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The Effect of Row Distances on Quinoa Yield and Yield Components in the Late Planting Period

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A B S T R A C T

The quinoa plant, with its grains, leaves and stems, is an important plant used in both human nutrition and animal nutrition. The increase of this plant's consumption made it necessary to increase its production. A number of studies have been done and are still underway to achieve maximum efficiency in production. In this study, the effects of Q52 quinoa variety were investigated on yield and yield components of different row spacings (20,40 and 60 cm) in the case of late planting (11 May 2018) according to the climatic conditions of Kahramanmaraş region. In this study, exit time, generative period, number of flowering days, number of grain filling, growing time, number of branches of per plant, plant height, main bunch length, grain length in the main bunch, rate of grained part in the main bunch, number of branches of per bunch, grain weight in the bunch, bunch weight, grain rate in the bunch, harvest index, thousand grain weight, grain yield decare, plant yield decare, protein rate, ash rate, oil rate, humidity rate and starch rate properties were examined.As a result of examinations the length of raw spacings in the main bunch and the proportion of the particle length in the main bunch are $p<0.05$ level, main bunch length, harvest index, grain yield per decare and plant yield per decare are significant differences in $p<0.01$ level, but in other features the observed differences were statistically insignificant. Here, it is seen that the highest values were obtained from 20 cm row plantings for both parameters where grain yield per decare ranged from 211.3 to 463.4 kg.

Keywords: Quinoa, Plant density, Yield, Yield Components

1. Introduction

Qinoa (*Chenopodium quinoa* Willd.) has a herbaceous plant structure used in human and animal nutrition in the Chenopodiaceae family (Akçay & Tan, 2018). It is a one-year, perennial plant that reproduces with seeds, pile-rooted, plant height ranging from 40 cm to 150 cm, leaves with green lobed or toothed, bunch of inflorescences, flower structure hermaphrodite, usually self-pollinated (Geren & Güre, 2017). Although it is not a real grain plant, it is in the group of cereals in the world (Geren et. al., 2014). It contains high levels of protein (8 to 22 %), oil (10 to 18 %), vitamin E and B, minerals (Ca, Mg, P, K, Fe, Cu, Mn, Zn) and starch (58.1 – 64.2 %) (Üçok et al., 2019). Some chemical composition of quinoa seeds (such as protein, oil, row fiber) is higher than other grain plants (wheat, corn, rice) (Repo- Carrasco et al., 2003). For this reason, quinoa has been used for making bread, pasta, salad, beer, baby food, pancakes, biscuits, cakes, crackers (Demir & Kılınç, 2016).

Being a drought- resistant plant (Gonzalez et. al., (2009), adapting to all kinds of soil and climatic conditions (Jacobsen et al., 2005), having a high nutritional value (Kaya & Karaer, 2017), as well as being a good planting plant (Aquilar& Jacobsen, 2003). The cultivation and use of quinoa plants in the world has increased rapidly (Tan &Yöndem, 2013). For this reason, in this study, it was aimed to investigate the effect of quinoa plant on yield and yield components by testing different row spacings in the late sowing period, thus providing maximum benefit in production under regional conditions.

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2. Material and Method

The trial was conducted in 2018 under the ecological conditions of Kahramanmaraş. In the study, "Q52" quinoa (*Chenopodium quinoa*Willd.) variety, which is well adapted to Mediterranean climatic conditions, was used as herbal material. According to the result of soil analysis taken at different depths, soil structure of the trial area; It has been observed that it has moderate low organic matter, clayey, salt-free, low phosphorous level with beneficial, high potassium level and neutral pH (Anonymous, 2018a).

Table 1- Kahramanmaraş climate data of 2018, when the experiment was conducted

Months	Max. Temperature (°C)	Min. Temperature (°C)	Average Temperature (°C)	Total Precipittion (mm)	Average Humidity (%)
March	19.7	9.6	14.2	47.4	60.8
April	25.5	12	18.4	71.6	45.3
May	28.8	15.7	21.7	28.1	52.6
June	32.5	19.9	25.4	39.4	49.1
July	35.6	23.2	28.6	0.3	46.2
August	36.8	23.3	29.1	0.0	43.8
September	34.7	21.0	27.2	0.6	38.4
Total (Season)	213.6	124.7	164.6	140.0	336.2
Average (Season)	30.5	17.8	23.5	23.3	48.0

Climate data of 2018 belong to the region where the study is conducted is givenin Table 1. According to these data, the total values of the minimum and maximum temperature values in the season were 124.7 ° C and 213.6 ° C respectively, while their average values were 17.8 ° C and 30.5 ° C, respectively. While the total amount of precipitation was 140.0 mm, the average amount of precipitation was 23.3 mm. During the rearing period, the average total temperature was 164.6 ° C, season average was observed to be 23.5 ° C. The average relative moisture content of the season has been realized 336.2% and the season average was 48.0% (Anonymous, 2018b). It was made planting, 11.05.2018 with 20 cm, 40 cm and 60 cm row spacing was established randomized trial design with 3 replications. The amount of seed to be thrown on the parcels was adapted according to Risi and Galwey (1991).

According to soil analysis results before planting, 5 kg/da N, 6 kg/da P_2O_5 and 6 kg/da K_2O were given. Approximately 35 days after planting, 3 kg of top fertilizer was applied. Irrigation was done according to the climatic conditions and the water requirement of the plant. The plant samples belonging to the research were collected by hand after the grains of the plants matured and the plant parts were completely dried. The seed samples obtained were ground through a 1 mm sieve and made ready for analysis. In the research, Q-52 quinoa exit time (days), generative period (days), number of flowering days (days), number of grain filling (days), growing time, number of branches of per plant, plant height (cm), main bunch length (cm), grain length in the main bunch (cm), rate of grained part in the main bunch (cm), number of branches of per bunch (piece), grain weight in the bunch (g), bunch weight (g), grain rate in the bunch (%), harvest index (%), thousand grain weight (kg), grain yield perdecare (kg/da), plant yield per decare (kg/da), protein ratio (%), ash ratio (%), oil ratio (%), humidity ratio (%) and starch ratio (%) were examined. The data obtained from the study were analyzed in ANOVA in SAS®9.0 (2004) package program, while Duncan multiple comparison test was used to determine the differences between the averages.

3. Results and Discussion

This the study was carried out in Kahramanmaraş ecological conditions; In Q-52 Quinoa variety, in the late planting period, different time intervals are applied, the exit time (days), generative period (days), number of flowering days (days), number of grain filling (days), growing time (days), number of branches of per plant (piece), plant height (cm), main bunch length (cm), grain length in the main bunch (cm), rate of grained part in the main bunch (cm), number of branches of per bunch (piece), grain weight in the bunch (g), bunch weight (g), grain rate in the bunch (%), harvest index (%), thousand grain weight (kg), grain yield per decare (kg/da), plant yield perdecare (kg/da), protein ratio (%), ash ratio (%), oil ratio (%), humidity ratio (%) and starch ratio (%)are shown in Table 2, Table 3 and Table 4.

As can be seen in Table 2, it was found that Q52 quinoa variety, in which different row spacing were tested in late sowing period, was statistically insignificant in terms of exit time. Çayğaracı (2018), in his study on the effect of different irrigation water and nutrient solution applications on the yield and quality of quinoa in the glass greenhouse with a 1 da in Bursa, planted the quinoa plant in May and reported that the plant's exit time was 9 days.

In the study, quinoa variety was found statistically insignificant in terms of generative period formation and number of flowerings days. In the studies conducted, Tan and Temel (2017) reported that the number of flowering days in the quinoa plant ranged from 71 to 96 days in different 2 locations (Iğdır and Erzurum) on average and the shorter number of flowering days in the Erzurum region. Geren and Güre (2017), reported that the number of flowering days in the quinoa plant ranged from 61.5 days to 84.0 days.

Table 2 - Q52 Qinoa variety average of properties exit time, generative period, number of flowering days, number of grain filling, growing time, number of branches in the plant, plant height characteristics.

Row Spacing	Exit time (days)	Generative period (days)	Number of flowering days (days)	Number of grain filling (days)	Growing time (days)	Number of branches of per plant (piece)	Plant height (cm)
20 cm	6.003	26.037	57.667	9.933	109.003	17.600	82.267
40 cm	6.003	26.000	58.667	8.667	109.040	21.400	79.267
60 cm	6.013	26.000	58.000	9.967	109.000	18.800	77.600
Average	6.007	26.012	58.111	9.522	109.014	19.267	79.711
	NI	NI	NI	NI	NI	NI	NI

* (Not Important).

It was determined that values of number of grain filling were statistically insignificant in Q52 quinoa variety, in which different distance between rows were tested. Çakmakçı and Temel (2019) found that the ripening period in the quinoa plant was between 131.5 days and 162.8 days. In terms of growing time, another feature, the differences were found to be statistically insignificant either. In the trials conducted, Kır and Temel (2017) reported that the growing time in quinoa genotypes varied between 146.49 and 162.87 days, and that the varieties due to being early or late. In another study, Jacobsen (2003) found that the average growing times of different quinoa varieties were 157 days in the first year, 121 days in the second year, and 153 day in the third year. Spehar and Barros Santos (2005), reported that the growing time varies between 80 and 126 days in different quinoa varieties at 20 cm row distance under Brazilian ecological conditions.

In Q52 quinoa variety, differences in the number of branches of per plant were found to be statistically insignificant (Table 2). Curti et al. (2012) found that the number of branches varies between 1 and 24 in different quinoa varieties. In their study, Kır and Temel (2017) reported that the number of branches of per plant of quinoa plant has a value between 20.13 and 26.33 and the number of branches is due to genetic differences between the varieties. Dumanoğlu et al. (2016) determined the number of branches of per plant as 4 – 8 pieces/plant. Önkür and Keskin(2019) determined the number of branches in the quinoa plant as on average of 17.5, 35.0, 52.5 and 70.0 cm at a row spacing of 21.6, 24.7, 25.6 and 23.6 pieces/plant respectively.Difference between quinoa samples obtained from trial was found statistically insignificant in terms of plant height (Table 2). In other studies, Curti et al. (2012) noted that plant heights varied between 23.2 and 181.0 cm in different quinoa genotypes. Tan and Temel (2017) found that plant lengths in Erzurum and Iğdır locations were between 83.3 cm and 111.4 cm on average, and plant length was higher in Iğdır location.Kır and Temel (2017) reported that the average plant height was 118.27 cm among the genotypes, and this result was due to the genetic structure and environmental conditions of the varieties.Temel and Keskin, (2019) in the study of different inter and intra row spacing in quinoa plants, the highest plant height is 137.7 cm (35 cm inter row and 40 cm intra rows distances) and the lowest plant height is 104.1 cm (17.5 intra rows and 10 cm inter row distances).

Table 3 - Q52 quinoa variety average of properties main cluster length, grain length in the main cluster, ratio of grained part in the main cluster, Number of branches of per cluster, Grain weight in the cluster, Cluster weight, Grain ratio in the cluster, Harvest index

Row Spacing	Main bunch length (cm)	Grain length in the main bunch (cm)	Ratio of grained part in the main bunch (%)	Number of branches of per bunch (piece)	Grain weight in the bunch (gr)	Bunch weight (gr)	Grain ratio in the bunch (%)
20 cm	21.933 b	13.133 b	63.013 b	12.267	0.002	0.006 b	44.517
40 cm	20.467 b	15.467 a	77.987 a	13.000	0.004	0.008 a	41.913
60 cm	25.133 a	16.067 a	64.177 b	13.733	0.003	0.005 b	45.530
Average	22.511	14.889	68.392	13.000	0.003	0.006	43.987
	**	*	*	NI	NI	**	NI

0.01 Important (**), 0.05 Important (*), NI (Not Important)

As can be seen in Table 3, it was determined that Q52 quinoa variety, in which different row spacings were tested in late planting period, was statistically significant ($p < 0.01$) in terms of main bunchlength. It has been observed that the main bunchlength varies between 20.467 - 25.133 cm and the highest main bunchlength between 60 cm row spacing (25.511 cm) and the lowest main bunchlength is 40 cm row spacing (20.467 cm). The average main bunchlength was found 22.511 cm.Geren et al. (2015), found the highest main bunchlength 53.3 cm and 70 cm row spacing and the lowest main bunch length 38.3 cm and 17.5 row spacing in quinoa where different row spacing were tried.

Grain length in the main bunch, was found to be statistically significant ($p < 0.05$) in the Q52 quinoa variety. It was determined that the grain length in the main bunchvaries between 13.133 and 16.067 cm and grain length in the main bunch highest is 60 cm row spacing (16.067) and grain length in the main bunchin the lowest main bunchis 20 cm row spacing (13.133 cm). In the average grain length in the main bunch was found 14.889 cm (Table 3).

It was observed that the effect of quinoa variety on the ratio of grained part in the main bunchwas statistically significant ($p < 0.05$). It was found that the ratio of grained part in the main bunchchanged from 63.013% to 77.987%, and the ratio of grained part in the main bunchhighest was within 40 cm row spacing distance (77.987%), and the ratio of the grained part in the main bunchlowest was within 20 cm row spacing distance (63.013%).The average ratio of grained part in the main bunchwas found to be 68.392% (Table 3).Kır and Temel, (2017) observed that the ratio of grained part in the main bunch in the quinoa plant changed from 61.14% to 74.06%. As it is known, main bunchlength is an important feature that directly affects the yield. However, how much part of the grained in the bunch is an even more important feature. The length of the grain, which has not been able to fill the grain successfully, will be so low on the yield.Although grain formation in the bunchis a genetic feature, it is also affected by stress conditions (Çayğaracı, 2018).

In the study, it was found that the number of branches in the bunchin quinoa variety was statistically insignificant (Table 3). The number of branches of per bunch of quinoa were determined between 13.0 to 41.7 by Geren et al. (2014); 11-141 units by Bhargava et al. (2007), 7-19 by Basra et al. (2014).

The effect of plant density was found statistically insignificant in the investigation of grain weight in the bunch.According to the values obtained, the grain weight in the bunch ranged from 0.002-0.004 g, the lowest grain weight was obtained from 20 cm and the highest grain weight was obtained from the 40 cm row spacing.

The effect of plant density on the bunch weight was found to be statistically significant ($p < 0.01$).However, they found to be effect of grain ratio in the bunch statistically insignificant.It was observed that the bunch weight ranged from 0.005 to 0.008 g and the highest bunch weight was determined 40 cm row spacing and the lowest bunch weight was 60 cm row spacing. Average bunch weight was found to be 0.006 g (Table 3).

In the study, the effect of Q52 quinoa variety on the harvest index was found to be statistically significant ($p < 0.01$).It was determined that the harvest index ranged between 5.123% - 11.293% and the highest harvest index was 60 cm row spacing (11.293%) and the lowest harvest index was 40 cm row spacing (5.123%). The average harvest index was found to be 7.437%(Table 3). Kaya (2010) has planted the Quinoa plant in the Çukurova Region at a distance of 50 cm row spacing in 2009 and found that the harvest index varies between 39-42%. In another study, Bertero et al. (2004) emphasized that the harvest index is an important yield component because it is less affected by different environmental conditions than grain yield.Önkür and Keskin (2019) found that the harvest index ranged between 39.5% and 50.1% at different row spacing inquinoa.

Table 4 - Q52 quinoa variety average of properties thousand grain weight, grain yield decare, plant yield decare, protein ratio, ash ratio, oil ratio, moisture ratio, starch ratio

Row Spacing	Thosand grain weight (kg)	Grain yield decare (kg/da)	Plant yield decare (kg/da)	Protein ratio (%)	Ash ratio (%)	Oil ratio (%)	Moisture ratio (%)
20 cm	1.673	25.067 a	463.43 a	17.407	5.290	6.347	9.297
40 cm	1.750	15.453 b	333.43 b	17.710	4.770	6.290	9.520
60 cm	1.753	18.413 b	211.31 c	18.207	5.040	6.637	9.467
Average	1.726	19.644	336.057	17.774	5.042	6.424	9.428
	NI	**	**	NI	NI	NI	NI

0.01 Important (**),NI (Not Important)

In the data of the study, it was noted that the differences in weight of thousand grainsdue to applications were statistically insignificant (Table 4).Olgun et al. (2015) recorded that the average weight of thousand grains of the quinoa plant is 2.82 g in terms of quality characteristics. In some other research, 2.0-3.1g inweight of thousand grains, Tan and Temel (2018), 10 different quinoa genotypes in two different locations 2.0-3.1g ; Kır and Temel (2017) cultivated different types of quinoa plants in watery conditions and obtained 2.0-2.7g.Olgun et al. (2015) recorded that the average thousand grain weight of the quinoa plant is 2.82 g in terms of quality characteristics.

In terms of grain yield per decare, the differences between row spacings were statistically significant ($p < 0.01$). Grain yield perdecare varies between 15.453 – 25.067 kg / da and the highest grain yield is between 20 cm row spacing (25.067 kg /da), and the lowest decare grain yield is between 40 cm row spacing (15,453 kg / da). The average yield per decare was found to be 19.644 kg /da. Bhargava et al. (2007) reported that the highest grain yield of quinoa was 983 kg / da and the lowest grain yield was 32 kg / da at 10 cm rows spacing in North India.Prommarak (2014) found that the highest grain yield was 706.8 kg / da at 10 cm row spacing in the study in which different row spacing were tested. Geren et al. (2015) determined that the highest grain yield was 320.8 kg / da between the 35 cm row space in 2014 and the lowest grain yield was 240.7 kg / da in the 70 cm row space in 2013, in the quinoa where different row spacings were applied under Bornova ecological conditions.

In addition, it was determined that plant yield feature was statistically ($p < 0.01$) affected by plant density. Plant yield perdecare varies between 211.31 and 463.43 kg / da and the highest plant yield perdecareis 20 cm row space (463.43 kg / da), and the lowest plant yield decare is 60 cm row space (211.31 kg / da). Average plant yield perdecare was recorded at 336.057 kg / da (Table 4).

It has been determined that protein, ash, oil, moisture and starch ratios of Q52 quinoa varieties are not statistically affected by the applications for sowing frequency (Table 4). In some previous studies, the rate of protein in quinoa was determined by Repo - Carrasco et al. (2003) found an average of 14.4%.Temel and Keskin, (2019) found that the ratio of crude protein ranged from 13.5% to 17.7% in the study of different row space in the quinoa plant.

Regarding the protein ratio, the variety used in some sources has been found to exceed 20% according to the applications (Tan and Yöndem, 2013; Tan and Temel, 2018). The ratio of fat is Tan et al. (2019) determined between 4.37-7.08% in different quinoa genotypes.Stikic et al. (2012) determined the moisture content is between 10.08-10.87%, protein content is between 15.69-17.41, ash content is between 3.59-7.06%, starch content is between 49.55-58.65% and fat ratio is between 4.79-5.20% in quinoa variety.On the other hand, Pulvento et al. (2012) noted that the ash content, protein fat, carbohydrate and fiber content of the quinoa, in which salt content was applied different irrigation, ranged between 3.63-4.11%, 14.7-16.6%, 5.2-5.8%, 53.9-57.5% and 16.2-21.6% .

4. Conclusion

In many studies on quinoa, it has been reported that the properplanting time in the Mediterranean and Aegean conditions is in Marchand April.Accordingly, in this study conducted in the province of Kahramanmaraş in the Mediterranean region, May planting is evaluated as late planting. However, in cases where late sowing is required due to reason ssuch as climatic conditions orcroprotation, determining the appropriate sowing frequency is an essential condition for the yield and yield components to reach maximum benefit under appears to be an essential condition. Accordingly, the differences observed in the characteristic ssuch as main bunch length in the Q52 quinoavariety, grain length in the main bunch, rate of grained part in the main bunch, bunch weight, harvest index, grain yield per decare and plant yield per decare in the lateplanting period, are statistically significant, other features (exit time, generative period, number of flowering days, number of grainfilling, growing time, number of branches of per plant, plantheight,number of branches of perbunch,grain weight in the bunch, grain rate in thebunch, (%), weight of thousand grain, protein ratio, ashratio , oilratio, moistureratio and starchratio) was determined that it is not important.

Here, the highest plant yield per decare and grain yield per decare were obtained from the planting in the 20 cm row spacing of the plant density. Although the development of the plants in this row range is more competitive than others, it has been observed that the yield amount remains above the others due to the high number of plants per decare.

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