated height of quinoa plant (Mohaddesi et al., 2010). The plant height response to different levels of nitrogen consumption was also noted by some researchers (Elbehri et al., 1995; Jacobsen et al. 2005).

Here, plant height also increased with increasing N levels in each of the studied densities. The split application and stage of N use in each of the applied densities led to increased height of the plant. The results showed the highest plant height (93.6 cm) was obtained from the interaction of the three-stage split application at 180 kg of N with a seed density of 10 kg/ha, which increased by 78.4% compared to the lowest plant height due to the interaction of seed density (6 kg/ha) and 120 kg of N used in the two-stage split application (Table 5).

Grain yield improved with increasing seed consumption and consequently elevated seed density. The yield increased from 1716.3 to 362.9 kg/ha by an increase in the amount of consumed seeds from 6 to 10 kg/ha. The decreased yield by increasing planting distance (reduced seed density) can be explained by the fact that high planting distance was not compensated by more number of plants. The superior production in the superior treatment can be attributed to a sufficient number of plants and also to the proper plant uptake from available resources (Mohaddesi et al., 2010).

Late consumption of nitrogen fertilizer in three-stage split application increased the yield. An increase in the amount of nitrogen increased the yield of quinoa grain s significantly. The lowest average yield (2,393.4 kg/ha) was recorded with N use of 120 kg/ha at two-leaf and budding stages, and the highest average (2899.6 kg/ha) belonged to 180 kg of N treatment at two-leaf, budding, and pollination onset stages. Increasing the stage of N fertilizer use at levels of 120, 150, and 180 kg led to increased yield by 3.4%, 1.5%, and 3.32%, respectively. Increases in the amount of nitrogen from 120 to 150 and 150 to 180 kg/ha resulted in improved yields of 5.5 and 3.5%, and 11.1 and 13.1%, respectively, in the two- and three-stage split applications. These results are consistent with those obtained by Wopereis-Pura (2002), who concluded that late consumption of nitrogen in rice increased yields by 0.4 and 1 tons/ha in wet and dry seasons, respectively.

Numerous studies have been conducted on the timing and amount of N fertilizer use to determine fertilizer recommendations for different rice cultivars (Walker et al. 2006). During 1970-1980, nitrogen management research mostly focused on increasing nitrogen efficiency by reducing its depletion, hence farmers were advised to use the fertilizer as two- or three-stage split applications during the growing season (Buresh, 2007). Therefore, the amount and timing of N fertilizer use is important for optimum grain yield (Walker et al. 2006). In the present study, the interaction of levels and stages of N fertilizer use on grain yield revealed a rising trend of changes at all N levels with increasing seed density (Fig. 1). An increase in the grain yield was observed with increased number of split applications at any level of nitrogen. Grain yield was maximal (3740 kg/ha) by the interaction of 180 kg N treatment at three stages with 10 kg/ha of seeds, which was placed in the highest statistical group. This treatment had an elevation of 1.7 times compared with the least yield (1305 kg/ha) obtained from the interaction of 120 kg N treatment at two stages with 6 kg/ha of seeds (Fig. 1). This trend of change was repeated in all the treatments.

Table 5. Comparison of average interaction effects of seed amounts and different levels of nitrogen on some traits of quinoa in two years

Seed amounts**	Nitrogen*	P.H. (cm)	L.A. (cm^2/plant)	L.D.W (gram/m^2)	P.D.W. (gram/m^2)	Pan.L. (cm)	Pan.D (cm)	S. Pan no. (per plant)	TGW (gram)
D1	N1	52.50^{n}	15.27^{a}	1.10^{u}	89.50^{zd}	8.10^{s}	2.05^{u}	3.50^{n}	1.51^{r}
	N2	53.50^{n}	15.67^{b}	1.11^{u}	91.50^{zc}	9.25^{r}	2.54^{s}	4.50^{m}	1.54^{qr}
	N3	60.50^{k}	16.37^{c}	1.17^{tu}	96.00^{zb}	10.65^{op}	2.64^{r}	6.50^{l}	1.74^{p}
	N4	68.00^{h}	16.68^{d}	1.22^{t}	98.50^{za}	11.25^{no}	2.95^{q}	7.50^{k}	1.84^{o}
	N5	71.00^{g}	16.83^{e}	1.44^{s}	101.00^{z}	12.70^{lm}	3.65^{l}	9.25^{j}	2.05^{n}
	N6	77.50^{e}	17.05^{f}	1.61^{r}	106.00^{y}	13.70^{jk}	4.25^{h}	10.45^{l}	2.30^{jk}
D2	N1	52.50^{n}	17.23^{g}	1.76^{q}	109.50^{x}	9.50^{qr}	2.35^{t}	4.50^{m}	1.61^{q}
	N2	55.50^{m}	17.36^{h}	1.89^{p}	114.50^{w}	11.25^{no}	2.65^{r}	6.50^{l}	1.85^{o}
	N3	56.50^{lm}	17.48^{h}	1.97^{p}	117.50^{v}	11.90^{mn}	3.05^{p}	7.25^{kl}	2.05^{n}
	N4	59.50^{k}	18.73^{i}	2.33^{o}	124.00^{u}	12.65^{lm}	3.35^{n}	9.50^{j}	2.15^{m}
	N5	60.50^{k}	18.94^{i}	2.61^{n}	129.50^{t}	13.70^{jk}	3.59^{lm}	11.25^{hi}	2.20^{lm}
	N6	65.50^{i}	19.15^{j}	2.60^{n}	135.50^{s}	14.50^{ghi}	4.05^{i}	11.25^{hi}	2.40^{hi}
D3	N1	57.50^{l}	19.41^{k}	2.70^{m}	139.50^{r}	10.25^{pq}	2.55^{s}	4.50^{m}	2.00^{n}
	N2	59.50^{k}	19.68^{l}	2.96^{l}	145.50^{q}	12.25^{lm}	3.10^{p}	6.50^{l}	2.15^{m}
	N3	63.50^{j}	19.86^{m}	3.05^{k}	150.00^{p}	12.95^{kl}	3.41^{n}	9.50^{j}	2.34^{ij}
	N4	68.50^{h}	20.12^{n}	3.28^{j}	157.50^{o}	13.97^{ij}	3.66^{l}	11.25^{ih}	2.43^{ghi}
	N5	69.50^{gh}	20.36^{o}	3.37^{i}	164.00^{n}	14.66^{ghi}	3.98^{ij}	12.50^{g}	2.50^{fgh}
	N6	78.00^{e}	20.62^{p}	3.43^{hi}	173.00^{m}	15.25^{efg}	4.57^{f}	14.25^{f}	2.55^{f}
D4	N1	61.00^{k}	21.03^{q}	3.48^{h}	179.00^{l}	12.45^{lm}	3.21^{o}	5.25^{m}	2.25^{kl}
	N2	65.50^{i}	21.23^{r}	3.51^{gh}	190.00^{k}	13.90^{ij}	3.56^{m}	7.50^{k}	2.35^{ij}
	N3	68.00^{h}	21.38^{s}	3.58^{fg}	202.50^{j}	14.35^{hij}	3.96^{j}	11.50^{h}	2.47^{fgh}
	N4	70.50^{g}	21.58^{t}	3.59^{fg}	216.50^{i}	14.97^{fgh}	4.40^{g}	13.25^{g}	2.55^{f}
	N5	73.50^{f}	21.72^{t}	3.63^{f}	229.00^{h}	15.75^{ef}	4.77^{e}	15.50^{e}	2.64^{e}

			u						
	N6	81.00^{d}	21.91 u	3.66^{f}	241.00^{g}	16.72^{cd}	5.37^{c}	16.50 d	2.69^{e}
D5	N1	56.00^{l} m	22.16 v	3.85^{e}	260.00^{f}	14.39^{gh} i	3.87^{k}	6.50^{l}	2.64^{e}
	N2	73.67^{f}	22.46 w	4.03^{d}	271.00^{e}	15.75^{ef}	4.82^{e}	10.50^{i}	2.69^{e}
	N3	74.50^{f}	23.30 w	4.14^{c}	284.00^{d}	15.97^{de}	5.25^{d}	15.50^{e}	2.88^{d}
	N4	84.00^{c}	24.82 x	4.19^{c}	290.00^{c}	17.02^{c}	5.39^{c}	17.50^{c}	2.98^{c}
	N5	89.50^{b}	26.44 y	4.28^{b}	299.00^{b}	18.24^{b}	5.66^{b}	18.50 b	3.35^{b}
	N6	93.67^{a}	28.15^{z}	4.45^{a}	323.50^{a}	21.50^{a}	5.91^{a}	19.50^{a}	3.85^{a}

Averages with at least one similar letter in each column do not have a statistically significant difference (Duncan 5%).
N1 and N2: 120 Kg ha^{-1} two times (two leaves and floral initiation) and three times (two leaves, floral initiation, and beginning of flowering stages), N3, N4: 150 Kg ha^{-1} two times (two leaves and floral initiation) and three times (two leaves, floral initiation and beginning of flowering stages), N5 and N6: 180 Kg ha^{-1} two times (two leaves and flora initiation) and three times (two leaves, floral initiation, and beginning of flowering stages), and ** D1, D2, D3, D4 and D5 are 6, 7, 8, 9, and 10 Kg ha^{-1} with plant distances on rows 2,4,6, 8, and 10, respectively.

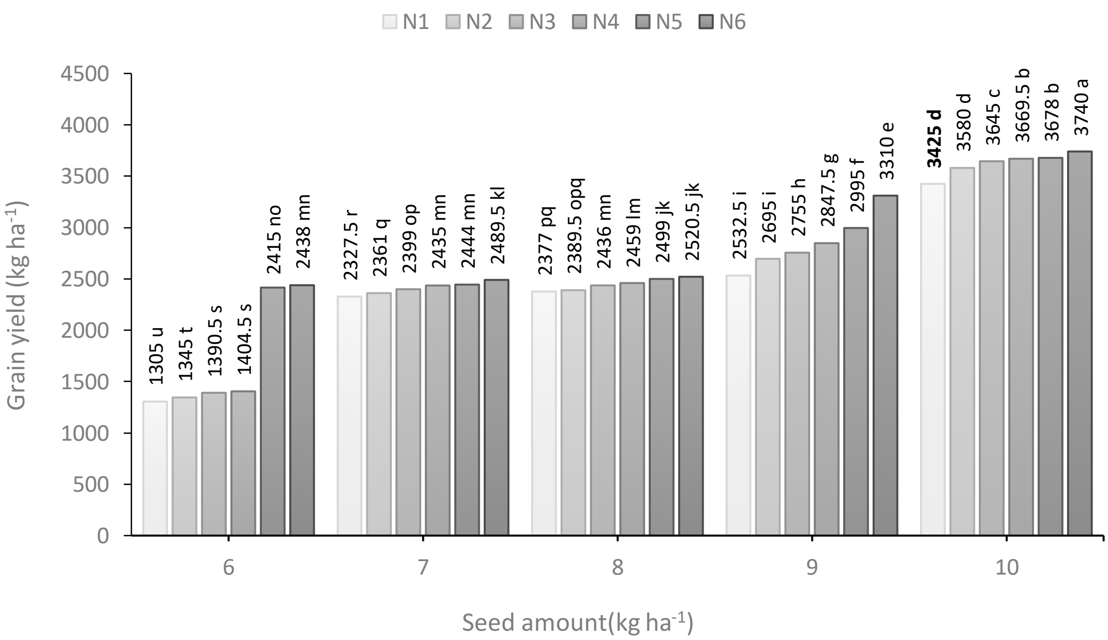

Figure 1. Comparison of the average interaction effects of seed amounts and different levels of nitrogen on grain yield of quinoa in two years.
Averages with at least one similar letter have no statistically significant difference (Duncan 5%)

Conclusion

The results of a two-year experiment in this study showed that a seed amount of 10 kg/ha was appropriate to achieve an optimum plant density for maximum grain yield of quinoa during summer cultivation in Kharameh region. Grain yield increased by about 1.2 times with the highest grain consumption level compared to the lowest density (6 kg/ha). Significant differences were observed between grain yield at 120, 150, and 180 kg/ha of nitrogen in both two- and three-stage split applications, with the latter resulting in a higher yield than the two-stage split application at each of the tested levels. However, increasing the split application from two to three stages did not increase the yield as did increasing nitrogen levels. In the present study, the best N application was the treatment with 180 kg of pure N fertilizer use at three stages (two-leaf, budding, and pollination onset). According to the results and the trend of changes in the yield by grain amount and increasing nitrogen levels, the variety cultivated in this experiment seems to have the ability to tolerate higher amounts of grain s and more fertilizer use. To achieve higher yields, it is recommended to conduct experiments with higher grain amounts per unit area and higher nitrogen levels.

Acknowledgements
The authors sincerely appreciate the farm owner, the researchers at the National Salinity Research Center and the Seed and Seedling Improvement Research Institute, who helped us with the research.

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