

STUDIES ON THE ADAPTATION OF QUINOA (*CHENOPODIUM QUINOA* WILLD.) TO EASTERN ANATOLIA REGION OF TURKEY

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ABSTRACT

Quinoa (*Chenopodium quinoa* Willd.), an Andean crop, is native food plant of high nutritional value and its cultivation is increasing rapidly in the World. Background studies should be conducted on the determination of appropriate quinoa varieties for different ecologies for its cultivation to become widespread in a healthy way. This study was conducted in 2015 and 2016 in Erzurum and Igdir non-irrigation conditions in the Eastern Anatolia of Turkey. The locations have different ecological characteristics from each other. The field experiments were conducted with 9 varieties in each location in a randomized complete blocks experimental design with four replications. The grain yield and some related characteristics were examined in the study. The grain yield and related characteristics of quinoa varied significantly depending on varieties and locations in the study. According to the two-year results, quinoa cultivation is a risky in Erzurum which has a high altitude and short vegetation period. The grain yields ranged between 110-599 kg ha⁻¹ and was found to be quite low. In the Igdir location, 933-1646 kg ha⁻¹ of seed yield was obtained from the varieties. The earliest cultivar is Q-52, it has matured in Erzurum at 102 days, Igdir at 118 days. The latest maturation (138 days) was determined in the Oro de Valle cultivar in Igdir conditions. According to these results, moqu Arrochilla, Q-52, Oro de Valle, French Vanilla and Rainbow cultivars can be recommended for non-irrigated conditions of these locations provided that it is seeded early in the spring. However, Erzurum and similar locations are not suitable for the agriculture of this plant due to short plant growing period.

Key words: *Chenopodium quinoa*, adaptation, seed yield, highlands, dry conditions.

INTRODUCTION

The quinoa (*Chenopodium quinoa* Willd.), which originated from the South America, has become highly popular among health-conscious consumers throughout the world. For this reason, studies have been started on adaptation and breeding in many countries. The importance of quinoa is that the seeds have a high

nutritional value. The average percentage of protein in the seeds varies from 7.5% to 22.1% depending on the variety (Cardozo and Tapia, 1979; Wright *et al.*, 2002). The quinoa seeds, which contain all the amino acids needed by the human body, are in the full protein category (Johnson and Aguilera, 1980). Another important feature of the quinoa is that it is gluten-free. In this regard, it is an important source of food for celiac patients (gluten allergy) to meet protein and carbohydrate needs (Jacobsen, 1993). Its seeds are rich in minerals such as Ca, Mg, K, Fe, Cu and Mn and A, B, C and E vitamins (Repo-Carrasco *et al.*, 2003).

Quinoa seeds with high nutritional value are used in human nutrition in many different forms. Its consumption is increasing day by day, especially in USA and EU countries. For this reason, the importance of quinoa agriculture and production is increasing. More scientific research is needed in different regions in order for quinoa farming to spread healthily. One of the most common failures in quinoa cultivation is the lack of appropriate genotypes. There are thousands varieties or ecotypes of quinoa both cultivated and wild in South America. It is important to test these materials in various ecologies to determine their suitability. Because the yield varies greatly depending on genotypes and locations (Miranda *et al.*, 2012). There are many records that quinoa is resistant to abiotic stress factors and is grown at high altitudes (Jacobsen, 2003; Bhargava *et al.*, 2007). But, adaptation studies have to be carried out in order to determine appropriate varieties in different ecologies. Eastern Anatolia Region is the highest altitude region of Turkey and the plant growing season is very short. However, there are microclimates in the region that have different ecological characteristics. It is expected that the performances of the different genotypes vary in different microclimates within the region. The main goal of this study is to evaluate the adaptability of some quinoa cultivars in two different locations of Eastern Anatolia Region.

MATERIALS AND METHODS

The study was conducted in non-irrigated experimental areas of Ataturk University Faculty of Agriculture (Erzurum), and Iğdir University Faculty of Agriculture (Iğdir) in 2015 and 2016. Nine quinoa (*Chenopodium quinoa* Willd.) cultivars obtained from different sources at two different locations were evaluated for seed yield and related characteristics. Field experiments were established on March 29th, 2015 and April 6th, 2016 in Iğdir; May 5th, 2015 and May 10th, 2016 in Erzurum. In the each experiment, 9 quinoa cultivars were sown in a randomized complete blocks experimental design with four replications. During the seeding, 2500-3000 g ha⁻¹ seeds were spread with 35 cm row spacing by hand at 1.5-2 cm sowing depth on parcels (Tan and Yondem, 2013; Geren *et al.*, 2015). Plot size was 6 rows of 4 m, with an inter-row spacing of 0.35 m. Nitrogen was supplied at sowing (75 kg N ha⁻¹) and again during vegetative growth before flowering (50 kg ha⁻¹). Phosphorus was applied at a dose of 80 kg P₂O₅ ha⁻¹ for one time when the seed bed was prepared (Jacobsen *et al.*, 1994; Schulte auf'm Erley *et al.*, 2005; Yazar *et al.*, 2013; Tan and Yondem, 2013; Geren *et al.*, 2015). The weed control in the parcels is

done by mechanical methods like cutting and picking. Harvests by hand in the end of September were done at physiological maturity, which was defined as the date when seeds from the main panicle become resistant when pressed (Bertero *et al.*, 2004). The maturation period, plant height, seed yield and harvest index were determined for the cultivars that came to harvest stage.

The data obtained from the study were subjected to the variance analysis according to the randomized complete blocks experimental design. Differences between the averages were determined with the LSD multiple comparison test. Since the first year data cannot be obtained in the Erzurum location, the results are one-year.

Table 1. Monthly temperature and precipitation during the study months of 2015, 2016 and long year average in Erzurum and Igdır locations.

Months	Temperature ($^{\circ}\text{C}$)						Precipitation (mm)					
	Erzurum			I dır			Erzurum			I dır		
	LYA	2015	2016	LYA	2015	2016	LYA	2015	2016	LYA	2015	2016
April	5.5	5.3	7.1	13.3	16.4	14.7	51.4	88.6	39.4	34.5	44.1	20.1
May	10.6	10.6	10.5	17.8	21.3	18.7	70.3	81.5	64.8	47.1	41.5	23.5
June	14.9	17.0	14.8	22.1	28.5	23.0	46.3	28.5	88.6	33.0	27.8	26.9
July	19.3	21.2	19.0	25.9	31.8	26.2	26.0	5.8	17.8	13.8	3	32
August	19.4	21.2	21.0	25.1	30.2	27.5	15.9	38.8	13.6	9.6	14.3	7.8
September	14.5	18.3	12.7	20.0	27.2	20.2	22.7	3.9	17.6	11.1	1.4	19.8
Total/Mean	14.0	15.6	14.2	20.7	25.9	21.7	232.6	247.1	241.8	149.1	129.4	110.1

LYA: Long Year Average

Locations where the studies are conducted have very different ecological characteristics (Table 1 and 2). Erzurum is the province which has the highest altitude in the Eastern Anatolia Region with its location 1860 m above sea level. Winter period is long, cold and snowy, summer months are relatively cool and short. Last frosts of spring may extend to May and first frosts of autumn start in September. Therefore, the plant cultivation season is shorter in Erzurum than in other provinces. Igdır is the province which has the lowest altitude in the region with its 876 m altitude. The plant cultivation season is long in Igdır which has the characteristics of microclimate in the Eastern Anatolia Region. Summer months are hot and dry, evaporation is high. Thus, agricultural soils usually have saline characteristics. While locations are similar in terms of the soil texture class, they are different with regard to electrical conductivity (EC), pH, CaCO_3 and available phosphorus and potassium for plants. The soils in Igdır location have the characteristics of being slightly saline, slightly alkaline and mid-calcareous, differently from Erzurum location (Table 2).

Table 2. Some physical and chemical properties of soils in research areas

Soil Properties	Erzurum	Igdir
Texture class	Clay-loamy	Clay-loamy
EC (ms cm ⁻¹)	0.48	2.00
pH	7.1	7.9
CaCO ₃ (%)	2.5	6.5
K (kg K ₂ O ha ⁻¹)	1380	3430
P (kg P ₂ O ₅ ha ⁻¹)	74	80
Organic matter (%)	1.4	1.6

RESULTS AND DISCUSSIONS

Days to harvest of quinoa varied significantly with regard to varieties and locations, and the variety x location interaction was found to be statistically significant (Table 3).

Table 3. Days to harvest and plant height of some quinoa cultivars grown in Erzurum and Igdir non-irrigated conditions.

Cultivars	Days to Harvest (days)			Plant Height (cm)		
	Erzurum	Igdir	Mean	Erzurum	Igdir	Mean
Q-52	102	118	110 F	55.4	90.4	72.9 BC
Rainbow	128	136	132 A	80.6	100.2	90.4 A
Red Head	124	132	128 BC	79.8	100.7	90.3 A
Sandoval Mix	121	133	127 C	73.3	100.5	86.9 A
Cherry Vanilla	125	134	129 ABC	71.5	100.4	86.0 A
French Vanilla	109	137	123 D	64.3	99.4	81.9 AB
Mint Vanilla	129	135	132 A	78.2	94.2	86.2 A
Oro de Valle	122	138	130 AB	62.0	101.0	81.5 AB
Moqu Arrochilla	110	118	114 E	57.3	77.3	67.3 C
Mean	119 B	131 A	125	69.2 B	96.0 A	82.6
<i>Cultivar</i> x <i>Location</i>	5.3**			10.1*		

*: 0.05, **: 0.01, Upper case within the same column and row are significantly different at 1%.

The earliest cultivar is Q-52, it has matured in Erzurum at 102 days, Igdir at 118 days. The latest maturation (138 days) was determined in the Oro de Valle cultivar in Igdir conditions. Although the location of the Igdir is warmer than that of Erzurum, because of early seeding, cultivars have been maturing longer. Quinoa is a plant that reaches flowers under short day conditions. For this reason, the plants bloom without completing their growth and development in late sowing. The maturation period was shorter in Erzurum conditions, because the seeding was

made late. Differences in the maturation period due to genotypes and locations are also revealed in other studies (Berterao *et al.*, 2004; Szilagyi and Jornsgard, 2014). The plant height of the quinoa cultivars showed significant differences due to genetic characteristics and different ecological factors (Table 3). Because of the longer development period in the Igdirdir location, the plants were longer than the Erzurum location. Oro de Valle (101.0 cm) in Igdirdir and Rainbow (80.6 cm) in Erzurum were found as the tallest cultivars. The differences in the plant heights of cultivars may have resulted from their genetic properties and different reactions to the environment conditions. Similar results have been found in studies conducted in other regions with different ecological characteristics using different genotypes (Pulvento *et al.*, 2010; Bhargava *et al.*, 2007). Seed yields in the study showed significant changes depending on the locations and cultivars (Table 4). Moqu Arrochilla (976.8 kg ha⁻¹) was the most productive cultivar as the average of the locations. Seed yield in the Igdirdir location (1362.4 kg ha⁻¹) is significantly higher than the Erzurum location (252.3 kg ha⁻¹). The low seed yields in the Erzurum location are quite obvious (110.2-599.0 kg ha⁻¹). Cultivar x location interaction was found to be important in seed yield (P<0.05). The highest seed yield was determined in the Moqu Arrochilla cultivar grown in Igdirdir conditions, followed by Q-52, Oro de Valle, French Vanilla and Rainbow varieties grown in the same location.

Table 4. Seed yield and harvest index of some quinoa cultivars grown in Erzurum and Igdirdir non-irrigated conditions.

Cultivars	Seed Yield (kg ha ⁻¹)			Harvest Index (%)		
	Erzurum	Igdirdir	Mean	Erzurum	Igdirdir	Mean
Q-52	208.3	1592.5	900.4 ab	6.5	26.7	16.6 AB
Rainbow	211.3	1342.8	777.0 abc	6.9	21.9	14.4 ABC
Red Head	110.2	1230.8	670.5 bc	3.1	20.6	11.8 BC
Sandoval Mix	242.4	1409.9	826.1 ab	5.7	22.1	13.9 ABC
Cherry Vanilla	599.0	1137.3	868.1 ab	13.7	19.9	16.8 AB
French Vanilla	357.1	1399.1	878.2 ab	11.2	24.7	18.0 A
Mint Vanilla	140.0	933.3	536.6 c	4.8	15.6	10.2 C
Oro de Valle	178.8	1486.0	832.4 ab	5.7	23.3	14.5 ABC
Moqu Arrochilla	223.7	1729.8	976.8 a	6.6	30.0	18.3 A
Mean	252.3 B	1362.4 A	807.4	7.1 B	22.8 A	15.0
<i>Cultivar x Location</i>	409.1*			6.3*		

* and lower letters: 0.05, ** and upper case: 0.01, Different letters within the same column and row are significantly different at 1%.

The Igdirdir location has a temperate climate than Erzurum (Table 1). Plants in this area were planted earlier and had a longer development period. Also, the fact that the soil of the region has a slightly saline character may be effective for high yields. Because the quinoa performs better in slightly saline soils (Jacobsen, 2003; Wilson *et al.*, 2002). In Erzurum, seed yields were found to be very low because

the plants could not find a sufficient growth period. Although plants have technically reached harvesting stage, the majority of their panicles have not been seeded. Studies conducted with quinoa varieties in different parts of the world have shown that the seed yield varies between 250-5000 kg ha⁻¹. These results are due to the different performance of the varieties in different ecological conditions (Miranda *et al.*, 2012). The harvest index values of quinoa varieties varied significantly between 10.2-18.3% (Table 4). Moqu Arrochilla, French Vanilla, Cherry Vanilla and Q-52 cultivars have higher harvest index than others. Since the location of Iğdir is a more suitable for seed production, harvest index values in this locality are found high. Bhargava *et al.* (2007) and Bertero *et al.* (2004) found significant differences in quinoa harvest index according to varieties and locations.

CONCLUSION

The results of this study revealed that quinoa can be grown in the non-irrigated conditions of Eastern Anatolia, a high altitude region in Turkey. Quinoa has a high yield potential in Iğdir and similar locations which have low altitude and long cultivation season. Moqu Arrochilla, Q-52, Oro de Valle, French Vanilla and Rainbow cultivars can be recommended for non-irrigated conditions of these locations provided that it is seeded early in the spring. However, Erzurum and similar locations are not suitable for the agriculture of this plant due to short plant growing period.

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