Turkish Journal of FIELD CROPS

*Turk J Field Crops 2023, 28(1), 26-36*
*DOI: 10.17557/tjfc.1226196*

# INFLUENCES OF SOWING DATE AND HARVEST STAGE ON DRY MATTER YIELD AND FORAGE QUALITY OF QUINOA (*Chenopodium quinoa* Willd.)

*Emine BUDAKLI CARPICI[1*], Sebiha EROL[2], Barıs Bulent ASIK[3], Omer ARSLAN[2]*

*[1]Bursa Uludag University, Faculty of Agriculture, Department of Field Crops, Bursa, TURKEY*
*[2]Bursa Uludag University, Graduate School of Natural and Applied Sciences, Bursa, TURKEY*
*[3]Bursa Uludag University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Bursa, TURKEY*
*[*]Corresponding author: ebudakli@uludag.edu.tr*

Received: 29.12.2022

**ABSTRACT**

**Sowing dates and harvest stages are very important to obtained better forage yield and quality. The goal of the study was to ascertain how the quinoa growing conditions in Marmara will be affected by the sowing dates and harvest stages. In 2018 and 2019, the experiment was conducted in an experimental field in the Agricultural Application and Research Area of Bursa Uludag University's Agriculture Faculty. The field experiment was set up using three replicates of a split-plot randomized complete blocks design. Titicaca variety of quinoa was used as a plant material in the study. Four different sowing dates (15 April, 1 May, 15 May and 1 June) were considered in the main plot and three different harvest stages (beginning of flowering, full flowering and seed setting) in the sub-plot. In this study, plant height, dry matter yield, crude protein, crude protein yield, neutral detergent fiber, acid detergent fiber, the relative feed value, and macro and micro elements were examined. The two-year findings show that sowing on May 1 produced the maximum dry matter yield (2798 kg ha$^{-1}$) and crude protein yield (584 kg ha$^{-1}$). In terms of harvest stages, seed setting stage came to the fore in terms of high forage (4001 kg ha$^{-1}$) and crude protein yield (746 kg ha$^{-1}$).**

**Keywords: Dry matter yield, harvest stages, hay quality, quinoa, sowing dates**

## INTRODUCTION

The quinoa, which takes its origin from the Andes mountains in South America, has spread all over the world from here. The remaining parts of the plant, which has been grown for grain by the people of this region for a long time, have also been used in ruminant nutrition (Bazile et al., 2015; Temel and Keskin, 2019). Quinoa hay and straw have been used in South America for centuries to feed cattle, sheep, horses and pigs (FAO, 1994). Quinoa hay, which is loved by cattle as a fodder plant, is a material rich in protein, carotenoids and ascorbic acid (Bhargava et al., 2007). Quinoa is a fast growing and easily ensiled plant. Due to its easy cultivation, it is grown as a feed source in organic agriculture. In general, 3-3.5 months after planting, quinoa can produce silage material with sufficient dry matter content and high crude protein content (Tan and Yondem, 2013). It is also very advantageous as a second crop as it is harvested in a short time (Uke, 2016). With the use of suitable genotypes, a high amount of forage yield can be obtained. By choosing the right variety, the hay yield can reach 10 ton ha$^{-1}$ in dry conditions and over 20 tons ha$^{-1}$ in irrigated conditions in well-maintained fields (Kaoutar et al., 2017; Tan and Temel, 2017; Tan and Temel, 2018; Temel and Keskin, 2019; Temel and Surgun, 2019; Temel and Yolcu, 2020). In contrast, Kaoutar et al. (2017) reported that 4.7-15.2 t ha$^{-1}$ dry matter yield was produced in Moroccan environments, whereas Kakabouki et al. (2014) reported 8.2-9.17 t ha$^{-1}$ in Greece. The dry matter digestibility of quinoa hay is between 63% and 69%, and the crude protein content ranges from 13% to 22% (Van Schooten and Pinxterhuis, 2003). The forage produced from quinoa is fed to animals as green or by making silage (Tan and Temel, 2020). There are few studies on the impact of varied sowing dates and harves stages on forage productivity, forage quality, and macro-micro elements of forage, despite the fact that studies on the forage yield and quality of many quinoa varieties have been undertaken. The present study was aimed to determine the effect of sowing dates and harvest stages on the dry matter yield and forage quality of quinoa.

## MATERIALS AND METHODS

The study was carried out in the experimental area of Faculty of Agriculture Agricultural Application and Research Center of Bursa Uludag University in 2018 and 2019 (40° 11ˈ N, 29° 04ˈ E). Climate data during the two growing seasons and long terms (LT) are presented in Table 1. Long-term represents average value of collected data about monthly mean temperatures, mean relative humidity (%) and total precipitation in the period 1975-2014. When the LT average data for Bursa Province from April to September are reviewed, it is discovered that there were 218.2 mm of total precipitation, 20.4°C on average, and 60.5% relative humidity. The total precipitation in the second year of the experiment was lower than the LT and the first year. It was discovered after analyzing the temperature measurements for the six months that the experiment's average temperature was similar to the average for several years. Table 2 contains a list of the soil characteristics in the study area from 0 to 20 cm deep. The soil analysis's findings were contrasted with those of the references (Muftuoglu et al., 2014). In the experiment, the main plot and the sub-plot were each subjected to four different sowing dates (15 April, 1 May, 15 May and 1 June), as well as three different harvest stages (beginning of flowering, full flowering and seed setting). Titicaca variety of quinoa was used as a plant material in the study. The Titicaca variety developed in Denmark is a day neutral plant (Tan and Temel, 2019). Row spacing was 35 cm, sowing rate was 3 kg per hectare, and sowing depth was 1.5 to 2 cm (Tan and Temel, 2017). 6 rows were manually seeded in each of the experiment's 10.5 $m^2$ plots, which were 5 m × 2.1 m in size. During the sowing phase, 75 kg of N and 80 kg $P_20_5$ per hectare were applied. After the plants had grown to a height of 30 to 40 cm, an additional 50 kg of N fertilizer was added to the soil per hectare (Geren, 2015). As a nitrogen and phosphorus fertilizer source, respectively, ammonium sulfate (21% N and TSP-44% P) were utilized. A roller was utilized to remove the parcel after sowing, and drip watering was used to assure germination and emergence. Weeds were removed by hand hoeing. The distance between the soil's surface and the plant's tip was used to calculate the plant's height (cm). For this purpose, 10 randomly selected plants were used. After removing the edge effects in each plot, 2.8 $m^2$ sections were cut by hand. The samples were dried for 48 hours at 65 °C, weighed, and an estimation of the dry matter % was made. Dry matter yield was determined on the basis of fresh forage yield and the percentage of dry matter. Dry samples were grounded for the analyses. Nitrogen (N) content was determined using the Kjeldahl method, and crude protein was estimated using the formula N x 6.25 (AOAC, 1997). On the ground samples, acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses were carried out (Van Soest et al., 1991). In addition, relative feed value (RFV) was calculated using the obtained data (Van Dyke and Anderson, 2000). In a microwave oven of the Berghof MWS2 model, plant samples were digested using a solution of nitric acid and hydrogen peroxide ($HNO_3$ + $H_2O_2$). A Perkin Elmer Optima 2100 DV ICP OES was used to analyze the resulting solution for the elements phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca) and microelements (Cu, Fe, Mn, and Zn) (Kacar, 2014). With the use of the JUMP package program, the data were subjected to analysis of variance using the "Randomized Complete Blocks Design." The LSD test and 5% probability levels were both used to determine the separate groups, and the probability levels used in the significance tests were 1% and 5%, respectively.

**Table 1.** Climate data in 2018, 2019 and LT.

| | MT (°C) | | | TP (mm) | | | RH (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| Months | LT | 2018 | 2019 | LT | 2018 | 2019 | LT | 2018 | 2019 |
| April | 13.0 | 15.8 | 12.8 | 66.0 | 14.2 | 43.6 | 66.1 | 70.8 | 69.7 |
| May | 17.4 | 19.9 | 19.8 | 43.4 | 89.8 | 48.6 | 62.0 | 76.5 | 65.9 |
| June | 22.5 | 23.5 | 24.5 | 36.5 | 59.2 | 31.0 | 57.8 | 70.1 | 65.4 |
| July | 24.8 | 26.1 | 24.8 | 17.7 | 15.4 | 21.2 | 56.2 | 63.2 | 59.7 |
| August | 24.5 | 26.4 | 25.2 | 13.8 | 2.0 | 31.4 | 57.3 | 59.7 | 62.3 |
| September | 20.2 | 21.8 | 21.5 | 40.8 | 46.6 | 12.4 | 63.8 | 67.6 | 63.2 |
| Total/Avg. | 20.4 | 22.3 | 21.4 | 218.2 | 227.2 | 188.2 | 60.5 | 68.0 | 64.4 |

MT: Mean temperature, TP: Total precipitation, RH: Relative humidity

**Table 2.** Soil characteristics of the study fields.

| | 2018 | | 2019 | |
|---|---|---|---|---|
| Characteristic | Value | Class | Value | Class |
| Sand, % | 36.8 | Soil texture Clay (C) | 28.0 | Soil texture Clay (C) |
| Loam, % | 17.3 | | 19.2 | |
| Clay, % | 45.9 | | 52.8 | |
| pH | 7.675 | Slightly alkaline | 7.522 | Slightly alkaline |
| EC, µS $cm^{-1}$ | 721.2 | Low | 813.7 | Low |
| $CaCO_3$, % | 4.10 | Medium | 3.75 | Medium |
| Organic matter, % | 2.08 | Low | 2.29 | Low |
| Nitrogen (N), % | 0.098 | Medium | 0.195 | High |
| Phosphorus (P), mg $kg^{-1}$ | 21.15 | Sufficient | 28.78 | High |
| Potassium (K), g $kg^{-1}$ | 0.632 | Very high | 0.589 | Very high |
| Iron (Fe) mg $kg^{-1}$ | 13.63 | High | 12.77 | High |
| Copper (Cu), mg $kg^{-1}$ | 4.95 | Sufficient | 5.46 | Sufficient |
| Zinc (Zn), mg $kg^{-1}$ | 1.71 | Sufficient | 1.56 | Sufficient |
| Manganese (Mn), mg $kg^{-1}$ | 66.25 | High | 53.91 | High |

## RESULTS

Data discussion were only carried out for main factors and binary interactions found to be significant. That is; triple interactions were not elaborated separately in the parameters in which binary interactions were found significant.

*Plant height (cm)*

The main effects of the year (Y), sowing dates (SD), and harvest stages (HS) on plant height were discovered at the 1% level of significance in the research (Table 3). The tallest plant (69 cm) measured in 2019. According to SD, the plants seeded on April 15 produced the highest plants (74 cm), while those sown on June 1 produced the lowest plants (53 cm) (Table 5). It has also been reported by many researchers that plant length is shortened due to the delay in SD in quinoa (Iliadis et al., 1999; Fernando et al., 2012; Hirich et al., 2014; Ramesh, 2016; Temel and Yolcu 2020; Oktem et al., 2021). In late sowing, quinoa is exposed to increased temperature and light intensity, and in this case, plants can reach harvest maturity without adequate vegetative development (Temel and Yolcu, 2020). The seed-setting stages produced the tallest plants (87 cm), while the beginning of the flowering stage, when the effects of the HS were assessed, produced the shortest plants (42 cm) (Table 5). Yolcu (2018) stated that plant height increased significantly with delayed harvest, and this was due to plants having a longer growing period in late harvests. Yilmaz et al. (2021) stated that the highest plant height in quinoa was obtained from the dough stage and that the plant height increased by approximately 11% in the dough stage compared to the flowering stage. The effects of Y x SD, Y x HS and SD x HS interactions on plant height showed statistically important differences (Table 3). The highest plant heights (80 cm and 76 cm) in terms of Y x SD interaction were determined in the sowings made on 15 April 2018 and 1 May 2019. After the first ST in 2018, plant height decreased significantly in sowings made on 1 May and 15 May, but the opposite situation occurred in 2019. The interaction of Y x SD becomes crucial as a result of this situation (Figure 1). According to Temel and Yolcu (2020), the annual temperature, precipitation amount, and distribution are the primary factors influencing the change in plant heights in quinoa. In terms of Y x HS interaction, the highest plant heights (89 cm and 85 cm) were obtained from the harvests made during the seed setting stage in both years (Figure 1). When the interaction of SD x HS is examined; the highest plant height was determined as 108 cm in the seed setting stage and sown on 15 April, while the lowest plant height was 34 cm in the plants seeded on 1 June and cut begining of flowering (Figure 1).

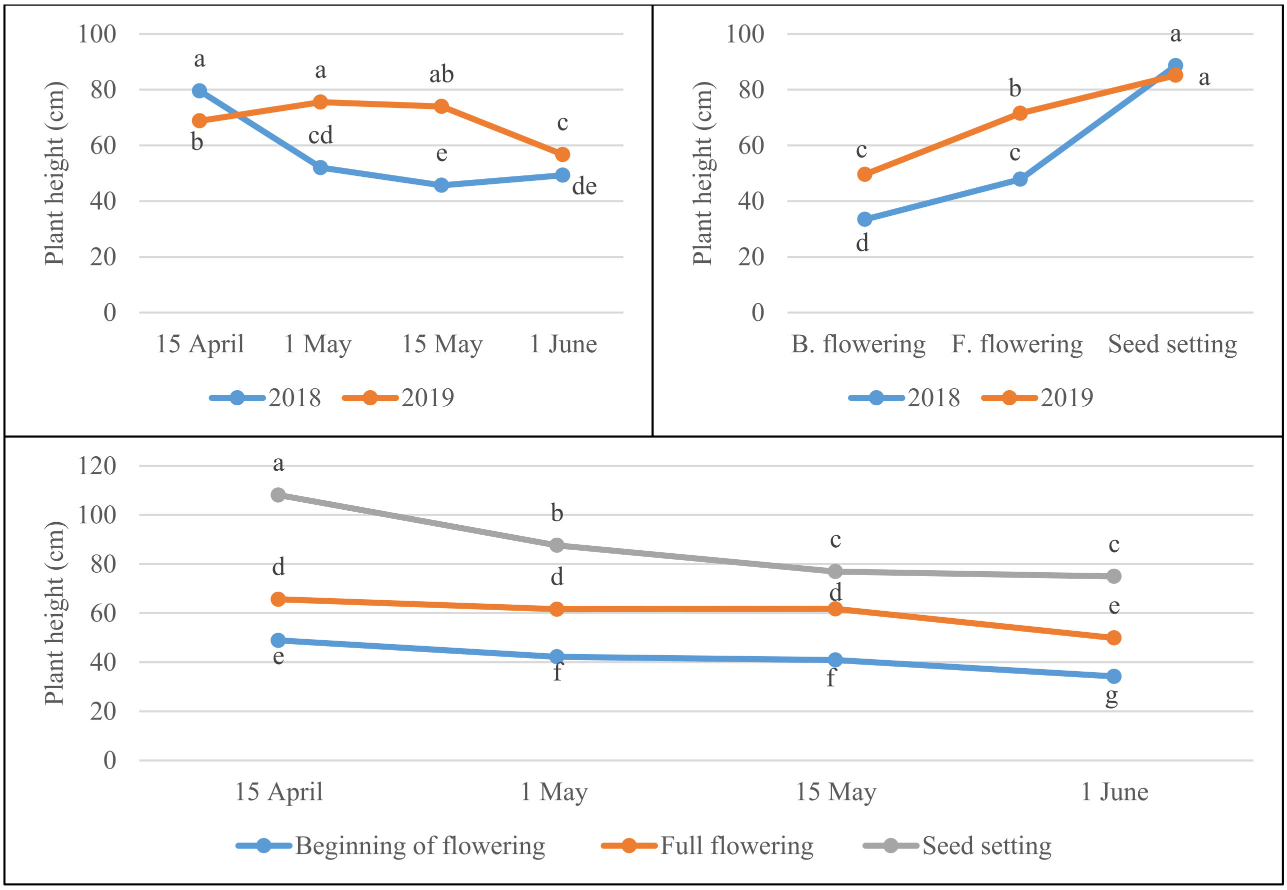


**Figure 1.** Effects of Y x SD, Y x HS and SD x HS on plant height.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

*Dry matter yield (kg ha$^{-1}$)*

At the 1% probability level, the effects of Y, SD, and HS on dry matter yield and binary interactions were statistically significant (Table 3). The maximum dry matter yield (2719 kg ha$^{-1}$) was obtained in 2019. According to SD, the maximum dry matter yield (2798 kg ha$^{-1}$) and the lowest dry matter yield (2050 kg ha$^{-1}$) were obtained from the 1 May and 1 June sowing, respectively (Table 5). Jacobsen and Stolen (1996) stated that low temperatures at SD affected germination negatively and reduced yield and yield characteristics. Yolcu (2018) stated that SD affect the dry matter yield of quinoa significantly, that the plants have the opportunity to develop their vegetative development in longer day conditions in the early sowings compared to the late sowings, and thus the yield is significantly reduced in late sowings. Furthermore, according to Bertero et al. (2000), the quinoa plant produces less leaves when the temperature is high and the day is short. The beginning of the flowering stage produced the least dry matter yield (1015 kg ha$^{-1}$) whereas the seed setting stage produced the greatest dry matter yield (4001 kg ha$^{-1}$) (Table 5). Many researchers have also stated that harvest stages affect dry matter yield in quinoa (Uke et al., 2017; Yolcu, 2020; Yilmaz et al., 2021). In addition, Van Schooten and Pinxterhuis (2003) stated that the dry matter ratio of the quinoa plant shows a significant change depending on the development periods. In terms of Y x SD interaction, the highest dry matter yields (3409 kg ha$^{-1}$ and 3263 kg ha$^{-1}$) were obtained from sowing on 1 May 2019 and 15 May 2019. While the dry matter yields were 2187 kg ha$^{-1}$ and 1866 kg ha$^{-1}$ in sowings made on May 1 and May 15 in 2018, the dry matter yield increased by 56% and 75%, respectively, on the same dates in 2019 (Figure 2). This situation caused the interaction of Y x SD to be important. Y x HS interaction was another important factor affecting the dry matter yield, and the highest dry matter yields were obtained from the harvests made during the seed setting stage in both years, with 4037 kg ha$^{-1}$ and 3965 kg ha$^{-1}$, respectively (Figure 2). The plants seeded on April 15 and May 1 during the seed setting stage had the highest dry matter yields (4555 kg ha$^{-1}$ and 4456 kg ha$^{-1}$) measured in terms of SD x HS (Figure 2). According to Temel and Yolcu (2020), the dry matter yield ranged between 5.3-22.3 t ha$^{-1}$ depending on the SD and HS, however Yilmaz et al. (2021) claimed that it varied between 10.29-13.85 t ha$^{-1}$ depending on the variety and sowing dates. Contrary to these results, Uke (2016) reported that dry matter yield varies between 2048-4319 kg ha$^{-1}$ depending on the harvest periods. Dry matter yield of quinoa varies considerably depending on the ecological conditions and the selected variety.

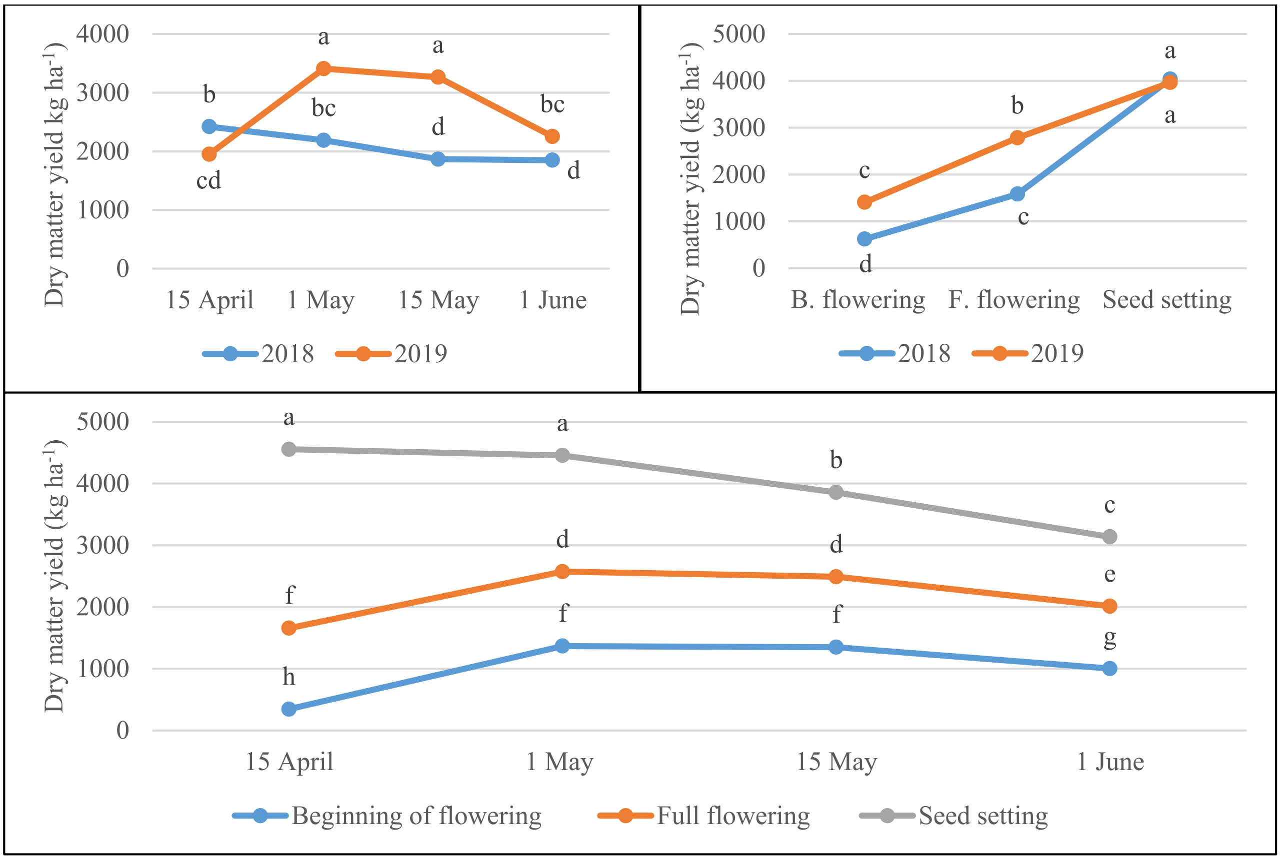


**Figure 2.** Effects of Y x SD, Y x HS and SD x HS on dry matter yield.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

**Table 3.** Variance analysis of PH, DMY, CP, CPY, ADF, NDF and RFV

| Source of variation | df | PH | DMY | CP | CPY | ADF | NDF | RFV |
|---|---|---|---|---|---|---|---|---|
| **Year (Y)** | **1** | ** | ** | ns | ** | ns | ns | ns |
| **Sowing dates (SD)** | **3** | ** | ** | ns | ** | ns | ns | ns |
| **Y X SD** | **3** | ** | ** | * | ** | ns | ns | ns |
| **Harvest stages (HS)** | **2** | ** | ** | ** | ** | ** | ** | ** |
| **Y x HS** | **2** | ** | ** | ** | ns | ** | ns | ns |
| **SD X HS** | **6** | ** | ** | * | ** | ** | ** | ** |
| **Y X SD X HS** | **6** | ** | * | ns | ns | ns | ns | * |

* Significant at p<0.05; ** Significant at p<0.01, ns: Non-significant

PH: Plant height, DMY: Dry matter yield, CP: Crude protein, CPY: Crude protein yield, ADF: Acid detergent fiber, NDF: Nötr detergent fiber, RFV: Relative feed value

*Crude protein (%)*

Crude protein content was affected by HS, Y x SD, Y x HS and SD x HS (Table 3). The highest crude protein content (27.06%) was obtained from begining of flowering stage, whereas the lowest content (18.53%) determined in seed setting stage (Figure 3). Peterson and Murphy (2015) stated that quinoa has an extremely high protein and low fiber content when harvested close to the flowering stage. While Yilmaz et al. (2021) reported that the maximum crude protein content was obtained during the flowering stage, Temel and Yolcu (2020) asserted that the crude protein ratio varied by year and that the highest values were from the harvest done at the end of the vegetative phase. Regarding the Y x SD interaction, the plants sown on 1 June and 15 April in 2019 had the highest crude protein contents (24.95 % and 24.86 %), whereas the plants sown on 1 May in 2019 had the lowest crude protein contents (20.52 %). With the delay of sowing in 2018, the crude protein content initially increased and then showed a decreasing and increasing trend. On the other hand, the opposite situation occurred in 2019. This has caused the interaction of Y x SD to be important (Figure 3). According to Temel and Yolcu (2020), these variations in crude protein concentration may result from different plant heights as determined by Y and SD. Actually, the plant height was longer in the sowing made on May 1 in 2019 compared to the others. In addition, the crude protein content of the plant decreased significantly during this period. This is a predictable outcome because taller plants will have more stems that are cellulose and lignin-rich (Temel and Yolcu, 2020). Y x HS is a strong interaction that affects crude protein content as well. In both trial years, the beginning of flowering produced the highest crude protein contents (27.32 % and 26.81 %), while the harvest in 2018 at the seed setting stage yielded the lowest value (Figure 3). At a 5% level of significance, it was determined that the SD x HS interaction for crude protein content was statistically significant (Table 3). In the SD x HS interaction, the plots that were seeded on April 15 and harvested at the beginning of the flowering stage had the greatest crude protein content. The plots that were seeded on May 15 and harvested at the seed-setting stage yielded the data with the lowest crude protein content (Figure 3). While the changes in crude protein content were similar in begining of flowering and full flowering stages compared to ST, there was a significant decrease in crude protein content in seed setting stage, especially on May 15 SD. Due to this situation, there has been a significant SD x HS interaction.

*Crude protein yield (kg ha $^{-1}$)*

Crude protein yield was affected by Y, SD, HS, Y x SD, SD x HS (Table 3). The year 2019 recorded the greatest crude protein yield (595 kg ha$^{-1}$). In terms of SD, plots seeded on May 1 had the highest production (584 kg ha$^{-1}$), whereas plots sowed on April 15 had the lowest (462 kg ha$^{-1}$) (Table 5). The maximum crude protein yield among HS was recorded during the seed setting stage with 746 kg ha$^{-1}$, while the lowest yield among HS was found at the beginning of flowering (Table 5). Temel and Yolcu (2020) stated that the changes in crude protein yield changed according to the years depending on the harvest stages, but the crude protein yield increased in late harvests. At the 1% level of significance, the Y x SD interaction was revealed to be important for crude protein yield. The plants sown on May 15, 2019, and May 1, 2019 had the highest yields of crude protein, whereas the plants planted on June 1, 2018 and May 15, 2018, produced the lowest yields (Figure 4). While crude protein yield increased by 55% on 1 May 2019 compared to 15 April of the same year, it rose by 0.2% in 2018, indicating the importance of the Y x SD interaction. Low or high crude protein yields may have resulted from variations in dry matter yields and crude protein levels as determined by SD. Due to the fact that crude protein yield is a result of dry matter yield values and crude protein content. According to our findings, the maximum dry matter yields were recorded in the 1 May and 15 May 2019 sowings. (Table 5). Thus, high crude protein yields may be possible. According to Temel and Yolcu (2020), as the SD was delayed, the crude protein yield dramatically dropped, which is consistent with our findings. The plots that were sown on April 15 and May 1 and harvested during the seed setting stage had the highest crude protein yields (926 kg ha$^{-1}$ and 904 kg ha$^{-1}$) according to SD x HS interaction. Plots planted on April 15 and picked at the start of flowering yielded the least crude protein yield (97 kg ha$^{-1}$) (Figure 4). The changes in crude protein yield in begining of flowering and full flowering stages were low and similar depending on the SD. However, this change was very high in the seed setting stage, especially in the 15 April and 1 May sowings. This situation has caused the binary interaction to become important. Plants that were sown on March 25 and collected during the full flowering stage provided the most crude protein, according to Temel and Yolcu (2020).

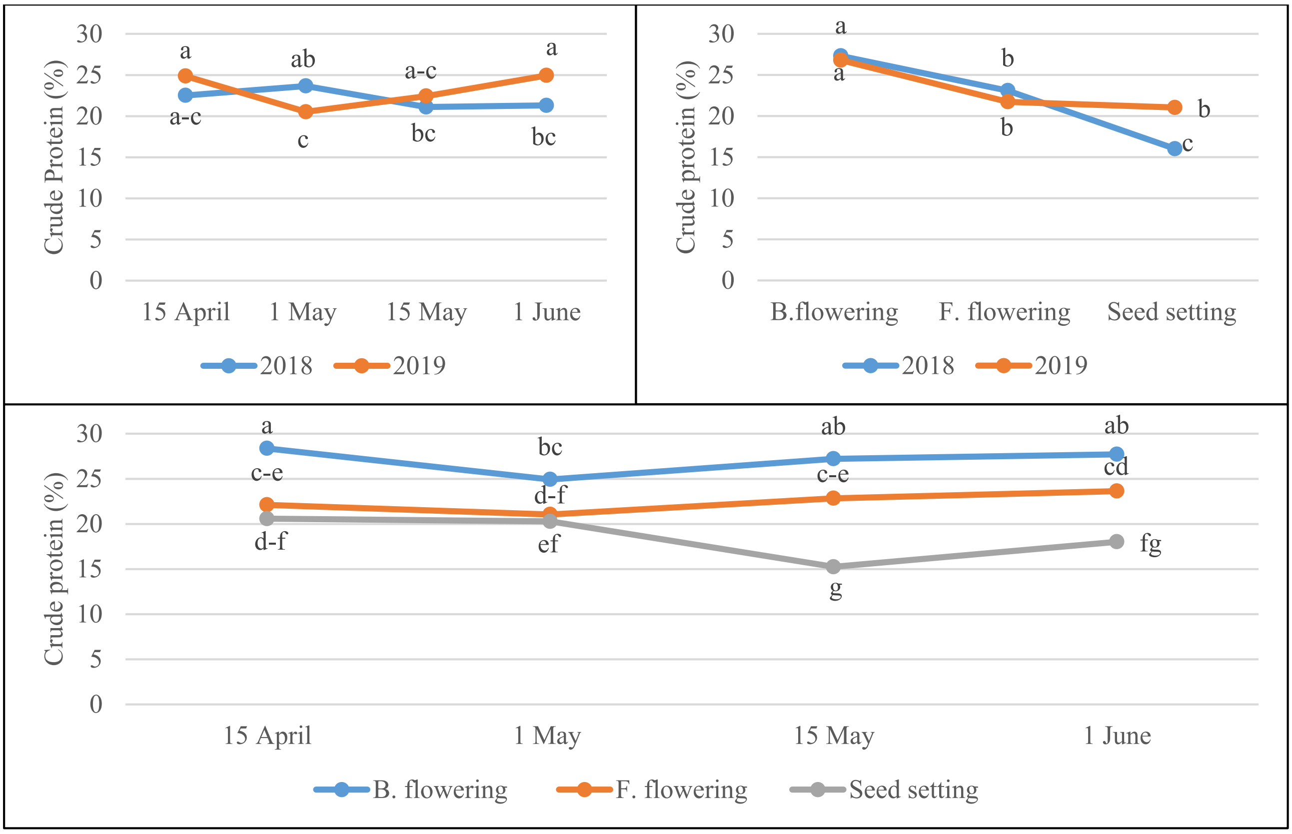


**Figure 3.** Effects of Y x SD, Y x HS and SD x HS on crude protein.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

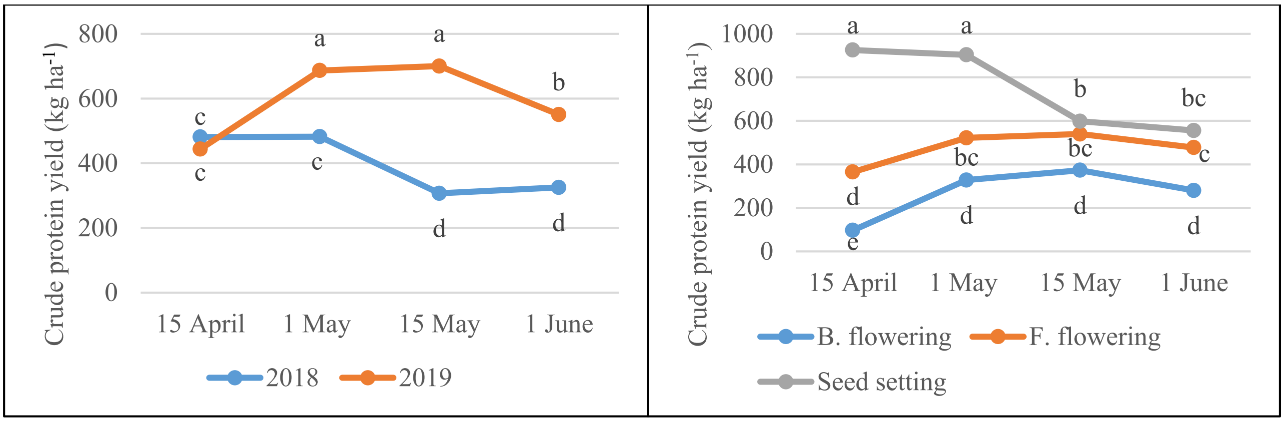


**Figure 4.** Effects of Y x SD and SD x HS on crude protein yield.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

*ADF (%)*

In terms of ADF content, the effect of HS was statically important (Table 3). The seed setting stage had the greatest ADF content (23.73%), whereas the beginning of flowering stage had the minimum (Figure 5). Peiretti et al. (2013) and Uke (2016) stated similar results, but Yilmaz et al. (2021) observed that the highest ADF contents (27.02%) was obtained from flowering stage. The ADF content of several quinoa genotypes varied from 17.5 to 26.8% in anthesis and from 21.8 to 30.6% in grain filling stages, according to Shah et al. (2020). Another significant interaction for ADF content is Y x HS. The maximum ADF content (25.83%) was obtained at the seed setting stage in 2018, while the lowest amounts were found at the beginning of flowering in 2019 and beginning of flowering in 2018. While ADF content rose by 53.02% at the seed setting stage compared to the full flowering stage of the same year, it fell by 11.84% in 2019 and this led to the relevance of the Y x HS interaction (Figure 5). At a 1% level of significance, the SD x HS interaction was determined to be statistically significant for ADF content (Table 3). Plots planted on

April 15 and collected at the seed-setting stage had the greatest ADF content (25.81%), while plots planted on April 15 and harvested at the beginning of flowering had the lowest ADF content. The ADF content of the plants in the sowings made on May 1 increased by 75.51% in the begining of flowering stage compared to the sowings on April 15, while they decreased by 20.72% and 3.33% in the full flowering and seed setting stages, respectively (Figure 5). Contrary to the results we obtained in the research, Temel and Yolcu (2020) stated that the interaction of SD x HS in quinoa did not affect the ADF content.

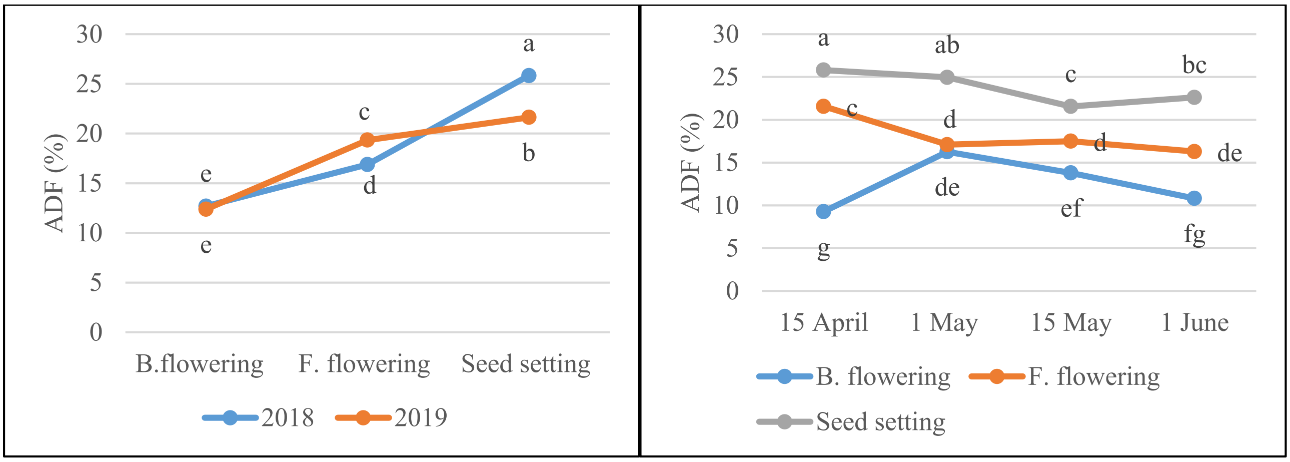


**Figure 5.** Effects of Y x HS and SD x HS on ADF content.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

*NDF (%)*

The effect of HS was statistically significant in term of NDF content (Table 3). The maximum NDF concentration (40.73%) was found in the HS during the seed setting stage, whereas the lowest ADF content (28.96%) was found at the beginning of flowering (Figure 6). These results coincided with the findings of Uke (2016). On the other hand, Temel and Yolcu (2020) and Yilmaz et al. (2021) claimed that harvest stages had no effect on quiona NDF levels. At a 1% level of significance, the SD x HS interaction was revealed to be statistically important for NDF content (Table 3). Plots planted on April 15 and cut at the seed setting stage had the lowest NDF content (22.22%), whereas those planted on April 15 and harvested at the seed setting stage, and planted on June 1 and cut at the seed setting stage, respectively had the highest NDF levels (42.71% and 40.82%) (Figure 6). The NDF content of the plants in the sowings made on May 1 increased by 4.71% in the begining of flowering stage compared to the sowings on April 15, while they decreased by 4.89% and 1.12% in the full flowering and seed setting stages, respectively. Contrary to our research results Temel and Yolcu (2020) stated that the maximum NDF content was taken in the plots seeded in March 15 and cut in the full flowering stage.

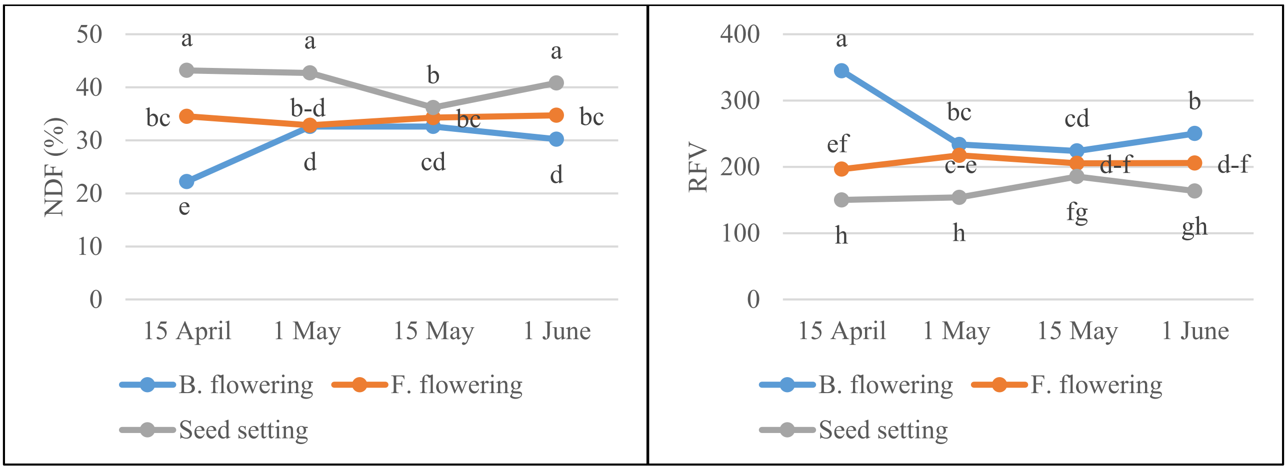


**Figure 6.** Effects of SD x HS on NDF and RFV.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

*RFV*

The effect of HS was statistically significant in term of RFV (Table 3). The greatest RFV among the HS was acquired from begining of flowering with 263.22, whereas the least RFV (163.27) was determined in seed setting stage (Figure 6). Contrary to our research results Temel and Yolcu (2020) and Yılmaz et al. (2021) stated that the RFV of quiona was not affected by HS. At a 1% level of significance, the SD x HS interaction was revealed to be statistically significant for RFV content (Table 3). Plots seeded on April 15 and cut at the beginning of flowering stage had the highest RFV (344.84), whereas the plots planted on April 15 and cut at the seed setting stage had the lowest RFV (150.10) (Figure 6). The RFV in the sowings made on May 1 dreased by 32.22 % in the begining of flowering stage compared to the sowings on April 15, while they decreased by 10.66 % and 2.54 % in the full flowering and seed setting stages, respectively. Contrary to our research results Temel and Yolcu (2020) stated that the RFV of quiona was not affected by SD x HS interaction.

*Some macro and micro element contents*

The effect of Y was statistically significant in term of P, Ca, Fe, Cu and Zn contents of plant (Table 4). The highest P, Cu and Zn contents were taken in 2018 and the highest Ca and Fe contents were taken second year (Table 6). At the 1% probability level, the impact of SD on the K, Fe, and Zn levels was statistically significant (Table 4). The highest K (75.04 g $kg^{-1}$) and Fe (191.55 ppm) was obtained in the plants sown on April 15 and the highest Zn content (32.74 ppm) was taken in the plants sown on June 1 (Table 6). The effect of HS was statistically significant in term of P, K, Fe, Cu and Zn content (Table 4). The highest values were obtained from early harvests and the amount of these elements decreased depending on the maturation of the plants (Table 6). At a 1% level of significance, it was determined that the Y x SD interaction was significant for P content. The highest P content (4.05 g $kg^{-1}$) was founded in the plants sown on April 15, 2019 (Figure 7). According to SD x HS interaction, the highest Fe content was taken from the plants which were planted in April 15 and cut during the begining of flowering stage (Figure 8). At a 1% level of significance, the SD x HS interaction was determined to be statistically significant for the Cu content (Table 4). In the SD x HS interaction, the plants that were sown on June 1 and harvested at the begining of flowering had the highest Cu content (Figure 8). Another significant interaction for P, K, Ca, Na, Fe and Cu contents is Y x HS (Table 4). The highest P (4.62 and 4.11 g $kg^{-1}$), K (82.44 and 82.66 g $kg^{-1}$) and Na (3.7 and 3.73 g $kg^{-1}$) contents were taken at the begining of flowering stage in 2018 and 2019. The highest Ca contents (21.95 and 20.85 g $kg^{-1}$) were taken at the full flowering and seed setting stage in 2019. The highest Fe content (199.97 ppm) was taken at the begining of flowering stage in 2019. The highest Cu content (7.69 ppm) was taken at the full flowering stage in 2018 ((Figure 9 and Figure 10).

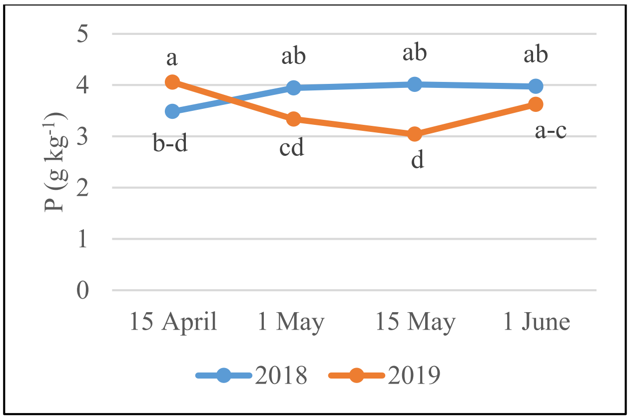


**Figure 7.** Effects of Y x SD on P content.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

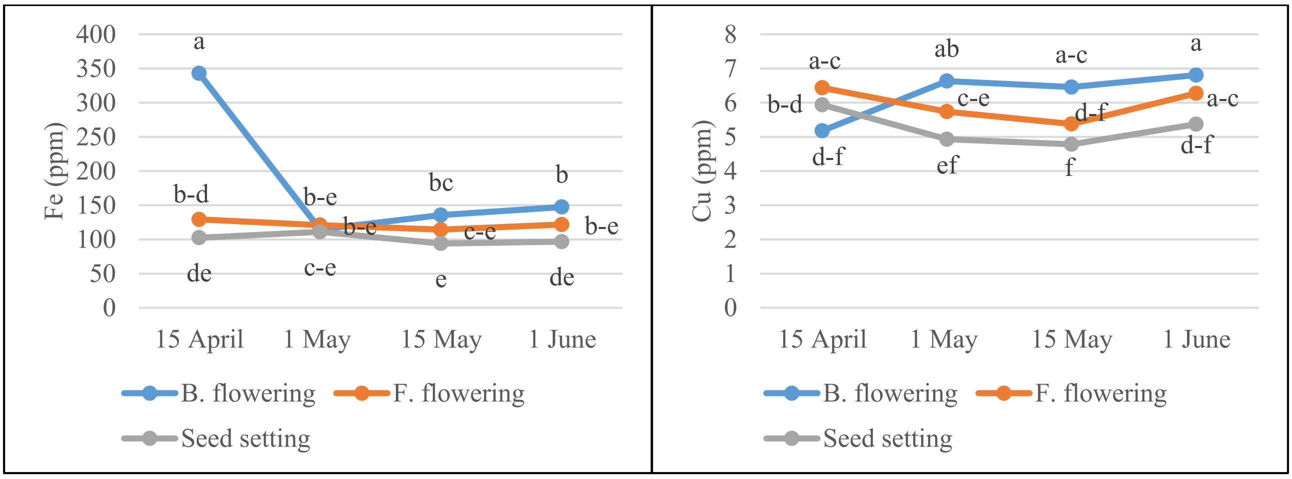


**Figure 8.** Effects of SD x HS on Fe and Cu contents.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

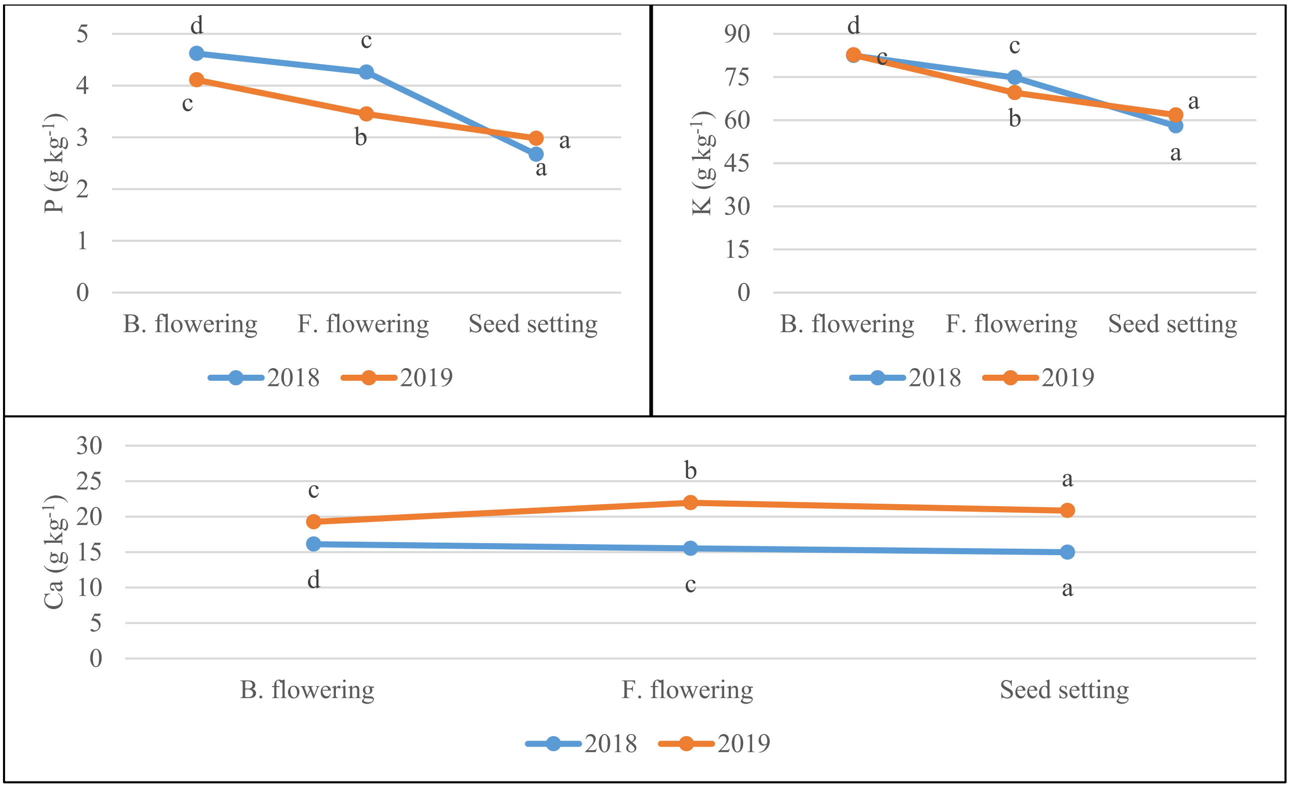


**Figure 9.** Effects of Y x HS on P, K and Ca contents.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

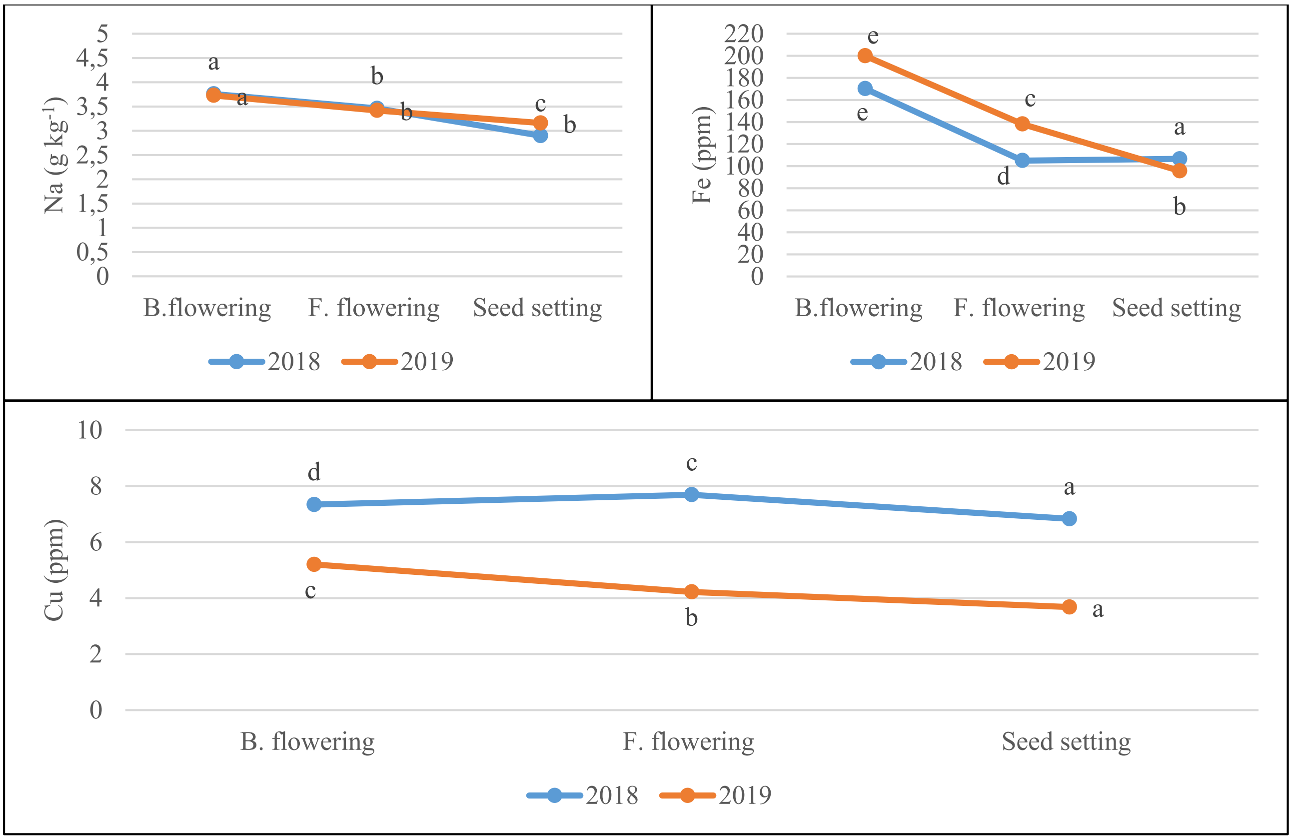


**Figure 10.** Effects of Y x HS on Na, Fe and Cu contents.
For P 0.05, the LSD test indicates that values with the same letters are not significant.

**Table 4.** Variance analysis of some macro and micro elements

| Source of variation | df | P | K | Ca | Na | Fe | Cu | Zn |
|---|---|---|---|---|---|---|---|---|
| **Year (Y)** | **1** | * | ns | ** | ns | * | ** | ** |
| **Sowing dates (SD)** | **3** | ns | ** | ns | ns | ** | ns | ** |
| **Y X SD** | **3** | ** | ns | ns | ns | ns | ns | ns |
| **Harvest stages (HS)** | **2** | ** | ** | ns | ** | ** | ** | ** |
| **Y x HS** | **2** | * | * | * | ** | * | ** | ns |
| **SD X HS** | **6** | ns | ns | ns | ns | ** | ** | ns |
| **Y X SD X HS** | **6** | ns | ns | ** | ** | * | ns | ns |

* Significant at p<0.05; ** Significant at p<0.01, ns: Non-significant

**Table 5.** Plant height, dry matter yield, crude protein, crude protein yield, ADF, NDF and RFV of quinoa as affected by SD and HS as means of two years

| SD | Plant height (cm) | Dry matter yield (kg ha$^{-1}$) | Crude Protein (%) | Crude protein yield (kg ha$^{-1}$) | ADF (%) | NDF (%) | RFV |
|---|---|---|---|---|---|---|---|
| 15 April | 74 a | 2186 c | 23.69 | 462 c | 18.88 | 33.31 | 230.46 |
| 1 May | 64 b | 2798 a | 22.09 | 584 a | 19.44 | 35.45 | 201.68 |
| 15 May | 60 b | 2565 b | 21.77 | 504 b | 17.62 | 34.36 | 204.94 |
| 1 June | 53 c | 2050 c | 23.13 | 438 c | 16.57 | 35.25 | 206.57 |
| HS | | | | | | | |
| Beginning of flowering | 42 c | 1015 c | 27.06 | 269 c | 12.54 | 28.96 c | 263.22 a |
| Full flowering | 60 b | 2183 b | 22.41 | 476 b | 18.11 | 34.09 b | 206.26 b |
| Seed setting | 87 a | 4001 a | 18.53 | 746 a | 23.73 | 40.73 a | 163.27 c |
| Y | | | | | | | |
| 2018 | 57 b | 2080 b | 22.15 | 399 b | 18.47 | 35.42 | 206.75 |
| 2019 | 69 a | 2719 a | 23.19 | 595 a | 17.79 | 33.77 | 215.08 |

Means followed by the same letters are not different for P ≤ 0.05 according to LSD test.

**Table 6.** P, K, Ca, Na, Fe, Cu and Zn contents of quinoa as affected by SD and HS as means of two years

| SD | P (g kg$^{-1}$) | K (g kg$^{-1}$) | Ca (g kg$^{-1}$) | Na (g kg$^{-1}$) | Fe (ppm) | Cu (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|
| 15 April | 3.77 | 75.04 a | 17.70 | 3.46 | 191.55 a | 5.85 | 30.23 b |
| 1 May | 3.64 | 72.05 ab | 18.13 | 3.40 | 115.58 b | 5.77 | 28.82 b |
| 15 May | 3.53 | 68.54 c | 17.73 | 3.40 | 114.67 b | 5.54 | 28.07 b |
| 1 June | 3.80 | 70.49 bc | 18.89 | 3.36 | 122.03 b | 6.15 | 32.74 a |
| HS | | | | | | | |
| Beginning of flowering | 4.36 a | 82.55 a | 17.69 | 3.75 | 185.12 a | 6.27 a | 34.16 a |
| Full flowering | 3.86 b | 72.18 b | 18.74 | 3.44 | 121.61 b | 5.96 a | 30.84 b |
| Seed setting | 2.83 c | 59.86 c | 17.92 | 3.03 | 101.13 c | 5.26 b | 24.90 c |
| Y | | | | | | | |
| 2018 | 3.85 a | 71.74 | 15.54 b | 3.37 | 127.30 b | 7.29 a | 33.54 a |
| 2019 | 3.51 b | 71.33 | 20.69 a | 3.44 | 144.61 a | 4.36 b | 26.39 b |

Means followed by the same letters are not different for P ≤ 0.05 according to LSD test.

## CONCLUSION

The two-year average results showed that sowing dates and harvest stage had a substantial impact on quinoa forage yield and quality. In the experiment, the highest hay yield (2797.95 kg ha$^{-1}$) and crude protein yield (584.40 kg ha$^{-1}$) were obtained from sowing on 1 May. In terms of harvest stages, the seed setting stage stood out due to high forage and crude protein yield. As a result, for forage production in the region, sowing should be done in the beginning of May, and harvesting should be delayed until later in the season. In addition, it would be useful to conduct additional studies on the digestion rate of the material obtained during this harvest stage. Due to its resistance to salty conditions, this plant can be given priority in conditions where other forage plants (vetch, maize etc.) cannot be grown.


## ACKNOWLEDGEMENTS

Scientific Research Projects Coordination Unit of Bursa Uludag University (BUU-BAP) provided funding for the investigation. We are really grateful that the BAP council has supported this project (No: OUAP(Z) - 2018/6).


## LITERATURE CITED


AOAC International. 1997. Official methods of analysis of AOAC international, 16th ed., 3rd rev. Method 955.04. The Association, Gaithersburg, MD.

Bazile, D., D. Bertero and C. Nieto. 2015. State of the art report on kinoa around the world in 2013, Oficina Regional De La Fao Para América Latina Y El Caribe, 250-266

Bertero, H.D., R.W. Kingand and A.J. Hall. 2000. Photoperiod and temperature effects on the rate of leaf appearance in quinoa (*Chenopodium quinoa*). Australian Journal of Plant Physiology 27: 349–356.

Bhargava, A., S. Shukla and D. Ohri. 2007. Genetic variability and interrelationship among various morphological and quality traits in quinoa (*Chenopodium quinoa* Willd.). Field Crops Research 101: 104-116.

FAO 1994. Plant production and protection series. In J. E. Hernandez and J. Leon (Eds.), Neglected Crops 1492 from a Different Perspective. No. 26, Available at http://www.fao.org/docrep/T0646E/T0646E00.htm (Access date: March 01, 2021).

Fernando, S.V., S.V. Edmar, G.B. Marcelo and S. Lucas. 2012. Development and productivity of quinoa sown on different dates during off-season. Rev Cienc Agron. 43: 510-515.

Geren, H., 2015. Effects of different nitrogen levels on the grain yield and some yield components of quinoa (*Chenopodium quinoa* Willd.) under Mediterranean climatic conditions. Turkish Journal of Field Crops 20(1): 59–64.

Hirich, A., R. Choukr-Allah and S.E. Jacobsen. 2014. Quinoa in morocco–effect of sowing dates on development and yield. Journal of Agronomy and Crop Science 200: 371-377.

Iliadis, C., T. Karyotis, S.E. Jacobsen. 1999. Effect of sowing date on seed quality and yield of quinoa (*Chenopodium quinoa*) in Greece, in crop development for the cool and wet regions of Europe. Workshop on Alternative Crops for Sustainable Agriculture of the COST Action 814, BioCity, Turku, Finland, 226-231.

Jacobsen, S.E. and O. Stolen. 1996. Temperature and light requirements for the germination of quinoa (*Chenopodium quinoa*). COST 814, February 1996, Workshop held in Copenhagen, Denmark. European Commission, pp.87-102.

Kacar, B. 2014. Soil analysis, Nobel Academic Publications (3rd Edition).

Kakabouki, I., D. Bilalis, A. Karkanis, G. Zervas, E. Tsiplakou, D. Hela. 2014. Effects of fertilization and tillage system on growth and crude protein content of quinoa (*Chenopodium quinoa* Willd.): An alternative forage crop. Emir. J. Food Agric. 2014. 26(1): 18–24.

Kaoutar, F., H. Abdelaziz, B. Ouafae, C. Redouane, R. Ragab. 2017. Yield and dry matter simulation using the saltmed model for five quinoa (*Chenopodium quinoa*) accessions under deficit irrigation in South Morocco. Irrigation and Drainage, http:// onlinelibrary. wiley.com/doi/10.1002/ird.2116/epdf

Muftuoglu, M., Y. Cikili and C. Turkmen. 2014. Soil and plant fertility analysis, Nobel Academic Publishing, p. 236.

Oktem, A., A.G. Oktem and O.F. Birden. 2021. Impact of sowing dates on forage value of quinoa (*Chenopodium quinoa* Willd.) under semi-arid conditions. International Journal of Innovative Approaches in Agricultural Research 5 (2): 172-183.

Peiretti, P.G., F. Gai and S. Tassone. 2013. Fatty acid profile and nutritive value of quinoa (*Chenopodium quinoa* Willd.) seeds and plants at different growth stages. Animal Feed Science and Technology 183: 56-61.

Peterson, A.J. and K.M. Murphy. 2015. Quinoa cultivation for temperate North America: considerations and areas for investigation. quinoa: Improvement and Sustainable Production, First Edition. Edited by Kevin Murphy and Janet Matanguihan, pp.173-192.

Ramesh, K. 2016. Evaluation of quinoa (*Chenopodium quinoa* Willd.) at different dates of sowing and varied crop geometry in semi-arid regions of Telangana. College of Agrıculture Rajendranagar, Hyderabad-500 030 Professor Jayashankar Telangana State Agricultural University. Master of Science in Agriculture.

Shah, S.S., L. Shi, Z. Li, G. Ren, B. Zhou and P. Qin. 2020. Yield, agronomic and forage quality traits of different quinoa (*Chenopodium quinoa* Willd.) genotypes in Northeast China. Agronomy 10: 1908.

Tan, M. and S. Temel. 2017. Determination of dry matter yield and some properties of different quinoa genotypes grown in Erzurum and Iğdır conditions. Iğdır Univ. J. Inst. Sci. & Tech. 7(4): 257-263.

Tan, M. and S. Temel. 2018. Performance of some quinoa (*Chenopodium quinoa* Willd.) genotypes grown in different climate conditions. Turkish Journal of Field Crops 23(2): 180-186.

Tan, M. and S. Temel. 2020. Determination of roughage production of different quinoa (*Chenopodium quinoa* Willd.) varieties in dry conditions of Eastern Anatolia. International Journal of Agriculture and Wildlife Science (IJAWS) 6(3): 554-561.

Tan, M. and Yondem, Z. 2013. A New Crop for Human and Animal Nutrition: Quinoa (*Chenopodium quinoa* Willd). Alinteri 25:62–66.

Tan, M. and S. Temel. 2019. Quinoa in Every Aspect: Importance, Use and Cultivation. Ankara, Turkey: IKSAD Publishing House.

Temel, I. and B. Keskin. 2019. The effects of different row spacing and intra-row spacing on hay yield and some yield components of quinoa (*Chenopodium quinoa* Willd.). Journal of the Institute of Science and Technology 9(1): 522-532.

Temel, S. and S. Yolcu. 2020. The effect of different sowing time and harvesting stages on the herbage yield and quality of quinoa (*Chenopodium quinoa* Willd.). Turkish Journal of Field Crops 25(1):41-49.

Temel, S. and N. Surgun. 2019. The effect of different nitrogen and phosphorus doses on hay yield and quality of quinoa. Journal of the Institute of Science and Technology 9(3): 1785-1796.

Temel, S. and S. Yolcu. 2020. The effect of different sowing time and harvesting stages on the herbage yield and quality of quinoa (*Chenopodium quinoa* Willd.). Turkish Journal of Field Crops 25(1):41-49.

Uke, O., H. Kale, M. Kaplan, A. Kamalak. 2017. Effects of maturity stages on hay yield and quality, gas and methane production of quinoa (*Chenopodium quinoa* Willd.). KSU J. Nat. Sci. 20(1): 42-46.

Uke, O. 2016. Effects of harvest times on herbage yield and quality of quinoa and teff plants. Erciyes University Institute of Natural and Applied Sciences Graduate Thesis, Kayseri.

Van Dyke, N.J. and P. M. Anderson. 2000. Interpreting a forage analysis. Alabama cooperative extension. Circular ANR-890.

Van Schooten, H.A. and J.B. Pinxterhuis. 2003. Quinoa as an alternative forage crop in organic dairy farming. Optimal Forage Systems for Animal Production and the Environment Grassland Science in Europe, 26-28 May 2003, Pleven, Bulgaria, 8: 445–448.

Van Soest, P.J., J.B. Robertson and B.A. Lewis. 1991. Method for dietary fiber, neutral detergent fiber, and nostarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.

Yilmaz, S., I. Ertekin and I. Atis, 2021. Forage yield and quality of quinoa (*Chenopodium quinoa* Willd.) genotypes harvested at different cutting stages under mediterranean conditions. Turk J Field Crops 26(2): 202-209.

Yolcu, S. 2018. Determination of sowing and harvest times on hay yield and quality of quinoa (*Chenopodium quinoa* Willd.) plant grown under irrigated conditions in Igdır. Igdır University Institute of Natural and Applied Sciences Graduate Thesis, Igdır.