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Original article

Impact of Sowing Dates on Forage Value of Quinoa (*Chenopodium quinoa* Willd.) Under Semi-arid Conditions

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Abstract

This study was aimed to determine forage value of quinoa at the different sowing dates under semi-arid 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. In the research plant height, stem diameter, number of branches per plant, biomass yield, dry forage yield and harvest index were investigated. As a result of the research, statistically significant differences were seen between sowing dates at tested characteristics (P≤0.01). As a result of the research, statistically significant differences were seen between sowing dates at tested characteristics (P≤0.01). Plant height ranged from 81.8 cm to 109.4 cm, stem diameter from 9.0 mm to 12.6 mm, number of branches per plant from 10.3 to 12.7 number. The highest biomass yield was obtained from 1 April sowing date with 1751.40 kg da-1 whereas the lowest biomass yield was seen at June 15 sowing date with 1295.28 kg da-1. Dry matter yield values were between 415.8 (15 February) and 546.88 kg da-1 (1 April). Harvest index values were between 39.3% and 42.0%. Quinoa yield characteristics in generally increased from 15 February to 1 April sowing dates, but after 1 April sowing dates decreased. Higher values were obtained from April and May sowing dates. The most suitable planting date for quinoa plant in semi-arid climatic conditions was determined as 1 April and can be recommended in similar ecologies.

Keywords: Quinoa, Sowing time, Biomass, Dry matter, Harvest Index.

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INTRODUCTION

New alternative plants are sought in order to close the growing roughage gap in the world and to ensure adequate and balanced nutrition of animals. Quinoa (*Chenopodium quinoa* Willd) plant has attracted attention in recent years due to its high nutritional value.

Quinoa is a one-year, seed-growing plant. Quinoa plant is resistant to extreme climatic and soil conditions (Garcia, 2003). Root development is good under arid conditions (Gonzalez et al., 2009). Quinoa plant tolerates many negative factors such as drought, soil and irrigation water salinity, diseases and pests (Jacobsen et al., 2003). Quinoa plants can be grown easily in semi-arid climatic conditions (Jensen et al., 2000; Geerts et al., 2008). 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.

Quinoa is seen as an alternative plant in animal nutrition due to its rapid growth and easy cultivation (Bertero and Ruiz, 2010. Quinoa plants can produce a quality feed material with low fiber and high protein content when harvested in appropriate growth periods (flowering) (Peterson and Murphy, 2015).

In a study conducted by Risi and Galwey (1991) under the Cambridge-England ecological conditions, three different sowing times (25 March, 14 April and 7 May) were tested. The researchers emphasized that the highest biomass yield (696 kg da^{-1}) was obtained from the plantings carried out on 25 March. Jacobsen and Stolen (1996) reported that low temperatures in planting affected germination negatively and decreased yield and yield characteristics.

In an experiment conducted by Munir (2011) stated that the most positive result in terms of yield and yield elements was obtained from late sowing time. Spehar and Barros Santos (2005) emphases that plant height, stem thickness, dry matter yield, grain yield and harvest index values vary depending on the growing conditions.

Tan and Temel (2017) stated that the types of Sandoval Mix, Cherry Vanilla and Red Head quinoa are suitable for hay production. Kaya et al., (2017) stated that it was obtained 1114.67 kg da^{-1} fresh grass and 344.97 kg da^{-1}) dry grass from the quinoa plant as a feed source. Gesinski (2008) stated that the biomass yield of quinoa in five different ecological conditions in Europe (Valdichiani Italy), Larisa (Greece), Uppsala (Sweden), Copenhagen (Denmark) and Bydgoszcz (Poland) were 832 kg da^{-1}, 978 kg da^{-1}, 182 kg da^{-1}, 147 and 1793 kg da^{-1}, respectively.

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. Researchers recorded the highest plant height value with 111.7 cm in sowing on April 1, and the lowest in sowing on March 1 with 63.8 cm in Izmir conditions.

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 yield per decare decreased from 211 kg to 45 kg and plant height 140 cm to 90 cm as the sowing time shifted from 5 March to 2 May. Pulvento et al. (2010), in a study they conducted in Italian ecology for two years, stated that the plant heights of KVLQ52OY and Regalona Baer quinoa genotypes varied between 82.0-91.0 cm and 104.0-113.0 cm, respectively.

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. It was reported that yield, dry matter yield and harvest index decreased as the planting times progressed. Lavini et al. (2014), reported that quinoa harvest index values were 30-57%, 48-59% and 24-51% in Italy, Turkey and Morocco ecological conditions, respectively.

Spehar and Da Silva Rocha (2009) stated that biomass yield and harvest index values in quinoa plant were 742.0 kg da^{-1} and 31.0%, respectively. Curti et al. (2012) conducted with 34 quinoa populations in Argentina ecological conditions. They stated that the number of branches in plant varied between 0 and 24 and the average number of branches was 8.7 units $plant^{-1}$.

Oktem et al. (2020) stated that cluster number of quinoa 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 reported between 2.325 g and 2.426 g, hectoliter weight between 69.17 and 69.83 kg hl^{-1} and grain yield 168.0 kg da^{-1} and 226.8 kg da^{-1}.

The aim of this study was to determine forage value of the quinoa plant and determine the most suitable planting time.

MATERIAL and METHODS

The research area is in Harran Soil Series which has a widespread 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 was low. Cation exchange capacity was high and 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^{-1})	K_2O (kg da^{-1})	Fe (ppm)	Zn (ppm)
0-20	1.37	0.098	7.5	22.3	2.8	93.4	1.23	0.67

The experimental field was 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 2. 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 not seen in the August and September and rainfall was very low in June and July.

In the research, Q-52 variety (*Chenopodium quinoa Willd*) was used as plant material. Research was conducted in 2016 in Eyyubiye trial area of Harran University, Sanliurfa. The study 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 soil 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^{-1} N, 6 kg da^{-1} P_2O_5 and 6 kg da^{-1} K_2O were applied according to soil analysis results. When the plants reached 30 cm height 6 kg da^{-1} pure nitrogen was applied as top fertilizer.

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

Months	Ave. Temp. (ºC)	Max. Temp. (ºC)	Min. Temp. (ºC)	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).

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. Plant height, stem diameter and number of branches per plant characteristics were measured on randomly selected 25 plants in the center of each plot. Plant height was measured using a tall ruler. Stem diameter was determined with a digital vernier caliper. All the quinoa plants on the two rows in the middle of each plot were harvested for determination of biomass yields. Two rows on the outside of each parcel are left as the edge effect.

To determine dry matter yield, in each plot, the wet weight of a randomly selected plant sample was taken and cut to a length of 5-10 cm, dried in a drying cabinet at 70 °C until it stabilized (72 hours) and its dry weight was determined. After determining the dry weight/wet weight ratio, DM yields were calculated by multiplying this ratio by the biomass yield.

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

Plant Height

Plant height values were given Table 3. There were significant differences among planting dates at the plant height ($P \leq 0.01$). Plant height ranged from 81.8 to 109.4 cm. The highest plant height value was obtained from 1 May sowing date whereas the lowest plant height value was seen at 15 February sowing date (Table 3). Similar findings were reported by Iliadis et al. (1999) that plant height decreased from 140 cm to 90 cm as the sowing time shifted from 5 March to 2 May. Pulvento et al. (2010), emphasis in parallel with our findings that plant height ranged between 82.0 and 113.0 cm in quinoa plant. Geren et al. (2014) stated higher plant height values than our findings. It was reported that the highest plant height value was 111.7 cm in sowing on April 1, and the lowest plant height was 63.8 cm on March 1 sowing date.

Stem Diameter

There were significant differences among planting dates at the stem diameter ($P \leq 0.01$). Stem diameter varied from 9.0 to 12.6 mm (Table 3). The highest stem diameter value was obtained from 1 and 15 April sowing date whereas lowest value was determined on 15 June sowing date. Stem diameter was affected by sowing dates. It was determined that stem diameter values were lower at the early and late sowing dates. Spehar and Barros Santos (2005) emphases that stem thickness vary depending on the growing conditions. Jacobsen and Stolen (1996) reported that low temperatures in planting affected germination negatively and decreased yield and yield characteristics.

Table 3. Plant height, stem diameter and number of branches per plant values of Quinoa plant grown at the different sowing dates

Sowing dates	Plant height (cm)**	Stem diameter (mm)**	Number of branches per plant (number)**
15 February	81.8 ı†	10.0 e	11.3 bc
1 March	101.4 e	12.1 bc	11.7 bc
15 March	106.9 c	12.5 ab	12.0 ab
1 April	109.4 a	12.6 a	12.7 a
15 April	108.2 b	12.6 a	12.0 ab
1 May	105.1 d	12.3 ab	11.7 bc
15 May	100.5 f	11.8 c	11.7 bc
1 June	87.3 g	11.0 d	10.3 d
15 June	82.6 h	9.0 f	11.0 cd
Average	98.13	11.54	11.6
LSD	0.435	0.371	0.807

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

Number of Branches Per Plant

There were significant differences among planting dates at the number of branches per plant ($P \leq 0.01$). Number of branches per plant were between 10.3 and 12.7 number (Table 3). Our findings are in accord with another researcher. Curti et al. (2012) stated that the number of branches in plant varied between 0 and 24 and the average number of branches was 8.7 units/ plant.

The highest number of branches per plant values were obtained from 1 April sowing date whereas the lowest value was found at 1 June sowing date. The highest number of branches per plant values were seen at spring mounts such as 15 March, 1 April and 15 April sowing dates. Since more suitable temperature and humidity values are observed for plants in spring, there is an improvement in vegetative properties. It was emphasis that yield characteristics vary depending on the growing conditions (Spehar and Barros Santos, 2005).

Biomass Yield

Significant differences were found among planting dates at the biomass yield ($P \leq 0.01$). Biomass yield ranged between 1281 kg da^{-1} and 1751.4 kg da^{-1}. The highest biomass yield value was obtained from 1 April sowing date. Biomass yield values were the lowest at the 15 February sowing dates (Table 4). Biomass yield increased from 15 February to 1 April sowing time, but it was seen a decrease between 1 April and 15 June sowing time. Hirich et al. (2014) reported that yield decreased as the planting times progressed. As seen in Table 1, recorded the low temperature during February and the high temperature in the month of June adversely affected plant growth and as a result, biomass yield was found to be low. In the spring months of April and May, an increase in biomass yield was observed due to the improvement in temperature and rainfall conditions. Jacobsen and Stolen (1996) reported that low temperatures in planting affected germination negatively and decreased yield and yield characteristics. Munir (2011) stated that the most positive result in terms of yield and yield elements was obtained from late sowing time which is proper climatic conditions.

Similar biomass yield values to our results in quinoa reported by Gesinski (2008) as 1793 kg da^{-1} in Bydgoszcz (Poland) conditions. Kaya et al. (2017) stated that it was obtained 1114.67 kg da^{-1} biomass yield from the quinoa. Lower biomass yield values were reported in different ecological conditions. Spehar and Da Silva Rocha (2009) stated lower biomass yield than our findings as 742.0 kg da^{-1}. Biomass yield in Valdichiani (Italy), Larisa (Greece), Uppsala (Sweden), Copenhagen (Denmark) and Bydgoszcz (Poland) conditions was reported as 832 kg da^{-1}, 978 kg da^{-1}, 182 kg da^{-1}, 147 and 1793 kg da^{-1}, respectively (Gesinski, 2008).

In the regression analysis, a polynomial curve was obtained between biomass yield and sowing dates. A relationship was found between the sowing dates and biomass yield in quinoa at $R^2 = 0.919$ (R^2 denotes the coefficient of determination). The equation of the relationship was $y = -27.593x^2 + 261.17x + 1126.6$. According to regression analysis (Fig. 1); there was no statistically significant increase in biomass yield after 1 April sowing date (1751.4 kg da^{-1}). According to research results, 1 April sowing date was seen proper at quinoa cultivation in semi-arid conditions.

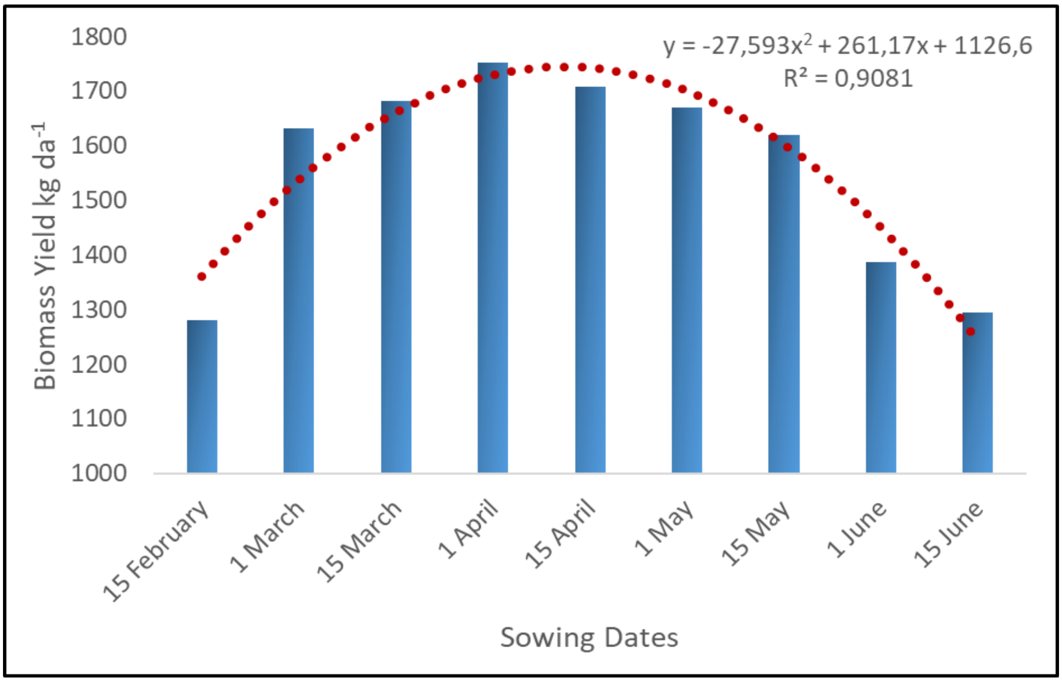

Figure 1. Biomass yield values and regression analysis equation

Dry Matter Yield

Planting dates at the dry matter yield was found statistically significant ($P \leq 0.01$). Dry matter yield values were between 415.8 and 546.88 kg da^{-1} (Table 4). Spehar and Barros Santos (2005) emphases that dry matter yield values vary depending on the growing conditions.

The highest dry matter yield was obtained from 1 April sowing date. Kaya et al., (2017) reported that it was obtained 344.97 kg da^{-1}) dry matter from the quinoa plant as a feed source. The lowest dry matter yield values were seen at 15 June sowing dates. Hirich et al. (2014) reported that yield decreased as the planting times progressed. While lower dry matter yield was obtained in early and late sowing periods, dry matter yield was found as higher in April and May which be the spring months.

It is stated that low temperatures in planting affect germination negatively and decrease yield and yield characteristics (Jacobsen and Stolen, 1996). Since the climatic conditions were better in April and May, the plant development was better. As can be seen from Table 4, also higher biomass yield was obtained from April and May sowing dates. Munir (2011) stated that the most positive result in terms of yield and yield elements was obtained from proper sowing time for climatic factors. Spehar and Barros Santos (2005) emphases that yield values vary depending on the growing conditions.

Table 4. Biomass yield, dry matter yield and harvest index values of Quinoa plant grown at the different sowing dates

Sowing dates	Biomass yield (kg da^{-1})**	Dry matter yield (kg da^{-1})**	Harvest index (%)**
15 February	1281.00 ı†	415.80 h	39.7 d
1 March	1632.12 e	501.48 e	40.7 c
15 March	1682.52 c	517.54 c	41.0 bc
1 April	1751.40 a	546.00 a	41.7 ab
15 April	1708.56 b	525.84 b	42.0 a
1 May	1670.76 d	509.88 d	41.0 bc
15 May	1619.52 f	497.28 e	39.7 d
1 June	1386.84 g	456.96 f	39.7 d
15 June	1295.28 h	431.76 g	39.3 d
Average	1558.7	489.171	40.53
LSD	6.109	6.484	0.833

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

Harvest Index (%)

Significant differences were found among planting dates at the harvest index ($P \leq 0.01$). Harvest index ranged between 39.3% and 42.0%. The highest harvest index value was obtained from 15 April sowing date (Table 4). Since the plant growth is better in spring sowing times, the harvest index was found higher. Harvest index values were the lowest at the 15 June sowing dates. But harvest index values were the lowest on 15 February, 15 May, 1 June and 15 June sowing dates and all were in the same statistical group. The harvest index values at different sowing times have changed depending on the plant growth. Spehar and Barros Santos (2005) emphases that harvest index values vary depending on the growing conditions. Hirich et al. (2014) stated that harvest index decreased as the planting times progressed. Research results is in accord with another study. It was reported that quinoa harvest index values were 30-57%, 48-59% and 24-51% in Italy, Turkey and Morocco ecological conditions, respectively (Lavini et al. (2014). Lower harvest index values (31.0%) than our findings were reported by Spehar and Da Silva Rocha (2009).

CONCLUSIONS

As a result of the research, statistically significant differences were seen between sowing dates at tested characteristics ($P \leq 0.01$). Plant height ranged from 81.8 cm to 109.4 cm, stem diameter from 9.0 mm to 12.6 mm, number of branches per plant from 10.3 to 12.7 number. The highest biomass yield was obtained from 1 April sowing date with 1751.40 kg da^{-1} whereas the lowest biomass yield was seen at June 15 sowing date with 1295.28 kg da^{-1}. Dry matter yield values were between 415.8 (15 February) and 546.88 kg da^{-1} (1 April). Harvest index values were between 39.3% and 42.0%. Quinoa yield characteristics in generally increased from 15 February to 1 April sowing dates, but after 1 April sowing dates decreased. Higher values were obtained from April and May sowing dates. The most suitable planting date for quinoa plant in semi-arid climatic conditions was determined as 1 April and can be recommended in similar ecologies.

Conflict of Interest

The authors declare that they have no conflict of interest.

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