Turk J
Field Crops
2022, 27(1), 78-86
DOI: 10.17557/tjfc.1071283

THE EFFECTS OF DIFFERENT SOWING TIMES AND HARVEST STAGES ON FORAGE YIELD AND QUALITY IN BUCKWHEAT (*Fagopyrum esculentum* Moench)

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

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

Received: 10.02.2022

ABSTRACT

This study was carried out to determine the effects of different sowing times and harvest stages on the yield and forage quality of buckwheat in Marmara's conditions. The experiment was conducted in 2018 and 2019 in Bursa Uludag University Agricultural Application and Research Area using the Gunes variety as plant material. The experiment arranged randomized complete block design with split plot arrangement having three replications. Four different sowing times (15 April, 1 May, 15 May and 1 June) and three different harvest stages (flowering, milky and dough) were considered in the main plot and sub-plot, respectively. Results showed that higher plant height and dry matter yield values were obtained from plants sown on 15 April and harvested during the milky or dough stages. The highest crude protein ratio, crude protein yield and relative feed value, and the lowest acid detergent fiber and neutral detergent fiber values were determined in plants that were sown early and harvested during flowering stage. In general, delaying the harvest stage increased the yield of buckwheat but negatively affected the forage quality.

Keywords: Buckwheat, dry matter yield, harvest stage, quality, sowing time

INTRODUCTION

Buckwheat production worldwide is estimated to be at 3.8 million tons, with the majority of this production occurring on the Asian continent (Bicer, 2019). China, Russia, Ukraine and Kazakhstan are among the countries where the buckwheat plant is grown the most (Er, 2018). Although buckwheat is a very new plant for our country, it has many uses. Particularly due to the plant's rapid vegetative growth and high dry matter yield, it has been considered as an alternative roughage source in recent years (Amelchanka et al., 2010; Kalber et al., 2012). This plant has recently been used into ruminant rations in a variety of forms, including fresh, silage, and grain (Amelchanka et al., 2010; Keles et al., 2017). Kara and Yuksel (2014) reported that the feed quality of buckwheat is poorer than alfalfa and sainfoin, but is comparable to that of corn, sorghum, sunflower and triticale. While buckwheat harvested during the early flowering period (5-6 weeks) contains a 15-20% crude protein content, this value may decrease to as little as 9% depending on maturation (Björkman and Chase, 2017).

Turkey's agricultural-ecological structure is suitable to successfully growing a variety of forage plants that can meet the demand for high-quality roughage. Buckwheat is one of the most important species among the alternative plants that could be produced in Turkey to increase the amount of high-quality roughage. It can reach milky stage in a short time due to its rapid growth. Therefore, it is possible to grow buckwheat as roughage in early spring and autumn in locations with a Mediterranean climate where the fields were previously uncultivated (Yavuz, 2014; Er, 2018).

Determining the appropriate sowing date to achieve high yield and quality is a critical factor for not only buckwheat, but for all plants. The climatic factors of the region should be considered while determining the optimal sowing date for buckwheat because buckwheat is a sensitive plant that is susceptible to both frost and high temperatures during flowering (Kaya, 2018). Harvesting is an important stage that affects yield and quality of buckwheat to be used as roughage. It has been determined that buckwheat grass harvested at 100% flowering period yields more but has a lower quality compared to the that harvested at 50% flowering period (Surmen and Kara, 2017). Keles et al. (2012) reported a 5501-5900 kg ha^{-1} dry matter yield for buckwheat grown in Konya's conditions and harvested at the milky stage. Kara (2014) determined that 8530 kg ha^{-1} dry matter yield was obtained from the harvest collected during the stage when the grains had turned 50% brown, but the harvest was more suitable in terms of forage quality and economy during full flowering. Gullap et al. (2021) reported that the highest dry matter yield (4784 kg ha^{-1}) was recorded when the buckwheat was harvested at the full flowering stage.

This study was conducted to determine the optimal sowing time and harvesting stage for buckwheat grown under the ecological conditions of Bursa for high forage yield and quality.

MATERIALS AND METHODS

Experimental materials

The research was conducted in 2018 and 2019 in the experimental area of Bursa Uludag University's Faculty of Agriculture Agricultural Application and Research Center (40° 11ˈ N, 29° 04ˈ E). Gunes cultivar, which was developed by Bahri Dagdas International Agricultural Research Institute, was employed as plant material in the research. The Bahri Dagdas International Agricultural Research Institute registered the Gunes variety as the first buckwheat variety in Turkey in 2014. Although is highly adaptable to all regions of Turkey, the variety demands for a humid and cool climate with low temperature for optimal yield. This variety has a short vegetation period (8-14 weeks), white flowers, and an average height range of 85-100 cm (Anonymous, 2014).

Bursa province generally has a temperate climate, although both the mild and warm climate of the Sea of Marmara in the north and the harsh climate of Uludag in the south are occasionally encountered. The hottest months are July-August, while the coldest are December-January in the province (Anonymous, 2020). The monthly total precipitation (mm), mean temperature (°C), relative humidity (%) values of 2018, 2019, and the long period (1975-2014) are given in Table 1. When the six months (April-September) of Bursa Province's long-term average data are examined, it is seen that the total precipitation amount is 218.2 mm, the average temperature is 20.4 °C, and the relative humidity is 60.5%. While the total precipitation in May and June 2018 (the time of the experiment) was higher than in 2019, the total precipitation in August 2019 was much higher than the average of both 2018 and many other years. When the temperature values for the 6 months are examined, it was seen that the average temperature for the years during which the experiment was conducted was similar to the average of many years. Some soil properties of the experimental region from 0 to 20 cm depth are given in Table 2. The findings of the soil analysis were compared to the reference values (Muftuoglu et al., 2014).

Table 1. Precipitation, mean temperature and relative humidity in 2018, 2019 and long-term in Bursa

	Mean temperature (°C)			Precipitation (mm)			Relative Humidity (%)		
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

LT: Long-term (1975-2014).

Table 2. Properties of the experimental area soils in 2018 and 2019.

	2018		2019	
Properties	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
Total nitrogen (N), %	0.098	Medium	0.195	High
Available phosphorus (P), mg kg^{-1}	21.15	Sufficient	28.78	High
Available potassium (K), g kg^{-1}	0.632	Very high	0.589	Very high
DTPA- iron (Fe) mg kg^{-1}	13.63	High	12.77	High
DTPA- copper (Cu), mg kg^{-1}	4.95	Sufficient	5.46	Sufficient
DTPA- zinc (Zn), mg kg^{-1}	1.71	Sufficient	1.56	Sufficient
DTPA- manganese (Mn), mg kg^{-1}	66.25	High	53.91	High

Experimental design

The experimental design was the Randomized Complete Blocks with three replications arranged in Split Plots. Sowing times (15 April, 1 May, 15 May and 1 June) were placed into the main plots and the harvest stages (flowering, milky and dough) into the subplots. The harvest times made depending on the sowing times and harvest periods in 2018 and 2019 are given in Table 3. Row spacing was set at 25 cm, the sowing rate was 80 kg ha^{-1} and sowing depth was 3-4 cm. In the experiment, the size of the plots were 7.5 m^2 (5 m x 1.5 m) and 6 rows were sown manually in each plot. Fertilizers were added as such: 60 kg N ha^{-1} and 60 kg $P_2 0_5$ ha^{-1} at sowing date. Ammonium sulfate (21%N) was used as a nitrogen fertilizer source and Triple Super Phosphate (TSP-44% P) was employed as a phosphorus source. Following sowing, a roller was rolled through the experiment area and drip irrigation was utilized to ensure germination and emergence of the seeds. After emergence, drip irrigation was applied at the beginning of flowering, during the intensive flowering stage, and during the milk and dough stages. Weeds were manually removed through hand hoeing.

Table 3. Harvest times of buckwheat in 2018 and 2019.

Sowing time	2018			2019		
	Harvest stage			Harvest stage		
	Flowering	Milk	Dough	Flowering	Milk	Dough
15 April	29 May	12 June	19 June	23 May	10 June	17 June
1 May	4 June	19 June	25 June	10 June	18 June	25 June
15 May	19 June	4 July	22 July	18 June	2 July	19 July
1 June	9 July	22 July	10 August	5 July	23 July	6 August

Measurements, harvest, and analyses

The average plant height was determined by measuring 10 randomly selected plants from the soil level to the tip of the plant. The leaves of these plants were then plucked and dried separately, and the percentage of leaves per plant was calculated by proportioning the leaves to the total plant weight. The plants were harvested from ground level using a sickle in the middle two rows of the plots after removing 0.5 m from both edges of the rows (2 rows x 0.25 m x 4 m=2 m^2). The samples were dried at 70 °C for 48 hours and weighed to calculate dry matter yield and the dry samples were grounded in preparation for analysis. The Kjeldahl method was used to determine the nitrogen (N) content, and the crude protein content was calculated using the formula N x 6.25 (AOAC, 1997). The amount of neutral detergent fiber (NDF) and acid detergent fiber (ADF), which form the cell walls in the ground samples, was determined according to the method described by Van Soest et al. (1991). The relative feed value (RFV) was determined using the equations developed by Van Dyke and Anderson (2000). To begin calculating the relative feed value, dry matter digestion (DMD %) is calculated from the ADF value (DMD % = 88.9 - (0.779 x % ADF)). Depending on the live weight of the animal, dry matter consumption (% DMI) is calculated from the NDF value (DMI % = 120 / NDF). Finally, DMD % and DMI % values are incorporated into the formula to calculate the RFV.

RFV = DMD % × DMI x 0.775

All data were subjected to analysis of variance using the JUMP-7 package program in accordance with the 'Randomized Complete Blocks Design'. The significance tests employed probability levels of 1% and 5%, 5% probability levels were used in the determination of different groups, and the LSD test was used to determine distinct groups.

RESULTS AND DISCUSSION

The data obtained in this study on the effects of different sowing times and harvest stages on the forage yield and quality of buckwheat were subjected to analysis of variance. First order (two-way) and second order (three-way) interactions were significant for the analyzed traits (Table 4). Therefore, the following tables were arranged considering these significant interaction components.

Table 4. The results of analysis of variance combined over two years.

Source of Variation	df	PH	SD	LR	DMY	CP	CPY	ADF	NDF	RFV
Year	**1**	**	**	**	ns	**	**	ns	ns	ns
Sowing time (ST)	**3**	**	**	**	**	**	**	ns	*	*
Y X ST	**3**	**	**	**	**	ns	ns	ns	*	*
Harvest stage (HS)	**2**	**	ns	**	**	**	ns	**	**	**
Y x HS	**2**	**	ns	**	ns	ns	ns	*	ns	*
ST X HS	**6**	**	ns	**	*	**	**	ns	ns	
Y X ST X HS	**6**	ns	*	**	**	ns	ns	**	*	**

PH: Plant height, SD: Stem diameter, LR: Leaf rate, DMY: Dry matter yield, CP: Crude Protein, CPY: Crude protein yield, ADF: Acid detergent insoluble fiber, NDF: Neutral detergent insoluble fiber, RFV: Relative feed value
* Significant at $p<0.05$; ** Significant at $p<0.01$, ns: Non-significant

Plant height

The effects of the interactions year x sowing time, year x harvest stage, and sowing time x harvest stage on plant height were significant (P≤ 0.01). The greatest plant height (78.42 cm) was observed in a plant sown on 1 May 2019. This value was followed by one sown on 15 April (77.53 cm) which was statistically in the same group as the plant with the highest height. The lowest value of plant height (41.49 cm) was found for the plant sown on 1 June 2018 (Table 5). Kaya (2018) reported that plant height gradually decreased with the delay of sowing time in buckwheat, and that the height of plants sown on May 21 decreased by approximately 26% compared to those sown on April 20 in their study. Similarly, Gunes et al. (2012) and Acar (2019) also reported that plant height in buckwheat was influenced by sowing time and shortened as the sowing time was delayed. This may be the result of an increase in temperature and light intensity with later sowings as Jung et al. (2015) reported that the growth and yield of buckwheat were closely related to temperature, precipitation, and sunshine duration. In the study, while the plant height decreased by 42.80% from the first to the last sowing time in 2018, it decreased by 13.88% during the same period in 2019, making the interaction of year x sowing time a significant factor (Table 4 and Table 5). In terms of harvest stages, the greatest plant height (86.24 cm) was measured during the dough stage in 2019, and the lowest plant height (64.68 cm) during the dough stage in 2018 (Table 5). A rapid increase in height generally continues up until the flowering stage in plants. In plants with simultaneous flowering, height growth stops with flowering. However, in species that continue to grow after flowering, such as buckwheat, growth continues (Gullap et al., 2021). Polat (2019) reported that the greatest plant height was 89.79 cm with a 75% seed setting period under Konya's ecological conditions. When the interaction of sowing time x harvest stage is examined, the greatest plant height of 87.32 cm was obtained from plants sown on 1 May and harvested during the dough stage. This was followed by plants sown on 15 April and harvested during the dough stage, which were statistically in a similar group (Table 6).

Table 5. The means of plant height measured at different sowing times and harvest stages in the field trial run with significant year x sowing times and year x harvest stage interaction.

Sowing times	Year		Harvest stage	Year	
	2018	2019		2018	2019
15 April	72.54 b	77.53 a	Flowering	49.90 e	57.58 d
1 May	71.94 b	78.42 a	Milk	64.82 c	79.16 b
15 May	53.22 d	74.58 ab	Dough	64.68 c	86.24 a
1 June	41.49 e	66.77 c			

**: significant at P ≤ 0.01. Means followed by the same letters are not different for P ≤ 0.05 according to LSD test.

Table 6. The means of plant height measured at different sowing times and harvest stages in the field trial run with significant sowing time x harvest stage interaction.

	Harvest stage		
Sowing time	Flowering	Milk	Dough
15 April	53.99 e	84.39 a	86.74 a
1 May	60.38 d	77.84 b	87.32 a
15 May	57.72 de	66.27 c	67.70 c
1 June	42.87 f	59.44 d	60.08 d

**: significant at P ≤ 0.01. Means followed by the same letters are not different for P ≤ 0.05 according to LSD test.

Stem diameter

The stem diameter was significantly affected by the combination and interaction of the year x sowing time x harvest stage (P≤ 0.05). The highest stem diameter of 5.21 mm obtained from plants sown on 15 April 2018 and harvested during the milk stage. On the other hand, the lowest stem diameters (3.79 mm and 3.84 mm) were obtained from plants sown on 1 June 2018 and harvested during the dough stage, and on 1 June 2018 and harvested during the flowering stage (Table 7). In the same harvest stage of 2018, there was a bigger difference between stem diameter development than in 2019, depending on the sowing times. In 2018, stem diameter decreased by 27 % from the first to the last sowing time in the dough stage, depending on the sowing times, but this decrease was only by 6 % in 2019. In this case, the interaction of year x sowing time x harvest stage was significant. Contrary to our study's results, Karatas et al. (2020) reported that sowing times had no effect on the stem diameter.

Leaf rate

The effects of the interactions year x sowing times x harvest stage interaction on the leaf rate were found to be significant (P≤ 0.01). The highest leaf rate (48.30%) was determined in plants sown on 1 June in 2018 and harvested during the flowering stage, while the lowest leaf rate (18.13%) was determined in plants sown on 15 April in 2019 and harvested during the dough stage. In all other sowing occasions in the study except for the 15 May sowing in 2018, the leaf rate decreased gradually due to the progress of the harvest stage. Contrary to our study's results, Gullap et al. (2021) reported that the leaf ratio of buckwheat increased depending on the delaying of harvest stage. On the other hand, Alkay and Kokten (2020) reported that the leaf rate of buckwheat gradually decreased as a result of later sowing, and therefore the highest leaf rate (15.91%) was obtained by sowing on April 25. In our study, the rate of leaves detected at the milky stage was 30.62% was higher than that reported by Keles et al. (2012). This may be related to the difference of genotypes, as well as ecological factors and different cultural practices. In the first year of the experiment, while the leaf rate was 36.36% at the first sowing time during the flowering stage, it was 48.30% at the last sowing time. In 2019, the leaf rate decreased by about 4% in the same stages, and in this case, the interaction of year x sowing time x harvesting stage was significant (Table 7).

Table 7. The means of stem diameter and leaf rate measured at different sowing times and harvest stages in the field trial run with significant year x sowing times x harvest stage interaction.

Years	Sowing times	Stem diameter (mm)			Leaf rate (%)		
		Harvest stage			Harvest stage		
		Flowering	Milk	Dough	Flowering	Milk	Dough
2018	15 April	4.67 e-h	5.21 a	5.19 ab	36.36 e	21.80 kl	19.80 lm
	1 May	5.19 ab	4.88 b-f	5.13 a-d	39.61 cd	25.61 ıj	23.84 jk
	15 May	4.34 ıj	4.47 g-ı	4.28 ıj	31.49 f	30.51 fg	36.58 e
	1 June	3.84 k	4.02 jk	3.79 k	48.30 a	44.54 b	28.21 gh
2019	15 April	4.96 a-e	4.93 a-e	5.14 a-c	42.07 bc	20.00 lm	18.13 m
	1 May	4.75 e-g	4.79 ef	4.83 d-f	30.49 fg	26.08 h-j	21.92 kl
	15 May	4.59 f-ı	4.93 a-e	4.98 a-e	36.64 e	26.73 hı	24.31 ı-k
	1 June	4.78 e-g	4.43 hı	4.82 d-f	38.19 cd	26.41 hı	25.98 h-j

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

Dry matter yield

Dry matter yield was significantly affected by the interaction of year x sowing time x harvest stage ($P \leq 0.01$). The highest dry matter yield (4560.9 kg ha^{-1}) was obtained from plants sown on 15 April 2019 and harvested during the milky stage. The lowest dry matter yield (1459.6 kg ha^{-1}) was obtained from plants sown on 1 June 2018 and harvested during the flowering stage (Table 8). When Table 8 is examined, it is seen that while the dry matter yield obtained from plants sown on 1 May and harvested during the milky stage decreased by 22.56% by 15 May in 2018, it increased by 4.79% during the same period in 2019. In addition, while the dry matter yield from milky stage to dough stage increased by 10% in the first sowing time in 2018, it decreased by 14% during the same period in 2019. This may be due to the significance effect of the interaction of year x sowing time x harvest stage. In general, the yield may have differed as a result of the cooler and wetter July and August experienced in 2019 compared to 2018. This statement is supported by Temel and Yolcu (2020), having reported that sowing and harvesting times can have different effects on plant development periods depending on the annual changes in climatic conditions. In studies on this subject, it has been established that dry matter yield varies significantly depending on sowing times. For example; Omidbaigi and Mastro (2004) reported that in Iranian conditions, the highest dry forage yields were obtained by sowing on 5 July (25.2 g $plot^{-1}$) and 5 August (24.6 g $plot^{-1}$), Koksal (2017) reported that in Yozgat's conditions, the highest hay yield was obtained by sowing on 5 July (4420 kg ha^{-1}) in the first year and on 5 August (2410 kg ha^{-1}) in the second year of the experiment. In our study, dry matter yield had a moderate increase depending on the harvesting stage, but this increase differed significantly according to the sowing times. Some studies investigating the effect of harvesting stages discovered that dry matter yield increased gradually depending on the harvest periods (Kara, 2014; Polat, 2019; Gullap et al., 2021). For instance, Kara (2014) reported that dry matter yield in buckwheat varies year to year and increases approximately 6.3 times from the beginning of flowering to the period at which 50% of the grains have turned brown. Surmen and Kara (2017), on the other hand, reported that in Aydın's ecological conditions, the dry matter yield of pure buckwheat was 5497.5 kg ha^{-1} at 50% flowering period and 5085.2 kg ha^{-1} at 100% flowering period. The dry matter yields obtained in our research were lower than the yields obtained in previous studies on this subject. This may be owing to ecological, cultivar, and agronomic differences.

Crude protein

The effect of the sowing time x harvest stage interaction on the crude protein content of buckwheat showed statistically significant differences in the results ($P \leq 0.01$). As for the sowing time x harvest stage interaction, the highest crude protein ratio (22.66 %) was obtained from plants sown on 15 May and harvested during the flowering stage, while the lowest crude protein ratio (14.75 %) was obtained from plants sown on 15 May and harvested during the dough stage (Table 9). Different results were obtained from studies investigating the effect of sowing time on the crude protein ratio of buckwheat. The results obtained in our research overlapped with some of these studies and differed greatly from others. For example; Koksal (2017) reported that in Yozgat's conditions, the highest crude protein ratio (15.81%) was obtained from sowing on 19 May in the first year of the experiment, and that the effects of sowing times on crude protein ratio were insignificant in the second year. On the other hand, Alkay and Kokten (2020) reported that sowing time significantly affected the crude protein ratio in buckwheat, the highest crude protein ratio (9.88 %) was obtained from the plot sown on 5 May, and that the lowest value (8.76 %) was obtained from that sown on 25 May. Björkman and Chase (2017) determined that the crude protein ratio in buckwheat varies between 15 and 20 % prior to flowering and that these values later decrease to 9 % depending on maturity. Surmen and Kara (2017) reported that in Aydın's ecological conditions, the crude protein rate in pure buckwheat was 15.89 % in the 50 % flowering period and 13.56% in the 100 % flowering period. In our study, the crude protein ratios measured during the flowering stage were higher. This may be a result of differences in cultivar, ecological factors, and agronomic practices. Dvoracek et al. (2004) emphasized that the reason for the change in the protein ratio in the buckwheat plant is due to climatic factors rather than genotype.

Table 8. The means of dry matter yield and ADF measured at different sowing times and harvest stages in the field trial run with significant year x sowing times x harvest stage interaction.

Years	Sowing times	Dry matter yield (kg ha^{-1})			ADF (%)		
		Harvest stage			Harvest stage		
		Flowering	Milk	Dough	Flowering	Milk	Dough
2018	15 April	2940.7 e-g	3931.0 bc	4319.7 ab	27.58 e-g	33.63 a-c	28.32 d-f
	1 May	2435.0 f-ı	3791.1 bc	4285.5 ab	23.41 g-ı	36.47 a	33.70 a-c
	15 May	2122.7 ıj	2935.9 e-g	3578.4 cd	26.30 e-h	26.59 e-h	27.17 e-h
	1 June	1459.6 k	2308.3 hı	2041.8 ıj	25.92 e-h	27.11 e-h	26.87 e-h
2019	15 April	2950.3 e-g	4560.9 a	3942.3 bc	22.68 hı	30.30 b-e	32.57 a-d
	1 May	2976.1 e-g	2922.4 e-g	3958.9 bc	24.19 f-ı	28.12 d-g	30.41 b-e
	15 May	2413.5 g-ı	3062.5 de	3010.5 e	19.89 ı	28.52 d-f	29.64 c-e
	1 June	1581.1 jk	2978.8 ef	2827.3 e-h	20.03 ı	34.73 ab	28.13 d-g

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

Table 9. The means of crude protein (%) and crude protein yield (kg ha^{-1}) measured at different sowing times and harvest stages in the field trial run with significant sowing time x harvest stage interaction.

Sowing time	Crude protein (%)			Crude protein yield (kg ha^{-1})		
	Harvest stage			Harvest stage		
	Flowering	Milk	Dough	Flowering	Milk	Dough
15 April	21.61 a	12.80 e	11.40 e	638.3 a	546.1 b	464.6 cd
1 May	19.39 b	15.18 d	15.19 cd	524.4 bc	500.7 bc	621.3 a
15 May	22.66 a	15.97 cd	14.75 d	512.6 bc	479.0 b-d	482.5 b-d
1 June	19.45 b	16.17 cd	16.85 c	296.4 e	426.8 d	413.4 d

**: significant at P ≤ 0.01. Means followed by the same letters are not different for P ≤ 0.05 according to LSD test.

Crude protein yield

The effect of sowing time x harvest stage interaction on crude protein yield was found to be significant at the 1% probability level (Table 4). The highest crude protein yield (638.3 kg ha^{-1} and 621.3kg ha^{-1}) were detected in plots sown on 15 April and harvested during the flowering stage, and on 1 May and harvested during the dough stage. Especially, the high dry matter yield of buckwheat sown on 1 May and harvested during the dough stage caused the crude protein yield to be high. The lowest crude protein yield (296.4 kg ha^{-1}) was obtained from the plots sown on 1 June and harvested during the flowering stage (Table 9). Since crude protein yield is the product of dry matter yield and crude protein ratio, crude protein yield decreases in late sown and late harvested plants as a result of the decrease in both crude protein ratio and dry matter yield as Temel and Tan (2002) reported that the decrease in crude protein yield was due to the rapid decrease in hay yield resulting from the delay in sowing time. Alkay and Kokten (2020) reported that the crude protein yield of buckwheat grown in Bingol's conditions varied between 89.0-127.0 kg ha^{-1} and the crude protein yields obtained 25 April, 5 May, and 15 May sowing times were higher than crude protein yield obtained latest sowing time (1 June). Although the results obtained in our research are partially parallel with those of Alkay and Kokten (2020), the crude protein yields detected in our study were higher. This situation may be primarily explained by the variability of dry matter yields among different ecologies. Surmen and Kara (2017), who examined the effects of harvest stages in buckwheat-soybean mixtures, reported that the crude protein yield in buckwheat was 871.9 kg ha^{-1} at the 50% flowering stage and 689.3 kg ha^{-1} at the 100% flowering stage.

ADF

The effect of the interaction of year x sowing time x harvest stage on the ADF ratio was found to be significant at the 1% probability level (Table 4). The highest ADF ratio was found in plants sown on 1 May in 2018 and harvested during the milky stage, and the lowest in those sown on 15 May 2019 and harvested during the flowering stage. In some sowing times, there is a continuous increase trend depending on the harvest stage, while in some there is a fluctuating course. The fact that these trends are different between years has caused the triple interaction to be significant. For example, In the sowings made on April 15, 2018, depending on the harvest periods, the ADF ratio increased by 21.93% in the milky stage compared to the flowering stage, while this increase rate was 2.68% in the dough stage. On the other hand, at the same sowing time in 2019, these rates were 33.60% and 43.61%, respectively (Table 8). As the plant ages, the cell walls thicken, and the amount of structural substances in the plant increases. In this case, it leads to a decrease in the crude protein ratio, while the components representing the fibrous tissue such as ADF and NDF are increased. In the early phases of plant development, the stems contain nutrients in similar amounts to the leaves, and as the plant matures, the nutritional value of the stem decreases faster than that of the leaves (Gullap et al., 2021). Alkay and Kokten (2020) reported that the highest rate of ADF (42.04 %) in buckwheat was obtained by sowing on 15 May. The ADF values detected in our research were considerably lower than those of Alkay and Kokten (2020). Surmen and Kara (2017) reported that the ADF ratio increased from 28.04 % to 35.82 % in between 50% flowering and full bloom and Gullap et al. (2021) reported that it increased from 22.65 % to 29.66 % from the beginning of flowering to full bloom. Gullap et al. (2021) reported that the rate of ADF is higher in years when better plant growth is observed, structural substance production is increased, and accordingly, the dry matter yield is higher.

NDF

The effect of the interaction of year x sowing time x harvest stage on the NDF ratio of buckwheat was significant at the 5% probability level (Table 4). The highest NDF ratio was obtained from the plots sown on 1 May in 2018 and harvested during the milky stage, while the lowest was obtained from those sown on 15 May 2019 and harvested during the flowering stage. While the NDF ratio decreased from the first sowing time (15 April-42.08 %) to the last sowing time (1 June- 39.40 %) in 2018 in the harvests made during the milky stage, the NDF ratio increased in the same periods in 2019 (Table 10). In this case, the triple interactions were important. Alkay and Kokten (2020) reported that the highest rates of NDF (45.11% and 44.35%) were obtained by sowing on 5 May and 25 May, while the lowest NDF ratios resulted from sowing on 25 April and 15 May. In our research, the NDF rate of buckwheat increased gradually with the delay of the harvesting stage in all applications except for the 1 May and 15 May sowings in 2018, and 15 May and 1 June sowings in 2019. Surmen and Kara (2017) reported that the NDF ratio increased by approximately 28% from 50% flowering to 100% flowering. On the other hand, Gullap et al. (2021) reported that the highest NDF rate was obtained from harvesting at the full flowering and 50% flowering stages.

Table 10. The means of NDF and RFV measured at different sowing times and harvest stages in the field trial run with significant year x sowing times x harvest stage interaction.

Years	Sowing times	NDF (%)			RFV		
		Harvest stage			Harvest stage		
		Flowering	Milk	Dough	Flowering	Milk	Dough
2018	15 April	33.05 ıj	42.08 b-f	44.08 a-e	190.48 bc	139.61 g-k	143.48 g-k
	1 May	36.43 f-j	49.11 a	47.32 ab	185.62 b-d	115.39 k	124.79 jk
	15 May	40.14 c-h	36.60 f-j	37.92 e-ı	158.92 d-h	175.48 c-f	166.11 c-g
	1 June	34.74 h-j	39.40 d-ı	40.42 c-h	185.13 b-d	160.18 d-g	156.66 d-ı
2019	15 April	31.43 j	41.85 b-g	45.81 a-c	211.43 ab	146.42 f-j	128.99 h-k
	1 May	36.82f-j	38.26 e-ı	42.48 b-f	177.93 c-e	163.44 c-g	142.79 g-k
	15 May	30.86 j	41.38 b-g	40.85 c-h	221.40 a	150.24 e-j	150.23 e-j
	1 June	35.61 g-j	45.04 a-d	43.53 a-e	192.76 a-c	128.04 ı-k	143.22 g-k

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

RFV

The effect of triple interaction on RFV was found to be significant at the 1% probability level (Table 4). According to Table 10, the highest RFV was obtained from the plots sown on 15 May in 2019 and harvested during the flowering stage, and the lowest value was obtained from plants sown on 1 May in 2018 and harvested during the milky stage. In sowing times, there is a continuous increase trend depending on the harvest stage, while in some there is a fluctuating course. The fact that these trends are different between years has caused the triple interaction to be significant. For example, the RFV values detected in different harvest periods from the plants sown on April 15 in 2018 and 2019 clearly show this situation (Table10). The relative feed value (RFV) was developed in the USA to measure the nutritional value of alfalfa but is now used for other feeds as well. ADF and NDF values are used to calculate the relative feed value. The relative feed value is based on a value of 100 calculated from the 41% ADF and 53% NDF content of fully bloomed alfalfa hay. As the relative feed value falls below 100, the quality of the feed decreases; if it rises, the feed's quality increases. Accordingly, if NYD is below 75, it is considered to be of 5th quality, 75-86 of 4th quality, 87-102 of 3rd quality, 103-124 of 2nd quality, 125-150 of 1st quality, and above 150 is considered to be the best quality (Canbolat and Karaman, 2009). Therefore, low ADF and NDF values are desirable to achieve high RFV. In the study, the ADF and NDF ratios of plants sown on 15 May and harvested during the flowering stage in 2019 were lower than the plants with all other sowing times and harvesting stages. According to the two-year average results, the yield and quality characteristics of buckwheat planted for hay production are significantly affected by varying sowing and harvesting stages. Accordingly, to obtain high dry matter yield from buckwheat, sowing should be done during the early period (15 April) and the resulting plants should be harvested during the milky or dough stage. In terms of obtaining a high crude protein yield and RFV, sowing should be done during the early period (15 April) and harvesting should be done during the flowering stage. It has been determined that buckwheat that sown and harvested at the appropriate time provides very high yields and is of sufficient quality for hay production. For this reason, buckwheat is believed to be a potential alternative feed source to aid in closing the roughage shortage.

ACKNOWLEDGEMENTS

This research was supported by the Unit of Scientific Research Projects, Bursa Uludag University (OUAP(Z)-2018-6). We thank the BAP council for their contribution to this study. This research includes a part of the master's thesis (part of 2019 data) prepared by Omer ARSLAN.

LITERATURE CITED

Acar, O. 2019. The effect of different sowing time on yield and yield components in buckwheat. Master Thesis, Ankara University Graduate School of Natural and Applied Sciences Department of Field Crops.

Alkay, R. and K. Kokten. 2020. Effects of sowing time on herbage yield and quality in buckwheat varieties under Bingol conditions. Tr. J. Nature Sci. 9(1): 29-34.

Amelchanka, S.L., M. Kreuzer and F. Leiber. 2010. Utility of buckwheat (*Fagopyrum esculentum* Moench) as feed: Effects of forage and grain on in vitro ruminal fermentation and performance of dairy cows. Anim.Feed Sci.Technol. 155(2-4): 111-121.

Anonymous. 2014. Variety features. Bahri Dagdas International Agricultural Research Institute Directorate (Accessed October 10, 2021)

Anonymous. 2020. https://tr.wikipedia.org/wiki/Bursa, (Accessed October 15, 2020)

AOAC International. 1997. Official Methods of Analysis of AOAC International, 16th ed., 3rd rev. Method 955.04. The Association, Gaithersburg, MD.

Bicer, A. 2019. The effects of organic fertilizer doses on yield and some quality characteristics on buckwheat (*Fagopyrum esculentum* Moench.) grown as second crop. Master Thesis, The Graduate School of Natural and Applied Science of Siirt University.

Björkman, T. and L. Chase. 2017. Information for buckwheat growers.http://www.hort.cornell.edu/bjorkman/lab/buck/guide/forage.php. (Accessed October 23, 2020)

Canbolat, O. and S. Karaman. 2009. Comparison of in vitro gas production, organic matter digestibility, relative feed value and metabolizable energy contents of some legume forages. J. Agric. Sci. 15(2):188-195.

Dvoracek, V., P. Cepkova and A. Michalova. 2004. Protein content evaluation of several buckwheat varieties. Proceedings of the 9th International Symposium on Buckwheat. Prague. pp: 734-736.

Er, M. 2018. The nutritive value of buckwheat hay or silage and its effect on milk yield of dairy goat. Master Thesis, The Graduate School of Natural and Applied Science of Adnan Menderes University.

Gullap, M.K., M. Tan, S. Severoglu and A. Yazici. 2021. The effects of harvest stage on hay and seed yields and some properties in buckwheat (*Fagophyrum esculentum* Moench). Ataturk Univ. J. Agric. Fac. 52 (1): 20-26 (in Turkish).

Gunes, A., I. Topal, H. Koc, A. Akcacik, H. Bayrak, G. Ozcan, M. Tas and R. Acar. 2012. Effects of different planting times on the yields and some yield components of buckwheat (*Fagopyrum esculentum* Moench.). Medicinal and Aromatic Plants Symposium, 1315 September 2012, p:10-14, Tokat (in Turkish).

Jung, G.H., S.L. Kim, M.J. Kim, S.K. Kim, J.H. Park, C.G. Kim and S. Heu. 2015. Effect of sowing time on buckwheat (*Fagopyrum esculentum* Moench) growth and yield in Central Korea. J Crop Sci.& Biotech. 18(4):285-291.

Kalber, T., M. Kreuzer F. Leiber. 2012. Silages containing buckwheat and chicory: quality, digestibility and nitrogen utilisation by lactating cows. Arch Anim Nutr. 66(1): 50-65.

Kara, N. 2014. Yield and mineral nutrition content of buckwheat (*Fagopyrum esculentum* Moench): the effect of harvest times. Suleyman Demirel Uni., J Fac. Agric. 9 (1):85-94 (in Turkish).

Kara, N. and O. Yuksel. 2014. Can we use buckwheat as animal feed? Turk J Agric & Natur Sci. 1(3): 295-300.

Karatas, R.,B. Ozyilmaz, O. Koyuturk, L. Yazici and S. Gokalp. 2020. The effect of different planting times on yield and yield components of buckwheat (*Fagopyrum esculentum* Moench) in Tokat conditions. Turkey 13. National, I. International Field Crops Congress Special Issue:159-165 (in Turkish).

Kaya, E. 2018. Effect of different sowing norms and times on yield and some yield components at buckwheat (*Fagopyrum esculentum* Moench) in Kutahya - Altıntas conditions. Master Thesis. Eskisehir Osmangazi University Graduate School of Natural and Applied Sciences Department of Field Crops, Eskisehir.

Keles, G., S. Ates, A. Gunes and I. Halici. 2012. Nutritive value and fermentation characteristics of buckwheat silage ensiled with chemical or biological additives. Selcuk J. Agric. & Food Sci. 26 (4): 33-36.

Keles G., F. Yildiz-Akgul, V. Kocaman. 2017. Performance and milk composition of dairy goats as affected by the dietary level of stoned olive cake silages. Asian- Australas J. Anim. Sci. 30(3): 363-369.

Koksal, S. 2017. Buckwheat (*Fagopyrum esculentum* Moench) cultivation in Yozgat ecological conditions. Master Thesis. Bozok University Graduate School of Natural and Applied Sciences Department of Field Crops, Yozgat.

Muftuoglu, M., Y. Cikili, C. Turkmen. 2014. Soil and Plant Fertility Analysis, Nobel Academic Publishing, p. 236.

Omidbaigi, R. and G. Mastro. 2004. Influence of sowing time on the biological behaviour, biomass production, and rutin content of buckwheat (*Fagopyrum esculentum* Moench). Italian J. Agron. 8(1): 47-50.

Polat, H.I. 2019. The investigation of some yield and quality proporties in different growth periods of buckwheat (*Fagopyrum esculentum* Moench.) Master Thesis. Selcuk University Graduate School of Natural and Applied Sciences Department of Field Crops, Konya.

Surmen, M. and E. Kara. 2017. Yield and quality features of buckwheat-soybean mixtures in organic agricultural conditions. Turk. J. Agric. Food Sci. & Tech. 5(13): 1732-1736.

Temel, S. and M. Tan. 2002. A research on determination of seeding and cutting time in common vetch (*Vicia sativa* L.) under Erzurum conditions. Ataturk Uni. J. Agric. Fac. 33 (4):363-368.

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.). Turk. J. Field Crops. 25(1):41-49.

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

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.
Yavuz, H. 2014. Effect of different sowing density on yield and some quality properties of buckwheat (*Fagopyrum esculentum* Moench.) in Aydın ecological conditions. *Master Thesis.* Adnan Menderes University Graduate School of Natural and Applied Sciences Department of Field Crops, Aydin.