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Effects of Ascorbic Acid Foliar Spraying and Nitrogen Fertilizer Management in Spring Cultivation of Quinoa (*Chenopodium quinoa*) in North of Iran

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ABSTRACT: In order to study effects of ascorbic acid foliar spraying and nitrogen fertilizer management on yield and some attributes of Quinoa (Chenopodium quinoa) plant, an experiment in factorial format was conducted in randomized complete block design with 3 replicates in Lahijan city (Guilan province, north of Iran. Factors of experiment consist of ascorbic acid foliar spraying with 3 levels (a1: control (without ascorbic acid spraying), a2: 1500 mg/L, a3: 3000 mg/L) and nitrogen fertilizer with 5 levels (n1: control (0 kg/ha pure nitrogen), n2: 50 kg/ha, n3: 100 kg/ha, n4:150 kg/ha and n5: 200 kg/ha pure nitrogen from source of urea (46%)). Measured traits were grain yield, panicle weight, 1000 grain weight, plant height and stem diameter. The obtained results of this experiment showed that, the effect of ascorbic acid foliar spraying and also nitrogen fertilizer application on all studied traits was significant at 1% probability level. On the other hand, the interaction of ascorbic acid spraying × nitrogen fertilizer on grain yield and plant height was significant (p<0.01).

Keywords: Ascorbic acid, Nitrogen, Chenopodium quinoa, Yield, North of Iran

INTRODUCTION

Quinoa has been an important food grain source in the Andean region since 3000 b.c. (Tapia, 1982) and occupied a place of prominence in the Inca empire only next only to maize (Cusack, 1984). Quinoa is grown in a wide range of environments in the South American region (especially in and around the Andes), at latitudes from 20◦Nin Columbia to 40˚S in Chile, and from sea level to an altitude of 3800 m (Risi and Galwey, 1989). The distribution starts from Narino to the Salares of southern Bolivia that includes countries like Ecuador, Peru and northern Argentina (Jujuy and Salta provinces) (Wilson, 1990). The Atacama Desert forms a break in the distribution of the crop, which continues further south into Chile (Bhargava *et al.*, 2006).

Quinoa is a gynomonoecious annual plant with an erect stem, and bears alternate leaves that are variously coloured due to the presence of betacyanins. The inflorescence is a panicle, 15–70 cm in length and rising from the top of the plant and in the axils of lower leaves. The fruit is an achene, comprising several layers, viz. perigonium, pericarp and episperm (Bhargava *et al.*, 2006).

Ascorbic acid is an organic compound with antioxidant properties. The molecular formula of ascorbic acid is $C_6H_8O_6$ with the molecular weight of 176.13. It is a white solid, but impure samples can appear yellowish. It dissolves well in water to give mildly acidic solutions. Ascorbic acid can be slightly dissolved in ethanol, but not in diethyl ether, chloroform, benzene, petroleum ether or lipid (Zhang, 2012).

Ascorbic acid plays role in plant growth and development, cell division, cell wall metabolism and cell expansion, shoot apical meristem formation, root development, photosynthesis, regulation of florescence and regulation of leaf senescence. Also, it is cofactors for enzyme activity, and effects on plant antioxidation capacity, heavy metal evacuation and detoxification and stress defense (Zhang, 2012).

Nitrogen (N) fertilizer use has played a significant role in increase of crop yield (Modhej et al., 2008). Nitrogen is one of the macronutrients that required by plants in comparatively larger amounts than other elements (Marschner, 1995). Nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle (Lincoln and Edvardo, 2006).

The response of nitrogen application on growth, development and yield of quinoa genotypes were studied by Basra *et al.* (2014) They reported that, nitrogen level of 75 kgN/ha was proved to be best level for nitrogen supplementation of soil for quinoa growth and development to harvest maximum economic harvest under agro-ecological conditions of Faisalabad.

The aim of current study was investigating the influence of foliar application of ascorbic acid and different nitrogen fertilizer levels on yield and several attributes of quinoa plant in spring cultivation in north of Iran.

MATERIALS AND METHODS

In order to study effects of ascorbic acid foliar spraying and nitrogen fertilizer management on yield and some attributes of Quinoa (Chenopodium quinoa) plant, an experiment in factorial format was conducted in randomized complete block design with 3 replicates in Lahijan city (Fig. 1) with 37°11' N latitude and 50°0' E longitude (Guilan province, north of Iran). Soil analysis results showed that (Table 1), the soil texture was loam and pH 7.5. Factors of experiment consist of ascorbic acid foliar spraying with 3 levels (a1: control (without ascorbic acid spraying), a2: 1500 mg/L, a3: 3000 mg/L) and nitrogen fertilizer with 5 levels (n1: control (0 kg/ha pure nitrogen), n2: 50 kg/ha, n3: 100 kg/ha, n4:150 kg/ha and n5: 200 kg/ha pure nitrogen from source of urea (46%)). Measured traits were grain yield, panicle weight, 1000 grain weight, plant height and stem diameter. Seeds were sown in pots at 21 March 2014. In each pot, one seed was planted.

The pots diameter was 27 cm and its depth was 29 cm. The data were analyzed using MSTATC software. Also, the figures were drawing by EXCEL software. The Duncan's multiple range tests (DMRT) was used to compare the means at 5% of significant.

Fig. 1. Location of study area, Lahijan city situated in north of Iran.

Table 1. The results of soil analysis at the experimental sites.

Depth	0-30 cm	Soil texture	Loam clay
Clay (%)	20.5	E.C. (ds m^{-1})	0.33
Silt (%)	44	Total nitrogen (%)	0.02
Sand (%)	35.5	P (mg/kg)	39.19
pH	7.5	K (mg/kg)	340.53

RESULTS AND DISCUSSION

A. Grain yield

With attention to results of data variance analysis table (Table 2), the effect of acid ascorbic foliar spraying and also nitrogen fertilizer application showed significant differences at 1% probability level on grain yield. On the other hand, the interaction effect of ascorbic acid foliar spraying × nitrogen fertilizer on grain yield was significant at 1% probability level (Table 2).

Results showed that, with increasing concentration of ascorbic acid foliar spraying on plants the grain yield positively increased (Fig. 2). Between ascorbic acid spraying levels, the highest amount of grain yield was obtained from a3 treatment (3000 mg/L) with 25.89 g/plant. Also, the lowest grain yield with 14.16 g/plant was found from a1 treatment (control). Shehata *et al.*, (2007) on bean; Rizwan *et al*. (2011) on rice; Meena et al. (2012) on Withania somnifera L.Dunal; Bakry e*t al.* (2013) on wheat and Darvishan *et al.* (2014) on corn were reported same results about increasing of yield by ascorbic acid application.

According to Basra *et al.* (2014), it can be concluded that quinoa is highly responsive to nitrogen fertilizer. Among nitrogen fertilizer treatments, the maximum grain yield with 30.24 g/plant was recorded from n5 treatment (200 kgN/ha). On the other hand, the minimum grain yield between nitrogen treatments was recorded from n1 treatment (control) with 9.95 g/plant (Fig. 3). Similar results were obtained by Berti *et al.* (2000) and Basra *et al.* (2014).

With attention to interaction effect levels of ascorbic acid foliar spraying × nitrogen fertilizer on grain yield (Table 3), the highest amount of grain yield with 40.07 g/plant was obtained from a3n5 treatment (ascorbic acid with 3000 mg/L concentration × nitrogen fertilizer at 200 kgN/ha). The lowest grain yield with 6.73 g/plant was recorded from a1n1 treatment (without ascorbic acid and nitrogen usage).

B. Panicle weight

Panicle weight was significantly enhanced by ascorbic acid foliar spraying and nitrogen fertilizer usage (with 99% confidence coefficients) but interaction effect of ascorbic acid foliar spraying × nitrogen fertilizer was non significant on it (Table 2). With regards to Fig. 4, increasing ascorbic acid concentration, positively increased the panicle weight. Between ascorbic acid spraying levels, the maximum panicle weight with 30.98 g/plant was obtained from a3 treatment (3000 mg/L). Also, the minimum panicle weight was recorded from control treatment with 16.75 g/plant. Similar results in rice and wheat were reported by Rizwan *et al.*, (2011) and Bakry *et al.*, (2013) respectively.

Between nitrogen levels, the highest panicle weight was recorded from 200 kgN/ha application with 34.69 g/plant. The lowest amount of this trait with 13.16 g/plant was recorded from control treatment (Fig. 5). Similar results were obtained by Basra *et al.*, (2014).

C. 1000 grain weight

Data presented in Table 2 showed that, the effect of ascorbic acid foliar spraying and nitrogen fertilizer treatments had significant differences in 1% probability level on 1000 grain weight. But interaction effect of ascorbic acid foliar spraying × nitrogen fertilizer was not significant on it.

Among the ascorbic acid spraying levels (Fig. 6), the highest 1000 grain weight was recorded from a3 treatment (3000 mg/L) with 2.667 g. On the other hand, the lowest 1000 grain weight with 2.327 g was obtained from control treatment. Similar results in corn was recorded by Darvishan *et al.*, (2013).

Between the nitrogen fertilizer levels (Fig. 7), the maximum value of 1000 grain weight was recorded from n5 treatment with 2.854 g. On the other hand, the n4 treatment with 1000 grain weight of 2.713 g, placed in same statistically level with n5 treatment. Also, the lowest 1000 grain weight between nitrogen levels with 2.114 g was recorded from control treatment. The n2 treatment (50 kgN/ha) with 1000 grain weight of 2.204 statistically was placed in same level with control treatment. Similar results were obtained by Basra *et al.* (2014).

D. Plant height

A significant influence ($p<0.01$) was observed by usage of different ascorbic acid foliar spraying and nitrogen fertilizer treatments on plant height (Table 2). Also, the interaction effect of ascorbic acid foliar spraying × nitrogen fertilizer on plant height was significant ($p<0.01$).

With attention to Fig. 8, which showed ascorbic acid spraying treatments, the maximum plant height with 108.8 cm was recorded from a3 treatment (3000 mg/L). On the other hand, the lowest plant height with 87.66 cm was recorded from control treatment. The a2 treatment (1500 mg/L) with plant height of 88.89 cm was placed in same statistically level with control treatment. Abd El-Halim (1995) reported that foliar application of ascorbic acid on tomato plants significantly increased growth parameters (stem length, number of branches, leaves, flowers and fruit set as well as dry weight of shoot per plant) in comparison with control plants. El-Zohiri (2009); Khalil *et al.*, (2010) on *Ocimum basilicum*; Abo-Hinna and Merza (2012) on potato; Abdelraouf and Ahmed (2013) on wheat and Ahmed Mayi *et al.*, (2014) were reported same results about increasing the plant height affected by ascorbic acid application.

With attention to Fig. 9, between nitrogen fertilizer levels, the maximum plant height with 104.6 cm was recorded from 200 kgN/ha. Also, use of 150 and 100 kgN/ha respectively with plant height of 101.6 and 99.81 cm was placed in same statistically level with 200 kgN/ha. On the other hand, the lowest plant height with 84.21 cm was obtained from control treatment. The n2 treatment with plant height of 85.35 cm placed in same statistically level with control treatment. Similar results were obtained by Schulte *et al.*, (2005); Shams (2011); Gomaa (2013) and Basra *et al.*, (2014).

With regards to interaction effect levels of ascorbic acid foliar spraying × nitrogen fertilizer on plant height (Table 3), the highest amount of plant height with 123 cm was obtained from a3n5 treatment (ascorbic acid with 3000 mg/L concentration × nitrogen fertilizer at 200 kgN/ha). Also, the a3n4 and a3n3 treatments respectively with 120.8 and 119 cm were placed in same statistically level with a3n5 treatment. The lowest plant height with 80.69 cm was recorded from a1n1 treatment (without ascorbic acid and nitrogen fertilizer usage).

E. Stem diameter

Results of variance analysis (Table 2) indicated that there was a significant difference between ascorbic acid foliar spraying and nitrogen fertilizer treatments on stem diameter (with 99% confidence coefficients). But, interaction effect of ascorbic acid foliar spraying × nitrogen fertilizer on this trait was non significant.

The highest stem diameter between ascorbic acid foliar spraying levels was obtained from a3 treatment (3000 mg/L) with 9.54 mm. On the other hand, the lowest stem diameter was recorded from control treatment with value of 6.74 mm (Fig. 10).

Among the nitrogen fertilizer levels (Fig. 11), the maximum value of stem diameter was related to n5 treatment with 9.68 mm. on the other hand, the lowest stem diameter with 6.52 mm was recorded from control treatment. Also, the n2 treatment with stem diameter of 7.03 mm placed in same statistically level with control treatment. Similar results were obtained by Sa-nguansak (2004); Gomaa (2013) and Basra *et al.* (2014).

Table 2. Analysis of variance related to the traits of quinoa plant under ascorbic acid and nitrogen fertilizer application.

Source of variance	df	Grain yield (g/plant)	Panicle weight (g/plant)	1000 grain weight (g)	Plant height (cm)	Stem diameter (mm)
				Ms		
Replication	2	2.362^{ns}	7.040^{ns}	0.033^{ns}	20.405^{ns}	0.748^{ns}
Ascorbic acid (A)	2	550.440^{**}	787.947^{**}	0.475^{**}	2105.898^{**}	30.275^{**}
Nitrogen (N)	4	621.467^{**}	684.658^{**}	0.910^{**}	827.573^{**}	14.994^{**}
Interaction (A× B)	8	16.819^{**}	17.551^{ns}	0.022^{ns}	118.700^{**}	0.829^{ns}
Error	28	5.039	8.419	0.040	27.745	0.467
Cv%		11.73	12.58	8.11	5.54	8.52

ns, ** and * respectively: non significant, significant at 1% and 5% level

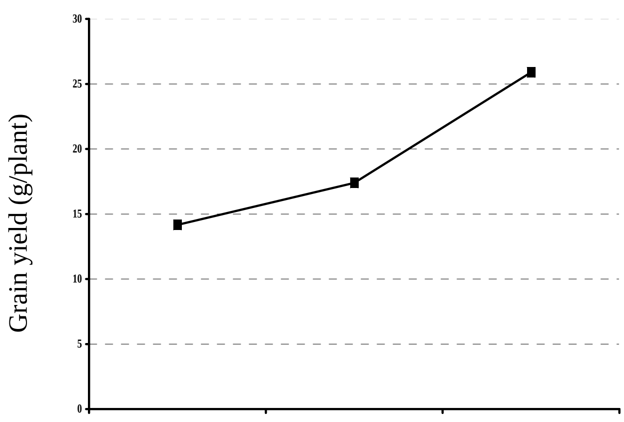

Fig. 2. Effect of ascorbic acid foliar spraying on grain yield.

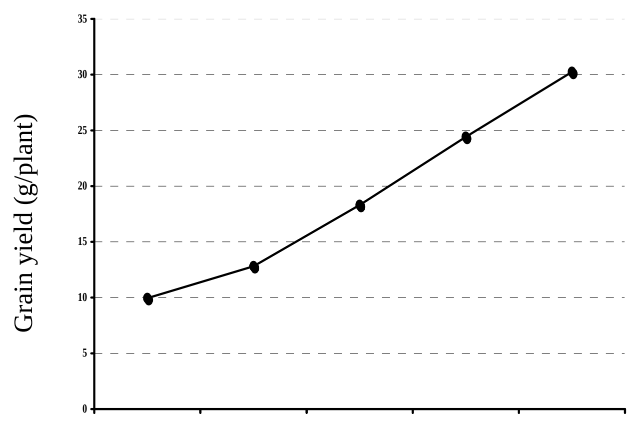

Fig. 3. Effect of nitrogen fertilizer on grain yield.

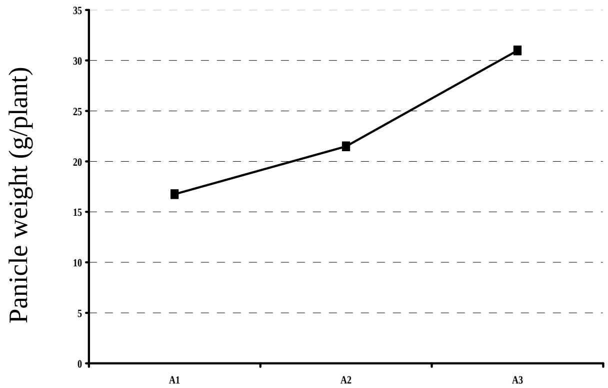

Fig. 4. Effect of ascorbic acid foliar spraying on panicle weight.

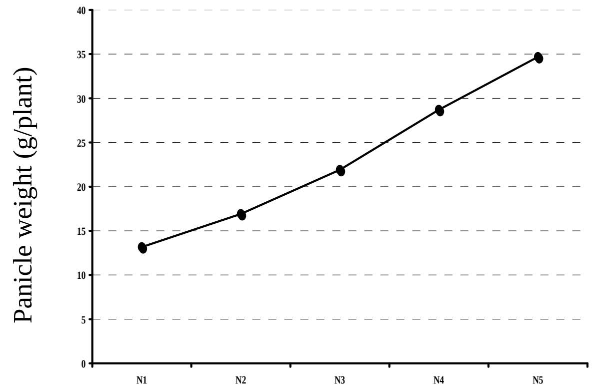

Fig. 5. Effect of nitrogen fertilizer on panicle weight**.**

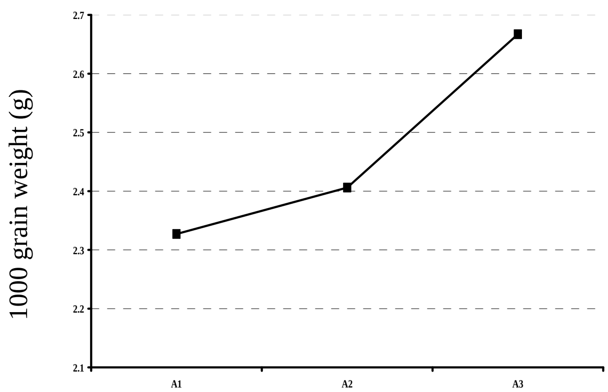

Fig. 6. Effect of ascorbic acid foliar spraying on 1000 grain weight.

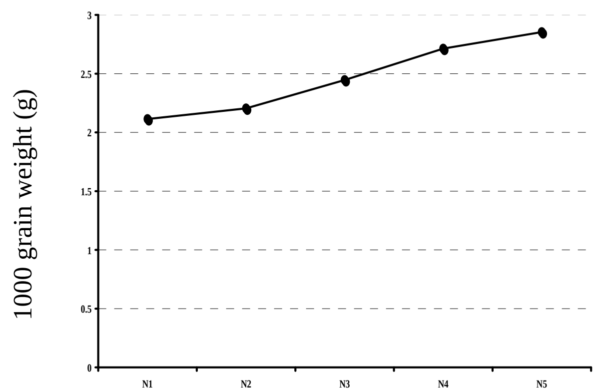

Fig. 7. Effect of nitrogen fertilizer on 1000 grain weight.

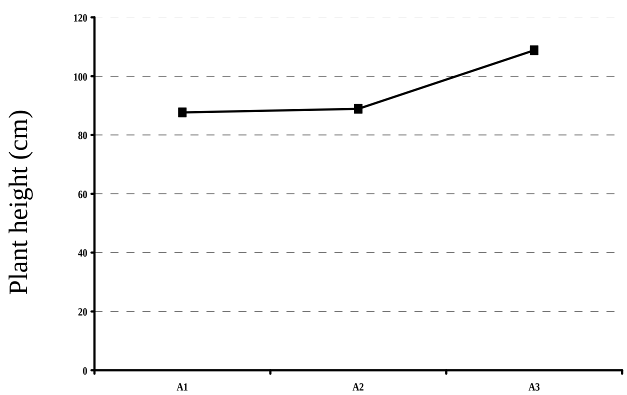

Fig. 8. Effect of ascorbic acid foliar spraying on plant height.

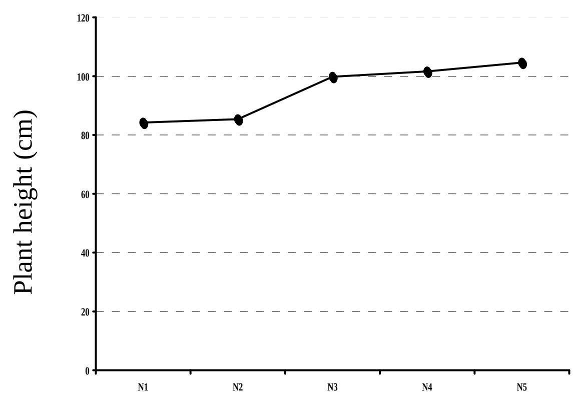

Fig. 9. Effect of nitrogen fertilizer on plant height**.**

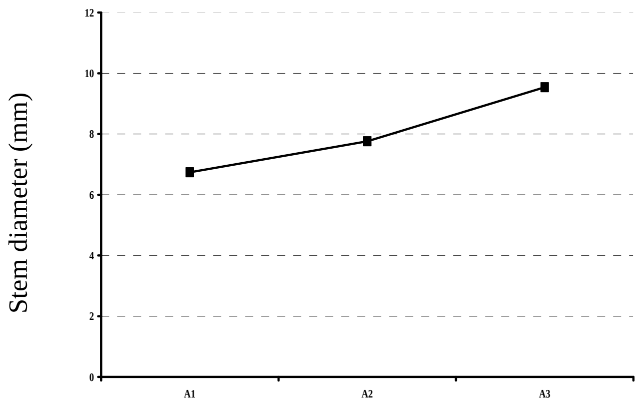

Fig. 10. Effect of ascorbic acid foliar spraying on stem diameter.

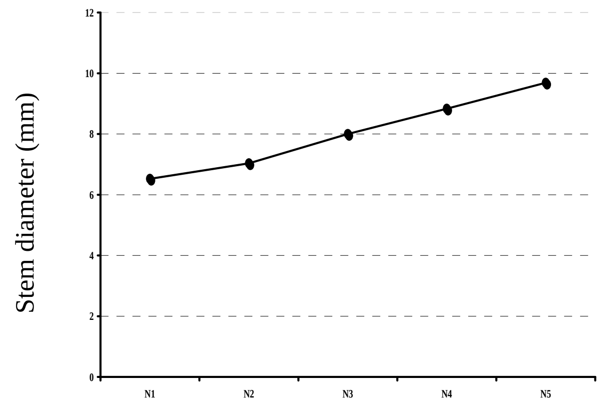

Fig. 11. Effect of nitrogen fertilizer on stem diameter.

Table 3. The interaction effect of ascorbic acid foliar spraying and nitrogen fertilizer on grain yield and plant height.

Treatments	Grain yield (g/plant)	Plant height (cm)
A_1N_1	6.73 i	80.69 e
A_1N_2	8.90 hi	82.57 cde
A_1N_3	13.93 fg	89.68 bcde
A_1N_4	18.43 e	91.53 bcd
A_1N_5	22.80 d	93.80 b
A_2N_1	8.93 hi	81.97 de
A_2N_2	12.13 gh	82.37 cde
A_2N_3	16.97 ef	90.70 bcde
A_2N_4	21.03 de	92.37 bc
A_2N_5	27.87 c	97.03 b
A_3N_1	14.20 fg	89.97 bcde
A_3N_2	17.40 ef	91.10 bcd
A_3N_3	24 d	119 a
A_3N_4	33.77 b	120.8 a
A_3N_5	40.07 a	123 a

Within each column, means followed by the same letter do not differ significantly at $P<0.05$

CONCLUSIONS

With attention to obtained results of current study, the effect of ascorbic acid foliar spraying and also nitrogen fertilizer application on all studied traits was significant at 1% probability level. On the other hand, the interaction of ascorbic acid spraying × nitrogen fertilizer on grain yield and plant height was significant ($p<0.01$).

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