

Response of the Quinoa Genotypes to Different Locations by Grain Yield and Yield Components

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Abstract – In this study, the response of some of the quinoa genotypes (7 genotypes) to different locations was explored. Experiments were carried out in two different locations Amasya (altitude 820 m) and Tokat (altitude 560 m). Locations were distinctive for climatic, soil and adaptation conditions. The experiments were designed in a randomized complete block design with two replications. Seeds were sown with a density of 500 seed per square meter. Fertilizer rates were applied as 90 kg N and 60 kg P₂O₅ per hectare. This study explored some of the traits such as flowering time, plant height, the main panicle length, the panicle number per plant, hectoliter weight, the number of plant per square meter, thousand seed weight, grain yield were evaluated. The average of genotypes, locations as well as GxL interactions were significantly different for all evaluated traits. The highest grain yield was obtained from C. Quinoa Ames genotypes with 471.5 kg da⁻¹ at Amasya location. The lowest grain was obtained from C. Quinoa (black) with 121.5 kg da⁻¹ at Tokat location. Genotypes were changed between 76-93 days for flowering time, was also changed between 35-93 cm for plant height, 12-35 cm for the main panicle length, 9-23 for the panicle number per plant, 63-65 kg hl⁻¹ for hectoliter weight, 17-35 for the number of plant per square meter, 1.0-3.0 g for thousand seed weight,. Amasya location had higher values than Tokat location for all investigated traits. Amasya location was more suitable for quinoa growing.

Keywords – Quinoa, Genotype, Yield, Turkey.

I. INTRODUCTION

Quinoa (*Chenopodium quinoa* Wild.) extending to the origin of the Andes, and are one annual plant belonging to the Chenopodiaceae family. The world has about 243 thousand hectares of plantation area and 192.5 thousand tons of production [2]. Countries where production is carried out; Peru, Bolivia and Ecuador. Bolivia with 173.960 hectares in terms of sowing area and Peru comes to the fore with the production quantity and yield (114 343 tonne and 168 kg/da respectively). The world quinoa production volume is approximately 152% increase in the

last five years have shown, Peru has the largest share in the increase in the volume of production [2]. Quinoa is a dicotyled allotetraploid (2n = 4x = 36) plant that is physiologically found in the C-3 group [20]. The plant; tolerance to drought, soil salinity and frost events, as well as the ability to adapt to a wide range of conditions, even in marginal areas ([18], [35]). Studies conducted in our country have determined that the Black Sea region is suitable for the quinoa cultivation [36]. Plants are cultivated in rainy seasons in countries, Peru, Bolivia, Chile, that are produced at the time of sowing ([1], [23]). Although systematically quinoa is not cereal, it is considered as a pseudo cereal due to its use in the world owing to its use in the production of some cereal products (bread, cookies, cakes, biscuits). Having an important place in human nutrition; protein, starch, essential amino acid content, rich in fat and minerals, the protein content of the quinoa varieties among 12-23%, the starch content is about 60%, the fat content is between 2% and 10% ([13], [34]). In addition, the development of various food products and the creation of alternative products is extremely important for celiac disease since the quinoa plant hasn't contain gluten proteins [33]. Studies done with gluten-free flours have shown that breads made with quinoa flour are better than breads made from other flour, rice, corn etc., in terms of volume and texture [15]. Quinoa (% 0.18) has a lower value than the wheat (% 0.39) in terms of the amount of resistant starch, having similar effect on the dietary fiber and digestive system, [26] which is an important parameter for determining starch quality [28].

II. PROCEDURE FOR PAPER SUBMISSION

Seven quinoa genotypes were used in the study. Climate parameters of the research sites are shown in Table 1, soil properties in Table 2.

Table 1. Climatic conditions of test area*

Locations		Months								Total/Average
		March	April	May	June	July	August	Sept.	Oct.	
Tokat	Precipitation (mm)	59.0	34.5	34.8	35.4	0.2	7.6	0.2	55.6	227.3
	Long Years	57.1	23.6	31.9	48.5	3.8	4.4	19.6	51.8	240.7
	Average Temp (°C)	8.1	10.0	16.9	20.0	23.5	24.3	23.2	16.1	17.8
Amasya	Long Years	9.7	13.5	18.0	21.0	24.8	25.6	22.5	15.7	18.9
	Precipitation (mm)	69.0	21.0	59.4	94.2	0	20.0	20.6	39.0	323.2
	Long Years	58.8	26.9	65.2	81.5	6.9	12.9	28.8	28.7	309.7
	Average Temp (°C)	6.7	8.6	15.9	19.1	21.6	23.4	21.4	14.1	16.4
	Long Years	7.6	10.9	16.0	18.9	22.5	23.6	20.2	13.8	16.7

General Directorate of Meteorology. *; The year 2015 is climate data.

Table 2. Physical and chemical properties of soil testing ground*

Locations	Sturcture	Total salt (µS/cm)	pH	Lime (%)	P ₂ O ₅ (kg/da)	K ₂ O (kg/da)	Organic Subs. (%)
Tokat	Clay-Loam	0.032	7.47	2.42	2.04	152.32	1.98
Amasya	Clay-Loam	0.021	7.42	1.12	3.15	187.50	2.09

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Table 3. Some quinoa used in test area and providing that instructions

Genotypes	Institution Offered	Origin
Chenopodium quinoa (white)	Field Crops Center Res. Inst.-Turkey Seed Gene Bank	Peru
Chenopodium quinoa (black)	Demak Food Industry and Trade L.C	Colombiya
Chenopodium quinoa (red)	Demak Food Industry and Trade L.C	Colombiya
Q52	Detay J.S.C	Chile
Q11(non-saponin)	BGCI (India)	Ethiopia
C. quinoa Wild Ames 22474	USDA	Peru
C. quinoa Wild PI512430	USDA	Chile

Sowing was 16.6.2015 in Tokat conditions and 19.6.2015 in Amasya 20 cm between rows and each genotype was made by hand as four rows. Field experiments were made randomized block experimental design with two replications parcel dimensions 5 m x 0.8 m = 4m² was set and no gap between the parcels. The planting depth was adjusted to 1 cm with 2 kg da⁻¹ seed calculation as approximately 550 plants/m² and seeding with the marker was carried out [30]. Before sowing in the experiment, fertilizer was applied as 5 kg da⁻¹ N and 6 kg da⁻¹ P₂O₅, and an additional 3 kg da⁻¹ N application was made about 35-40 days after the date of genotype germination. Regarding the regional conditions, irrigation was carried out by drip irrigation method at certain intervals (15 days) after planting. The harvest was carried out when the leaves of the plants dried up and dropped to about 14% moisture. The harvest was made manually at Tokat location 21.10.2015, and 25.10.2015 at Amasya location. In the evaluation of the obtained data, M-STATC program was used for statistical analysis and made according to randomized block design ([14], [37]). In the study, the differences between the averages were compared according to the Duncan test.

III. RESULTS-DISCUSSIONS

Flowering Time

The difference between the genotypes in terms of flower-

-ring time was found to be 5% in Amasya location and 1% in Tokat location, 76-91.5 days in Tokat location and 77.5-93.0 days in Amasya location (Table 4). In the study conducted, genotypes early flowering in Tokat location Q11, WildPI, in Amasya location; WildPI and White. The genotypes with the longest flowering period were; Tokat and Amasya locations were Red, Q52. Many researchers have reported that environmental conditions are also influenced by the different flowering times of quinoa genotypes ([3], [4], [8], [12]). According to the average results of Amasya-Tokat locations; grain yields of Q11, White, Black genotypes among early flowering genotypes were low in both location and grain yield of late flowering Ames species was found to be high (Table 4). It is also stated in different studies that genotypes with long flowering time have an increase in grain yields [11]. There was a difference of 1% between locations in terms of flowering times in the study. The average flowering time of the genotypes at Amasya location was 85.1 days. Whereas, it was 81.2 days at Tokat location. The short or long flowering periods of locations depend on genotype x environment interaction and the climate factors during the vegetation period [6].

Plant Height

The plant height of the genotypes were 35.4-93.1 cm in Tokat location and 43.5-93.4 cm in Amasya location and the difference between genotypes was found to be 1 (Table 4).

Table 4. Flowering and plant height in some quinoa genotypes

Genotypes	Flowering Time (day)			Plant Height (cm)		
	Tokat	Amasya	Combined Loc.	Tokat	Amasya	Combined Loc.
C. Quinoa (black)	79.5 bc**	82.5 cd*	81.00 cd**	35.4 d**	45.6 b**	40.5 d*
C. Quinoa (white)	79.0 bc	81.5 cd	80.25 cd	88.5 a	93.0 a	90.7 ab
C. Quinoa (red)	91.5 a	93.0 a	92.25 a	37.1 d	46.6 b	41.9 d
Q52	85.0 ab	90.5 ab	87.75 ab	82.3 b	91.7 a	87.0 bc
Q11	76.5 c	84.0 bcd	80.25 cd	93.1 a	93.4 a	93.2 a
C. quinoa Wild A	81.0 bc	86.5 abc	83.75 bc	43.5 c	43.5 b	43.5 d
C. quinoa Wild PI	76.0 c	77.5 d	76.75 d	82.2 b	85.6 a	83.9 c
Means	81.2 b	85.1 a**	83.1	66.0 b	71.3 a*	68.7
V.C.	2.22	3.27	2.82	2.32	3.02	2.72

*, **; It is important at the level of 5% and 1% respectively

The highest plant height in the experiment was obtained from the Q11 genotype at both loci. Changes in the genotype of the plant and its environmental conditions have been identified in studies on the subject ([5], [19],

[21], [22]). In Amasya location, the plant height is long (Table 4), and in Tokat location for the higher yield of the PI genotype, which is higher than the average plant height (Table 7), at both loci can be explained by the positive relationship between plant size and grain yield [6]. In addition, the plant height (Table 4) indicates that the Ames genotype, which is short in both loci, has high grain yield (Table 7), owing to the main panicle length (Table 5) and plant number per square meter (Table 6).

Main Panicle Length

The difference between the genotypes in terms of main panicle length was found to be significant at 1% in both loci, panicle lengths varying between 12.5-34 cm in Tokat location and 13.4-35.5 cm in Amasya location (Table 5). It was determined that the Ames genotype (respectively; 34.0-35.5 cm) was the highest in Tokat-Amasya locations and the Red genotype (Table 5) had the lowest main

panicle length in both loci. Ames and PI genotypes were found high both the main panicle length and the grain yields (Table 7). Since there was a positive and significant relationship between the main panicle length and grain yield, it was important to use the long panicle genotypes in breeding studies ([5], [7]). There was a significant difference of 1% between the genotypes in terms of the main panicle length among the locations.

Panicle Number Per Plant

The difference between the genotypes in terms of Panicle Number Per Plant was significant at the 1% level in Amasya and Tokat locations and varied between 9.3-23.4 in the Tokat location and 10.2-23.6 in the Amasya location (Table 5). In the study conducted, the highest value was obtained from Q11 genotype in Tokat location and the lowest value was obtained from Black genotype. In the Amasya location; Q11 has the highest, Red has

Table 5. The main panicle length and the number of panicle per plant in some quinoa genotypes

Genotypes	Main Panicle Length (cm)			Number of Panicle Per Plant (kernel)		
	Tokat	Amasya	Combined Loc.	Tokat	Amasya	Combined Loc.
C. Quinoa (black)	15.3 f**	16.2 e**	16.2 e**	9.3 d**	12.4 de**	10.8 de**
C. Quinoa (white)	20.8 d	21.5 c	21.5 c	16.8 b	17.6 bc	17.2 b
C. Quinoa (red)	12.5 g	13.4 f	13.4 f	10.2 d	10.2 e	10.2 e
Q52	23.4 c	23.8 c	23.8 c	10.4 d	13.6 d	12.0 d
Q11	18.0 e	19.0 d	19.0 d	23.4 a	23.6 a	23.5 a
C. quinoa Wild A	34.0 a	35.5 a	35.5 a	18.3 b	18.6 b	18.4 b
C. quinoa Wild PI	30.6 b	29.6 b	29.6 b	14.0 c	15.0 cd	14.5 c
Means	22.1 b	22.7 a**	22.4	14.6	15.8	15.2
V.C.	3.04	2.89	2.96	4.67	4.69	4.69

*, **; It is important at the level of 5% and 1% respectively

the lowest value (Table 5) and the difference between the locations is found to be insignificant. In studies conducted, researchers reported that there was a positive correlation between the panicle number per plant and grain yield [6]. In our study, it was observed that the Q11 genotype, which had a high number of panicle in the plant at both loci, was above the grain yield average (Table 7). The Ames genotype, which is not in the higher group in terms of the panicle number per plant, has the highest grain yield in both loci, which can be explained by the high level of other parameters with high positive correlation on yield

[31]. There was no difference between genotypes in Tokat-Amasya locations.

Hectoliter Weight

Tokat location ranged from 63.6 to 65.9 kg hl⁻¹ and the Amasya location ranged from 64.5 to 65.7 kg hl⁻¹ (Table 6). Hectoliter weight is an important parameter in processing industry, storage and is significantly influenced by genotype and environmental factors. Differences between genotypes were observed at 1% level at both loci.

In the studies done, the researchers reported that the

Table 6. Hectolitre weight and the number of plant per square meter in some quinoa genotypes

Genotypes	Hectolitre Weight (kg)			Number of Plant Per Square Meter (kernel)		
	Tokat	Amasya	Combined Loc.	Tokat	Amasya	Combined Loc.
C. Quinoa (black)	64.4 bc**	64.8 bc**	64.6 cd**	22.2 b**	22.7 c**	22.5 d**
C. Quinoa (white)	64.5 bc	64.6 c	64.5 cd	33.2 a	32.0 b	32.6 ab
C. Quinoa (red)	63.6 c	64.5 c	64.0 d	17.3 b	23.7 c	20.5 d
Q52	64.9 abc	65.0 abc	65.0 bc	22.5 b	32.2 b	27.3 c
Q11	65.2 ab	65.4 ab	65.3 ab	34.6 a	35.2 a	34.9 a
C. quinoa Wild A	65.9 a	65.7 a	65.8 a	34.2 a	35.6 a	34.9 a
C. quinoa Wild PI	64.6 abc	65.0 abc	64.8 bc	30.5 a	31.9 b	31.2 b
Means	64.7 b	65.0 a*	64.8	27.8 b	30.5 a*	29.1
V.C.	0.52	0.30	0.43	5.74	2.33	4.24

*, **; It is important at the level of 5% and 1% respectively

hectolitre weight varied between 61.5-74.7 kg hl⁻¹ and there were significant differences between the genotypes ([10], [27], [29]), and some researchers reported that the difference was insignificant [20].

The Number of Plant Per Square Meter

The highest value Q11 in the Tokat location is the lowest value Q (red) genotypes, while the Amasya location is Ames and Black respectively. Q11 and Ames

genotypes were the highest and Red was the lowest in both locations. The differences between the genotypes are due to differences in genotype and environmental interactions as well as with the ability to withstand low rainfall and high temperatures (July, August, September) [29]. Researchers have reported that planting time affects the number of plants in the unit ([22], [23]). The difference between locations in terms of the number of plant per square meter was found to be significant at 5% level.

Thousand Weight

While the Ames genotype had the highest value in the Amasya location, Ames and Q11 genotypes had the highest values in Tokat (Table 7). At both locations the Black genotype had the lowest value. Different researchers have reported that thousand weight change between 1.9-4.3 g in their studies, and that sowing time affects thousand weight; more nutrients are stored in grains with early sowing; they reported that the grains were thin and a thousand grains fell ([21], [22], [30]). In our study, the

weight of thousand quinoa genotypes lower than that of researchers may be due to the delay of sowing time. According to the average results of both locations; coarsed-grained of Ames genotype was also high to grain yield (Table 7). Researchers have reported a positive and significant relationship between grain yield and thousand weight [6].

Grain Yield

The genotypes were found to be 121.5-449.5 kg da⁻¹ in Tokat location and 146.0-471.5 kg da⁻¹ in Amasya location and the difference between genotypes was found to be 1%. Ames, the highest grain yield in Tokat-Amasya locations, was obtained from the lowest Black genotypes. From the combined locations, the highest grain yield was obtained from Ames genotype and the Black genotype lowest. Yield; the plant's genetic potential is the result of the effects of environmental factors and cultivation techniques together. At both loci, Ames genotype has high grain yield value.

Table 7. The thousand weight and grain yield in some quinoa genotypes

Genotypes	Thousand Weight (g)						Yield (kg/da)					
	Tokat		Amasya		Combined Loc.		Tokat		Amasya		Combined Loc.	
C. Quinoa (black)	1.4	e**	1.5	e**	1.4	e**	121.5	f**	146.0	f**	133.8	f**
C. Quinoa (white)	1.6	d	1.6	d	1.6	d	227.5	d	243.5	d	235.5	d
C. Quinoa (red)	1.5	e	1.5	e	1.5	e	139.0	f	149.0	f	144.0	f
Q52	2.7	b	2.7	b	2.7	b	174.0	e	188.5	e	181.3	e
Q11	3.1	a	3.2	a	3.2	a	327.0	c	342.0	c	334.5	c
C. quinoa Wild A	3.1	a	3.2	a	3.2	a	449.5	a	471.5	a	460.5	a
C. quinoa Wild PI	2.1	c	2.2	c	2.1	c	399.0	b	425.0	b	412.0	b
Means	2.2		2.3		2.2		262.5 b		280.8 a*		271.6	
V.C.	1.41		1.47		1.44		1.89		3.66		2.97	

*, **; It is important at the level of 5% and 1% respectively

Differences in temperature and precipitation between locations have affected some physiological parameters of plants (germination, sprouting etc.), resulting in varying grain yields between locations [20]. In studies performed at different locations, researchers reported that grain yield varied from 50.0 to 600.0 kg da⁻¹ ([5], [16], [38]). The Tokat location was 18.3 kg da⁻¹ lower than the average grain yield of Amasya and the difference between locations was found to be significant at 1% level. It is known that GxE interactions show significant differences in efficiency in different groups and environments [38]. According to the results of both locations, genotypes with the highest grain yield are generally found to have high values in terms of properties such as thousand weight, the number of plants per square meter, hectoliter weight and main panicle length. In the studies conducted, some researchers found that there was a positive correlation between the weight of thousand weight, the weight of hectoliter and the main panicle length [6].

IV. CONCLUSION

In the study conducted, significant differences were found between the genotypes in terms of the characters studied. In Tokat and Amasya ecological conditions, the conclusion has reached that Ames and PI genotypes can be successfully grown under the conditions of the region

because they have high grain yield and perform well in terms of the yield components examined. Due to the high nutrient content and gluten-free structure, it is necessary to continue the agronomic and breeding studies of quinoa, which is potentially used by celiac disease, to increase yield and quality parameters and to propose grower of superior genotypes.

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