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Determination of dry matter yield, some morphological characteristics, and rootworm infestation in local sainfoin populations

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Abstract: Sainfoin (*Onobrychis sativa* L.) is a valuable forage plant that is drought-resistant and has good nutritional value. However, for many years, various rootworms that damaged sainfoin have caused a decrease in its cultivation areas, and a variety resistant to rootworms has yet to be developed in scientific research. Local populations are of great importance to studies aiming to one day develop resistant varieties. This research aimed to determine the hay yield, forage quality, morphological characteristics, and rootworm infestation of local sainfoin genotypes from six villages in the Erzurum Province of Türkiye. The research took place in 2017, and forage yield, forage quality, some plant characteristics, and the rootworm infestation of local sainfoin genotypes were examined between 2018 and 2021. According to the data obtained from the study, yield, forage quality, morphological characteristics, and the rootworm infestation of local sainfoin genotypes showed significant changes according to year and genotype. Sainfoin is a high-yielding crop in the first three years after sowing; the dry hay yield decreases after this period. This study revealed that local sainfoin genotypes have a strong potential for developing new varieties. For this reason, breeding should be initiated using populations from Arıbahçe and Göztepe, which have high yields, and Güneyköy, where rootworm infestation is not found.

Key words: *Onobrychis sativa*, local populations, rootworms, hay yield, hay quality

1. Introduction

Sainfoin is a valuable legume forage plant used in pastures and agricultural lands for animal feeding. It has high hay yield and nutritional value and is drought and cold-resistant (Demircioğlu et al., 2023). It can easily grow in low-fertile soil, increasing soil fertility and helping prevent erosion. However, some root weevils threaten sainfoin agriculture and cause a decrease in production areas. These are the larvae of insects called *Bembecia scopigera* (Lepidoptera) and *Sphenoptera carceli* (Coleoptera), which feed by opening galleries in the roots of the plant, causing them to die (Tamer et al., 1997; Açıkgöz, 2021). While *S. carceli* is found only in Anatolia and Greece, *B. scopigera* is widespread in Europe, Russia, and the Mediterranean. The adult species fly very well and can, therefore, spread easily. *B. scopigera* spends all its life stages—except the first—in the galleries they form in the root (Gültekin and Güçlü, 1997). The fact that the larvae live in the root collar of the plant and the soil makes chemical control difficult. In addition, chemical control is not practical or economical in field conditions. Plants damaged by rootworms begin to die in the year following sowing, and the sainfoin field becomes sparse in the third year (Açıkgöz, 2021). Therefore, the cultivation areas of sainfoin, an important legume forage crop in the continental climate zones worldwide, are decreasing.

Intensive studies have been carried out to develop resistant varieties in Türkiye and other countries where sainfoin cultivation is common, but successful results have not yet been achieved (Tan, 2018; Açıkgöz, 2021). A study examining 297 genotypes from three cultivated species found no lines or varieties resistant to these rootworms (Büyükburç et al., 1991). For this reason, in addition to classical breeding studies, research has been initiated to obtain insect-resistant transgenic plants (Çöçü, 2008).

Local populations are plant genetic resources necessary for the continuity of agricultural production because these plants contain genes resistant to many diseases and pests and are drought and cold-resistant. Local genotypes are needed to combat global climate change and drought, making themselves felt worldwide. These genetic resources must be protected and used to develop new varieties. Yield and the morphological and phenological characteristics of local varieties may differ significantly from cultivated

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varieties (Ünal and Fırıncıoğlu, 2007). The eastern Anatolian region of Türkiye is a unique source for local populations of forage crops such as alfalfa and sainfoin. Local populations have grown there for hundreds of years; the region is also important for animal husbandry. In eastern Anatolia, an important sainfoin cultivation area in Türkiye, healthy growing sainfoin plants are found in old fields infested with rootworms. Elçi et al. (1995) stated that plants exist there that continue to live for 3–4 years even though larvae can be found in their roots. These genotypes are a significant opportunity for the development of resistant varieties. This study aimed to determine the characteristics of local populations taken from the Erzurum region and create an infrastructure for future breeding of these genotypes.

2. Materials and methods

The research was carried out to determine the yield, morphological and forage quality characteristics, and rootworm infestation of local sainfoin (*Onobrychis sativa* L.) populations taken from six different villages in Erzurum, the largest province in eastern Anatolia.

2.1. Collection of sainfoin populations

The material in the study consists of local plant populations obtained from six different villages in four districts of Erzurum. These local populations were recorded using the names of the villages where they were obtained (Table 1). In addition to these local populations, the Özerbey-03 variety, registered by the Central Research Institute of Field Crops in 2003, was also included in the study as a control.

2.2. Establishing the field experiment and obtaining data

The field study was carried out in April 2017 in a field infested with rootworms on the land of Atatürk University's Agricultural Research and Application Center. During the research, row spacing was set at 50 cm, planting depth at 5 cm, and seed amount at 120 kg ha^{-1} (Tan, 2018). Fertilizer was applied to the trial area at a standard dose of 50 kg N da^{-1} + 50 kg P_2O_5 ha^{-1} (Tan and Serin, 1997). Nitrogenous fertilizer was applied only during the first year, and phosphorus fertilizer was applied every year after that. Six populations and control variety were planted in three repetitions according to the completely randomized design experiment method, and the yield and several other characteristics were monitored between 2018 and 2021. Mechanical control of weeds was carried out only at the beginning of the first year of development. There was no irrigation in the research area, and the plants were grown in dry conditions. Harvest was carried out once each year during the 50% flowering period, and plant height, stem thickness, number of stems, and leaf ratio were determined during this period. During the harvest, 10 plants were removed from each plot, and the presence of rootworms in their roots (+/–) was recorded. An area of 3 m^2 was harvested from each parcel, weighed when wet, and then dried in a drying oven set at 70 °C to determine the dry matter yield. Crude protein ratios were performed using the Mikro Kjeldahl method, according to Kacar and Inal (2013), and acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses were performed using an ANKOM Fiber Analyzer, according to Van Soest et al. (1991). Examination of rootworm infestation began in the first year of the field trial (5 years), and additional data was gathered in 2018 (4 years).

2.3. Statistical analysis

The obtained data were subjected to variance analysis according to the randomized complete blocks arrangement with the help of SAS software. The differences between means found to be significant were compared and grouped according to Duncan's Multiple Range Test (Yıldız and Bircan, 1991).

2.4. Soil and climate characteristics of the research site

The soil in the experiment area belongs to Atatürk University's Plant Production and Application Center, where the experiment was carried out, and is in the clay-loam texture category. It was determined that the soil of the experiment area was salt-free, alkaline, not overly calcareous, poor in organic matter, rich in potassium for plants, and insufficient in terms of available phosphorus.

Table 1. Local populations and their sources in Erzurum Province.

Village	District	Coordinates	Altitude
Özerbey-03 (Control)	-	-	-
Arıbahçe	Yakutiye	40.071286, 41.169446	1695 m
Yoncalık	Azizye	40.056884, 40.924233	2040 m
Gelinkaya	Aziziye	40.014281, 40.918164	2044 m
Güneyköy	İspir	40.487807, 41.002847	1472 m
Öztoprak	İspir	40.523452, 41.064578	1532 m
Göztepe	Pazaryolu	40.371818, 40.722368	1450 m

Erzurum, located in eastern Anatolia, has the highest altitude in Türkiye, and the altitude of Erzurum's city center is 1860 m. Continental climatic features are dominant in much of the province. Winters are long and harsh, and summers are short and dry. The climate data for Erzurum, where the experiment was conducted, for the years 2018–2021 and the long-term average are given in Table 2. The years during which the research was conducted were drier than the average for many years, except for 2018. Each of the trial years was significantly warmer than the long-term average. More rainfall was measured between May and September 2018 compared to other years. In May especially, extreme rainfall occurred (140 mm).

3. Results

During the first year of the research, the average plant height was measured as 117.1 cm (Table 3). In the following years, plant height decreased to 107.6 cm, 106.9 cm, and 49.4 cm, respectively. The decline in the last year is quite evident and statistically significant. The plant height of the populations showed significant changes over increasing years. While Arıbahçe and Göztepe had the tallest populations in 2018, the plants in Yoncalık in 2019, Gelinkaya in 2020, and Güneyköy in 2021 were taller than the others. The stem thickness of the populations increased over the years; in the first three years, Arıbahçe exhibited a thicker handle, and in the last year, Öztoprak's plant population had a thicker handle. In the first year, the number of stems per plant was determined to be 5.4. In the second year, stem density increased and was determined as 22.1 units/plant. The number of stems decreased to 13.6 and 6.0 units/plant in other years. The leaf ratio of the weed was highest in the Güneyköy population (43.6%) in 2018, which was higher than the leaf ratio of the control variety. In the second year, there was a general decrease in leaf ratio, but the leaf ratios of the Arıbahçe and Yoncalık populations were high (40.3% and 45.2%). In the third and fourth years, the Özerbey-03 variety and Yoncalık population, respectively, had more leaves (Table 3).

During the research, the highest sainfoin dry matter yield was in 2018, in the first yield year, but this decreased in subsequent years (Table 4). The average dry matter yield of the sainfoin populations in 2018, 2019, 2020, and 2021 was 9387, 7746, 7390, and 1061 kg ha^{-1}, respectively. In the first year, the Arıbahçe and Göztepe populations were more productive than the others. The high productivity of the Göztepe population continued in the second year, and the Öztoprak and Gelinkaya populations were more productive in the third and fourth years. According to the four-year average data, all the local populations examined were more productive than the control (Figure). In the first three years of the research, the crude protein content was, on average, 17.4%–17.7%, and in the last year it decreased significantly to 14.9%. The Yoncalık population generally had a higher crude protein content than the others. The ADF rate of sainfoin was high in the first two years and

Table 2. Some climate data of Erzurum Province for 2018–2021 and the long-term average (LTA, 1929–2017).

Months	Total precipitation (mm)					Mean temperature (°C)				
	2018	2019	2020	2021	LTA	2018	2019	2020	2021	LTA
January	24.8	13.9	2.8	14.3	16.5	–7.2	–8.0	–8.8	–7.4	–10.4
February	9.8	26.9	14.8	27.6	19.7	–4.3	–8.4	–6.2	–5.0	–8.9
March	30.0	20.5	37.6	66.8	33.7	4.7	–3.0	2.5	–2.0	–2.1
April	11.0	68.9	57.8	13.4	55.4	7.4	4.2	5.6	8.9	5.5
May	140.0	63.8	118.0	32.8	68.6	11.3	12.0	11.0	13.4	10.5
June	76.8	23.6	34.6	16.0	43.6	14.6	17.8	15.7	17.5	14.9
July	24.8	3.0	30.0	15.4	22.8	20.1	19.0	19.9	20.6	19.3
August	33.0	11.6	16.2	25.8	16.2	19.8	20.2	18.9	20.0	19.5
September	11.3	21.4	35.8	31.6	21.3	15.5	14.6	17.2	14.2	14.2
October	60.1	7.6	4.0	60.6	48.8	9.4	9.8	9.8	7.1	7.8
November	18.9	6.2	26.2	29.8	26.5	2.3	0.1	1.4	2.5	0.1
December	46.8	23.2	4.9	12.2	22.6	–2.7	–3.5	–5.7	–5.2	–7.2
Total/Mean	487.3	290.6	382.7	346.3	395.7	7.6	6.3	6.8	7.1	5.3

[1]The data was obtained from Erzurum Regional Directorate of Meteorology.

Table 3. Some morphological values of some sainfoin populations (2018–2021).

Years	Populations	Plant height (cm)	Stem thickness (mm)	Number of branches (unit/plant)	Leaf ratio (%)
2018	Özerbey-03	110.0±8.6	3.68±0.5	5.0±1.7	42.7±1.8
	Arıbahçe	130.0±9.1	4.01±0.4	6.0±1.0	39.2±1.0
	Yoncalık	125.0±11.7	2.95±0.1	7.0±1.0	40.4±0.7
	Gelinkaya	105.0±13.2	3.43±0.5	6.0±0.0	39.8±1.4
	Güneyköy	100.0±18.0	3.56±0.3	5.0±1.0	43.6±0.8
	Öztoprak	120.0±4.3	3.02±0.6	5.0±1.0	39.3±0.7
	Göztepe	130.0±6.2	3.14±0.1	4.0±1.0	40.5±1.1
Mean		117.1±14.8 A	3.39±0.5 A	5.4±1.2 C	40.8±1.8 B
2019	Özerbey-03	115.0±7.0	3.56±0.4	18.0±3.0	18.6±1.3
	Arıbahçe	115.0±8.6	4.02±0.3	19.0±3.6	40.3±1.5
	Yoncalık	130.0±6.2	3.10±0.3	24.0±4.5	45.2±2.7
	Gelinkaya	120.0±4.3	3.50±0.3	21.0±1.7	19.5±0.6
	Güneyköy	38.0±8.8	3.85±0.1	23.0±2.6	18.5±1.2
	Öztoprak	115.0±4.3	3.82±0.2	25.0±6.2	16.5±0.9
	Göztepe	120.0±4.3	3.24±0.5	25.0±6.2	18.5±1.4
Mean		107.6±30.0 B	3.58±0.4 A	22.1±4.5 A	25.3±11.4 D
2020	Özerbey-03	85.0±2.6	3.78±3.2	12.0±2.6	54.6±1.2
	Arıbahçe	110.0±8.6	4.56±0.1	13.0±2.0	42.8±1.1
	Yoncalık	108.0±6.0	3.30±0.7	14.0±1.0	52.5±0.9
	Gelinkaya	125.0±10.4	3.65±0.1	14.0±1.0	43.4±0.7
	Güneyköy	110.0±10.0	3.47±0.2	16.0±1.7	38.1±1.7
	Öztoprak	110.0±4.3	3.90±0.1	14.0±1.0	44.4±1.2
	Göztepe	100.0±6.2	3.17±0.2	12.0±1.0	47.1±0.8
Mean		106.9±13.0 B	3.69±1.1 A	13.6±1.8 B	46.1±5.5 A
2021	Özerbey-03	35.0±7.0	3.60±0.4	5.0±1.0	26.0±0.6
	Arıbahçe	52.0±8.1	4.03±0.4	7.0±1.7	57.7±1.2
	Yoncalık	40.0±6.2	3.33±0.4	7.0±1.0	54.3±0.8
	Gelinkaya	48.0±2.6	4.00±0.2	5.0±0.0	48.6±1.5
	Güneyköy	85.0±6.2	3.50±0.4	6.0±1.0	29.9±1.7
	Öztoprak	45.0±2.6	4.20±0.2	5.0±0.0	53.7±1.3
	Göztepe	41.0±2.6	2.40±0.2	7.0±1.0	38.7±1.7
Mean		49.4±16.4 C	3.58±0.6 A	6.0±1.2 C	44.1±12.1 C
General mean		95.3±33.1	3.56±0.7	11.8±7.2	39.1±11.9
F test					
Year		**	ns	**	**
Population		**	**	*	**
Year x Population		**	ns	ns	**

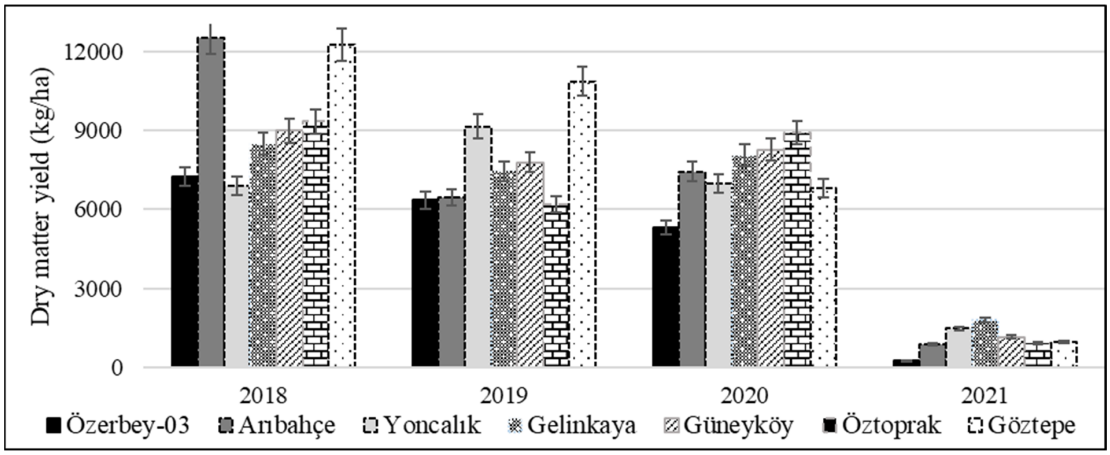

Figure. Dry matter yields of sainfoin populations according to year.

lower in the next two years. However, the NDF rates were determined to be higher than the others in the very last year. The populations had different ADF and NDF contents according to years (Table 4).

The place where the field experiment was established is an area where sainfoin was grown in previous years and infested with rootworms. For this reason, rootworms that damaged sainfoin roots were observed in the first year of the research. Rootworm infestation was observed in the Öztoprak and Göztepe populations from the seeding year to the last year. Rootworm infestation was found in the Gelinkaya population from the third year onward and in the Arıbahçe and Yoncalık populations from the fourth year onward. In the control variety, rootworms were detected in 2021, the last year of the research. The Güneyköy population was the only tested plant in this study free of rootworm infestation for five years (Table 5).

4. Discussion

The four-year data revealed that some morphological features of sainfoin showed significant changes according to years and genotypes. The best development of sainfoin occurs in the few years after planting, and its development then weakens (Tan, 2018). The economic life of the plant is considered to be 4 to 6 years (Tan and Sancak, 2009; Demircioğlu et al., 2023). In this study, plant height was high in the first yield year after planting (2018) and decreased in subsequent years. On the other hand, stem thicknesses increased every year. The number of stems per plant increased in 2019 and 2020 and became thinner in 2021. Among all populations, those with higher values than the control in terms of plant height, number of stems, stem thickness, and leaf ratio were identified. Similar results were reported by Stevovic et al. (2012). Jafari et al. (2014) also found similar results. Ünal and Fırıncıoğlu (2007) determined the plant height as 76.3–81.6 cm, stem thickness as 3.03–3.30 mm, and the number of stems per plant as 13.6–17.1 cm in the sainfoin populations examined. Erkovan and Tan (2009) found the plant height of sainfoin in the first and fourth years to be 106.9 cm and 67.2 cm; the authors determined the plant density to be 95.5 units m^{-2} and 29.1 units m^{-2}.

Dry matter yields may vary depending on genotype, ecological factors, and maintenance procedures. Studies on sainfoin have revealed that the annual dry matter yield of the plant is around 3.90–11.49 t ha^{-1} (Türk and Çelik, 2006; Türk et al., 2011; Jafari et al., 2014; Taşkın, 2019; Çaçan et al., 2023). In general, local populations appear to be more productive than the control variety in our study (Figure). The productivity of the Arıbahçe and Göztepe populations was higher. Çaçan et al. (2023) also found that local varieties gave higher yields than control varieties. While high yields are obtained in sainfoin in the first few years after planting, the yields decrease significantly after the fourth and fifth years (Tan, 2018). In this study, the highest yield was obtained in 2018, the first yield year, and a significant decrease was observed in 2019. This may be due to 2019 being the year with the lowest rainfall (Table 2). Erkovan and Tan (2009) determined that the dry matter yield, 10.16 t ha^{-1} in the first yield year, decreased to 4.10 t ha^{-1} in the fourth yield year. According to this study, sainfoin resulted in an economic yield for three years after planting. The decrease in plant density per unit area and rootworm infestation affected this (Tables 3 and 4). Rootworms began to appear on the sainfoin roots from the first year onward. The significant decrease in productivity of the Öztoprak and Göztepe populations in the second year may be due to rootworms. In the fifth year, Rootworm infestation was detected in the Özerbey-03 variety, which was used as a control in this study. The Güneyköy population is the only variant in which rootworms were not encountered during the research period. No significant decrease in productivity was observed in that particular population over the years. Tan and Sancak (2009), Açıkgöz

Table 4. Dry matter yield and some forage quality parameters of sainfoin populations (2018–2021).

Years	Populations	Dry matter yield (kg ha^{-1})	Crude protein ratio (%)	ADF (%)	NDF (%)
2018	Özerbey-03	7252±126.2	17.6±1.5	35.9±2.3	46.8±7.2
	Arıbahçe	12523±216.2	17.3±0.7	36.4±8.7	47.8±0.6
	Yoncalık	6883±10.4	19.7±0.2	38.7±3.6	49.3±0.5
	Gelinkaya	8480±118.7	16.8±1.7	40.7±1.4	50.4±3.5
	Güneyköy	8985±52.6	15.8±0.9	35.8±7.4	45.4±6.5
	Öztoprak	9338±24.6	18.6±0.7	40.7±3.5	50.9±5.3
	Göztepe	12250±117.2	18.3±0.6	36.9±2.6	48.8±0.8
Mean		9387±275.1 A	17.7±1.5 A	37.9±4.6 A	48.5±4.1 B
2019	Özerbey-03	6343±124.2	17.2±1.1	34.2±1.8	47.2±2.3
	Arıbahçe	6445±61.93	17.2±0.9	35.8±2.5	49.6±5.6
	Yoncalık	9143±81.8	18.3±0.3	36.9±3.8	48.2±4.1
	Gelinkaya	7448±42.2	16.5±2.1	39.6±1.7	50.7±3.4
	Güneyköy	7790±28.5	16.4±0.5	36.5±1.1	46.2±0.8
	Öztoprak	6200±44.0	18.4±0.2	41.2±1.2	50.1±2.5
	Göztepe	10850±128.1	17.7±0.2	35.4±1.4	47.4±0.9
Mean		7746±176.8 B	17.4±1.1 A	37.1±2.9 A	48.5±3.1 B
2020	Özerbey-03	5290±130.7	16.6±3.1	33.5±3.1	48.1±3.1
	Arıbahçe	7429±108.7	18.6±1.0	33.5±5.9	50.4±7.6
	Yoncalık	6984±41.9	18.5±0.5	35.8±2.5	50.9±3.8
	Gelinkaya	8053±91.2	17.2±0.8	37.2±0.8	46.8±2.6
	Güneyköy	8257±62.6	15.9±0.7	37.2±0.7	47.6±0.8
	Öztoprak	8915±47.8	17.7±0.5	38.8±3.0	48.3±1.3
	Göztepe	6802±211.8	17.6±1.8	34.8±3.7	48.6±4.1
Mean		7390±211.8 B	17.4±1.5 A	35.8±3.3 AB	48.7±3.5 B
2021	Özerbey-03	251±4.4	15.5±0.5	34.9±5.1	52.3±0.8
	Arıbahçe	889±14.7	15.9±1.3	31.4±4.2	51.9±2.1
	Yoncalık	1471±10.6	14.2±0.9	31.9±3.6	52.5±3.5
	Gelinkaya	1778±2.7	14.5±0.7	34.5±1.5	52.8±1.3
	Güneyköy	1159±6.2	13.9±0.2	37.3±1.2	55.2±0.4
	Öztoprak	904±6.4	15.3±1.0	33.9±1.3	56.1±0.5
	Göztepe	972±7.5	15.2±1.1	32.4±6.4	56.6±5.1
Mean		1061±46.5 C	14.9±1.0 B	33.8±3.7 B	53.9±2.8 A
General Mean		6396±363.6	16.9±1.7	36.1±3.9	49.9±4.1
F test					
Year		**	*	**	**
Population		**	**	*	ns
Year x Population		**	ns	ns	ns

Table 5. The presence of rootworm in the roots of sainfoin (2017–2021).

Years	Populations	Rootworm in root	Years	Populations	Rootworm in root
	Özerbey-03	-		Özerbey-03	-
	Arıbahçe	-		Arıbahçe	+
	Yoncalık	-		Yoncalık	+
2017	Gelinkaya	-	2020	Gelinkaya	+
	Güneyköy	-		Güneyköy	-
	Öztoprak	+		Öztoprak	+
	Göztepe	+		Göztepe	+
	Özerbey-03	-		Özerbey-03	+
	Arıbahçe	-		Arıbahçe	+
	Yoncalık	-		Yoncalık	+
2018	Gelinkaya	-	2021	Gelinkaya	+
	Güneyköy	-		Güneyköy	-
	Öztoprak	+		Öztoprak	+
	Göztepe	+		Göztepe	+
	Özerbey-03	-			
	Arıbahçe	-			
	Yoncalık	-			
2019	Gelinkaya	+			
	Güneyköy	-			
	Öztoprak	+			
	Göztepe	+			

+: infested

(2021), and Demircioğlu et al. (2023) also reported that rootworm damage to sainfoin began in the second year.

In the first years of the research, crude protein content was high. On the other hand, NDF rates were higher in the last year (Table 4). This shows that sainfoin produces forage with high nutritional value in the first three years after planting, and the forage quality decreases in the following years. Borreani et al. (2003) reported that sainfoin produces high-quality forage the year after planting due to its high crude protein and relatively low NDF content. Turk et al. (2011) determined the crude protein ratio in sainfoin to be 15.67%–19.79%, the ADF rate 28.30%–37.02%, and the NDF rate 37.35%–48.86%.

According to these results, local sainfoin varieties have a strong potential for developing new varieties. Accordingly, breeding work should be initiated using the Arıbahçe and Göztepe variants, which are highly productive, and the Güneyköy populations, which are not contaminated with rootworms.

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