THE EFFECTS OF VARIOUS ROW SPACING AND SOWING PERIODS ON THE PLANT PROPERTIES OF QUINOA (*Chenopodium quinoa* Willd.)

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Abstract. Quinoa is a highly nutritional plant that could adapt to different growth conditions. Thus, it is cultivated and consumed globally. However, to grow quinoa outside its indigenous geography, factors such as the sowing period and row spacing should be determined in advance to maximize yield. Thus, the present study aimed to determine the differences that could be observed throughout the total growth period of quinoa with different sowing periods and row spacing applications under Mediterranean climatic conditions. The study findings demonstrated that the plant branch count varied between 1.3 and 20.2, the plant height varied between 30.9 and 104.0 cm, the main panicle length varied between 15.0 and 41.2 cm, the plant weight varied between 0.01 and 52.2 g, the plant yield in parcel varied between 71.2 and 3199.1 g and the harvest index varied between 5.1 and 52.5%. According to the results quinoa should be sowed in the first or second half of April in the region based on the climate, and the ideal row spacing should be 40 cm. The analysis revealed that this row spacing leads to maximum yield, while sowing period could vary due to the impact of climatic factors.
Keywords: *ecologycal impact, harvest index, panicle length, plant height, plant yield*

Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a plant that has been known for a long time cultivated in the Andean region for centuries to consume the seeds and leaves (Jacobsen, 2017). However, the cultivation and consumption of quinoa became popular globally during the last three decades (Wu et al., 2017). Today, it is cultivated in more than 90 countries, 80% of the cultivation is in Bolivia and Peru, while the remaining 20% is distributed among several countries (Bazile et al., 2016).

The popularity of quinoa is due to its high nutritional content, adaptability and ability to grow in harsh climatic conditions, making it an ideal crop for drought-prone and saline agricultural lands (Bazile et al., 2016). Due to its outstanding nutritional properties, the global quinoa market is currently increasing rapidly (Jacobsen, 2017). In addition to its high protein content, the plant is rich in nutrients including balanced amino acids and high mineral concentrations. Studies demonstrated that only a limited number of grain seeds do not contain gluten and the quality of the mineral, vitamin, antioxidant and protein content is comparable to casein. It was also evidenced to have high levels of essential amino acids such as lysine (Wu et al., 2016).

Another factor in the prevalence of quinoa cultivation is its adaptation to various ecological conditions. In other words, quinoa could survive 4000 m above the sea level and in temperatures between -8 and 38 °C. However, despite its wide ecological range, significant yield differences are observed based on the variety, and soil, water and climate conditions (Scanlin and Lewis, 2017). For instance, high temperatures during flowering and grain filling periods significantly reduces yield (Hinojosa et al., 2018). In fact, during the flowering period, night temperatures between 20 and 22 °C reduces grain yield by

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23% to 31% (Lesjak and Calderini, 2017). On the other hand, the impact of heat stress, duration, intensity and the rate of temperature increase is a complex function (Wahid et al., 2007), and heat stress leads to different reactions among plant species based on the duration of temperature increase and the plant development period in which heat stress occurs. In general, the plant flowering stage is more susceptible to heat stress when compared to the vegetative stages (Prasad et al., 2017).

Perhaps the most important agricultural application that affect crop yield is the sowing density. In each cultivation system, there is a plant density that would maximize the consumption of available resources (such as water, nutrients and daylight) and allows the achievement of the maximum yield (Sangoi et al., 2000).

Based on the above-mentioned information, determination of the most adequate sowing period and sowing density would balance the plant requirements and environmental conditions to maximize the yield and quality in quinoa cultivation. Due to these requirements, the present study aimed to determine the possible variations based on different sowing periods and row spacing within the overall quinoa plant growth period and identify certain properties of the quinoa plant in Mediterranean climate conditions.

Materials and Methods

The present study was conducted for two years in Kahramanmaras province ecological conditions during 2016 and 2017 in Turkey. In the experiments, "Q52" quinoa variety, compatible with the Mediterranean climate conditions, was employed. The study area soil analysis results are presented in *Table 1* and climate data are presented in *Table 2*.

Table 1. *Some soil characteristics of experimental areas in the 2017-2018*

Soil properties		**Saturation (%)**	**pH**	**EC dS m $^{-1}$**	**Lime (%)**	**Organic Matter (%)**	**P_2O_5 (kg da $^{-1}$)**	**K_2O (kg da $^{-1}$)**
2017	Values	58.00	7.76	0.32	24.48	2.28	3.20	98.64
	Comments	Clay-Loamy	Light Alkaline	Light Saline	More Lime	Middle	Low	High
2018	Values	79.00	7.40	0.11	23.00	2.09	5.62	61.2
	Comments	Clay	Neutral	Saltless	Limy	Middle	Poor	High

As seen in *Table 1*, the test site soil content was low in phosphorus content, adequate in potassium, and moderate in organic matter content for both years of experiment. However, based on the year and location, soil saturation changed from clayey-loamy to clayey, and it was determined that the soil was slightly alkaline-neutral, slightly salty-salt-free, highly calcareous-calcareous.

It was observed that the total historical precipitation was 135.5 mm and the mean precipitation in the season that the experiment was conducted was 22.6 mm as seen in *Table 2*. During the experiments, total and average precipitation figures were 176.2 and 29.4 mm for the first year, 140.0 and 23.3 mm for the second year. It was determined that the average precipitation in both years was higher than the historical average precipitation. The seasonal average temperatures in the region were 21.7 °C and 11.5 °C, respectively. In the study, the mean temperature was 23.2 °C in the 2017 cultivation period, and the mean temperature was 23.5 °C in the 2018 cultivation period, and both figures were higher than the historical average.

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Table 2. *Some meteorological parameters of experimental areas at Kahramanmaras in 2017 and 2018 and irrigation dates*

Months	Max. Temperature (°C)			Min. Temperature (°C)			Average temperature (°C)			Total rainfall (mm)			Average relative humidity (%)		
	2017	2018	1963-2018	2017	2018	1963-2018	2017	2018	1963-2018	2017	2018	1963-2018	2017	2018	1963-2018
March	17.9	19.7	15.9	7.2	9.6	5.8	12.2	14.2	10.4	74.2	47.4	97.5	55.1	60.8	60.4
April	21.8	25.5	21.3	10.1	12	9.9	15.7	18.4	15.2	68.1	71.6	72.7	49.7	45.3	57.5
May	26.2	28.8	26.7	14.2	15.7	14.2	19.6	21.7	20.0	105.0	28.1	40.0	54.9	52.6	54.6
June	33.3	32.5	32.0	19.9	19.9	18.9	26.2	25.4	24.9	3.1	39.4	7.8	43.3	49.1	48.8
July	39.1	35.6	35.7	23.9	23.2	22.2	30.9	28.6	28.3	0.0	0.3	2.7	34.9	46.2	49.9
August	37.9	36.8	36.1	23.7	23.3	22.2	29.8	29.1	28.4	0.0	0.0	2.3	46.2	43.8	51.2
September	36.4	34.7	32.6	21.1	21.0	18.5	27.7	27.2	24.9	0.0	0.6	10.0	38.3	38.4	48.8
Total (Season)	212.6	213.6	200.3	120.1	124.7	111.7	162.1	164.6	152.1	176.2	140.0	135.5	322.4	336.2	371.2
Average (Season)	30.4	30.5	28.6	17.2	17.8	16.0	23.2	23.5	21.7	29.4	23.3	22.6	46.1	48.0	53.0

Irrigations									
2017	March 24	April 20	April 28	May 11	June 09	June 21	July 01	July 10	July 25
2018	March 26	April 17	April 28	May 13	June 08	June 21	June 28	July 21	August 09

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The mean relative humidity in Kahramanmaras was 53.0% in the season, 58.1% throughout the year, while it was 46.1% and 48.0%, respectively in the 2017 and 2018 cultivation seasons (Anonymous, 2019).

The experiment was set up with random plots with different sowing times (ST) (March 23, April 6, 20, May 11 in 2017; March 26, April 2, 13, and 26 in 2018), and different row spacing (RS) (20, 40 and 60 cm) in sub-plots and 3 repetitions. The plants were sowed with 20 cm, 40 cm and 60 cm (4 rows per lot) row spacing on the lines marked with a hand marker and at 1-2 cm depth. The size of the plots was 4 m^2, 8 m^2 and 12 m^2. The TKW value of the seed material used was 2.15 g, and the amount of seed sown in the experimental plots was 1.2 kg da^{-1}. Based on the soil nutrient content (*Table 1*), pre-sowing fertilization was conducted with 0.6 kg ha^{-1} N, 0.6 kg ha^{-1} P and 0.6 kg ha^{-1} K. After sowing, when plants were about 20 cm high, net 0.7 kg ha^{-1} N was applied in the second fertilization. Based on the climate conditions, the plots were irrigated based on the water requirement of the quinoa plant (*Table 2*). Weed control was conducted manually based on the weed prevalence in the field.

The observations in the research were determined as the number of brances in the plant (NBP), the plant height (PH), the main panicle length (MPL), plant weight (PW), the plant yield per parcel (PY) and harvest index (HI) (Kır and Temel, 2017). The data obtained from the research were analyzed through variance analysis by means of SAS (version 6.03) program, and Duncan multiple comparison test was implemented to determine the significance levels of the differences among the implementations.

Results and Discussion

The results of the analysis of variance conducted on the data obtained with various sowing time and row spacing applications during the two years of experiment and the comparison of the data averages are presented in *Table 3* (*Tables 3.1, 3.2, 3.3*).

Table 3.1. *Means and F values of different years, sowing dates and row spacings on the phenological characteristics of quinoa in 2017 and 2018*

	NBP	PH	MPL	PW	PY	HI
Year						
2017	4.173 B	77.628 B	24.410 B	14.331 B	1378.05 B	31.703 A
2018	15.653 A	84.162 A	28.150 A	25.448 A	2271.21 A	24.875 B
F values	**4146.52****	**27.76****	**96.53****	**1186.07****	**893.55****	**295.26****
Sowing Time						
23/26 March (I)	8.139 C	89.636 A	33.228 A	32.109 A	2067.26 A	28.876 B
06/02 April (II)	8.504 C	81.122 B	22.444 C	21.779 C	1826.71 B	31.326 A
20/13 April (III)	10.241 B	87.822 A	23.336 C	24.366 B	1884.32 B	29.202 B
04 May/26 April (IV)	12.767 A	65.000 C	26.111 B	1.302 D	1520.23 C	23.752 C
F values	**140.36****	**81.71****	**164.86****	**1658.62****	**57.91****	**65.40****
Row Spacing						
20 cm	9.489 B	76.846 B	25.202 C	16.844 C	1636.39 C	30.891 A
40 cm	10.183 A	82.944 A	27.408 A	22.152 A	2048.02 A	30.821 A
60 cm	10.067 A	82.896 A	26.229 B	20.673 B	1789.49 B	23.155 B
F values	**4.60***	**11.66****	**10.47****	**67.18****	**80.72****	**302.20****

*: p<0.05, **: p<0.01, IS: insignificant, NBP: the number of brances in the plant, PH: the plant height, MPL: the main panicle length, PW: single plant weight, PY: the plant yield per parcel, HI: harvest index

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***Table 3.2.** Means and F values of year x sowing time, year x row spacing and sowing time x row spacing interactions on the phenological characteristics of quinoa in 2017 and 2018*

Year X Sowing Time							
2017	I	2.533	95.689	39.211	21.387	1803.387	27.851
	II	3.587	87.311	19.978	16.257	1579.199	34.241
	III	4.594	93.222	20.139	17.090	1870.377	27.163
	IV	5.978	34.289	18.311	2.591	259.256	37.558
2018	I	13.744	83.583	27.244	42.832	2331.136	29.900
	II	13.422	74.933	24.911	27.302	2074.228	28.411
	III	15.889	82.422	26.533	31.642	1898.271	31.241
	IV	19.556	95.711	33.911	0.013	2781.207	9.947
F values		**18.91****	**217.66****	**227.60****	**244.77****	**344.78****	**332.78****
Year X Row Spacing							
2017	20 cm	3.944	72.042	24.404	12.198	1281.360	35.305
	40 cm	4.858	82.567	25.633	15.010	1772.133	36.277
	60 cm	3.717	78.275	23.192	15.785	1080.670	23.528
2018	20 cm	15.033	81.650	26.000	21.489	1991.417	26.477
	40 cm	15.508	83.321	29.183	29.293	2323.908	25.365
	60 cm	16.417	87.517	29.267	25.560	2498.307	22.783
F values		**9.68****	**5.95****	**10.83****	**16.97****	**99.11****	**110.21****
Sowing Time X Row Spacing							
I	20 cm	7.500	83.367	32.383	24.823	1454.722	27.170
	40 cm	8.167	94.008	35.167	36.618	2615.743	33.065
	60 cm	8.750	91.533	32.133	34.887	2131.318	26.392
II	20 cm	8.113	75.333	20.467	20.647	1792.382	36.810
	40 cm	8.783	80.467	21.333	24.073	2093.707	30.745
	60 cm	8.617	87.567	25.533	20.618	1594.052	26.423
III	20 cm	9.608	84.033	20.925	20.560	1579.998	30.602
	40 cm	10.550	92.367	26.600	26.162	1961.240	27.925
	60 cm	10.567	87.067	22.483	26.377	2111.733	29.080
IV	20 cm	12.733	64.650	27.033	1.345	1718.452	28.982
	40 cm	13.233	64.933	26.533	1.753	1521.392	31.548
	60 cm	12.333	65.417	24.767	0.808	1320.850	10.727
F values		**1.28 IS**	**2.96***	**10.96****	**19.10****	**53.59****	**117.43****

*: p<0.05, **: p<0.01, IS: insignificant, NBP: the number of brances in the plant, PH: the plant height, MPL: the main panicle length, PW: single plant weight, PY: the plant yield per parcel, HI: harvest index

The number of branches per plant

Based on the study findings, there were statistically significant differences between Y, ST, Y x ST, Y x RS, Y x ST x RS factors ($p <0.01$) and RS ($p <0.05$) based on NBP property, while ST x RS interaction was insignificant. NBP was higher in 2018 (15.7) when compared to 2017 (4.2). The analysis of the applications based on ST demonstrated that the highest figure was obtained in the 4th sowing (12.8), and the lowest figures were obtained in the 1st and 2nd sowing. The analysis of RS application demonstrated that the lowest value was obtained with 20 cm row spacing and the other two RS applications yielded statistically the same figures.

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Table 3.3. *Means and F values of year x sowing time x row spacing on the phenological characteristics of quinoa in 2017 and 2018*

Year X Sowing Time X Row Spacing								
2017	I	20 cm	1.267	87.533	41.233	16.540	1151.840	25.373
		40 cm	3.767	103.133	39.800	21.080	2704.600	35.003
		60 cm	2.567	96.400	36.600	26.540	1553.720	23.177
	II	20 cm	4.360	80.200	19.000	14.287	2029.697	45.370
		40 cm	3.033	86.133	17.667	16.107	1801.383	32.067
		60 cm	3.367	95.600	23.267	18.377	906.527	25.287
	III	20 cm	4.083	85.467	17.050	15.287	1706.073	26.667
		40 cm	5.233	104.000	25.467	19.357	2113.863	25.503
		60 cm	4.467	90.200	17.900	16.627	1791.193	29.320
	IV	20 cm	6.067	34.967	20.333	2.680	237.830	43.810
		40 cm	7.400	37.000	19.600	3.497	468.697	52.533
		60 cm	4.467	30.900	15.000	1.597	71.240	16.330
2018	I	20 cm	13.733	79.200	23.533	33.107	1757.603	28.967
		40 cm	12.567	84.883	30.533	52.157	2526.887	31.127
		60 cm	14.933	86.667	27.667	43.233	2708.917	29.607
	II	20 cm	11.867	70.467	21.933	27.007	1555.067	28.250
		40 cm	14.533	74.800	25.000	32.040	2386.040	29.423
		60 cm	13.867	79.533	27.800	22.860	2281.577	27.560
	III	20 cm	15.133	82.600	24.800	25.833	1453.923	34.537
		40 cm	15.867	80.733	27.733	32.967	1808.617	30.347
		60 cm	16.667	83.933	27.067	36.127	2432.273	28.840
	IV	20 cm	19.400	94.333	33.733	0.010	3199.073	14.153
		40 cm	19.067	92.867	33.467	0.010	2574.087	10.563
		60 cm	20.200	99.933	34.533	0.020	2570.460	5.123
F values			**6.14****	**2.08 IS**	**6.16****	**17.86****	**35.98****	**86.71****

*: p<0.05, **: p<0.01, IS: insignificant, NBP: the number of brances in the plant, PH: the plant height, MPL: the main panicle length, PW: single plant weight, PY: the plant yield per parcel, HI: harvest index

In the Y x ST interaction, the lowest value was obtained in the first sowing (2.5) in 2017 and the highest value was obtained in the fourth sowing (19.5) in 2018. In the Y x RS interaction, the lowest value was determined with 60 cm RS (3.7) in 2017 and the highest was determined with 60 cm RS (16.4) in 2018. The lowest value in Y x ST x RS interaction was 1.3 (1^{st} sowing in 2017) and the highest value was 20.2 (4^{th} sowing in 2018).

Previous studies reported different values on the branching characteristics of the quinoa plant. Thus, Naik et al. (2020) reported 17.70 branches per plant, Onkur and Keskin (2019) reported 19.9-26.4 per plant, Afiah et al. (2018) reported 2.1-4.4 per plant, Al-Naggar et al. (2017) reported 7.0-20.0 per plant, Kır and Temel (2017) reported 15.1-26.0 per plant, Dumanoglu et al. (2016) reported 4.0-8.0 per plant, and Long (2016) reported 4.28-15.75 branches per plant. The wide range in reported values were due to employment of different varieties, ecological, climatic, soil structure differences, row spacing and sowing method. Although the present study data were compatible with these reports, the differences observed in the present study are explained below.

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The plant height (cm)

In the study, it was determined that there were statistical differences between Y, ST, RS, Y x ST, Y x RS, factors (p <0.01) and ST x RS (p <0.05) based on PH, while Y x ST x RS interaction was found to be insignificant. PH was taller in 2018 (84.2 cm) when compared to 2017 (77.6 cm). The analysis of the applications based on ST revealed that the highest values were obtained in first and third sowings (89.6 and 87.8 cm), while the lowest value was obtained in the second sowing (81.1 cm). The analysis of the RS application revealed that the lowest value was obtained with 20 cm row spacing and the other two RS produced statistically same values.

In Y x ST interaction, the lowest value was obtained in 4th sowing in 2017 (34.3 cm) and the highest was obtained in 4th sowing in 2018 (95.7 cm). Furthermore, 95.7 cm PH obtained in first sowing in 2017 was the second highest value. In the Y x RS interaction, the lowest PH was obtained with 20 cm RS in 2017 (72.0 cm), and the highest was obtained with 60 cm RS (87.5 cm) in 2018. The ST x RS interaction data revealed that the lowest value was 94.0 cm (1st; 40 cm) and the highest value was 64.7 cm (4th; 20 cm).

The PH data reported in other studies were 122.3 cm (Naik et al., 2020), 66.5-116.4 cm (Tan and Temel, 2018), 35.3-71.6 cm (Eltahan et al., 2019), 73.9-90.3 cm (Altuner et al., 2019), 49.3-101.5 cm (Geren and Gure, 2017), 55.4-101.0 cm (Tan and Temel, 2017), 48.5-94.1 cm (Geren, 2015) and 82-118 cm (Hirich et al., 2014), it was stated that the differences were due to varietal and ecological differences and various stress factors.

The main panicle length (cm)

The analysis of the differences in MPL property based on the applications, it was determined that the Y, ST, RS, Y x ST, YxRS, ST x RS, Y x ST x RS interactions (p <0.01) were significant. MPL was higher in 2018 (28.2 cm) when compared to 2017 (24.4 cm). The analysis of the applications based on ST demonstrated that the highest value was obtained in the first sowing (33.2 cm), and the lowest value was obtained in the second planting (22.4 cm). The analysis of the RS application findings revealed that the lowest value was obtained with 20 cm row spacing and the highest value was obtained with 40 cm row spacing.

The lowest Y x ST interaction was obtained in fourth sowing in 2017 (18.3 cm) and the highest was obtained in fourth sowing in 2018 (33.9 cm). The lowest Y x RS interaction was obtained with 60 cm RS in 2017 (23.2 cm), and the highest were obtained with 60 cm RS (29.3 cm) and 40 cm RS (29.2 cm) in 2018. The lowest ST x RS interaction was 20.5 cm (1st; 20 cm) and the highest was 35.2 cm (1st; 40 cm). Finally, the lowest Y x ST x RS interaction was 15.0 cm (2017; 4th; 60 cm) and the highest was 41.2 cm (2017; 1st; 20 cm).

Previous studies reported variable panicle length figures such as 31.1-42.8 cm (Altuner et al., 2019), 20.0-36.0 cm (Reguera et al., 2018), 17.8-25.3 cm (Rames et al., 2017), 24.3-29.1 cm (Long, 2016), 38.3-53.3 cm (Geren et al., 2015), 28.6-53.3 cm (Geren et al., 2014) and 15-57 cm (Hirich et al., 2014). The present study data were consistent with other studies.

Plant weight (g plant^{-1})

The analysis of the differences between the applications based on PW of the harvested samples revealed that Y, ST, RS, Y x ST, Y x RS, ST x RS, Y x ST x RS interactions (p <0.01) were statistically significant. PW was higher in 2018 (25.4 g plant^{-1}) when

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compared to 2017 (14.3 g plant^{-1}). The analysis of the applications based on ST demonstrated that the highest value was obtained in the first sowing (32.1 g plant^{-1}), and the lowest value was obtained in the fourth sowing (1.3 g plant^{-1}). The analysis of the applications based on RS revealed that the lowest value was 16.8 cm with 20 cm RS, while the highest value was 22.2 g with 40 cm RS.

The lowest Y x ST interaction was obtained in 4th sowing in 2017 (2.6 g plant^{-1}) and the highest was obtained in 1st sowing in 2018 (42.8 g plant^{-1}). The highest Y x RS interaction in 2017 was determined with 20 cm RS (12.2 g plant^{-1}), and in 2018, the highest value was determined with 40 cm RS (29.3 g plant^{-1}). The lowest ST x RS interaction was 1.3 g plant^{-1} in the 4th sowing with 20 cm row spacing, while the highest value was 36.6 g with 40 cm row spacing in the first sowing. The lowest Y x ST x RS interaction was 0.010 g plant^{-1} (2018; 4th; 20 and 40 cm) and the highest value was 52.2 g plant^{-1} (2018; 1st; 40 cm).

Afiah et al. (2018) analyzed 6 quinoa genotypes under the first and second crop conditions and found that the PW value ranged between 17.5 and 53.9 g plant^{-1}. On the other hand, Alandia et al. (2016) reported that different water regimes and different nitrogen applications led to changes in quinoa plant PW between 8.2 and 37.2 g plant^{-1}. While it was observed that the present study data were consistent with previous studies, it was suggested that the differences were due to the plant variety, and climate and cultural processes (Pulvento et al., 2010).

The plant yield per parcel (g ha^{-1})

In the experiment, the analysis of the differences between the harvested plant samples based on PY demonstrated that the Y, ST, RS, Y x ST, Y x RS, ST x RS, Y x ST x RS interactions ($p < 0.01$) were statistically significant. The analysis of the PY variable based on the years revealed that PY was higher in 2018 (227.12 g ha^{-1}) when compared to 2017 (137.81 g ha^{-1}). The analysis of the applications based on ST, the highest value was observed in the first sowing (206.73 g ha^{-1}), and the lowest was obtained in the fourth sowing (152.02 g ha^{-1}). The analysis based on the RS application revealed that the lowest value was 163.64 g ha^{-1} (20 cm) and the highest value was obtained with 40 cm row spacing (204.80 g ha^{-1}).

The lowest Y x ST interaction was observed in the 4th sowing in 2017 (25.93 g ha^{-1}) and the highest was observed in the fourth sowing in 2018 (278.12 g ha^{-1}). In Y x RS interaction, the lowest value was determined with 60 cm RS (108.07 g ha^{-1}) in 2017, and the highest value was observed with 60 cm RS (249.83 g ha^{-1}) in 2018. The ST x RS interaction data revealed that the lowest value was 132.09 g ha^{-1} (4th; 60 cm) and the highest value was 261.57 g ha^{-1} (1st; 40 cm). The analysis based on Y x ST x RS interaction revealed that the lowest value was 7.12 g ha^{-1} (2017; 4th; 60 cm) and the highest value was 319.91 g ha^{-1} (2018; 4th; 20 cm).

Altuner et al. (2019) investigated the effects of 2 quinoa varieties and 3 sowing times and determined the plant yield between 15.4 and 29.2 m^{-2} and Maliro et al. (2017) analyzed 11 quinoa genotypes under different water regimes and determined that the plant yield varied between 0.2 and 9.9 kg da^{-1}. Based on these data, the present study findings were consistent with other studies.

Harvest index (%)

The analysis of the differences between the HI data obtained with various applications in the study demonstrated that Y, ST, RS, Y x ST, Y x RS, ST x RS, Y x ST x RS

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interactions (p <0.01) were statistically significant. The analysis based on the years revealed that HI was higher in 2017 (31.7%) when compared to 2018 (24.9%). The analysis based on ST revealed that the highest value was obtained in the second sowing (31.3%), and the lowest was obtained in the fourth sowing (23.8%). The analysis based on the RS application showed that the lowest value was 23.2% (60 cm RS) and the highest value was obtained with 20 cm row spacing (30.9%). On the other hand, HI value obtained with 40 cm row spacing was the second highest (30.8%) and it was within the same group with 20 cm row spacing.

In Y x ST interaction, the lowest value was obtained in fourth sowing in 2018 (9.9%), and the highest value was observed in fourth sowing in 2018 (37.6%). In Y x RS interaction, the lowest value was determined with 60 cm row spacing in 2018 (22.8%), and the highest was determined with 40 cm row spacing in 2017 (36.3%). It was determined that the lowest value was 10.7% (4^{th}; 60 cm) and the highest value was 36.8% (2^{nd}; 20 cm) based on the ST x RS interaction data. Based on the Y x ST x RS interaction, the lowest value was 5.1% (2018; 4^{th}; 60 cm) and the highest value was 52.5% (2017; 4^{th}; 40 cm).

Eltahan et al. (2019) reported that HI varied between 16.4 and 46.6% in quinoa plants exposed to different salt stress in different row spacing applications, Onkur and Keskin (2019) reported that HI varied between 40.2 and 50.1% at different row spacing applications, Tan and Temel (2018) reported that HI varied between 5.6 and 38.0% in 10 genotypes at two different locations. Reguera et al. (2018) analyzed 3 quinoa genotypes in 4 different locations and reported HI values between 40 and 50% and analyzed 6 quinoa varieties in the first and second growth seasons and reported that HI varied between 31.4 and 40.3%. Geren and Gure (2017) reported that the HI value varied between 25.2 and 50.3% based on the administration of different nitrogen and phosphorus doses. Geren (2015) reported that the HI varied between 13.3-46.6 % at different nitrogen levels applications.

Conclusion

In the present study conducted in Kahramanmaras province, where the Mediterranean climate prevails, winters are temperate and rainy, and summers are hot and dry, it was determined that the differences between the applications conducted with different sowing times and row spacing were significant. These results demonstrated that the cultivation of 'Q52' quinoa cultivar was adequate for Kahramanmaras region.

On the other hand, it was determined that quinoa sowing should be conducted in the first or second half of April based on the climate conditions, and the ideal row spacing is 40 cm. While this spacing provides maximum benefits based on all investigated properties, it was suggested that the sowing time may vary since it could be effected by climatic factors more.

To improve the cultivation of quinoa, which is a novel crop in Turkey, it is very important to initially plan a good sowing calendar. The determination of the dates where the plant is exposed to the required temperatures, precipitation and relative humidity would increase the yield, which in turn would increase the interest in the cultivation of the plant.

Finally, agronomic guidelines should be developed for quinoa cultivation in Turkey and should be provided with adequate scientific knowledge for local communities, which would in turn will cultivate the crop nationwide. It was concluded that the varieties

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resistant to biotic and abiotic stress conditions that could be experienced regionally and nationwide should be determined, and further studies should be conducted on the development of new varieties.

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