E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(8): 93-97
Received: 12-05-2024
Accepted: 16-06-2024

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Adaptability and yield potential of quinoa as an introduction food crop under cold arid climatic conditions of Ladakh

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8b.1192

Abstract
Quinoa is adapted to grow under unfavorable soil and climatic conditions and has high nutritional value. The field experiment was carried out at High Mountain Arid Agriculture Research Institute, Ladakh during 2017 and 2018 to study whether the quinoa crop is adaptable to the Agri-environment of Ladakh as an introduction crop through different date of sowings and fertilizer levels. The experiment with four nitrogen levels (0, 75, 100, and 125 Kg ha^{-h}) and three date of sowing (24th May, 8th June and 22nd June) was conducted to estimate the adaptability and yield potential through evaluation of parameters like, Plant height(cm), days to maturity, Test weight, Harvest index and yield ha^{-h}. Results indicated that 125 kg N ha^{-h} with date of sowing at 8th of June is the best treatment combination with highest yield (14.97 q ha^{-h} in 2018 and 14.45 q ha^{-h} in 2017) whereas the lowest yield (4.66 q ha^{-h} in 2017 and 4.86 q ha^{-h} in 2018) was obtained in the treatment with 0 kg N ha^{-h} and date of sowing at 24th May under Ladakh climatic conditions.

Keywords: Ladakh, nitrogen level, quinoa, sowing date, yield potential and adaptability

Introduction
Quinoa (*Chinopodium quinoa* Wild) is a Pseudo-cereal and halophytic (salt loving) plant belonging to family Chenopodiaceae. Quinoa has been cultivated for thousands of years in the Andean region of Bolivia, Ecuador and Colombia. It is one of the main crops in Latin America, but recently has raised interest in North America, Asia and Europe. The popularity of crop throughout the world was reflected with an initiative by United Nations Organization for Food and Agriculture (FAO) which declare 2013 as year of Quinoa (Anonymus, 2013) [1] as its robust character of adaptability to grow under unfavorable soil and climatic conditions and has high nutritional value (Garcia *et al*. 2003) [12]. This crop has variety of uses in food, feed, food processing and other non-food industrial uses which makes this crop choice of future crops in many countries. Its unique benefits are related to its high nutritional value. Quinoa is considered the only food plant that contains all the amino acids in its protein which are very close to human standards established by FAO. Risi (1991) [19] studied that the amount of essential amino acids in quinoa protein are superior to wheat, barley and soybeans comprising favorably with milk protein, Table-1

Table 1: Nutritional composition of quinoa compared with staple foods (%)

Components (%)	Quinoa	Meat	Egg	Chease	Cow Milk	Human Milk
Proteins	13.0	30.0	14.0	18.0	3.5	1.8
Fats	6.10	50.0	3.20	--	3.5	3.5
Carbohydrates	71.00	--	--	--	--	--
Sugar	--	--	--	--	4.7	7.5
Iron	5.20	2.20	3.20	--	2.5	--
Calories per 100 g	350	431	200	24	60	80

Source: Agrifood report, 2009 MDRT-Bolivia

Ladakh region is situated at eastern trans Himalayan part of Jammu and Kashmir (India). Described as cold-arid desert, the area receives total annual precipitation of 80-120 mm. The temperature in summer rises to 30 °C while in winter, the temperature goes down to -20 °C. Intensive sun light, strong winds, high evaporation rate and fluctuating temperatures characterize the unique climate of the region (Misri, 1987) [17]. Drought and salinity are most common which have confined the agriculture to only 5-8% of total area and restricted the crop yields in most of the cereal crops in this area. The only way to improve the food crop production in this arid climatic conditions are, to diversify the crop production further and to introduce new climate resilient crops like Quinoa which is halophytic in nature and with the potential to become an important crop in the arid regions and saline habitats. Quinoa can be successfully grown on marginal soils showing very low nutrient requirement (Jacobsen, 2003) [16]. However on the other hand, Quinoa is highly responsive to nitrogen also (Erley *et al*., 2005) [7]. The use of modern commercial fertilizers in the agriculture production results in increased crop yields and better plant nutrition. Through these chemical fertilizers signifies themselves not only in increasing yields, but also an increase in the total biomass production.

Introduction of any new climate resilient crop to the area where agriculture is meager due to climatic conditions like aridity and water scarcity is very important, particularly such crop which suits for such climatic conditions for obtaining sustainability and crop diversity to the farming community. Preliminary knowledge about the crop agronomic parameters like date of sowing and minimal fertilizer requirement are somehow sufficient for introduction of crop to evaluate its adaptability into the new environment. Sowing parameter is crucial activity of quinoa cropping because the emergence of seedling effects plant density and final yield (FAO, 2011) [8]. The primary objective of the study was to evaluate the effect of different sowing dates with some nitrogen levels on yield potential of Quinoa under arid climatic conditions of Ladakh so that it can be introduced as additional food crop to the region.

Materials and Methods

Experimental Details

The experiment was carried out during 2017 and 2018 growing seasons (starts from April to October in Ladakh region) at experimental field research station of High Mountain Arid Agricultural Research Institute (HMAARI) –SKUAST-K, Leh (J&K)- India, which is situated at 34^0 14N, 77^0 43E and at an altitude of 3319 m above sea level. The experimental trial was started from last week of May in two consecutive years. The soil of experimental field was sandy loam (65-70% sand) with pH value 8.2. The total nitrogen available in the soil was at medium range (460 kg ha^{-1}), Phosphorus at low (19 kg per hectare) and Potassium was very high range (370 kg ha^{-1}). The experiment was carried out in factorial RBD design (4x3) with three replications; three sowing dates with 15 days gap (24th May,8th June and 22nd June) in two years and four nitrogen levels (0,75,100 and 125 kg ha^{-1}) were tested on Quinoa crop with the plot size of 1.5x2 m of each plot. One forth dose of nitrogen was applied before sowing and rest doses were applied in two splits.

Measurements and statistical analysis

Plant height (cm) was measured from 10 randomly selected plants. Days to maturity, yield and harvest index were measured on plot basis. Harvest index (HI) was calculated as the ratio between seed yield and total dry biomass (above the ground). Test weight was calculated from 1000 seed grain weight. The all data were statistically analyzed by using analysis of variance (ANOVA, Fisher, 1970) [11].

Result and Discussion

The results are summarized in the tables 2, 3, 4, 5 and 6. The different date of sowing and nitrogen level effects were main sources of variation in all the parameters tested, however the interactions between different date of sowings and nitrogen levels (SxN) were non-significant in yield, test weight and days to maturity. The fertilizer levels have also shown non-significant effect on days to maturity.

Plant Height (cm)

Plant height was significantly effected by both date of sowing and fertilizer levels in both years. The highest plant height (127.33 cm) was obtained from 125 kg N ha^{-1} with date of sowing at 8th of June, while as lowest plant height (84.33cm) was obtained from 0 kg of N ha^{-1} with the date of sowing in 24th of May. There was not much difference at average data from the two years, except date of sowings at 8th of June in 2017 and 2018 (Table-2) Plant height of quinoa increased with the increase in nitrogen level and specific date of sowing. Effect of nitrogen level is mainly due to the role of nitrogen in stimulating metabolic activity which contributes to the increase in metabolic net amount, consequently lead to inter-node elongation and increase plant height. (Jacobsen *et al*., 1994 [15], Erley *et al*., 2005 [7], Shams, 2012) [21]. Whereas date of sowing affects quinoa growth, germination and productivity which in turn affect the plant height (Hirich *et al*., 2014) [14]. Our findings are in agreement with those researcher's results.

Table 2: Effect of Fertilizer levels and sowing date on Plant height (cm) in Quinoa.

Fertilizer Levels	Different Sowing dates							
	S1(2017) 24 May	S1(2018) 24 May	S2(2017) 8Jun	S2(2018) 8June	S3 (2017) 22 June	S3(2018) 22June	Mean 2017	Mean 2018
F1(0kg ha^{-1})	93.00	94.00	91.66	90.33	94.33	94.00	92.99	92.77
F2(75kg ha^{-1})	92.66	94.66	92.00	92.33	93.00	92.33	92.55	92.21
F3(100kg ha^{-1})	94.33	92.66	89.66	91.66	92.66	92.00	92.21	91.77
F4(125kg ha^{-1})	94.33	93.66	90.33	92.33	93.00	91.00	92.55	92.55
Mean	93.58	93.66	90.91	91.66	93.25	92.33		
For comparing the means	SE(m) (2017)	SE(m) (2018)			CD at 5% (2017)	CD at 5% (2018)		
Spacing	0.45	0.40			1.32	1.19		
Fertilizer levels	0.52	0.47			NS	NS		
SxF	0.90	0.81			NS	NS		

SxF: Interaction NS: Non significant

Days to maturity

The Nitrogen x Date of sowing interaction was observed non significant in both years on days to maturity Table-3. However the date of sowing independently showed significant effect on days to maturity. Date of sowing at 8th June was earlier during 2017 (90.91 days on average) and date of sowing at 24th May was observed late (93.66 days on average) during 2018. Results showed that fertilizer levels have least or no effect on days to maturity but date of sowing significantly affect the days to maturity which is due to photo period differences and temperature, Bertero (2001) [4].

Table 3: Effect of Fertilizer levels and sowing date on Days to maturity in Quinoa

Fertilizer Levels	Different Sowing dates							
	S1 (2017) 24 May	S1 (2018) 24 May	S2 (2017) 8 June	S2 (2018) 8 June	S3 (2017) 22 June	S3 (2018) 22 June	Mean 2017	Mean 2018
F1(0kg ha-1)	85.66	84.33	96.66	94.33	96.33	99.66	92.88	92.77
F2(75kg ha-1)	88.33	89.33	105.00	102.66	99.00	101.93	97.44	97.97
F3(100kg ha-1)	92.33	92.00	125.00	125.00	106.00	104.33	107.77	107.11
F4(125kg ha-1)	92.33	93.00	127.33	125.40	106.66	105.00	108.77	107.8
Mean	89.75	89.66	113.50	107.46	101.99	102.73		
For comparing the means	SE(m) (2017)	SE(m) (2018)			C.D at 5% (2017)	C.D at 5% (2018)		
Sowing Date(S)	0.86	1.17			2.54	3.45		
Fertilizer levels(F)	1.00	1.36			2.94	3.99		
SxF	1.73	2.35			5.09	6.91		

SxF: Interaction NS: Non significant

Yield components and Yield

The interaction between nitrogen and date of sowing was not significant on test weight. But independently both nitrogen and date of sowing had significant effects on test weight. The highest test weight of quinoa (3.06 g) was found in treatment of 125 kg N ha^{-1} with date of sowing at 8th of May 2018 followed by (3.00 g) by same N level and date of sowing during 2017.

Table 4: Effect of Fertilizer levels and sowing date on Test weight (g) in Quinoa

Fertilizer Levels	Different Sowing dates							
	S1 (2017) 24 May	S1 (2018) 24 May	S2 (2017) 8June	S2 (2018) 8June	S3 (2017) 22 June	S3 (2018) 22 June	Mean 2017	Mean 2018
F1(0kg ha-1)	2.50	2.60	2.30	2.70	2.36	2.32	2.38	2.87
F2(75kg ha-1)	2.66	2.43	2.96	2.86	2.43	2.40	2.68	2.56
F3(100kg ha-1)	2.66	2.50	2.97	3.00	2.50	2.55	2.71	2.68
F4(125kg ha-1)	2.73	2.80	3.00	3.06	2.66	2.60	2.79	2.82
Mean	2.64	2.58	2.49	2.90	2.48	2.46		
For comparing the means	SE(m) (2017)	SE(m) (2018)			C.D at 5% (2017)	C.D at 5% (2018)		
Spacing	0.07	0.06			0.15	0.18		
Fertilizer levels	0.08	0.07			0.22	0.30		
SxF	0.14	0.12			NS	NS		

SxF: Interaction NS: Non significant

The lowest test weight (2.32 g) and (2.36 g) was in 0 kg N ha^{-1} with date of sowing at 22nd June during 2018 and 2017 respectively Table-4. This study has shown increasing levels of nitrogen increases the test weight of seeds. These findings are in agreement with the findings of Thanapornpoonpong (2004) [22] and Gomaa (2013) [13] who revealed that nitrogen fertilizer application increased the average thousand weight.

The interaction of nitrogen and date of sowing effect was significant on harvest index. The highest average harvest index (42.93% in 2017 and 42.56% in 2018) was observed from125 kg ha^{-1} with the date of sowing at 8th of June, whereas the lowest harvest index (15.23% in 2018 and 15.15% in 2017) was observed in 0 kg of N ha^{-1} with date of sowing at 24th May, Table-5. The present investigation revealed that the harvest index of quinoa increased with the increase in nitrogen level at specific date of sowing. Basra *et al.* (2014) [2] informed that harvest index increased by increasing nitrogen treatments from 0 to 100 kg N ha^{-1}. This is mainly due to the role of N in stimulating metabolic activity which contributed to the increase in metabolites amount most of which is used in building yield and its components (Shams, 2012) [21]. On the other hand particular temperature and photoperiod affects the quinoa germination and productivity. The sensitivity to photoperiod and temperature was the function of origin. (Bhargava *et al.* 2006 and Christiansen *et al.*, 2010) [5, 6]. With these findings it is observed that particular date of sowing are crucial factors affecting the plant growth and productivity.

The interaction of nitrogen and date sowing on grain yield of quinoa was found significant in both years. The individual effects of nitrogen and sowing date on quinoa yield where also significant. The highest yield (14.97 q ha^{-1} in 2018 and 14.45 q ha^{-h} in 2017) was obtained at 125 kg N ha^{-h} with date of sowing at 8th June, however the lowest grain yield (4.66 q ha^{-h} in 2017 and 4.86 q ha^{-h} in 2018) was obtained in 0 kg N ha^{-h} with date of sowing at 24th May. Over all the yield from the year 2018 was higher than the year 2017 Table-6. Yield of quinoa increased with increase in the nitrogen levels at specific date of sowing. Sowing is one of the most important activities of quinoa cropping which effects the crop growth and final yield (Hirich *et al.* 2014) [14]. Filali (2011) [9] and Benihabib (2005) informed that yield of quinoa varies with different sowing dates. On the other hand increase in nitrogen level increased the grain yield are supported by the findings of Erley *et al.* (2005) [7], Jacbsosen *et al.* (1994) and Gomaa (2013) [13].

Table 5: Effect of Fertilizer levels and Sowing date on Harvest Index in Quinoa

Fertilizer Levels	**Different Sowing dates**							
	S1(2017) 24 May	**S1(2018) 24 May**	**S2(2017) 8June**	**S2(2018) 8June**	**S3 (2017) 22 June**	**S3(2018) 22June**	**Mean 2017**	**Mean 2018**
F1(0kg ha^{-1})	15.50	15.23	21.36	21.73	20.15	20.44	19.00	19.13
F2(75kg ha^{-1})	16.20	15.80	33.08	34.50	28.20	31.86	25.82	27.38
F3(100kg ha^{-1})	22.76	22.53	40.76	41.13	36.70	35.23	33.40	32.96
F4(125kg ha^{-1})	33.36	33.10	42.93	42.56	35.53	35.30	37.27	36.98
Mean	21.95	21.66	34.53	34.98	30.7	30.70		
For comparing the means	SE(m) (2017)	SE(m) (2018)			C.D at 5% (2017)	C.D at 5% (2018)		
Spacing	0.42	1.77			1.25	5.21		
Ferlilizer levels	0.49	2.05			1.44	6.01		
SxF	0.85	3.55			2.50	10.42		

SxF: Interaction NS: Non significant

Table 6: Effect of Fertilizer levels Sowing date and on Yield.q/ha in Quinoa

Fertilizer Levels	**Different Sowing dates**							
	S1(2017) 24 May	S1(2018) 24 May	S2(2017) 8June	S2(2018) 8June	S3 (2017) 22 June	S3(2018) 22June	Mean 2017	Mean 2018
F1(0kg ha^{-1})	4.66	4.86	12.36	12.26	7.36	7.33	8.12	8.15
F2(75kg ha^{-1})	5.46	5.53	13.43	13.06	8.43	8.20	9.1	8.93
F3(100kg ha^{-1})	6.133	6.23	14.40	14.90	9.13	9.40	9.88	10.17
F4(125kg ha^{-1})	6.60	6.70	14.45	14.97	9.40	9.63	10.15	10.43
Mean	5.71	5.83	13.66	13.80	8.58	8.64		
For comparing the means	SE(m) (2017)	SE(m) (2018)			C.D at 5% (2017)	C.D at 5% (2018)		
Spacing	0.06	0.13			0.18	0.38		
Ferlilizer levels	0.07	0.15			0.21	0.44		
SxF	0.12	0.26			NS	NS		

SxF: Interaction NS: Non significant

Conclusion

Quinoa is known from its robust character of adaptability to grow under unfavorable soil and climatic conditions. This crop as an introduction was evaluated as a food crop through some agronomic parameters for adaptability and yield potential in high mountain cold arid region of Ladakh, India. The significant findings of our two year study on two factors, the four nitrogen levels and three date of sowing on quinoa crop showed that 125 kg N ha^{-h} with date of sowing at 8th of June is the best treatment combination to be adopted for this crop as good yield performer under Ladakh climatic conditions.

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