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Original article

Influence of Sowing Dates on Grain Yield and Some Cluster Properties of Quinoa (*Chenopodium quinoa* Willd.) Under Harran Plain Conditions

Abdullah Öktem [a, *], Ö. Faruk Birden [a] & A. Gülgün Öktem [a]

[a] Department of Field Crops, Faculty of Agriculture, University of Harran, Sanliurfa, Turkey

Abstract

Quinoa (Chenopodium quinoa Willd.) is grown for its tiny edible seeds. Its seeds are high in protein and fiber. The seeds are also high in fiber and oil and are a good source of iron, magnesium, phosphorus, potassium, calcium, zinc, copper, vitamin E, and a number of antioxidants. The plants are also frost-resistant, salt-tolerant, and can be grown in poor soils. Quinoa can be used in any number of sweet or savoury dishes and is commonly boiled like rice or ground as a flour to fortify baked goods. In recently, quinoa growing and consumption are increasing day by day in the world. This study was aimed to determine different sowing dates on the grain yield and some cluster and kernel properties of quinoa under Harran Plain Conditions. Research was conducted according to randomized complete blocks design with three replicates in Harran plain conditions in 2016, Sanliurfa, Turkey. Q-52 Quinoa (Chenopodium quinoa Willd.) variety was used as plant material. In the study 9 different sowing dates were used such as 15 February, 1 March, 15 March, 1 April, 15 April, 1 May, 15 May, 1 June and 15 June. As a result of the research; statistically significant differences were seen between sowing dates at tested characteristics (P≤0.01). Cluster number of plant ranged from 10.3 to 16.0 numbers, branches number of main clusters from 18.0 to 32.3 numbers and main cluster length from 31.6 to 46.2 cm. Thousand kernel weights were between 2.325 g and 2.426 g, hectoliter weight between 69.17 and 69.83 kg/hl and grain yield 168.0 kg/da and 226.8 kg/da. It was seen that tested characteristics generally increased from 15 February to 1 April sowing dates, but after 1 April sowing dates decreased. The highest grain yield was obtained from 1 April sowing date with 226.8 kg/da whereas the lowest grain yield was seen at June 15 sowing date with 168.8 kg/da.

Keywords: Quinoa, Sowing dates, grain yield, Harran Plain.

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* **Corresponding author:**

Abdullah Öktem, Department of Field Crops, Faculty of Agriculture, University of Harran, Sanliurfa, Turkey.
Email: aoktem@harran.edu.tr

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd) has attracted attention in recent years due to its high nutritional value and its resistance to extreme climate and soil conditions. Quinoa's homeland is the Andean region of South America. Quinoa has been cultivated in Bolivia and Peru for 5,000 years (Pearsall, 1992) and brought to the European continent in the early 1980s. Quinoa is cultivated in 173 242 ha area in the world and 146 735 tons of production is being done (Anonymous, 217). Peru (78 657 tons), Bolivia (66 792 tons) and Ecuador (14 580 tons) are among the countries that produce the most quinoa in the world (Anonymous, 2017).

Quinoa is a one-year, seed-growing plant. Root development is good under arid conditions (Gonzalez et al., 2009). It has an advanced and branched pile root that provides drought resistance. Plant height is between 40 and 150 cm in length (Bhargava et al., 2007). It has thick, steep, woody stems and broad leaves with alternating (spiral) lines. Leaves are lobed or toothed and often triangular.

It can adapt to any kind of soil. It is grown in marginal soils with poor drainage, alkalinity or acidity problems. It is moderately resistant to salinity and grows within the limits of 6-8.5 pH. It grows easily on well-drained, light, medium and heavy soils. Makes the best development in loamy-sandy soils.

Quinoa plant is resistant to extreme climatic and soil conditions (Garcia, 2003). Quinoa plant tolerates many negative factors such as drought, soil and irrigation water salinity, diseases and pests (Jacobsen et al., 2003). Cold resistance is not much, but it can tolerate light frosts (-1 ^{o}C). During flowering, sensitivity to cold increases (Aguilar and Jacobsen, 2003).

Quinoa plant is suitable for machine farming. It can be cultivated with seeder and can be harvested easily with combine harvester. Sowing time is the period when the soil temperature reaches 7-10 ^{o}C.

Quinoa seeds contains rich nutrients and minerals such as potassium, calcium, iron, copper, zinc, magnesium, manganese, vitamins E and B (Comai et al., 2007). Quinoa seeds have 60% starch, 5% ash and 4% crude cellulose. Protein content of quinoa seeds varies between 13 and 21% and oil content varies between 10 and 18%. Since quinoa seeds do not contain gluten, they are among the foods that can be used in the nutrition of celiac patients.

With favorable soil and climatic conditions, the GAP region offers good potential for quinoa. It is very important to determine the adaptation of the quinoa plant as an alternative plant to the GAP region. The aim of this study was to determine the adaptation ability of the quinoa plant to the conditions of Southeastern Anatolia Region and Harran Plain conditions of Turkey and determine the most suitable planting time.

Jacobsen and Stolen (1996) reported that quinoa was planted in late April, when soil temperature reached 8 °C under Danish ecological conditions. It was reported that low temperatures in planting before this period affected germination negatively and decreased the number and yield of plants per unit area.

In an experiment conducted by Munir (2011) with different quinoa cultivars under Faisalabad-Pakistan conditions in 2010. The effect of four different sowing times (15 October, 15 November, 15 December and 15 January) on the yield and yield factors were investigated. It is stated that the most positive result in terms of yield and yield elements is December 15 sowing time.

Hirich et al. (2014) conducted a study on the ecological conditions of Agadir/Southern Morocco in quinoa plant. Starting from 1 November, they planted 10 different sowing times at 15-day intervals. They reported that the highest grain yield was obtained from 15 November sowing date with 307 kg/da but there was no statistical difference between 1 November (303 kg/da) and 1 December (247 kg/da) sowing date. It was reported that grain yield, dry matter yield and harvest index decreased as sowing times progressed and the lowest grain yield was obtained from 15 March planting time with 13 kg/da.

In a study conducted by Risi and Galwey (1991) under the Cambridge-England ecological conditions in 1982, three different sowing times (25 March, 14 April and 7 May) were tested. The researchers emphasized that the highest grain yield (696 kg/da) was obtained from the plantings carried out on 25 March.

Iliadis et al. (1999) investigated three different sowing times (5 March, 1 April, 2 May) in the Central Greece region. They reported that the average seed yield per decare decreased from 211 kg to 45 kg as the sowing time shifted from 5 March to 2 May.

A study was conducted by Geren et al. (2014) to determine the effects of different sowing times (1 March, 15 March, 1 April, 15 April, 1 May, 15 May) on quinoa yield and some other yield traits in İzmir-Turkey conditions. The researchers stated that there were significant differences between planting times, plant height, cluster length and grain yield, but there was no significant difference in terms of hectoliter weight. According to researchers, the longest cluster length was determined in April 15 with 53.3 cm whereas the shortest cluster length was in October 15 with 28.6 cm. The highest grain yield was obtained from 15 April plantings with 238.8 kg/da, while the lowest grain yield was obtained from 1 March planting with 138.9 kg/da. It was reported that thousand grain weight varied from 3.495 g (1 March) to 3.238 g (15 May).

Material and Methods

The research area is located in Harran Soil Series which has a wide spread area in the region. The soils of this series are alluvial base material, flat and deep profile soils. The soil of the research field was clay, slightly alkaline, high in lime and very low in salt contents. The research soil has A, B, C horizons

and pH ranges between 7.3 and 7.8. Organic matter content is low and cation exchange capacity is high. KDK is increasing towards the lower layers depending on the clay content (Dinc et al., 1988). Field capacity of the soil was 33.8% on dry basis, permanent wilting point was 22.6% and bulk density was 1.41 g cm^3. Some chemical properties of research soil were given in Table 1.

Table 1. Some chemical properties of research soil

Deep (cm)	Organic Material (%)	Total Salt (%)	pH	Lime (%)	P_2O_5 (kg/da)	K_2O (kg/da)	Fe (ppm)	Zn (ppm)
0-20	1.37	0.098	7.5	22.3	2.8	93.4	1.23	0.67

Table 2. Monthly some climatic data during 2016 sweet sorghum growth period in Sanliurfa†

Months	Ave. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	Ave. Humidity (%)	Total Rainfall (kg/m^2)	Solar Period (hour/day)
January	4.7	13.7	-6.2	70.3	95.6	2.9
February	11.6	25.5	2.1	61.8	17.1	4.9
March	13.6	24.5	2.7	50.3	13.0	7.2
April	20.6	32.7	7.4	36.1	27.1	8.9
May	23.2	35.0	10.7	38.3	12.3	10.2
June	29.8	42.0	18.9	28.0	0.6	11.9
July	33.0	43.0	20.9	25.4	0.2	12.4
August	33.2	43.0	21.2	30.6	0.0	11.1
September	26.4	39.3	14.7	32.1	0.0	9.8
October	22.1	33.9	12.3	35.9	22.0	8.6
November	12.6	24.4	3.0	42.9	23.3	5.9
December	5.4	13.7	-2.2	70.1	101.1	2.5

†Data collected from the Sanliurfa Meteorological Station (Anonymous, 2016).

The experimental field is located in Harran Plain where the climate varies from arid to semi-arid. Table 2. provides the climatic data obtained from Sanliurfa City Meteorological Station. As can be seen from Table 1. that the weather is hot and dry in the months of June, July and August where maximum temperatures were all above 40 °C while the relative humidity was below 50%. Rainfall was very low from June to August in 2016.

In the research, Q-52 variety (*Chenopodium quinoa Willd*) was used as plant material. Field Trials were conducted in 2016 in Eyyubiye trial area of Harran University Department of Field Crops in Sanliurfa.

The research was carried out in randomized block design with 3 replications. Before planting, soil samples were taken from the research area and analyzed for nitrogen, phosphorus and potassium and fertilization was performed according to the analysis results. Before planting, the trial area was first

ploughed and cultivated, and then a disc-harrow was applied. After that, the soil was flattened and made ready for planting. Each plot area was 14 m^2 (5 m x 2.8 m) and consisted of four rows of 5 m in length. Quinoa seeds were sown by hand at a distance of 70 cm row space, 10 cm intra row space (Spehar and Da Silva Rocha, 2009) and a depth of 1 cm. Two kg of seed per decare (Risi and Galwey, 1991) was used. Before planting as a base fertilizer pure 6 kg/da N, 6 kg/da P_2O_5 and 6 kg/da K_2O were applied. About one month later after the emergence of the plants, pure 3 kg/da nitrogen was applied as top fertilizer.

After sowing, parcels were irrigated by sprinkler irrigation method and germination of seeds was provided. After the emergence of plants, plots were irrigated equally by the furrow irrigation system. Except grain yield all tested characteristics were measured on randomly selected 25 plants in the center of each plot. All the quinoa plants on the two rows in the middle of each plot were harvested for grain yield. Two rows on the outside of each parcel are left as the edge effect. An analysis-of-variance (ANOVA) was performed using Jump statistical package program to evaluate statistically differences between results. Means of the data obtained from research were compared using Duncan test at $P \leq 0.05$.

Results and Discussions

There were significant differences among planting dates at the cluster number of plant, branches number of main clusters and main cluster length ($P \leq 0.01$). Cluster number of plant ranged from 10.3 to 16.0 numbers. Branches number of main clusters varied from 18.0 to 32.3 numbers. Main cluster length were between 31.6 and 46.2 cm.

Table 3. Cluster number of plant, branches number of main cluster and main cluster length values of quinoa plant grown at the different sowing dates

Sowing dates	**Cluster number of plant (number)****	**Branches number of main cluster (number)****	**Main cluster length (cm)****
15 February	11.3 c†	19.3 b	33.3 g
1 March	14.0 b	30.0 a	39.7 d
15 March	14.3 b	32.0 a	41.9 c
1 April	16.0 a	32.3 a	46.2 a
15 April	14.7 ab	31.3 a	45.0 b
1 May	14.0 b	32.3 a	40.0 b
15 May	14.3 b	30.0 a	39.2 e
1 June	10.3 c	18.0 b	31.6 h
15 June	10.3 c	19.0 b	34.2 f
Average	13.24	27.13	39.01

†There is no statistical difference among values annotated with the same letter in a column according to Duncan test. **: Denotes $P \leq 0.01$

The highest cluster number of plant, branches number of main clusters and main cluster length was obtained from 1 April sowing date whereas the lowest values were obtained from 1 June sowing date. In generally tested characteristics increased from 15 February to 1 April sowing dates, but after 1 April sowing dates a decrease was seen again. Although Geren et al. (2014) reported higher cluster length values than our findings, they emphasis that the longest cluster length was obtained from sowing dates in April, in parallel with our findings.

Significant differences were found among planting dates at the thousand kernel weight, hectoliter weight and grain yield ($P \leq 0.01$). Thousand kernel weight values were between 2.325 g. and 2.426 g. The highest thousand kernel weights were obtained from 1 April sowing date. The lowest thousand kernel weight values were seen at 15 February, 1 June and 15 June sowing dates. Higher thousand kernel weight values (3.49- 3.24 g) than our findings were reported by Geren et al. (2014). But Kir and Temel (2016) stated similar thousand weight values (2.59 g) for Q-52 variety which was used in the present study as in parallel to our findings. In other studies, different thousand kernel weight values were reported as 3.24 g Geren et al. (2014) and 2.1-2.6 g (Kaya, 2010). Thousand kernel weight is generally affected by variety and growing conditions such as sowing date.

Hectoliter weight ranged between 69.17 and 69.83 kg/hl. The highest hectoliter weight value was obtained from 1 April sowing date. Hectoliter weight values were the lowest at the 15 February and 15 June sowing dates.

Grain yield varied from 168.0 kg da^{-1} and 226.8 kg/da. Similar findings are reported by Geerts et al. (2008), Kir and Temel (2016), Kaya (2010) and Iliadis et al. (1999), as 168-204, 236, 169-212, 45-211 kg/da, respectively. Although Bhargava et al. (2007) reported lower grain yield values (32.0-98.3 kg/da) than our findings, Risi and Galwey (1991) stated higher grain yield values (696 kg/da). Gesinski (2008) stated that quinoa grain yields were 138, 226, 26, 34 and 165 kg/da in five different countries of Europe, Valdichiani-Italy, Larisa-Greece, Uppsala-Sweden, Copenhagen-Denmark and Bydgoszcz-Poland, respectively.

Table 4. Thousand kernel weight, hectoliter weight and grain yield values of quinoa plant grown at the different sowing dates

Sowing dates	Thousand kernel weight (g)**	Hectoliter weight (kg ha^{-1})**	Grain yield (kg da^{-1})**
15 February	2.328 d†	69.17 e	168.0 h
1 March	2.408 c	69.67 c	205.8 e
15 March	2.421 ab	69.77 abc	214.2 c
1 April	2.426 a	69.83 a	226.8 a
15 April	2.424 ab	69.80 ab	218.4 b
1 May	2.420 b	69.73 bc	210.0 d
15 May	2.406 c	69.70 bc	201.6 f
1 June	2.330 d	69.33 d	184.8 g
15 June	2.325 d	69.17 e	168.8 h
Average	2.388	69.57	199.82

†There is no statistical difference among values annotated with the same letter in a column according to Duncan test. **: Denotes P≤0.01

Different sowing dates are reported by different researchers for quinoa around the world. According to previous studies, the best sowing date for quinoa plant under Faisalabad-Pakistan conditions were reported as 15 December (Munir, 2011), under Agadir/Southern Morocco conditions as 1-15 November (Hirich et al., 2014), under Cambridge-England conditions as 25 March (Risi and Galwey, 1991), under Greece conditions as 5 March-2 May (Iliadis et al., 1999) and under Turkey conditions 15 April (Geren et al., 2014).

In the present study, the highest grain yield were obtained from 1 April sowing date. Also grain yield values were the lowest at the 15 February and 15 June sowing dates. Our findings are supported by Geren et al. (2014). It was seen that tested characteristics generally increased from 15 February to 1 April sowing dates, but after 1 April sowing dates decreased.

Conclusions

It was seen that cluster number of plant, branches number of main cluster, main cluster length thousand kernel weight, hectoliter weight and grain yield values generally increased from 15 February to 1 April sowing dates, but after 1 April sowing dates decreased. The highest grain yield was obtained from 1 April sowing date with 226.8 kg da^{-1} whereas the lowest grain yield was seen at June 15 sowing date with 168.8 kg da^{-1}.

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