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CHANGE IN FORAGE QUALITY OF WHOLE PLANT, LEAF AND STEM ACCORDING TO SOWING AND HARVESTING PERIODS IN *Atriplex nitens* SCHKUHR GROWN WITHOUT FERTILIZER

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ABSTRACT

***Atriplex nitens*, which can grow in extreme ecological conditions and produce a high amount of forage material, has been seen as an important alternative forage source for livestock. With the present study, the effect of different sowing (mid-April, late-April, early-May, mid-May) and harvesting periods (end of vegetative period, beginning of flowering, full flowering period) on forage quality was tried to be determined. For this purpose, a study was planned in a randomized complete block design in split plots with three replications under irrigated conditions of Igdir during 2019 and 2020. The results of the analysis showed that the forage quality values of the stem, leaf and whole plant were statistically significant in terms of the sowing and harvesting periods. The crude protein content, dry matter digestible, disgestible energy, metabolic energy and relative feed value of the stem, leaf and whole plant increased with late sowing while acid detergent fiber and neutral detergent fiber ratios decreased. Similar results were obtained by moving harvests to an earlier time. As a result, in late sowing and early harvestings, it was determined that the stem, leaf and whole plant produced a low, very high and medium quality forage material, respectively.**

Keywords: Feed value, Harvest periods, Mountain spinach, Sowing times

INTRODUCTION

The genus A*triplex* is a member of the subfamily Chenopodiaceae, including species that many cultivated plant and forage crops cannot adapt to extreme environmental conditions such as high salinity and drought (Ortiz-Dorda et al., 2005; Flowers and Colmer, 2008; Tan and Temel, 2012). The species in this genus are widely used for different purposes (fuel, ornamental plants, erosion control and replanting of saline, alkaline and arid areas), and the above-ground biomass they produce is also preferred as a resource of quality roughage in animal nutrition (Mellado et al., 2006; Kronberg, 2015; Quiroz et al., 2021). *Atriplex nitens* Schkuhr is also well adapted to extreme climate and soil conditions (Dursun and Acar, 2015; Doudova et al., 2017). The plant grows naturally in most Asian countries (including Turkey) as well as in fields in the midwestern regions of Canada and the USA. And in these countries, the leaves of the plant are preferred as human food, and all plant parts as animal feed (Munra and Small, 1997; Redzic, 2006; Acar et al., 2017; Kadioglu et al., 2021). The plant can grow very quickly and produce above-ground biomass (31463-99898 kg ha^{-1}) at desired amounts from a unit area without fertilizer and irrigation (Keskin and Temel, 2022). As a matter of fact, Temel and Keskin (2022) reported that 110360-169470 kg ha^{-1} of fresh herbage and 27190-49060 kg ha^{-1} of dry hay yield were obtained from *Atriplex nitens* grown without fertilizer application, depending on the sowing and harvesting periods. However, there is no scientific study revealing the change in feed quality depending on sowing and harvesting periods in *Atriplex nitens*.

In recent years, alternative forage plants have been seen as an important potential in meeting the quality roughage needed for livestock. For this purpose, scientists focused on species that can adapt to extreme environment conditions and produce forage material economically (Mellado et al., 2006; Temel et al., 2015; Temel, 2018; Temel and Temel, 2018; Demiroglu Tocu and Ozkan, 2019; Temel et al., 2020; Temel and Tan, 2020; Pirasteh-Anosheh et al., 2021). On the other hand, it is desirable to have high quality as well as the amount of feed produced for a profitable livestock. Therefore, it is of great importance to know the quality of the produced forage and to investigate the factors affecting the quality. Scientists have stated that there are many features that reveal the nutritional content of forage, especially crude protein ratio, neutral detergent fibre, acid detergent fibre, acid detergent lignin, relative feed value, dry matter digestibility and metabolic energy values are the most appropriate factors (Ball et al., 2001; Masters et al., 2007). On the other hand, these feed quality values are significantly affected by ecological factors and agronomic practices as well as the genetic structure of the plants (Onal

Asci and Acar, 2018; Temel, 2017). Among agronomic practices, irrigation, fertilization, sowing norm, sowing time and harvest periods have significant effects on feed quality (Buxton, 1996; Zandi-Esfahan et al., 2010; Onal Asci and Acar, 2018; Tan and Temel, 2019; Temel and Keskin, 2019). Depending on these factors, feed quality values can differ according to the vegetative parts of the plant, and the leaves can produce much higher quality forage material than the stems (Fales and Fritz, 2007; Hatfield et al., 2007; Gulumser and Acar, 2012; Temel and Keskin, 2020). In addition, the feed quality values of these parts can differ in terms of the sowing and harvesting periods.

As a matter of fact, there is a decrease in the nutritional values of the forage depending on the increase in the amount of structural carbohydrates such as cellulose, hemicellulose and lignin with advanced maturity (Buxton, 1996; Temel et al., 2015; Temel and Keskin, 2019). Moreover, as the plants benefit more from ambient conditions such as light, water and nutrients in early sowings, they tend to form with thicker stems and cell walls (Onal Asci and Acar, 2018). Therefore, many scientific studies have been carried out on different alternative forage crops by considering the factors affecting the quality, and the important results have been obtained. However, there are no such scientific studies on *Atriplex nitens*, which can produce a high amount of feed material in a short growing period.

With the present study, it was tried to reveal the change in forage quality of whole plant, leaf and stem in *Atriplex nitens* in terms of the sowing and harvesting periods. Thus, it is thought that the results obtained will make important contributions to agronomic and breeding studies as well as producers.

MATERIALS AND METHODS

In the research, the Mountain spinach (*Atriplex nitens* Schkuhr) obtained from the Faculty of Agriculture, Selcuk University was used as plant material. The research was carried out under irrigated conditions in Igdir province, located in the north-east of Turkey, in 2019 and 2020. Some climatic values of the region where the research was conducted are presented in Table 1 (MGM, 2021). Considering the existing data, it was seen that the precipitation amount and relative humidity values in 2020 were much higher than both for long-years and 2019. Soil samples (0-30 cm) were taken from the experiment site before seeding, and the results showed that the soils had a clay-loam texture, very low organic matter (0.61%) and nitrogen content (0.3 kg ha^{-1}), very high potassium (550 ppm) content, being slightly alkaline (pH: 7.51) and saline (EC: 3.44 dS m^{-1}), with low available phosphorus (5.53 ppm) (Kacar, 2012).

Table 1. Some climatic characteristics of the experiment area*.

Months	Relative humidity (%)			Temperature (^{0}C)			Precipitation (mm)		
	LTA**	2019	2020	LTA	2019	2020	LTA	2019	2020
March	50.0	59.7	56.5	7.0	6.8	10.6	21.9	23.5	18.1
April	49.0	56.9	64.8	13.4	12.1	11.7	37.4	25.1	83.6
May	51.5	51.2	55.0	17.6	19.9	18.6	49.4	25.9	76.1
June	45.9	45.8	44.7	22.3	25.6	23.9	33.2	13.6	15.7
July	43.3	40.1	48.4	26.2	27.3	26.7	14.5	0.6	30.2
Mean/total	47.9	50.7	53.9	17.3	18.3	18.3	156.5	88.7	223.7

*MGM: 2021, **, long term average

The study was carried out in a randomized complete block design in split plots with three replications. Sowing times (mid-April, late-April, early-May, mid-May) were placed in the main plots and harvesting periods (end of vegetative period, beginning of flowering, full flowering period) in the subplots to reveal the change in forage quality of whole plant, leaf and stem in terms of the sowing and harvesting periods. Sowings in the first year was carried out on 14.03.2019, 28.03.2019, 08.04.2019 and 18.04.2019, and in the second year on 21.03.2020, 31.03.2020, 10.04.2020 and 20.04.2020 periods. Seeds were sown in 5 rows to 4 m long plots at 3-4 cm depth with 45 x 10 cm row spacing and intra-row spacing (Acar et al., 2019), and no fertilizer was applied at sowing. When 50% of the available water in the soil was depleted, the water needs of the plants were met by drip irrigation method until the sufficient amount of water regains the field capacity. Weeds in the experiment area were controlled by hoeing and hand pulling. When the plants reached the determined harvest period, 0.5 m from the plot heads and one row from the parcel edges were discarded as an edge effect, and the plants in the parcel were harvested at 10 cm stubble height. Then, the leaves and stems of 10 randomly selected plants from the cut area were distinguished from each other, and their fresh and dry weights by drying at 70 °C were determined. Afterwards, the dried stem and leaf samples were ground through a 1-mm screen size in a Wiley Mill and analyzed separately. The nutrient content of the whole plant was determined according to the weighted average based on their dry weights and the determined quality values for the leaves and stems. Crude protein ratio was calculated by multiplying the total nitrogen ratios determined by the method of Mikro Kjeldahl with a coefficient of 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined using the method developed by Van Soest et al. (1991). Dry matter digestibility (DMD), digestible energy (DE), metabolic energy (ME) and relative feed values (RFV) of forage samples were calculated by using the following equations (Fonnesbeck et al., 1984; Khalil et al., 1986; Sheaffer et al., 1995).

$$DMD (\%) = 88.9 - (0.779 \times ADF\%) \quad (1)$$

$$DE (Mcal\ kg^{-1}) = 0.27 + 0.0428 \times DMD\% \quad (2)$$

$$ME (Mcal\ kg^{-1}) = 0.821 \times DE (Mcal\ kg^{-1}) \quad (3)$$

$$DMI\ (dry\ matter\ intake) = 120 / NDF\% \quad (4)$$

$$RFV = (DMD \times DMI) / 1.29) \quad (5)$$

The data obtained from the research were subjected to analysis of variance in a randomized complete block design in split plots with the year replications in the JMP (5.0.1) statistical package program (SAS Institute, Cary, NC, USA) and the LSD test was used to group the significant means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Significance and the variance analysis results of the quality parameters examined in stem, leaf and whole plant of *Atriplex nitens* are presented in Table 2. When Table 2 is examined, it has been seen that the sowing and harvesting periods have a significant effect on the forage quality of whole plant, stem and leaf.

Table 2. Significance levels and LSD values of the examined quality parameters

VS	SCP	LCP	PCP	SNDF	LNDF	PNDF	SADF	LADF	PADF	SDMD	LDMD
Year (Y)	0.43**	0.93**	0.53**	ns	1.16**	ns	ns	0.73**	ns	ns	0.57**
ST	0.61**	1.32**	0.75**	1.64**	1.63**	1.24**	1.58**	1.04**	1.31**	1.23**	0.81**
Y×ST	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns	Ns
HS	0.38**	0.89**	0.41**	1.17**	1.10*	0.96**	1.22**	1.00*	0.91**	0.95**	0.78*
Y×HS	0.54**	ns	0.58**	ns	Ns	ns	ns	ns	ns	ns	Ns
ST×HS	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns	Ns
Y×ST×HS	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns	Ns

VS	PDMD	SDE	LDE	PDE	SME	LME	PME	SRFV	LRFV	PRFV
Year (Y)	ns	ns	0.02**	ns	Ns	0.02**	ns	1.14*	17.7**	ns
ST	1.02**	0.05**	0.03**	0.04**	0.04**	0.03**	0.04**	1.9**	25.0**	2.6**
Y×ST	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns
HS	0.71**	0.04**	0.03*	0.03**	0.03**	0.03*	0.03**	1.2**	17.2*	1.9**
Y×HS	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns
ST×HS	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns
Y×ST×HS	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns

*p < 0.05, **p < 0.01, ns: non-significant. S: Stem, L: Leaf, P: Plant, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, CP: Crude protein, DE: Digestible energy, DMD: Dry matter digestibility, ME: Metabolic energy, RFV: Relative feed value, ST: Sowing time, HS: Harvesting stage, VS: Sources of Variation

The mean crude protein ratios of the plant parts according to year, sowing and harvesting periods are listed in Table 3. Considering Table 3, it was determined that the crude protein content of whole plant, stem and leave was higher in 2019 than in 2020. This may be due to the lower stem/leaf ratio of plants showed weaker growth (thin stems) in 2019 when rainfall was less. Because increased stem thickness and therefore high stem/leaf ratio cause more structural-carbohydrates such as lignin, cellulose and hemicellulose, and less non-structural carbohydrates such as sugar and protein in feed materials (Fales and Fritz, 2007; Jung, 2012; Temel and Keskin, 2020). As a matter of fact, Temel and Keskin (2022) reported that *Atriplex nitens* had a higher leaf/stem ratio in years with lower precipitation, which supports our findings. On the other hand, it was found that the ADF and NDF ratios of the leaf were lower in 2019 than in 2020 (Table 4; Table 5), while the dry matter digestibility, metabolic energy and digestible energy content were higher (Table 6; Table 7; Table 8). As a matter of fact, it was observed that the leaf-blades were larger and the leaf-stalks were thicker (developed) in the plant in 2020 when the precipitation was high. This may have resulted in low protein content, dry matter digestibility, digestible energy and metabolic energy content, and high NDF and ADF contents. As a matter of fact, large leaves with thicker (advanced) leaf-stalks have thicker cell walls because they contain more densely compounds such as cellulose, hemicellulose and lignin (Fales and Fritz, 2007; Jung, 2012). In addition, the digestibility and energy content of feed materials with thick cell walls are lower (Collins and Fritz, 2003).

With the delay in sowing time, it was determined that crude protein content of the stem, leaf and whole plant increased (Table 3), but NDF and ADF ratios decreased (Table 4; Table 5). Accordingly, the lowest and highest forage quality values in stem, leaf and whole plant were measured in early sowing (I.ST) and late sowing (IV.ST), respectively. These differences may have arisen from the fact that the environmental conditions (water, light, temperature and nutrient element) differ depending on the sowing time and the plants (stem and leaf) benefit from the existing conditions in different degrees.

As a matter of fact, in the present study, it was observed that the plants formed more developed (thick and hard structure) stem-leaf in early sowings and yellowing-shedding had in the leaves on the lower part of the plant, and similar results were also reported by Temel and Keskin (2022). Since this will increase the stem/leaf ratio, it will cause an increase in the amount of cell wall components such as cellulose, hemicellulose and lignin in the whole plant and also in plant parts, and a decrease in the ratio of intracellular substances such as protein (Buxton, 1996; Collins and Fritz, 2003; Ozyigit and Bilgen, 2006; Jung, 2012; Onal Asci and Acar, 2018). In addition, Fales and Fritz (2007) stated that plants had less fiber content depending on the weak stem development and the reduced stem thickness in late sowing. Hence, it was reported that the protein content of *Chenopodium quinoa* and *Atriplex hortensis* was high due to the high leaf/stem ratio in late sowings, while the NDF and ADF content were low (Grzeszczuk et al., 2010; Temel and Yolcu, 2020).

Table 3. The changes in the crude protein ratios (CPR) of the plant parts according to year, sowing and harvesting periods (%).

	Sowing time (ST)	Stem CPR			Year	Leaf CPR			Year	Plant CPR			Year
		EVS	BF	FFS	Mean	EVS	BF	FFS	Mean	EVS	BF	FFS	Mean
2019	I.ST	7.2	5.5	4.2	6.4 a	24.7	23.2	21.3	23.9 a	13.6	10.7	8.9	12.0 a
	II.ST	8.5	6.0	4.4		24.9	23.4	21.5		14.8	11.3	8.9	
	III.ST	8.8	6.3	4.9		25.7	24.2	22.4		15.6	11.5	9.6	
	IV.ST	9.3	6.8	5.1		26.2	24.6	24.2		15.9	12.3	10.4	
2020	I.ST	7.5	3.3	3.0	5.4 b	20.9	20.3	18.4	21.5 b	12.7	7.8	6.8	10.1 b
	II.ST	7.8	4.2	3.8		21.8	20.5	20.0		13.2	8.4	8.0	
	III.ST	8.4	4.5	4.2		23.3	22.4	21.5		13.5	9.0	9.0	
	IV.ST	8.7	4.9	4.1		23.7	23.3	21.6		14.5	9.9	8.7	
HS mean		8.3 a	5.2 b	4.2 c		23.9 a	22.7 b	21.4 c		14.2 a	10.1 b	8.8 c	
Sowing time mean	I.ST				5.1 c				21.5 c				10.1 c
	II.ST				5.8 b				22.0 bc				10.8 bc
	III.ST				6.2 ab				23.2 ab				11.4 ab
	IV.ST				6.5 a				23.9 a				11.9 a

[a,b,c] Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

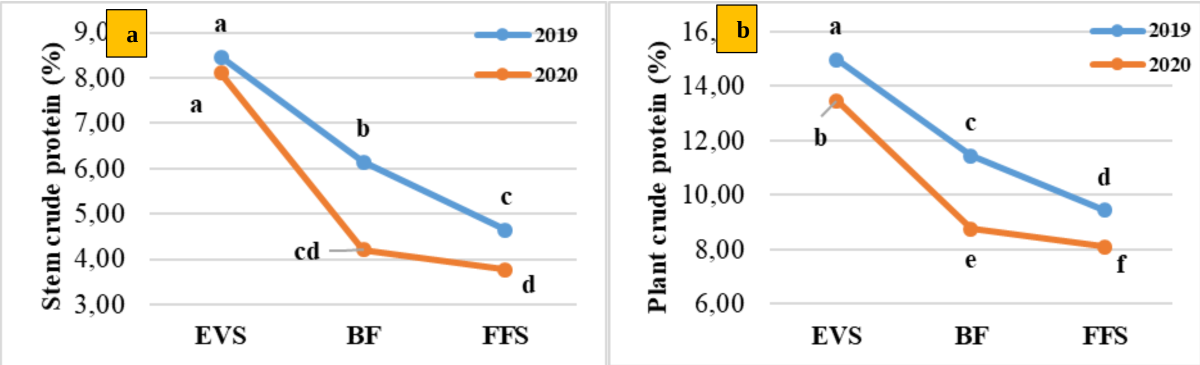
In the present study, dry matter digestibility, digestible energy and metabolic energy content of stem, leaf and whole plant were found to be higher in late sowing periods (Table 6; Table 7; Table 8). This was due to the fact that the NDF and ADF ratios were lower in the current periods. As a matter of fact, the dry matter digestibility is calculated using the ADF content, the digestible energy (DE) content from the dry matter digestibility and metabolic energy (ME) content from the DE. Therefore, as the ADF ratio of the forage decreases, the dry matter digestibility and accordingly the DE and ME content increase, and vice versa (Kutlu, 2008). Because the energy contents and digestibility of intracellular substances such as soluble carbohydrates, protein and fat are higher than the cell-wall substances such as lignin, cellulose, pectin and hemicellulose (Collins and Fritz, 2003). It was reported that the quinoa plant in the same subfamily had also high protein content and digestibility depending on the high leaf/stem ratio in recent sowings, but low NDF and ADF (Temel and Keskin, 2020; Temel and Yolcu, 2020).

Table 4. The changes in the neutral detergent fiber ratios (NDFR) of the plant parts according to year, sowing and harvesting periods (%).

	Sowing time (ST)	Stem NDFR			Year	Leaf NDFR			Year	Plant NDFR			Year
		EVS	BF	FFS	Mean	EVS	BF	FFS	Mean	EVS	BF	FFS	Mean
2019	I.ST	74.4	76.0	79.5	74.8	23.1	23.5	24.4	21.7 b	54.4	62.0	65.8	59.0
	II.ST	72.4	75.2	78.6		21.4	21.8	22.6		52.8	61.6	64.2	
	III.ST	72.4	74.7	77.0		20.4	20.9	22.0		54.6	61.1	61.7	
	IV.ST	71.6	72.1	73.7		19.6	19.8	20.8		51.6	58.0	60.0	
2020	I.ST	76.1	77.0	79.7	75.5	25.6	26.1	26.9	24.4 a	57.5	62.1	65.3	59.2
	II.ST	74.5	75.9	78.9		24.3	25.0	25.5		55.1	60.2	64.9	
	III.ST	72.5	74.2	77.2		23.5	24.0	24.6		53.1	59.7	62.9	
	IV.ST	71.7	73.2	74.6		21.4	22.5	23.3		52.2	57.5	60.4	
HS mean		73.2 c	74.8	77.4 a		22.4 b	23.0ab	23.8 a		53.9 c	60.3 b	63.1 a	
Sowing time mean	I.ST				77.1 a				24.9 a				61.2 a
	II.ST				75.9 ab				23.5 ab				59.8 b
	III.ST				74.7 b				22.6 bc				58.8 b
	IV.ST				72.8 c				21.2 c				56.6 c

[a,b,c] Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

In terms of binary interactions (year x harvesting period), only whole plant and stem crude protein ratio showed significant difference (Table 2). Accordingly, the highest stem CP ratio was measured from the harvest at the end of the vegetative stage in both years, but the lowest value from the cuttings at the full flowering period in 2020 (Figure 1a). The highest whole plant CP content was determined in the harvest at the end of the vegetative stage in 2019, and the lowest ratio was revealed in the harvest in full bloom stage in 2020 (Figure 1b). While the decrease in the stem and whole plant crude protein content in the full flowering stage in comparison with the beginning of flowering in 2020 was quite low, the fact that the drop in 2019 was greater may be a reason for the significance of year x harvest time interaction. These differences may be due to fact that the plant parts have different acide detergent fiber ratios as a result of the sowing dates, and that the plants formed harder and thicker stems during the full flowering period as a result of the rainy weather in 2020 compared to 2019. As a matter of fact, Temel and Keskin (2022) stated that *Atriplex nitens* formed more sufficient vegetative growth and thick-stemmed plants in rainy years and in late harvests. Because the increased stem thickness causes more structural carbohydrates such as lignin, hemicellulose and cellulose and less non-structural carbohydrates such as protein and sugar to be found (Fales and Fritz, 2007; Jung, 2012; Temel and Keskin, 2020).



[a,b,c] Plots followed by the same letters are not significant at $p \leq 0.01$. . EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage

Figure 1. The effect of year x harvesting period interaction on the stem (a) and whole plant (b) crude protein ratio.

Since the plant parts are succulent in the early development stages of forage plants, their cell walls are not well developed (Hoffman et al., 2003). Therefore, the number of young cells, cell division and the ratio of non-structural intracellular substances (protein synthesis and carbohydrate content) is high in these young leaf and stem tissues (Kacar et al., 2006; Onal Asci and Acar, 2018). Moreover, plants have weaker stems, larger leaf-blades and a higher leaf/stem ratio during early development (Temel and Keskin, 2022). However, the ratio of structural carbohydrates such as lignin, hemicellulose and cellulose increases and the CP content decreases with the increase in the stem/leaf ratio in advanced development periods. In the current study, it was observed that the leaf-blades of *Atriplex nitens* were larger and the stem-branches were more succulent in the early development period. However, it was observed that the plants that stay in the field for a longer period of time and benefit more from the ambient conditions had thicker-harder stems, and their bottom leaves also turned yellow. As a matter of fact, similar results were reported by Temel and Keskin (2022). For these reasons, it was determined that there were significant decreases in crude protein content and increases in NDF and ADF ratios of stem, leaves and whole plant as the harvesting period was delayed. Accordingly, the highest crude protein content and the lowest NDF and ADF ratios for stem, leaf and whole plant were determined in the early development period (Table 3; Table 4; Table 5). As a matter of fact, in a study conducted in *Atriplex nitens* as a whole plant, it was determined that crude protein content decreased and NDF and ADF ratios increased with the delay in harvesting period (Acar et al., 2019), and this was in line with our findings.

Table 5. The changes in the acid detergent fiber ratios (ADFR) of the plant parts according to year, sowing and harvesting periods (%).

Sowing time (ST)		Stem ADFR			Year	Leaf ADFR			Year	Plant ADFR			Year
		EVS	BF	FFS	Mean	EVS	BF	FFS	Mean	EVS	BF	FFS	Mean
2019	I.ST	45.5	48.0	50.6	46.2	13.1	13.7	14.5	12.4 b	33.0	38.9	41.6	36.1
	II.ST	44.7	46.7	48.9		12.2	12.5	13.3		32.2	38.0	39.7	
	III.ST	44.0	45.7	47.8		11.4	12.1	12.7		32.8	37.2	38.0	
	IV.ST	42.3	44.4	45.5		10.3	11.3	12.2		30.0	35.5	36.8	
2020	I.ST	47.6	48.5	50.8	47.1	14.8	15.6	16.0	14.1 a	35.5	38.9	41.3	36.6
	II.ST	46.3	47.3	49.2		14.0	14.9	15.5		33.8	37.3	40.3	
	III.ST	45.9	46.7	48.5		12.8	14.1	14.2		32.8	37.3	39.2	
	IV.ST	43.5	44.2	46.5		11.8	12.7	13.2		31.2	34.5	37.3	
HS mean		45.0 c	46.4b	48.5 a		12.5 b	13.4ab	13.9 a		32.7 c	37.2 b	39.3 a	
Sowing time mean	I.ST				48.5 a				14.6 a				38.2 a
	II.ST				47.2 ab				13.6 ab				36.9 ab
	III.ST				46.4 b				12.9 bc				36.2 b
	IV.ST				44.4 c				11.9 c				34.2 c

[a,b,c] Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

When Table 6, Table 7 and Table 8 were examined, it was observed that the highest stem, leaf and whole plant DMD, DE and ME contents were detected in early harvests, whereas these quality values decreased with the progression of development period. This is due to the low content of stem, leaf and whole plant ADF in the early growth period and high in the late development period. Because the increase in the stem/leaf ratio depending on the progress of development period causes an increase in the amount of cell wall components such as lignin, cellulose, cutin, hemicellulose and silicate that are difficult to digest (Frost et al., 2008). This significantly reduces the energy content and dry matter digestibility of the feed (Kutlu, 2008; Mountousis et al., 2008). As a matter of fact, studies on different alternative forage species revealed that crude protein, ME, DE and DMD contents decreased as the development period progresses, while ADF and NDF ratios increased (Zandi-Esfahan et al., 2010; Tiryakioglu and Turk, 2012; Oktay and Temel, 2015; Rasouli and Amiri, 2015; Temel, 2015; Temel et al., 2015; Uke, 2016; Abtahi and Zandi, 2017; Temel, 2018; Temel and Yolcu, 2020), and this was in line with our findings.

Table 6. The changes in the dry matter digestibility (DMD) of the plant parts according to year, sowing and harvesting periods (%).

Sowing time (ST)		Stem DMD			Year	Leaf DMD			Year	Plant DMD			Year
		EVS	BF	FFS	Mean	EVS	BF	FFS	Mean	EVS	BF	FFS	Mean
2019	I.ST	53.4	51.5	49.5	52.9	78.7	78.2	77.6	79.2 a	63.2	58.6	56.5	60.6
	II.ST	54.1	52.5	50.8		79.4	79.2	78.5		63.8	59.3	58.0	
	III.ST	54.7	53.3	51.7		80.0	79.5	79.0		63.3	59.9	59.3	
	IV.ST	55.9	54.3	53.5		80.9	80.1	79.4		65.5	61.3	60.2	
2020	I.ST	51.8	51.2	49.3	52.2	77.4	76.8	76.4	77.9 b	61.2	58.6	56.7	60.4
	II.ST	52.8	52.1	50.6		78.0	77.3	76.9		62.6	59.8	57.5	
	III.ST	53.1	52.5	51.1		78.9	77.9	77.9		63.4	59.8	58.4	
	IV.ST	55.0	54.5	52.7		79.7	79.0	78.7		64.6	62.1	59.8	
HS mean		53.9 a	52.7b	51.1 c		79.1 a	78.5ab	78.0 b		63.5 a	59.9 b	58.3 c	
Sowing time mean	I.ST				51.11 c				77.52 c				59.15 c
	II.ST				52.15 bc				78.19 bc				60.17 bc
	III.ST				52.73 b				78.87 ab				60.70 b
	IV.ST				54.31 a				79.64 a				62.25 a

a,b,c Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

Table 7. The changes in the digestible energy (DE) of the plant parts according to year, sowing and harvesting periods (Mcal kg^{-1}).

Sowing time (ST)		Stem DE			Year	Leaf DE			Year	Plant DE			Year
		EVS	BF	FFS	Mean	EVS	BF	FFS	Mean	EVS	BF	FFS	Mean
2019	I.ST	2.56	2.47	2.39	2.54	3.64	3.62	3.59	3.66 a	2.98	2.78	2.69	2.87
	II.ST	2.59	2.52	2.44		3.67	3.66	3.63		3.00	2.81	2.75	
	III.ST	2.61	2.55	2.48		3.69	3.67	3.65		2.98	2.83	2.81	
	IV.ST	2.66	2.59	2.56		3.74	3.70	3.67		3.08	2.89	2.85	
2020	I.ST	2.49	2.46	2.38	2.50	3.58	3.56	3.54	3.61 b	2.89	2.78	2.70	2.85
	II.ST	2.53	2.50	2.43		3.61	3.58	3.56		2.95	2.83	2.73	
	III.ST	2.54	2.52	2.46		3.65	3.61	3.61		2.98	2.83	2.77	
	IV.ST	2.63	2.60	2.52		3.69	3.65	3.64		3.04	2.93	2.83	
HS mean		2.58 a	2.53b	2.46 c		3.66 a	3.63ab	3.61 b		2.99 a	2.84 b	2.77 c	
Sowing time mean	I.ST				2.46 c				3.59 c				2.80 c
	II.ST				2.50 bc				3.62 bc				2.85 bc
	III.ST				2.53 b				3.65 ab				2.87 b
	IV.ST				2.59 a				3.68 a				2.94 a

a,b,c Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

Average relative feed values (RFV) of plant parts according to year, sowing time and harvest periods are presented in Table 9. According to this, it was determined that the RFV of the whole plant, stem and leaf increased with delayed sowings and early harvests. It is thought that this is due to the low rates of NDF and ADF in the whole plant, stem and leaf of *Atriplex nitens* in the current periods (Table 4; Table 5). Because RFV is determined by using the ADF and NDF values of the forage (Jeranyama and Garcia, 2004). Therefore, the low and high of these two values increase and decrease the relative feed value, respectively. In studies conducted with different forage crops and alternative species, it was stated that RFV's were high in the early development stages of the plants and these values decreased with the progress of the development stages (Panahi et al., 2012; Turk and Albayrak, 2012; Temel, 2019; Temel and Keskin, 2019; Temel and Yolcu, 2020). It was also reported that the plants had lower relative feed value in early sowing, but higher relative feed value in late sowing (Temel and Keskin, 2020; Temel and Yolcu, 2020; Hou et al., 2021), and this results were in line with our findings.

Table 8. The changes in the metabolic energy (ME) of the plant parts according to year, sowing and harvesting periods (Mcal kg^{-1}).

Sowing time (ST)		Stem ME EVS	Stem ME BF	Stem ME FFS	Year Mean	Leaf ME EVS	Leaf ME BF	Leaf ME FFS	Year Mean	Plant ME EVS	Plant ME BF	Plant ME FFS	Year Mean
2019	I.ST	2.10	2.03	1.96	2.08	2.99	2.97	2.95	3.00 a	2.44	2.28	2.21	2.36
	II.ST	2.13	2.07	2.01		3.01	3.00	2.98		2.46	2.31	2.26	
	III.ST	2.14	2.09	2.04		3.03	3.02	3.00		2.45	2.33	2.31	
	IV.ST	2.19	2.13	2.10		3.06	3.04	3.01		2.52	2.37	2.34	
2020	I.ST	2.04	2.02	1.95	2.06	2.94	2.92	2.90	2.96 b	2.37	2.28	2.21	2.34
	II.ST	2.08	2.05	2.00		2.96	2.94	2.92		2.42	2.32	2.24	
	III.ST	2.09	2.07	2.02		2.99	2.96	2.96		2.45	2.33	2.27	
	IV.ST	2.15	2.14	2.07		3.02	2.99	2.98		2.49	2.40	2.32	
HS mean		2.12 a	2.07 b	2.02c		3.00 a	2.98ab	2.96 b		2.45 a	2.33 b	2.27 c	
Sowing time mean	I.ST			2.02 c				2.94 c					2.30 c
	II.ST			2.06 bc				2.97 bc					2.34 b
	III.ST			2.07 b				2.99 ab					2.36 b
	IV.ST			2.13 a				3.02 a					2.41 a

[a,b,c] Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

Table 9. The changes in the relative feed values (RFV) of the plant parts according to year, sowing and harvesting periods (%).

Sowing time (ST)		Stem RFV EVS	Stem RFV BF	Stem RFV FFS	Year Mean	Leaf RFV EVS	Leaf RFV BF	Leaf RFV FFS	Year Mean	Plant RFV EVS	Plant RFV BF	Plant RFV FFS	Year Mean
2019	I.ST	66.8	63.1	57.9	66.0a	318.8	312.2	299.6	343.6a	108.0	88.1	79.8	96.7
	II.ST	69.5	65.0	60.1		347.5	339.9	325.3		112.5	89.7	84.0	
	III.ST	70.3	66.4	62.4		367.8	356.7	335.4		108.0	91.3	89.5	
	IV.ST	72.8	70.0	67.5		387.4	376.7	356.0		118.2	98.2	93.4	
2020	I.ST	63.4	61.8	57.7	64.5b	283.4	274.7	265.2	299.6b	99.2	87.8	81.0	95.6
	II.ST	66.0	63.9	59.7		300.6	287.9	281.7		105.7	92.5	82.5	
	III.ST	68.2	65.8	61.6		312.8	302.1	295.7		111.2	93.2	86.3	
	IV.ST	71.4	69.3	65.7		347.0	328.3	315.4		115.2	100.5	92.2	
HS mean		68.5 a	65.7b	61.6 c		333.2a	322.3ab	309.3b		109.8a	92.7b	86.1c	
Sowing time mean	I.ST			61.8 c				292.3 c					90.7 c
	II.ST			64.0 b				313.8 bc					94.5 b
	III.ST			65.8 b				328.4 ab					96.6 b
	IV.ST			69.4 a				351.8 a					103.0 a

[a,b,c] Values represented by the different letters in the same column differ statistically. EVS: end of vegetative stage, BF: beginning of flowering, FFS: full flowering stage, HS: harvesting period

As a result of the study, it was determined that stem, leaves and whole plant crude protein, relative feed values, digestible energy, metabolic energy and dry matter digestibility increased, while NDF and ADF ratios decreased. Similar results were obtained by moving harvests to an earlier time. In addition, considering the parameters examined, it was revealed that the stems were low, the leaves were high and the whole plant produced medium quality forage material. As a result, for a high quality herbage production in *Atriplex nitens*, it was concluded that sowings should be done at the earliest opportunity and harvesting should be done without delay.

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