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Aims and Scope

Turkish Journal of Range and Forage Science is the official publication of Society of Rangeland and Forage Science. The Journal is dedicated to publishing quality original material that advances rangeland management and forage crops production.

Turkish Journal of Range and Forage Science is a peer-reviewed, international, electronic journal covering all aspects of range, forage crops and turfgrass management, including the ecophysiology and biogeochemistry of rangelands and pastures, terrestrial plant–herbivore interactions, rangeland assessment and monitoring, effects of climate change on rangelands and forage crops, rangeland rehabilitation, rangeland improvement strategies, conservation and biodiversity goals. The journal serves the professions related to the management of crops, forages and grazinglands, and turfgrass by publishing research, briefs, reviews, perspectives, and diagnostic and management guides that are beneficial to researchers, practitioners, educators, and industry representatives.

Publication Date and Subscription Information

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TURKISH JOURNAL OF RANGE AND FORAGE SCIENCE

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The peer review process that has long time is an important problem. Naturally, the author(s) wish to take an answer about their submissions. Turkish Journal of Range and Forage Science aims to complete the all peer review process within 8 weeks after submission (one week for initial evaluation, 6 weeks for reviewer evaluation and one week for final evaluation).

The author(s) that submit an article to the Turkish Journal of Range and Forage Science consider accepting of these peer review conditions and procedures.

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A Review of the Current Status of Forage Crops Cultivation and Evaluation in Türkiye

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A B S T R A C T

With the changing market conditions in Türkiye, the shortage of quality roughage causes an increase in input costs. In the livestock sector, feeding and maintenance expenses are forcing the enterprises. Compared to the previous year, in 2022, there is a 5,6% decrease in total cattle presence and a 2,2% decrease in small ruminants.
Parallel to the increase in population, the importance of continuous and effective farming of forage crops and animal husbandry has emerged. The cultivation areas of forage crops have increased significantly since the 2000s, thanks to government subsidies. However, the current situation is not sufficient for feeding the livestock. In this article, the existence of bovine and small livestock is studied, and detailed current data on the roughage resources, cultivation areas and production amounts of Türkiye are presented. The availability of roughage resources to meet the needs of animal presence has been revealed. In addition, evaluations on what can be done to improve the production of quality roughage are presented. The future of the livestock sector depends on the government's encouragement of the producer to sustainable and effective forage crop farming.

1. Introduction

In terms of economic sustainability, animal production and agriculture sector should be well planned for adequate nutrition of people in every country. The most important roughage sources in the livestock sector are meadows and pastures. There is 14,6 million hectares (ha) of meadow-pasture area in Türkiye (TUIK, 2023a).

Meadows and pastures lose their productivity and cannot be used effectively due to many reasons such as Türkiye's arid climate, irregularities in the precipitation regime of the regions, and excessive and unconscious grazing that has been going on since the past (Kuşvuran et al., 2011). The inability to obtain the required yield for animal production from meadows and pastures leads to agriculture and production for forage crops. Forage crops agriculture, which is the most important way to reach consistent and safe high-quality roughage is the guarantee of livestock production (Akman et al.,2007).

In addition to its use in animal feeding, forage crops are also very valuable for the agro-ecosystem. For example, some forage crops such as alfalfa, vetch fix and clover keep nitrogen in the soil and enable the plants to grow in the following process to be more productive. Forage crops are harvested earlier than other product groups and are

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planted more frequently per unit area. It also plays a role in enriching the structure of the soil and preventing disasters such as soil and water erosion by reducing fallow areas (Sürmen and Kara, 2017).

Forage crops (Lucerne, sainfoin, common vetch etc.) have been cultivated in Anatolia since the Hittites. Since animal husbandry is an important source of livelihood for Türkiye from past to present, the cultivation of forage crops in Türkiye dates back to ancient times. Today, forage crops cultivation areas are increasing rapidly and new types are being added. Some new species such as Italian grass, fodder turnip, ryegrass are spreading throughout the country (Tan and Yolcu, 2021). On the other hand, although the states subsidizes the agriculture of forage crops for livestock production, Türkiye's forage crops production is not sufficient to meet the quality roughage needs of the country's livestock. Not enough roughage production is the most important problems of animal husbandry in Türkiye.

In summary, water resources are gradually decreasing and the effects of global warming and the damage to air and soil are increasingly felt. For this reason, it is of great importance for the livestock sector in Türkiye to determine the current situation of forage cultivation areas and to observe the change in cultivation areas in recent years. The paper, in the light of current data, the existing situation of forage crops, the situation of meeting the feeding of animal existence in Türkiye is revealed. An evaluation of increasing the agriculture of forage crops and indirectly contributing to the future of animal husbandry is presented.

2. Agricultural areas and distribution in Türkiye

Agricultural areas in Türkiye are 38.462 (1000 ha) in 2022. Meadow- pasture areas are 14.617 (1000 ha), Cereals and other crops products cultivation areas are 19.447 (1000 ha) and 2.960 (1000 ha) of these areas are fallow. Forage crops cultivation field is 2.757 (1000 ha). The share of this area in the Türkiye's total agricultural areas and the share of Cereals and other crops products area is 7,17% and 14,18%, respectively (Table 1). The share of forage crops in total agricultural area was 5% for the year 2007 (Yolcu and Tan, 2008) and 6,1% in 2020. Forage crops cultivation areas in Türkiye have increased gradually over the last two decades. It is thought that government subsidies contributed to this situation (Tan and Yolcu, 2021). However, the need for quality roughage for animal husbandry in Türkiye is always an ongoing problem and forage crops cultivation needs to be improved (Koç et al., 2012; Acar et al., 2020).

3. Forage Crops Cultivation in Türkiye

The cultivation areas where forage crops are cultivated, the production amounts of forage crops and green forage yield in Türkiye are seen in Table 2.

As of 2022, fodder crops are cultivated on an area of 2.757.082 ha in Türkiye and the amount of green forage production is 67.038.886 tons. Because of its high vitamin and nutritional value, good adaptation to the environment and longevity, lucerne is preferred for animal grazing and is a highly preferred forage crops in plant production (Okçu, 2020).

Table 1. Agricultural areas of Türkiye according to the statistical data of the year 2022*

Agricultural Areas	**Area (1,000 ha)**	**Ratio (%)[a]**
Cereals and other crop products (sown area)	16.487	42,9
Cereals and other crop products (fallow land)	2.960	7,7
Fruits, beverage, spice herbs	3.675	9,6
Vegetable gardens	718	1,9
Ornamental plant	6	0,02
Meadow and rangeland	14.617	38,0
Total	38.462	100
Forage Crops	**2,757[b]**	**7,17**

*(TUIK, 2023a).

[a] Statistics of the data obtained from the TUIK database have been calculated by the author.

[b] Forage crop area of Türkiye is 2.757.082 ha in 2022. The share of this area within the Agriculture areas has been calculated as 7,17%.

In terms of the size of the cultivation areas for the forage crops grown in Türkiye for 2022, lucerne comes first with 6,4 million decares (da). Maize, which is easy to ensilage and has a high digestibility for animals, ranks second as silage with approximately 5,3 million da. In short, both lucerne and maize silage outweigh the forage crops cultivation with 42,6% of all forage crops (Table 2).

Lucerne (19,1 million tons) and corn silage (28,6 million tons) showed themselves as the two most important crops that account for approximately 72% of forage crops agriculture in Türkiye. Oat with 3,6 million da and vetch on 3,4 million da were listed as other widely grown forage crops in Türkiye. When the production amounts are taken into consideration, oat (green grass), which increased the production from 3,8 million tons in 2021 to 4,6 million tons in 2022, took the third place. Vetch species (common vetch, hungarian vetch and other vetches) with a total production of approximately 4,1 million tons and sainfoin 1,8 million tons were the plants that support forage crops production (Table 2).

It is seen that among the forage crops cultivated in Türkiye, silage corn, forage turnip, forage beet and sorghum are the highest yielding forage crops, respectively. Sorghum is followed by Italian grass and sudan grass. The roughage source with the lowest yield is forage crops, meadow grass and wild vetch (Table 2). The use of the wild vetch plant as a forage crop is low. While the cultivation area was 25.613 da in 2019, it decreased to 20.432 da in 2022 (TUIK, 2023a).

The most widely cultivated forage plant species in Türkiye for many years are sainfoin, common vetch, lucerne and silage corn. In addition to these, farming fodder beet and forage peas have begun to be planned since the early 2000s. In the last years, new types of forage crops such as meadow grass, Italian grass, sorghum have started to be cultivated as an alternative to widely produced forage crops in Türkiye (Tan and Yolcu, 2021).

The cultivation areas and production amounts of new types of forage crops are gradually increasing. Italian grass production amount is 2,1 million tons (Table 2). The increase in production of these new species may have an impact on closing the livestock roughage deficit. The initiation of the production of alternative forage crops has not significantly affected the cultivation area of forage crops, which is a widely produced roughage source, but has greatly increased the area where forage crops are produced.

Table 2. Green productions, yields and cultivation areas of forage crops in Türkiye (2022)*

Forage Crops	**Cultivation Area (da)**	**Green Production (ton)**	**Ratio of cultivation area (%)[a]**	**Green Yield ($t\ da^{-1}$)[b]**
Sainfoin	1.618.249	1.786.207	5,87	1.104
Wild vetches	20.432	12.417	0,07	0.608
Corn (Silage)	5. 298. 522	28.558.983	19,22	5.390
Forage Beet	11.491	56.360	0,04	4.905
Forage Turnip	49.459	268.890	0,18	5.437
Wheat (Green)	168.327	310.966	0,61	1.847
Barley (Green)	292.728	482.665	1,06	1.649
Rye (Green)	106.546	150.885	0,39	1.416
Forage Pea (Green)	258867	475.005	0,94	1.835
Sudan grass	2.424	9.169	0,01	3.783
Vetch– (Common, hungarian and other vetches)	3.421.760	4.020.433	12,41	1.175
Clover	72	117	0,00	1.625
Lucerne	6.435.927	19.064.213	23,34	2.962
Meadow grass	4.955.951	3.683.405	17,98	0.743
Oats (Green)	3.607.194	4.649.051	13,08	1,289
Sorghum (Green)	29.205	117.076	0,11	4.009
Triticale (Green)	619.185	1.072.635	2,25	1.732
Grass pea (Green)	66.994	55.208	0,24	0.824
Italian ryegrass	539.944	2.122.105	1,96	3.930
Other forage crops[(9)]	16.932	28.424	0,06	1.679
Corn (for hay)	50.607	114.672	0,18	2.266
Total	27.570.816	67.038.886	100,00	--

*(TUIK, 2023a)

[a,b] Statistics of the data obtained from the TUIK database have been calculated by the author.

Lucerne, oat (green), common vetch, sainfoin, silage maize are the plants most grown in forage crops and evaluated as dry grass and green grass in Türkiye. When we examine the information on the regional distribution of the cultivation areas of these basic forage crops, it can be seen from the data on the cultivation areas to which region/regions each plant is more suitable (Table 3).

Lucerne (1.933.281 da) is the most cultivated in the Middle East Anatolia Region. Northeast Anatolian Region comes second with 1.212.882 da. Sainfoin is most cultivated in Northeast Anatolia (716.644 da) and Middle East Anatolia (420.553 da) regions. Since lucerne and sainfoin are forage crops that can withstand long and harsh winter conditions, the growing areas are high in the eastern regions. Oats are mostly cultivated in the Northeast Anatolia Region with 1.220.210 da (Table 3).

The largest cultivation area of silage corn is the Aegean Region with 1.470.186 da. The Aegean Region is followed by West Marmara, West Blacksea, West Anatolia and Mediterranean regions, respectively. Common vetch is grown more in Aegean Region (783.462 da) and Western Blacksea Region (583.889 da) (Table 3). Information on the change of cultivation areas of some forage crops by years is presented in Table 4.

Forage crops agriculture in Türkiye has been supported by the Decision of the Ministry of Agriculture and Rural Affairs numbered 2000/467 since 2000. The forage cultivation areas in Türkiye, which was 754.177 ha in the same year, expanded to2.757.082 ha in 2022 with a substantial increase of 265,6% (TUIK, 2023a). The support program is seen as an important contribution to improving forage crops production (Tan and Yolcu 2021).

Lucerne, silage corn, common vetch, sainfoin, oat (green) are the plants most grown in forage crops and considered as hay production and green material. Since 2010, there has been an increase of more than 100% in cultivation areas in silage maize. This situation is a result of the state subsidies implemented since the 2000s. It shows that farmers are also not indifferent to government incentives and silage corn agriculture is adopted (Acar et al., 2020).

Table 3. Regional distribution of some forage crops cultivation areas in Türkiye (2022)*

Statistical Regions	*Forage Crops Area (da)*				
	Lucerne	*Corn (Silage)*	*Oat (Green)*	*Vetches*	*Sainfoin*
Mediterranean	*210.473*	464.034	128.201	287.283	39.754
West Anatolia	515.522	526.295	22.263	365.048	29.533
West Blacksea	412.436	544.956	523.895	583.889	88.704
West Marmara	184.237	720.935	567.541	115.587	2659
East Blacksea	94.705	16.345	33.647	33.185	46.491
East Marmara	342.750	585.204	346.793	146.658	12.784
Aegean	*576.608*	1.470.186	500.489	783.462	34.058
Southeastern Anatolia	106.247	284.210	--	154.182	10.940
Northeast Anatolia	1.212.882	136.692	1.220.210	527.113	716.644
Middle Anatolia	843.636	396.435	223.573	274.310	215.824
Middle East Anatolia	1.933.281	90.584	11.235	148.163	420.553
Istanbul	3.150	12.039	29.347	2880	305
Total	6.435.927	5.247.915	3.607.194	3.421.760	1.618.249

*(TUIK,2023a).

Table 4. Changes of forage crops cultivation areas in Türkiye between 2005-2022*

Forage Crop/Area (da)	*Years*					
	2005	2010	2015	2020	2021	2022
Lucerne	.750.000	5.688.107	6.620.459	6.628.887	6.730.474	6.435.927
Corn (Silage)	1.800.000	2.844.728	4.105.412	5.205.892	5.248.424	5.247.915
Oat (Green)-	--	825 512*	825.890	3.240.182	3.740.583	3.607.194
Vetch (all)	2 500 000	4 288 400	4 365 182	3 759 436	3 652 849	3 421 760
Sainfoin	1.100.000	1.570.810	1.914.036	1.744.949	1.814.737	1.618.249

*(TUIK, 2023a).

*Oat data has been started to be compiled since 2012. The data of 2012 was taken as the closest year.

Lucerne cultivation areas, which were 3.750.000 da in 2005, reached 5.688.107 da in 2015. Lucerne cultivation areas increased by 51,7% from 2005 to 2015. There was no significant increase in cultivation areas after 2015. Likewise, there was no significant increase in sainfoin and vetch cultivation areas (Table 4).

Oat cultivation area has increased considerably over time. While it had a cultivation area of 825.890 da in 2015, it expanded to 3.607.194 da in 2022 with a substantial increase of 336,8%. Although there was a small decrease in 2022, it is thought that the areas where oat production is carried out in general will increase. The reason for this increase is considered to be the factors such as government incentives, widespread oat production among farmers, as well as ecological factors such as soil and climate (KUDAKA, 2022).

4. Animal Husbandry and Forage Crops in Türkiye

Türkiye's cattle stock was 18.157.971 in 2020 and decreased to 17.023.791 in 2022. In 2022, there was a decrease of 5,6% compared to the previous year. In the presence of small cattle, while the data for the year 2021 was 57.519.204, it decreased to 56.265.750 in 2022. In 2022, there was a decrease of 2,2% in the previous year (TUIK, 2023b). In order to find the annual life share and roughage requirement of Türkiye's livestock, the conversion process to cattle unit (CU) was applied (Table 5).

According to the Pasture Law dating 31/07/1998 and numbered 4342, using the cattle unit conversion coefficients, a detailed conversion process was applied according to all different ages and breeds under the category. While this process is being applied, separate coefficients are determined for each of the cow-heifer categories under the Cultural breed cattle breed, male and female under the buffalo breed, bull, ox and bull and lamb-goat category under the sheep and goat breed. A CU value close to the correct number cannot be found without a detailed calculation over the coefficients.

A cattle with a live weight of 500 kg (1 CU) should consume 4 kg/day of quality hay and 10 kg/day of quality green grass or silage corn to meet the nutrient requirement for survival (Alçiçek et al., 2010). The green grass or silage requirement of the livestock for the year 2022 was calculated as 17.499.827 x 10 x 365 = 63,9 million tons with the formula = CU x 10 kg/day x 365 days. Dry grass need was calculated as 17.499.827 x 4 x 365 = 25,6 million tons and the total annual roughage requirement was 89,5 million tons. The values found with the same formula for other years are also shown in Table 5.

On the other hand, Türkiye's roughage production from meadow, pasture (14,6 million tons) and forage crops (67,0 million tons) in 2022 was determined as 81,6 million tons in total. In this case, it has been observed that there is a deficit of 7,9 million tons of roughage for 2022 (Table 5). Based on these data, it is understood that the rate of meeting the need for quality roughage in the current production in 2022 is 91.2% compared to meadow, pasture and forage crops.

The reason for this high rate is due to the decrease in the number of animals in 2022. In 2022, there is a 4,3% decrease in the number of CU compared to the previous year. In parallel, there has been a decrease in the annual need for quality roughage. Annual total forage production has increased by approximately 8,4% from 2020 (75,3) to 2022 (81,6). When we look at the roughage deficit data of the last 5 years, an optimistic picture is not seen until 2022.

Table 5. Bovine and small livestock presence and roughage deficit in Türkiye 2018-2022 period

Years	Cattle Unit (CU)			Annual roughage requirement (million ton)			Annual roughage production (million ton)			Quality roughage deficit
	Cattle*	Small Ruminant	Total	Green +Slage	Hay	Total	Meadow-rangeland	Forage Crops	Total	(million ton)
2018	12.307.093	4.259.462	16.566.555	60,5	24,2	84,7	14,6	52,3	66,9	17,8
2019	12.746.515	4.487.547	17.234.062	62,9	25,2	88,1	14,6	55,5	70,1	18,0
2020	13.045.632	4.959.817	18.005.449	65,7	26,3	92,0	14,6	60,7	75,3	16,7
2021	13.004.988	5.282.111	18.287.100	66,8	26,7	93,5	14,6	60,3	74,9	18,6
2022	12.305.035	5.194.792	17.499.827	63,9	25,6	89,5	14,6	67,0	81,6	7,9

***** Equids (horse, donkey etc.) and camel are not included in the cattle presence.

For the year 2021, 18,6 million tons, for 2020 16,7 million tons of roughage deficit has occurred. The roughage meeting the need ratio for 2021 and 2020 are approximately 80%. The fact that the roughage deficit has decreased for 2022 should not be perceived as a positive situation. This situation, which occurs due to animal declines, is temporary and the result of many factors. For decades, it does not change the situation that forage crops production is not sufficient to feed livestock.

5. Conclusion

As in the whole world, the cheapest and most easily utilized roughage source in Türkiye is meadows and pastures. The meadow and pasture areas of Türkiye in 2022 are 14.617.000 ha. The ratio of meadow and pasture areas to land areas has remained constant for many years with 18,7%. This rate is far behind many European countries. In addition, due to changes in climatic conditions and unconscious grazing, it is not possible to obtain sufficient roughage yield from meadows and pastures.

Most of the roughage needed by the animals is obtained from meadows and pastures, whose quality roughage production potential is greatly reduced, and from grain straw and hay with very low nutritional value. This situation causes low yield in animal products. Forage crops, another source of quality roughage, are the insurance of both plant and animal production and are important for sustainable agriculture and high-quality roughage production.

Türkiye's forage crops cultivation areas have shown a great increase in the last 20 years. Forage crops cultivation area in 2022 is 2.757 (1000ha). The share of this area in the agriculture land is only 7,17% and its share in the land area is 14,18%. Although the cultivation area increases from year by year, the rate of increase is very low and cannot meet the needs of the livestock.

Türkiye's roughage production from meadow, pasture (14,6 million tons) and forage crops (60,3 million tons) in 2021 has been determined as 74,9 million tons. It has been observed that there is a deficit of 18,6 million tons of roughage for 2021 (Table 5). In this case, the ratio of quality roughage produced for the year 2021 to meet the animal presence is approximately 80%, for the year 2022 this ratio is 91,2%. The reason for the high rate of 2022 is entirely due to the decrease in the number of animals. Compared to the previous year, in 2022, the number of cattle decreased by 5,6% and the number of small ruminants by 2,2%.

Due to the shortage of quality roughage, in order to fill this forage deficit, it should be prevented that animals are fed with products that are not suitable for their physiology. On the other hand, small producers with 10-20 animals had to withdraw from the sector due to the increasing costs in the livestock sector, while large enterprises reduced the number of animals. Increases in forage crops production will also increase animal production. Forage crops agriculture is effective in solving pest and weed problems and will indirectly reduce diseases and increase plant and animal productivity.

In addition, the cultivation of forage crops will reduce the pressure on the pastures, on the other hand, will help protect natural resources and prevent water and soil erosion.

Special incentive policies should be implemented by the state to encourage forage crop cultivation. Instead of giving fixed supports, the support system should be renewed by making regional-oriented plans. Every local farmer should be taught the cultivation of forage crops suitable for ecological conditions, the cultivation areas of forage crops specific to the region should be expanded, and seed production should be increased. The importance of quality as well as yield for quality roughage should be explained to the farmers. Maintaining the quality of forage crops at a certain level by making better quality agriculture will also have a positive effect on animal production. In the triangle of environment, animals and farmers, it should be taken into account that sustainable agriculture can be realized with a business model that can positively affect the welfare of all.

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Determination of Dry Matter Yields and Quality Characters of Annual Ryegrass (*Lolium multiflorum* Lam.) Genotypes

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This study was carried out to determine yield and quality values of various annual ryegrass varieties genotypes. Five annual ryegrass and four genotypes improved at Aegean Agricultural Research Institute were used. Experiments were conducted at Institute's trial fields in 2020 and 2021. According to data combined over-years, differences between dry matter yields of genotypes were found to be statistically important. Dry matter yields ranged between 1550-1893 kg/da. In terms of quality parameters, differences were also significant. The values were 16.1 - 19.5% for protein contents, 31.7 - 34.7% for ADF and 47.8 - 51.9% for NDF. It was determined that annual ryegrass genotypes showed good performances at Aegean conditions.

1. Introduction

One of the most important problems of animal husbandry in our country is that our animals cannot be fed with quality forages that will reveal their yield potential. Approximately 78.6 million tons of quality forages, which is required by the current 17.1 animal units, cannot be produced in sufficient quantities in our country. The amount of forages produced in field crops is 16 million tons (Anonymous 2020a, 2020b). Despite the increase in the support given to the cultivation of forage crops in recent years, the production of forage crops still has not reached the desired level.

Today, annual grass is among the important forage plant species that can be used as a source of high quality and high yield forages. Annual grass, which belongs to the grass family, adapts to cool and humid climates, and can act as a biennial or short-lived. The optimum temperature for its cultivation is 20-25 ^{o}C. It has rapid growth and development and also gives multi cuttings. It is used in the crop rotation as a winter intermediate crop in temperate regions and positively reacts to irrigation and fertilization. It can be planted in a mixture with annual leguminous forage crops (*Trifolium resupinatum* and *Trifolium alexandrinum*). It is utilized as green, dry herbage and silage. It provides forages with high digestibility and energy content (Gençkan,1983; Açıkgöz, 2021).

Although annual grass grows best in fertile, well-drained soils it also adapts well to a wide variety of soil types. It can be grown in heavy, water-retaining acid and alkaline soils (5.0-7.8 pH), and it also has tolerance to moderate salinity (Gençkan, 1983, Ürem, 1985).

The annual grass cultivation area has been increasing in recent years, with a 1.14% share

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(253,297 da) in the total forage crops cultivation area (22,240,273 da) as of 2020, and a 1.67% share (373,275 da) in 2021 (Anonymous, 2021 and 2022). From annual ryegrass, 971,691 tons of green herbage was obtained in 2020, and 1 380,195 tons in 2021.

After, farmers' adoption of annual grass cultivation, the use of varieties developed abroad has become more common. After domestic breeding studies started by Aegean Agricultural Research Institute (AARI; ETAE in Turkish) in 1974, first Efe 82 variety was registered in 1982, and then Elif in 2018 and Zeybek19 in 2019 (Urem, 1985; Anonymous, 2022).

The study was carried out with the aim of determining the yield performances of the genotypes developed by AARI as well as the varieties developed abroad.

2. Materials and Methods

The study was carried out at the Aegean Agricultural Research Institute Menemen/İzmir experimental fields for two years in 2019-2020 and 2020-2021 production seasons. Varieties used in this study: tetraploid Trinova, Alberto, Koga, and Bartigra were improved and registered abroad and then registered in our country; Elif was developed and registered by AARI, and ETAE LM01, ETAE LM02, ETAE LM03, ETAE LM04 genotypes were newly improved. All these genotypes are tetraploid.

The experiment was set up in a randomized block design with four replications. The plots consisted of six rows with a spacing of 25 cm between rows. The plot size is 1.5 m x 5 m = 7.5 m². Trials were established on 19.11.2019 and 16.11.2020 by hand. Sowing depth was 2 cm and the sowing norm was 3 kg da^{-1}.

In both years of the experiment, fertilization was given with sowing: 6 kg pure nitrogen and 15 kg da^{-1} phosphorus (P_2O_5) as DAP fertilizer and 20 kg da^{-1} pure potassium (K_2O) as K_2SO_4. Top fertilization was given 10 kg da^{-1} pure nitrogen as CAN fertilizer during the boosting period. After each cutting, top fertilization was done twice with pure 5 kg da^{-1} nitrogen as CAN fertilizer. In the plots, weed control was made by hand, and with a hoe machine between plots when necessary, and water was given in with sprinkler according to the need. Herbicide with active ingredient against broad-leaved weeds was applied to the plot at 20 kg da^{-1}.

Although the cutting time was planned at 20% heading period, there were delays in cutting due to the pandemic in the first year and the plants were harvested at 50% heading period. In the second year, the cuttings were made as planned, when the plants were at 20% heading stage.

In the first year, a single cutting was performed between 21.04.2020 and 08.05.2020. In the second year, two cuttings were made. The first cutting was between 22.04.2021-06.05.2021 and the second cutting was between 10-28.05.2021.

After the plot harvest, the green herbage yield was found by weighing the fresh hay weights (kg da^{-1}). 0.5 kg samples taken randomly from green hay were dried in a drying cabinet at 60 °C for 48 hours and dry matter ratios were determined. Dry matter yield (kg da^{-1}) was calculated by using the dry matter ratio values.

After the dry matter samples were taken to determine dry matter yield, they were ground to pass through a 1 mm sieve (Brabender Ohg Duisburg) for quality analysis. Quality analyzes were made on these samples.

The amount of nitrogen in the dry matter samples was determined by the Dumas method (RapidN Cube, Elementar Analysensysteme GmbH, Germany). Crude protein is calculated by multiplying the determined nitrogen values by 6.25 (AOAC Official Method 990.03 (Anonymous, 2005). Amounts of acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined (separately) with Ankom fiber analyzer (ANKOM Fiber Analyzer, A220) according to the principles specified by Van Soest *et al.* (1991).

Digestible dry matter (DDM) is calculated by ADF% (DM basis), dry matter intake (DMI) by NDF% (DM basis), and relative feed value (RFV) by DDM and DMI values by following formulas (Sheaffer *et al*., 1995).

$$\%DDM = 88.9 - (0.779 \times ADF\%)$$

$$\%DMI = \frac{120}{NDF\%}$$

$$RFV = \frac{\%DDM \times \%DMI}{1.29}$$

Evaluation of the data obtained in the study; variance analyzes were performed on the year combination of the data obtained from field trials and laboratory analysis by using the Jump Statistical Package Program (Steel and Torrie, 1980; Yurtsever, 1984)

Mean long term, temperatures and monthly total rainfalls of the years where study was conducted were given at Table 1. First year's rainfall was lower than second year's and long-term rainfall. First and second years mean temperatures were similar to each other and higher than the long-term values (Anonymous, 2019-2021).

The experimental field is in Gediz loam (typic Ustorthent) soil structure (Anonymous, 1971).

Table 1. Climate data of Menemen province 2020-2021

Months	Air temperature (°C)									Rainfall (mm)		
	Mean			Minimum			Maximum					
	2019/20	2020/21	Longterm 1954-2018	2019/20	2020/21	Longterm 1954-2018	2019/20	2020/21	Longterm 1954-2018	2019/20	2020/21	Longterm 1954-2018
November	16.5	13.7	13.0	8.1	4.4	-1.6	26.9	23.0	26.3	59.2	3.0	74.1
December	10.4	12.4	9.6	2.2	4.1	-4.2	20.7	21.4	31.6	65.6	172.8	104.6
January	7.6	10.5	7.8	-1.3	-2.4	-7.2	18.8	22.3	33.6	47.2	164.0	94.9
February	9.9	10.7	8.9	-2.1	-0.7	-5.1	21.3	21.3	39.9	72.8	62.6	73.2
March	12.7	10.4	11.2	0.2	-0.6	-4.0	24.4	21.2	42.8	62.4	129.6	63.3
April	15.2	15.8	15.1	5.8	1.9	-0.9	26.3	30.2	42.1	52.2	33.2	41.0
May	20.7	21.6	20.1	8.5	9.4	3.3	39.7	36.1	44.1	48.6	0.2	27.6
June	23.9	24.9	24.7	12.3	13.0	7.3	34.7	37.6	41.2	34.2	16.8	9.5
Mean	**14.6**	**15.0**	**13.8**	**4.2**	**3.6**	**-1.5**	**26.6**	**26.6**	**37.7**			
Total										**442.2**	**582.2**	**488.2**

3. Results and Discussion

The green herbage and dry matter yield values obtained in the experiment are given in Table 2. In terms of green herbage yield: year, genotype and year*genotype interactions were found to be important as a result of the statistical analysis.

Green herbage yield was higher in the second year compared to the first year. In terms of green herbage yields, Koga variety and developed genotypes except ETAE LM 04 were in the first yield group. Average green herbage yields were between 9247-10045 kg da^{-1}. Although the differences between genotypes are significant, it has been determined that the genotype*year interaction is statistically significant and the differences between the genotypes in terms of green herbage yield depend on the year, as it is explained by Redfearn et al. (2005). ETAE LM 01 genotype, which was in the low yield group in the first year, was in the first yield group in the second year. ETAE LM 03 and ETAE LM 04, which were in the first yield group in the first year, could not take place in the first yield group in the second year. Studies on annual grass have been carried out in many regions of our country and different values have been obtained for green herbage. The green herbage yield values we obtained in this study were higher than 6997.3 and 6645.5 kg da^{-1}determined by Özdemir et al. (2019) in Bursa, and 3377-4458 kg/da determined by Vural and Kökten (2020) in Bingöl.

In terms of dry matter yield, genotype and year *genotype interaction were found to be statistically significant but year was insignificant. Elif variety was in the lowest yield group. Average dry matter yields were between 1550-1893 kg da^{-1}. The materials we developed were in the first yield groups with other genotypes and had high yield values. The differences between the genotypes are significant, it was also determined that the genotype*year interaction was statistically significant. ETAE LM 01 genotype and Koga variety were in the low yield group in the first year, but they rose up to the first yield group in the second year. On the other hand, ETAE LM 02 was in the first yield group in the first year and was in the lower yield group in the second year.

In relation to dry matter yields: Alison et al. (1989) determined 571-416 kg da^{-1}, West et al. (1989) had 691 kg da^{-1}, Yavuz et al. (2017) determined 666-937 kg da^{-1}in Samsun, Vural and Kökten (2020) attained 1044-808 kg da^{-1} in Bingöl, and Kurt and Başaran (2021) obtained 856-1077 kg da^{-1}in Tokat. The dry matter values obtained in our study were higher than those yields.

Crude protein, NDF and ADF ratios (%) of the genotypes used in the experiment are given in Table 3.

Table 2. Green herbage and dry matter yield values of genotypes (kg da^{-1})

Genotypes	Green herbage yield (kg da^{-1})		Mean	Dry matter yield (kg da^{-1})		Mean
	2020	2021		2020	2021	
ETAE LM 01	8331 ik	11506 a	9918 AB	1605 eg	1865 ad	1735 B
ETAE LM 02	9025 fi	10239 be	9632 AC	1824 ad	1689 cf	1757 AB
ETAE LM 03	9481 eg	10609 bd	10045 A	1885 ac	1901 ab	1893 A
ETAE LM 04	9619 ef	9210 fg	9414 BC	1897 ab	1769 af	1833 AB
Trinova	8775 gj	9987 de	9381BC	1766 af	1676 df	1721 B
Alberto	7494 l	11001 ab	9247 C	1704 bf	1764 af	1734 B
Elif	7618 kl	10982 ab	9300 C	1689 cf	1411 g	1550 C
Koga	8225 jl	10785 ac	9505 AC	1589 fg	1943 a	1766 AB
Bartigra	8531 hj	10121 ce	9326 C	1796 ae	1822 ad	1809 AB
Mean	**8567**	**10493**	**9530**	**1751**	**1760**	**1755**
Year			*			NS
Genotype			**			**
Genotype*year			**			**
CV (%)			5.7			8.1
LSD (%5)		1936.5	626.4		503.9	356.3

In terms of crude protein (CP) ratios (%), year, genotype and the interaction of year*genotype were found to be statistically significant. In first year, crude protein ratios of genotypes were significantly lower than the values obtained in the second year. In the second year, rainfall during the growing season was much higher and minimum temperatures were lower (Table 1) than the first year. These promoted the vegetative growth of the plant (Table 2). Besides, the same conditions might have caused the plant to better utilise the nitrogen fertilization. These may explain the relatively higher nitrogen content in the second year. These explanations are supported by the findings of the study of Solomon et al. (2017). Besides, as it is stated in materials and methods section, cutting time for the first year was relatively late compared to the second year. This may also explain the differences between CP ratios of the two years (Redfearn et al, 2002). The highest crude protein ratio was obtained from Bartigra variety with 19.5%, and the lowest crude protein ratio was obtained from Trinova variety with 16.1%. Except for ETAE LM 01, the genotypes were in the high crude protein group. However, it was determined that the genotype*year interaction was statistically significant. While Koga, Bartigra and ETAE LM 02, ETAE LM 03, and ETAE LM 04 genotypes were in the first yield group, ETAE LM 01 genotype was in the second yield group.

The reason for the differences between the crude protein data obtained from this study and the data obtained by other researchers (11.4% by Kavut and Geren (2018); 13.2% by Özdemir et al. (2019); 14.28-17.49% by Kurt and Başaran (2021) can be attributed to the differences between the cutting times, the varieties used, the soil and climate factors of the cultivation areas (Redfearn, 2002; Anonymous, 2023).

Table 3. Crude Protein, NDF and ADF ratios (%) of genotypes

Genotypes	Crude protein (%)			NDF (%)			ADF (%)		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
ETAE LM 01	11.6 fg	23.3 ad	17.4 BC	52.4 bc	43.3 fg	47.9 C	35.2 bd	28.8 gh	32.0 C
ETAE LM 02	13.5 ef	25.0 ac	19.3 AB	57.3 a	42.4 g	49.9 AC	38.0 a	28.1 h	33.0 AC
ETAE LM 03	13.0 ef	25.6 ab	19.3 AB	56.6 a	43.2 fg	49.9 AC	38.0 a	28.8 gh	33.4 AC
ETAE LM 04	14.5 e	21.5 d	18.0 AC	56.0 a	47.7 de	51.8 AB	37.0 ac	32.5 ef	34.7 A
Trinova	9.7 g	22.5 cd	16.1 C	56.0 a	47.9 d	51.9 A	37.6 ab	30.8 fg	34.2 AB
Alberto	10.0 g	22.8 bd	16.4 C	51.4 c	44.1 fg	47.8 C	34.2 de	29.2 gh	31.7 C
Elif	10.0 g	24.9 ac	17.5 BC	51.8 bc	44.4 fg	48.1 C	35.1 cd	29.9 gh	32.5 C
Koga	11.3 fg	25.7 a	18.5 AB	54.6 ab	44.8 eg	49.7 BC	36.4 ad	28.9 gh	32.6 BC
Bartigra	13.2 ef	25.8 a	19.5 A	55.7 a	45.8 df	50.7 AB	36.5 ad	29.7 gh	33.1 AC
Year	11.86 B	24.13A	**	54.64 A	44.84B	**	36.42A	29.63 B	**
Genotype			**			**			**
Genotype*year			*			**			*
CV (%)			9.4			3.6			4.3

LSD (%5)		4.0	3.3	5.3	5.3	5.3		2.1	3.3

In terms of ADF rates (%), year, genotype, year*genotype interaction was found to be statistically significant. ADF values were higher in the first year. The highest ADF ratio was obtained from ETAE LM 04 genotype with 34.7%. The standard cultivars Alberto and Elif and ETAE LM 01 genotype shared the lowest yield group statistically, with the lowest ADF ratios. Because the genotype*year interaction is statistically significant, the differences between genotypes depend on the year. In general, genotypes had high ADF ratios in the first year. While ETAE LM 02 and ETAE LM 03 genotypes were in the first yield group with the highest rate in the first year, they were in the lowest yield group in the second year, while Alberto and Elif varieties with low rates in the first year were in the higher yield group in the following year. In different studies ADF values were determined as 31.63% by Çolak (2015), and between 26.11- 33.30% by Türk et al. (2019).

In terms of NDF values (%), year, genotype, year*genotype interaction was found to be statistically significant. NDF values were higher in the first year. The highest NDF ratio was obtained from Trinova genotype with 51.9%. The lowest NDF value was found in the Alberto genotype with 47.8%. Although the differences between genotypes were significant, it was determined that the genotype*year interaction was statistically significant. In general, genotypes had higher NDF ratios in the first year. While ETAE LM 02 genotype was in the first yield group with the highest rate in the first year, it was in the lowest yield group with the lowest rate in the second year. Alberto and Elif varieties with high NDF ratios in the first year had low NDF ratios in the second year. Other researchers reported the NDF rates on different locations as similar or higher than our results (52.72-58.28% by Kurt and Başaran (2021); 59.67% by Şimşek (2015); 56.5% by Çetin (2017).

As previously mentioned, the plants were harvested at 20% heading period in the second year as planned so the quality was better with high crude protein and low NDF and ADF ratios, whereas plants were harvested at 50% heading in the first year which yielded lower quality values (Table 3). As it is also stated by Redfearn et al. (2002) and Solomon et al., (2017), CP values decreases as the growing season progressed, while NDF and ADF values increases (lowering the nutritive value).

DDM (%) and RFV values are given in Table 4.

In terms of DDM rate (%) year, genotype, year*genotype interaction was found to be statistically significant. In the first year lower DDM rates were obtained. ETAE LM 01 and Trinova genotypes gave the lowest DDM rates. However, although the differences between genotypes were significant, the fact that the genotype*year interaction was statistically significant showed that the differences between the genotypes depended on the year in terms of DDM values. ETAE LM 02 genotype had the lowest rate and took place in the last yield group in the first year and was in the first yield group in the second year. Kara (2016) found DDM as 64.18% in Aydın, which was similar to our results.

Table 4. Digestible dry matter (%) and relative feed value of genotypes in 2020 and 2021

Genotypes	**Digestible dry matter (%)**			**Relative feed value**		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
ETAE LM 01	61.4 eg	66.5 ab	63.9 A	109 df	143 ab	126 A
ETAE LM 02	59.3 h	66.9 a	63.2 AC	96 g	147 a	122 AB
ETAE LM 03	59.3 h	66.5 ab	62.9 AC	98 g	144 ab	121 AB
ETAE LM 04	60.1 fh	63.6 cd	61.8 C	100 ag	124 c	112 C
Trinova (st)	59.6 gh	64.9 bc	62.2 BC	99 fg	126 c	113 C
Alberto (st)	62.3 de	66.1 ab	64.2 A	113 d	140 ab	126 A
Elif (st)	61.6 ef	65.6 ab	63.6 A	110 de	138 ab	124 AB
Koga (st)	60.5 eh	66.4 ab	63.5 AB	103 dg	138 ab	121 AB
Bartigra (st)	60.5 eh	65.8 ab	63.1 AC	101 eg	134 ab	117 BC
Year	**60.52 B	65.8 A		**103.4 B	137.0 A	
Genotype	**			**		
Genotype*year	*			**		
CV (%)			1.8			5.5
LSD (%5)		2.6	2.2		15.4	12.9

In terms of relative feed value (RFV), year, genotype, year*genotype interaction was found to be statistically significant. RFV values were lower in the first year. The highest RFV was obtained from ETAE LM 01 and Alberto genotypes, while the lowest values were obtained from ETAE LM 04 and Trinova genotypes. Although the differences between genotypes are significant, the genotype*year interaction is statistically significant. ETAE LM 02 genotype had the lowest value in the first year and was in the last yield group, and it was in the first yield group in second year. Yavuz *et al*. (2015) determined the RFV between 109.3-122.83.

4. Conclusion

With this study, it has been shown that the varieties developed in our Institute have similar or superior yield and quality characteristics compared to standard varieties used. As a result of this study two genotypes ETAE LM02 and ETAE LM 04 are registered as Efe 2023 and Fırtına23, respectively. The registration process for other two genotypes (namely, ETAE LM 01 and ETAE LM 03) are still continuing. According to results of this study, annual ryegrass maintains high forage yield with high quality and can be used as a intercrop in winters at coastal and other places with mild climates in order to increase forage production. Therefore, as it is also stated by Solomon et al.,2017 (concluded from Lippke and Ellis,1997), they can be used as intercrops.

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Performances of Some Perennial Legume and Grass Mixtures under Rainfed Conditions of a Continental Climate Region

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Forage yield and the quality of the rangelands in Türkiye, especially in Central Anatolia, where the continental climate is dominant, are very low, and their vegetation is largely degraded due to mismanagement practices. The inadequacy of the forage crop production in agricultural land and the low yield and quality of forage are among the main problems of animal husbandry. The present study aimed to determine perennial legume and grass mixtures with high forage yield and quality under rainfed conditions of the continental climate region in Türkiye. The experimental design was randomized blocks with three replications. In the experiment, smooth brome (SB), intermediate wheatgrass (IW), alfalfa (A), sainfoin (S), and lesser burnet (LB) were sown as sole and mixed in different ratios. Two years averaged values of dry matter yield and crude protein, Acid Detergent Fiber (ADF), and Neutral Detergent Fiber (NDF) contents of dry matter varied between 2613 and 6268 kg ha^{-1};118 and 205 g kg^{-1}; 249 and 424 g kg^{-1}, 416 and 558 g kg^{-1}, respectively. Higher dry matter yields were obtained from A+S+IW+SB, S+LB+IW+SB, A+LB+IW+SB, S+IW, and A+IW+SB mixtures. The sole sowings of the SB, IW, and LB gave lower dry matter yields than the mixtures. Crude protein contents of alfalfa and sainfoin were higher than other sole sowings and mixtures. The ADF and NDF contents of mixtures were higher than those of sole sown of alfalfa, sainfoin, and lesser burnet, they were lower than those of IW and SB. In terms of dry matter yield, crude protein yield, ADF and NDF content, A+S+IW+SB, A+LB+IW+SB, and S+LB+IW+SB mixtures were superior to other mixtures and sole sowings. Alfalfa may be predominant in mixtures over time, and animal health problems may occur under grazing conditions. Therefore, the mixtures of A+S +IW+SB and A+LB+IW+SB can be recommended for mowing, while the S+LB+IW+SB mixture can be recommended for grazing.

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1. Introduction

As in the world, Türkiye's primary quality roughage sources are natural grazing lands and forage crop production in agricultural cultivated areas. Pasture-based livestock systems must meet the increasing demand for meat and milk by the increasing demand for meat and milk by increasing production volume with fewer resources (Lüscher et al., 2014). However, the yield of the rangelands in Türkiye, especially in Central Anatolia, where the continental climate is dominant, is very low, and their vegetation is largely degraded. Because of the high palatability of the legume species, and uncontrolled grazing, the rangelands in Central Anatolia are very poor in perennial forage legume species (Anonymous, 2012). With the current situation of the rangelands, the inadequacy of the growing areas of forage crops and the low yield and quality of forage are among the main problems of animal husbandry. High-quality roughage produced in Türkiye meets 37.6% of the forage needs of livestock, and the resulting forage deficit is trying to be completed using cereal straw and other crop residues (Yavuz et al., 2020). Fibrous forages, especially cereal straw, and stubble, have particular importance in the diet of ruminants in the Mediterranean production systems. (Bruno-Soares et al., 2000). As a result of the intensive use of cereal straw in animal feeding, the quality and quantity of animal products are naturally adversely affected. To meet the quality forage deficit of animal husbandry in Türkiye, growing areas of forage crops in agricultural land must be increased, and established pastures with mixtures of perennial legumes and grasses must be extended, especially in marginal areas. Legumes, especially the mixtures containing 30-50% legumes, have great potential to achieve this goal (Altın et al., 2021; Lüscher et al., 2014).

The benefits of mixtures of legumes and grasses are well known, but the water requirement for growing legumes limits their use in semi-arid and arid areas (Cui et al., 2013). Mixtures of grasses and legumes produce more biomass compared to sole sowings of grasses and legumes (Foster et al., 2014; Gökkuş et al., 1999; Sanderson et al., 2013; Serajchi et al., 2018) because they adapt better to changing environmental conditions during the growing season (Cox et al., 2017; Helgadóttir et al., 2018). The introduce of legumes into the mixtures with the grasses positively affects productivity (Barneze et al., 2020). Also, the primary benefit of legumes in the mixtures is to improve forage quality rather than yield (Bork et al., 2017). Nitrogen transfer from legumes to grasses is very important in low-input roughage production systems and the efficiency of N transfer can be enhanced by selecting compatible species or varieties (McElroy et al., 2016). Legumes provide many advantages by improving soil fertility with nitrogen fixation as well as the quantity and quality of the forage (Unathi et al., 2018). The functions of legumes reveal their importance in the development of roughage production systems (Malisch et al., 2017).

Before extensively using the mixtures of perennial legumes and grasses to solve the problem of quality roughage, first of all, it is necessary to determine the proper mixtures with high hay yield and quality for the ecological conditions of the region. Otherwise, it will not be possible to benefit from the advantages of legume and grass mixtures fully.

The present study aimed to determine the suitable mixtures of perennial legumes and grasses with high yield and quality for cutting under rainfed conditions of a continental climate region in Türkiye. The study investigated the forage yield and quality parameters of alfalfa, sainfoin, smooth brome, intermediate wheatgrass and lesser burnet species in sole sowings and their mixtures.

2. Materials and Methods

The study was carried out at the research and application fields of Kırşehir Ahi Evran University (39° 08' N, 34° 06' E, and 1084 m elevation) under rainfed conditions between 2013 and 2015. The Carlton cultivar of smooth brome (*Bromus inermis* Leyss.), Victoria cultivar of alfalfa (*Medicago sativa*), Bünyan 80 cultivar of lesser burnet (*Sanguisorba minor* Scop.), and local populations of intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.), and sainfoin (*Onobrychis sativa* Lam.) were used as plant materials (Table 1).

Table 1. Species and mixtures were tested in the study.

Species	**Pure sowing ratios**
Intermediate Wheatgrass	20
Smoot Brome (SB)	20
Alfalfa (A)	20
Sainfoin (S)	100
Lesser Burnet (LB)	30
Mixtures	**Seed Mixture ratios**
A+ IW	30% + 70%
A+SB	30% + 70%
A+IW + SB	30% +35% + 35%
A+S+IW+SB	15%+15%+35% + 35%
A+LB+IW+SB	15%+15%+35% + 35%
S+IW	30% + 70%
S+SB	30% + 70%
S+ IW + SB	30% +35% + 35%
S+LB+IW+SB	15%+15%+35% + 35%
LB+IW	30% + 70%
LB+SB	30% + 70%
LB+IW+SB	30% +35% + 35%

According to the results of the soil samples taken from the experimental area, the soil of the study area had a loamy texture at a depth of 0-30 cm, was slightly alkaline (pH 7.59), poor in organic matter (18.1 g kg^{-1}), and rich in available phosphorus (21.4 kg ha^{-1}), potassium (666.2 kg ha-1) and calcium (279 kg ha^{-1}).

The average temperatures in 2014 except September, November, and December were higher than the same months of 2015 (Table 2). Monthly average temperatures in 2014 were higher than the average long-term average. Total precipitation (471.4 mm) in 2015 was higher than those of 2013, 2014, and the long-term averages (254.7, 379.0, and 388.2 mm, respectively). The total precipitation in 2015, especially in June, was approximately four times higher than that of June 2014. Also, the total precipitation in 2013 and 2014 was lower than the long-term average total precipitation (Table 2).

Table 2. The monthly temperature, precipitation, and relative humidity values for the study area. *.

Months	Average Temperature (°C)				Total Precipitation (mm)				Relative Humidity (%)			
	2013	2014	2015	Long-term	2013	2014	2015	Long-term	2013	2014	2015	Long-term
January	1.4	1.9	1.2	-0.1	29.1	46.2	35.2	44.3	83.8	85.8	85.6	79.0
February	4.7	4.4	3.5	1.3	39.4	23.4	38.3	31.6	74.7	64.0	77.6	74.1
March	7.0	7.4	7.0	5.6	14.2	52.2	89.0	36.7	63.2	64.4	76.2	67.3
April	11.8	13.2	8.8	10.9	46.2	20.0	26.8	42.4	63.8	54.8	66.2	63.3
May	18.0	16.3	16.0	15.4	15.1	46.6	39.2	45.6	50.9	61.3	58.1	61.3
June	21.1	19.9	18.4	19.7	1.0	36.0	161.4	36.4	42.0	54.1	66.9	55.5
July	22.7	25.5	23.0	23.3	6.6	13.0	20.6	8.9	41.5	39.2	47.0	48.9
August	23.2	25.9	24.8	23.4	0.2	17.0	11.8	8.8	39.6	39.7	47.5	48.1
September	17.1	19.9	23.0	19.1	32.0	29.8	1.0	14.5	50.0	50.9	40.8	51.6
October	10.5	13.7	14.5	13.1	20.5	37.2	30.8	30.4	53.3	67.0	63.3	62.7
November	7.8	6.5	7.5	6.3	40.0	28.4	8.2	41.6	66.7	73.8	58.1	72.4
December	-2.1	5.9	-1.1	2.0	10.4	29.2	9.1	47.1	75.1	88.2	80.5	79.0
Total/Average	12.0	13.4	12.3	11.7	254.7	379.0	471.4	388.2	58.6	61.9	63.9	63.6

*Meteorological Service (1980-2020). Minister of Environment, Urbanization, and Climate Change Retrieved from https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace

The experimental field was plowed with a moldboard plow in the fall and prepared for sowing with rotary tillers in the spring. The experimental layout was randomized blocks with three replications. Species and mixtures were sown on April 13, 2013. The experimental plots were 2.8 × 6 m (16.8 m^2) with a 1 m buffer between each plot. Each plot consisted of 8 rows with row spacing of 35 cm. The seeds of species in the mixtures were manually sown in the same row and pressed with a roller. Before planting, 50 kg N ha^{-1} and 70 kg P ha^{-1} were applied with diammonium phosphate fertilizer. Ammonium sulfate fertilizer (40 kg N ha^{-1}) was applied to the experimental plots as the top fertilizer on April 5 in 2014 and 2015. The data of the study were not obtained in 2013 when the field experiment was established, general conditions of the experiment were monitored, and weed control and cleaning mowing were carried out. The data collection and observations were carried out in the 2nd and 3rd years of the study. The harvesting was carried out at the beginning of flowering in sole sowings and 10% flowering period of legumes in mixtures (Aponte et al., 2019). The mowing was done on May 14 for sainfoin + grass and lesser burnet + grass mixtures and on May 28 for alfalfa + grass mixtures in 2014. In the research, sole sowings and mixtures reached harvest maturity twice in 2015. The first mowing was done on May 12 for sainfoin + grass and lesser burnet + grass mixtures and on May 25 for alfalfa + grass mixtures in 2015. The second mowing of all sole sowings and mixtures was done on July 5.

Four quadrats (each 0.3 m^2) from each plot were harvested using shears at a height of 5 cm and weighed to determine the green forage yield. 500 g of fresh samples from each quadrat were taken and dried at 60 °C until reaching a constant weight and the dry matter (DM) yield for each plot was calculated (Biligetu et al., 2014). Contributions of the legumes and lesser burnet in the hay yield of the mixtures were determined as explained by Castillo et al. (2015). The dried forage samples from each plot were ground to 1 mm in a mill for quality analysis. The nitrogen content of the forage was determined by the Kjeldahl method, and the crude protein (CP) content was calculated by multiplying the total nitrogen value with a coefficient of 6.25 (AOAC, 1990). CP yields were calculated by multiplying the CP contents with the DM yields. Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) contents were determined using the ANKOM200 Fiber Analyzer (ANKOM Technology Corp. Fairport, NY, USA), which was developed according to the method suggested by Van Soest et al. (1991). Acid Detergent Lignin (ADL) content was determined according to ANKOM (2005).

Two years of data from the experiment were combined and subjected to analysis of variance (ANOVA) according to the randomized block designed in an arrangement of split plots in time defined by Steel and Torrie (1980) using the MSTAT C 1.2v. software. Duncan's multiple comparison test at P ≤0.05 was used post hoc to determine the differences among the mean values of treatments for statistically significant characters.

3. Results

The average DM yield in 2014 was significantly lower than that in 2015 (Table 3). The averaged DM yields over two years varied between 2613 and 6286 kg ha^{-1} depending on the treatments, and this variation was statistically significant (p ≤0.05). The mixture of A+S+IW+SB gave significantly higher DM yield than all of the sole sowings as well as all of the other mixtures with the exceptions of A+LB+IW+SB, A+IW+SB, S+LB+IW+SB and S+IW. Sole sowing of SB provided significantly lower DM yield than all of the mixtures as well as all of the sole sowings with the exceptions of IW and LB. On the other hand, mixtures with the exceptions of binary and triplet mixtures of LB provided significantly higher DM yield than all of the sole sowings. DM yields from binary and ternary mixtures of LB were not significant different from that of sole sowing alfalfa (Table 3). The interactions of years by treatments (sole sowings and mixtures) in DM yield were insignificant.

The contribution of A to the DM yields of mixtures was significantly (p ≤0.05) influenced by the years. In the second year, A contribution increased in all mixtures. The average A contribution in 2015 was significantly higher than 2014. (Table 3). The lowest A contribution was determined from the A+S+IW+SB mixture, and the highest contribution was obtained from the A+IW mixture. It was determined that the contribution of A in mixtures with IW and SB was relatively higher compared to those in the other mixtures. The contribution of A to the DM yields of the mixtures was generally related to the sowing ration of A in mixture. It can be point out that the botanical compositions of A+S+IW+SB and A+LB+IW+SB mixtures are more balanced than other A mixtures (Table 3). The interactions of years by mixtures in the contribution of A to the DM yield of the mixture were insignificant.

In the study, the average S proportion in the second year was slightly higher than that in the first year but the difference between the years in that perspective was not statistically significant (Table 3). According to the two-year averaged results, significant (p ≤0.05) differences were determined among the contribution percentage of S in the different mixtures (Table 3). The lowest S proportion was obtained from the A+S+IW+SB mixture and the highest from the S+SB mixture. As in A, increasing the sowing ratio of S in the mixture increased its contribution to the DM yields of the mixtures. The interactions of years by mixtures in the contribution of S to the DM yield of the mixture were insignificant.

The averaged proportion of the LB in the DM yields of the mixtures was not influenced significantly by the year. The proportion of the LB in the different mixtures was significantly different. This difference was due to the seeding ratio of LB in the mixture. Therefore, the proportion of LB in the DM yield of the quaternary mixture, S+LB+IW+SB, was significantly lower than those in the other mixtures with the LB. (Table 3). The interactions of years by mixtures in the contribution of LB to the DM yield of the mixture were insignificant.

The CP content was significantly (p ≤0.05) influenced by the years. Average CP content in 2014 was significantly lower than that in 2015 (Table 4). As average for two years, CP content varied between 118 g kg^{-1} and 205 g kg^{-1} depending on the treatment and this variation was statistically significant (Table 4). The mean CP content of sole sown A was significantly higher than that of all other sole sowings and mixtures. Sole sown grasses, IW, and SB showed significantly lower CP content than the other sole sowings and mixtures. The mixtures with A had higher CP content than those without A and increasing the proportion of A in the mixture increased the CP content of hay.

CP content of sole sown S was significantly higher than those of the sole sown grasses and LB as well as all of the mixtures. Binary or ternary mixtures of LB with grasses showed higher CP content than sole sown grasses (Table 4). The interactions of years by treatments in the CP ratio were not statistically significant.

Table 3. Dry matter yields (DM) of pure sowings and mixtures as well as contributions of alfalfa, sainfoin, and lesser burnet to the DM yields of the mixtures in the experimental years**.**

Species and Mixtures	DM (kg ha^{-1})			Contribution of A (%)			Contribution of S (%)			Contribution of LB (%)		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
IW$^{\pm}$	2727 f*	3077 d*	2902 e*									
SB	2486 f	2739 d	2613 e									
A	4144 de	4530 c	4337 cd									
S	4574 cd	4763 c	4669 c									
LB	2927 f	3201 d	3064 e									
A+ IW	5124 bc	5674 b	5399 b	60.3 a	65.2 a	62.8 a*						
A+SB	5262 abc	5572 b	5417 b	58.6 a	61.4 ab	60.0 ab						
A+IW+SB	5356 ab	6085 ab	5721 ab	48.3 ab	55.3 abc	51.8 bc						
A+S+IW+SB	5937 a	6598 a	6268 a	36.1 b	42.4 c	39.3 d	21.6 b	23.6 b	22.6 c*			
A+LB+IW+SB	5485 ab	6180 ab	5832 ab	41.6 b	48.8 bc	45.2 cd				22.2 b	19.1 c	20.7 b*
S+IW	5267 abc	6057 ab	5662 ab				38.8 a	41.9 a	40.4 ab			
S+SB	5172 abc	5847 ab	5509 b				39.9 a	46.1 a	43.0 a			
S+ IW+SB	5466 ab	5740 b	5603 b				36.8 a	40.6 a	38.7 ab			
S+LB+IW+SB	5731 ab	5997 ab	5864 ab				34.6 a	38.4 b	36.5 b	22.9 b	25.6 bc	24.3 b
LB+IW	3825 e	4125 c	3975 d							33.5 a	38.5 a	36.0 a
LB+SB	3741 e	4174 c	3958 d							31.7 ab	33.9 ab	32.8 a
LB+IW+SB	3845 e	4245 c	4045 d							34.4 a	35.1 ab	34.7 a
Mean	4534 B^{+}	4977 A	4755	49.0 B^{+}	54.6 A	51.8	34.3	38.1	36.2	28.9	30.4	29.7
CV (%)	9.00	8.28	6.49	14.56	12.10	12.25	13.71	12.03	18.29	17.80	16.30	12.71

$^{\pm}$) IW: Intermediate Wheatgrass, SB: Smoot Brome, A: Alfalfa, S: Sainfoin, LB: Lesser Burnet. *) Mean values indicated with the same lower-case letter in a column are not statistically significantly different from each other according to the Duncan test at $p \leq 0.05$. $^{+}$) Mean values with the same upper-case letter for a characteristic are not statistically significantly different from each other ($p \leq 0.05$).

Years and treatments did significantly ($p \leq 0.05$) affect the CP yield. The average CP yield in 2015 was significantly higher than that in 2014 (Table 4). Two years averaged values of CP yield varied between 324 kg ha^{-1} and 1074 kg ha^{-1} depending on the treatments, and this variation was statistically significant (Table 4). The quaternary mixture of A+S+IW+SB with the highest DM yield among the treatments gave a statistically significant higher CP yield than the other mixtures and all of the sole sowings. Sole sowings of grasses provided significantly lower CP yield than sole sowings of legumes and all of the mixtures. CP yield of sole sowing S was not statistically significant than that of A. The higher DM yield of S, but not statistically significantly higher than that of A, resulted in the CP yield of S being not significantly different from that of A while the CP content of A was significantly higher than that of S (Table 4). CP yields of binary and ternary mixtures of S, A, and LB with grasses were not significantly different than those of their sole sowings. The interactions of years by treatments in CP yield were insignificant.

NDF content was significantly ($p \leq 0.05$) influenced by the years and treatments. The average value of NDF in 2014 was significantly higher than that in 2015 (Table 5). NDF content of DM was also significantly changed by the treatments, and its two-year average values varied between 416 g kg^{-1} and 558 g kg^{-1} depending on the treatments. Sole sowing of LB showed significantly lower NDF content than all of the other sole sowings and mixtures. The highest NDF content among the treatments was determined in IW, and it was significantly higher than those of all of the other sole sowings and mixtures. The mixtures showed lower NDF content than sole sowing grasses but higher than sole sowing legumes and LB. The interactions of years by treatments in NDF content were not significant.

Years, treatments, and their interactions significantly ($p \leq 0.05$) affect the ADF content of DM from sole sowings and mixtures of the tested perennial legume and grass species. The average ADF content in 2014 was significantly higher than that in 2015 (Table 5). According to the two-year average of ADF content, it varied between 280 g kg^{-1} and 424 g kg^{-1} depending on the treatments (Table 5). ADF content of sole sowing IW was statistically significantly higher than the other sole sowings and all of the mixtures. Low leafiness and higher stem/leaf ratio in IW may be the reason for its higher ADF content. The lowest ADF ratio was recorded in the sole sown LB.

Table 4. Crude protein ratios (CP), and crude protein yields (CPY) of pure sowings and mixtures in the experimental years.

Species and Mixtures	CP ($g\ kg^{-1}$)			CPY ($kg\ ha^{-1}$)		
	2014	2015	Mean	2014	2015	Mean
IW±	115 j*	120 h*	118 ı*	315 d*	372 fg*	344 e*
SB	123 ıj	125 h	124 ı	304 d	343 g	324 e
A	203 a	207 a	205 a	843 b	940 bcd	892 bc
S	184 b	188 b	186 b	843 b	895 cd	869 bc
LB	151 g	154 f	152 g	444 c	493 ef	468 d
A+ IW	174 bc	183 bc	178 bc	890 ab	1036 abc	963 bc
A+SB	172 cd	181 bc	177 c	905 ab	1007 abcd	956 bc
A+IW + SB	161 defg	173 cd	167 de	862 b	1051 ab	957 bc
A+S+IW+SB	171 cde	172 cd	171 cd	1014 a	1133 a	1074 a
A+LB+IW+SB	164 cdef	167 de	166 de	897 ab	1033 abc	965 b
S+IW	159 efg	163 def	161 ef	840 b	986 bcd	913 bc
S+SB	157 fg	163 def	160 efg	814 b	951 bcd	883 bc
S+ IW + SB	151 g	152 f	152 g	825 b	875 d	850 c
S+LB+IW+SB	155 fg	157 ef	156 fg	888 ab	939 bcd	914 bc
LB+IW	135 h	137 g	136 h	512 c	564 e	538 d
LB+SB	134 hı	136 g	135 h	501 c	570 e	536 d
LB+IW+SB	134 hı	136 g	135 h	515 c	578 e	546 d
Mean	155 B+	160 A	158	718 B+	810 A	764
CV (%)	4.21	3.95	4.07	10.04	9.37	8.16

±) IW: Intermediate Wheatgrass, SB: Smoot Brome, A: Alfalfa, S: Sainfoin, LB: Lesser Burnet. *) Mean values indicated with the same lower-case letter in a column are not statistically significant different from each other according to the Duncan test at $p \leq 0.05$. +) Mean values with the same upper-case letter for a characteristic are not statistically significant different from each other ($p \leq 0.05$).

Years by treatment interaction for ADF was significant ($p \leq 0.05$). The ADF contents of IW and SB in 2014 were not significantly different from each other while the ADF content of IW was significantly higher than that of SB in 2015 (Table 5). This result may be because of the different responses of these two grass species to ecological conditions due to the decreasing temperature and increased precipitation in 2015, especially the increase in stem ratios at different levels (Barnes et al., 2003). Due to the same reasons, binary mixtures of A+SB, S+SB, and L+SB in 2015 showed lower ADF contents than their ternary mixtures while their ADF contents were not statistically significant from each other in 2014.

ADL content was significantly ($p \leq 0.05$) influenced by the years and treatments. As for ADF, the average ADL content in 2014 was also significantly higher than that in 2015 (Table 5). According to the two-year averaged values, the ADL content varied between 59 g kg^{-1} and 99 g kg^{-1} depending on the treatments (Table 5). ADL content of sole sowing S was significantly higher than those of other sole sowings and the mixtures. Sole sown SB had significantly lower ADL than the other sole sowings and the mixtures. ADL contents of sole sowing legumes and LB were significantly higher than those of sole sowing grasses and mixtures.

The effect of the years on the ADL content significantly ($p \leq 0.05$) changed depending on the treatments. ADL content of sole sowing LB in 2014 was significantly lower than the sole sowing legumes but significantly higher than the sole sowing grasses and the mixtures. In 2015, ADL content of LB was not significantly different from those of binary and ternary mixtures of grasses + legumes as well as quaternary mixtures of grasses + legumes + LB.

Table 5. The ADF, ADL, and NDF ratios of pure sowings and mixtures in two experimental years.

Species and Mixtures	ADF ($g\ kg^{-1}$ DM)			ADL ($g\ kg^{-1}$ DM)			NDF ($g\ kg^{-1}$ DM)		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
IW[±]	435 a[*]	412 a[*]	424 a[*]	76 g[*]	61 ı[*]	68 h[*]	574	542	558 a[*]
SB	426 a	390 b	408 b	65 h	53 j	59 ı	560	530	545 b
A	287 g	272 j	280 k	98 b	86 b	92 b	458	414	436 j
S	332 f	307 i	319 j	103 a	95 a	99 a	482	456	469 ı
LB	255 h	243 k	249 l	95 c	73 cde	84 c	431	401	416 k
A+ IW	363 de	334 fg	349 g	85 def	75 cde	80 de	507	454	480 ghı
A+SB	354 e	325 gh	340 hı	85 def	75 cde	80 de	503	459	481 ghı
A+IW + SB	351 e	342 ef	346 gh	86 def	76 cd	81 d	509	471	490 fg
A+S+IW+SB	334 f	334 fg	334 ı	85 def	77 c	81 d	506	461	484 gh
A+LB+IW+SB	327 f	315 hı	321 j	86 de	76 cd	81 d	491	451	471 hı
S+IW	396 b	364 c	380 c	88 d	77 c	82 cd	536	502	519 cd
S+SB	397 b	345 def	371 d	82 f	72 de	77 f	524	495	509 cde
S+ IW + SB	396 b	378 b	387 c	83 ef	71 ef	77 ef	531	509	520 c
S+LB+IW+SB	354 e	342 ef	348 gh	86 de	75 cde	80 d	517	479	498 ef
LB+IW	369 cd	350 de	360 ef	85 def	68 fg	76 f	523	491	507 de
LB+SB	374 cd	333 fg	354 fg	77 g	63 hı	70 gh	518	481	500 ef
LB+IW+SB	377 c	357 cd	367 de	77 g	65 gh	71 g	530	496	513 cd
Mean	360 A[+]	338 B	349	85 A[+]	73 B	79	512 A[+]	476 B	494
CV (%)	2.07	2.19	2.20	2.45	3.20	2.80	2.04	2.07	2.08

[±]) IW: Intermediate Wheatgrass, SB: Smoot Brome, A: Alfalfa, S: Sainfoin, LB: Lesser Burnet. [*]) Mean values indicated with the same lower-case letter in a column are not statistically significantly different from each other according to the Duncan test at $p \leq 0.05$. [+]) Mean values with the same upper-case letter for a characteristic are not statistically significantly different from each other ($p \leq 0.05$).

4. Discussion

Higher total precipitation and lower mean temperature in the year 2015 compared to the year 2014 resulted in higher DM yield and CP content of DM. The plant grown under higher temperature condition produced less leaf and more stem compared to grown under cooler condition. Consequently, produced forage contains higher fibrous and less CP content (Barnes et al., 2003). Climate conditions in the second year, plants produced much more leaf, causing an increase in CP ratios and a decrease in ADF and NDF ratios. In addition, as the maturation stage progresses, the fiber and lignin content in the plant increases, and the forage quality decreases (Grev et al., 2017; Suryanah et al., 2018).

In the study, the mixtures were superior to the sole sowings of mixture component species in the DM yield. The superiority of mixtures to sole sown species has also been reported in previous studies (Albayrak & Türk, 2013; Annicchiarico et al., 2019; Dhakal & Islam, 2018; Meza et al., 2022; Serajchi et al., 2018; Yavuz & Karadağ, 2016). Also, Sanderson et al. (2005) reported that the yields obtained from multiple legume-grass mixtures were higher than those of the simple mixtures.

The increased contribution of the legumes and LB to the DM yields of the mixtures in 2015 resulted in higher CP content as compared to that in 2014. Due to the effect of A in the mixture, the CP ratio of the mixture of LB with A and IW (A+LB+IW+SB) was higher than those of sole sown LB. The effect of legumes in the mixture on yield and quality was higher than that of grasses (Elgersma & Søegaard, 2016).

The results of the study revealed that the CP ratios of sole sown A and S were higher than those of sole sown grasses and their mixtures, and the CP ratios of the mixtures were higher than those of sole sown grasses. Due to symbiotic nitrogen fixation of A and S legume species, their higher CP content is an expected result. This result was in line with the findings reported by Tessema and Feleke (2018), who reported that sole-sown legumes and legume-grass mixtures have higher CP and lower fiber contents than sole sown grasses. Growing legumes with grasses increases the CP content of the mixtures compared to sole sown grasses (Sturludóttir et al., 2014). Similarly, the other researchers have also reported that CP ratios of sole sown legumes are higher than those of sole sown grasses and their mixtures (Ćupina et al., 2017; McDonald et al., 2021; Yavuz & Karadağ, 2016).

Higher averaged DM yield and higher averaged CP content in the year 2015 resulted in higher CP yield as compared to the year 2014. The CP yield increased with the increase in DM yield and CP ratio of species and mixtures. Solati et al. (2018) emphasized a linear relationship between forage yield and protein yield.

The mixtures showed lower NDF content than sole sowing grasses but higher than sole sowing legumes and LB. The mixtures were expected to have lower NDF contents than sole grasses and higher NDF contents than legumes. The legumes in the mixture caused a decrease in the NDF concentration, whereas the grasses increased (Brink et al., 2015). Tessema and Baars (2006) emphasized that sole sown legumes, and legumes-grass mixtures had higher CP and lower fiber contents compared to sole sown grasses. Also, grasses have higher NDF content than legumes (Hoffman et al., 2001), and the addition of legumes to grasses in mixtures decreases the ADF and NDF ratios whereas it increases the CP ratio (Yüksel & Balabanli, 2021). The contribution of legumes in mixtures is significant because they increase dry matter intake and milk production (Johansen et al., 2018), and cattle prefer legumes rather than grasses under free grazing conditions (Villalba et al., 2015). Baron et al. (2000) indicated that the differences in nutritional values among the species were related to the leaf/stem ratio rather than the mass and morphology of the grass. Therefore, despite the high CP content of S as a legume, sainfoin-grass mixtures had a higher NDF ratio than alfalfa-grass mixtures. The results are in line with the findings of Albayrak et al. (2011) who reported that binary and ternary alfalfa-grasses mixtures had lower NDF ratios than sainfoin-grass mixtures.

Cooler temperatures and higher precipitation in 2015 may have increased leaf proportion of forages and this situation caused lower fiber content (Barnes et al., 2003) as compared to that in 2014. Low leafiness and increasing stem/leaf ratio by maturation in IW may be the reason for its higher ADF content. The lowest ADF ratio was obtained in the sole sown LB. The high leaf ratio of LB may be a reason for its low ADF content (Açıkgöz, 2021; Kaplan et al., 2014). Mülayim et al. (2009) have reported that the CP ratio of LB was higher than that of the grasses and similar to legumes whereas the crude fiber ratio was much lower than that of other forage crops. Elgersma et al. (2014) also obtained the lowest ADF and NDF values in pure sown LB. The grasses in the mixtures cause an increase in the ADF ratios of the mixtures whereas the legumes cause a decrease. The nutritional quality of mixtures is mainly related to the legumes (Gierus et al., 2012). The increase of the A ratio in the mixture positively affects the quality parameters including ADF and NDF (Yüksel & Balabanli, 2021).

Cinar and Hatipoglu (2015) reported that the ADF ratios in sole sown alfalfa, dallis grass, Bermuda grass, Rhodes grass, and alfalfa-grasses mixtures varied between 26.7%, and 40.2% and Zemenchik et al. (2002) reported the ADF ratios ranged between 25.5 and 26.9% for smooth brome + Caucasian clover and between 26.9 and 28.5% for orchardgrass + Caucasian clover mixtures. Jeranyama and Garcia (2004) determined the mean ADF ratio for alfalfa + grasses mixtures as 39%, and 49% for smooth brome at the heading stage. The differences in harvest time, mixture ratio, and climatic factors such as temperature and precipitation may have led to differences in ADF content among the experiments. Bhattarai et al. (2016) emphasized that the nutritional value of sainfoin varies not only with the maturity stage but also with different experimental conditions and locations during the same growing period.

ADL contents of sole sown legumes and LB were significantly higher than those of sole sown grasses and the mixtures. Legume species contain more ADL than the grasses (Lardy, 2018). Due to the lower ADL content of the grasses, the mixtures of legumes and grasses contain lower ADL than the pure sown legumes but higher ADL than the pure sown grasses. The ADL ratios in alfalfa-grass silage were reported as 5.1%, and the ADL ratios in the hay of cool-climate grasses mixture as 3.8% (Mandebvu et al., 2001). The ADL value was also reported between 5.12 and 8.44% for five different alfalfa varieties (Bani et al., 2007), 10.87% for alfalfa, and 11.87% for sainfoin (Canbolat & Karaman, 2009), and 5.45% for intermediate wheatgrass (Gürsoy et al., 2021). The differences in ADL ratios between the aforementioned studies and our results were probably originated form the differences in plant materials and the ecological conditions of study areas.

5. Conclusions

The results of the study revealed that the yield and quality performances of legume-grass mixtures were higher compared to the performances of sole legume or grass sowings. In an overall evaluation of DM yield, CP yield, ADF, and NDF ratios, which are important indicators of forage quality, the A+S+IW+SB, A+LB+IW+SB, and S+LB+IW+SB mixtures were superior to other mixtures and sole sowings. These mixtures can be used in similar ecological conditions, as in Central Anatolia, in producing high-quality hay or establishing artificial pastures. However, as the research findings emphasize, A may become dominant in A+S+IW+SB and A+LB+IW+SB mixtures over time, which may cause animal bloating problems; therefore, these mixtures should be evaluated by mowing or care should be taken if the mixtures in question are to be grazed. On the other hand, the S+LB+IW+SB mixture can be preferred for quality roughage production in both grazing and mowing conditions.

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Evaluation of Phytoremediation Capacity of Guinea grass (*Panicum maximum*): A Focused Review

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A B S T R A C T

Environmental contamination from heavy metals has grown to be a significant problem on a global basis. Due to the mobilisation of heavy metals during ore extraction and subsequent processing for diverse applications, they have been dispersed into the environment. Utilising plants for pollutant extraction, degradation, or volatilization is possible. Using plants and the bacteria that live on them to clean up the environment is known as phytoremediation.
The bioaccumulation of elements in the body tissues of hyperaccumulator plants is used in phytoextraction, phytofiltration, phytostabilization, phytovolatilization, phytodesalination, and phytomining processes. As they move from low trophic levels to high trophic levels, their concentrations rise (a process also named as biomagnification). Recent studies indicate ability of *Panicum maximum* to clean places that have been contaminated with diversified heavy metals and other types of pollution.

1. Introduction

The accumulation of organic sludge, industrial chemicals, heavy metals, and household trash in seas and rivers has led to water pollution, while the emission of harmful gaseous elements from factories and automobiles has led to air pollution (Corami, 2023) and the contamination of water bodies. One of the major environmental issues facing humanity today is the growing discharge of untreated wastewater from mining and industry, as well as excessive fertiliser use for agriculture and soil contamination from heavy metals (Prommarach et al., 2022). Heavy metal pollution is a severe issue for the environment worldwide. Particularly in mining regions, the microbiological life in soil is severely harmed by cadmium (Cd) and lead (Pb) (Xiao et al., 2020). Due to its phytotoxicity, cadmium has generated significant environmental issues requiring for methods to lower its concentration in the environment (Rabelo et al., 2017).

Despite all the financial advantages of cement manufacturing, heavy metals, a byproduct of the process, can pose major risks to the environment and public health. The levels of heavy metals lead (Pb), cadmium (Cd), copper (Cu), chromium (Cr), zinc (Zn), and manganese (Mn) in the factory wastes are higher than allowed (Javanmardi et al., 2022).

A significant amount of coal overburden is produced along with the extraction of coal, and this overburden is piled on the nearby ground in the form of external dumps. Groundwater and surrounding soil contamination brought on by heavy metals, land degradation, and loss of biodiversity are the main issues connected to coal overburden dumps (Kumar et al., 2023).

According to Sajjad et al. (2022), the presence of plastics in soils raises the concentration of potentially harmful metals (As, Zn, Cu, and Pb),

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causes an excessive loss of soil water, and may limit microbial activity. In addition to other organic pollutants, soil pollution caused by explosives is a significant environmental hazard. Ground and surface fluids, soils, and sediments are contaminated by explosive compounds that are entered into the environment during manufacturing, processing, and disposal processes at military facilities (Singh & Mishra, 2014).

While certain agricultural plants are naturally able to tolerate fluoride (F−), most are inhibited in their development and metabolism by excess fluoride (Gadi et al., 2021). Worldwide, P losses from agricultural areas have grown to be a serious environmental issue. Although several methods (including cultural practises like non-till, crop rotation, buffer strips, cover crops, and the application of chemical amendments) have been investigated to decrease P mobility in P-enriched soils, these methods typically do not result in lower in situ soil P concentrations. Several studies have demonstrated that chemical amendments, such as gypsum and materials containing aluminium, can immobilise phosphorus (P) by generating insoluble complexes, hence lowering the likelihood of P movement off-site. But significant problems regarding the stability and liability of P immobilised by soil amendments over the long run remain unsolved (Silveira et al., 2013).

In 31 nations around the world, there are operational nuclear power reactors. The primary sources to the nuclear waste, outside reactor operating, are mining, fuel manufacture, fuel reprocessing, and military actions. The waste streams could pose a radioactive concern to the environment due to the existence of numerous long-lived radionuclides with different oxidation states, including plutonium (Pu), neptunium (Np), americium (Am), and curium (Cm). Nuclear waste frequently contains significant amounts of cesium (137Cs) and strontium (90Sr). Due to their lengthy half-lives and simple translocation into the human body, these radionuclides are able to cause potential health risks. Along with radionuclides, heavy metal pollution is a significant problem. In small amounts, heavy metals are found naturally in the crust of the planet and are also necessary for life's metabolic processes. These heavy metals' bioaccumulation has dangerous side effects. These contaminants enter into human bodies directly through polluted drinking water or the food chain. Scientists from all over the world are working on environmentally friendly solutions to fix the soil and water supplies because of this issue. The waste can be cleaned by using a variety of physical and chemical approaches, but these processes are highly expensive, difficult, and have several adverse effects. Phytoremediation is one of the effective strategies that has been pursued actively to address these drawbacks. The procedure is simple, easy, and incredibly cost-effective. With this method, low- and moderately contaminated locations are effectively decontaminated using plants and the bacteria they are connected with. For the successful rehabilitation of contaminated water and soil systems, numerous plant species are utilised. Remediation of these systems has become a crucial problem as a result of several human activities that significantly increased the amount of heavy metals and radionuclides in these systems. Additionally, the size of the contaminated sites is growing as a result of these activities (Sharma et al., 2015).

2. Phytoremediation

Heavy metal accumulation in the environment is attracting the attention of the scientific community, which is looking for alternatives that may minimise the effects that are brought on by this process (Carrasco-Gil et al., 2012). In order to replace the harmful components with biocompatible, non-toxic, and environmentally friendly materials, scientists are developing green synthesis techniques. The ability of plants to endure dangerous soil minerals and organic compounds as well as their capacity to defend themselves against environmental dangers are well established. For protection against chemicals, plants have a variety of defense mechanisms. Hazardous metals can have their redox states changed into non-toxic ones by using reducing enzymes and proteins that sequester toxic metals (Oza et al., 2020). The cultivation of metal-accumulating plants, which encourage the uptake and accumulation of soil pollutants in their biomass, is one of these solutions (Pramanik et al., 2018).

In Phytoremediation, plants are utilised to decrease the negative effects of heavy metals in the environment (Ashraf et al., 2019). Phytoremediation is a new alternative technology to traditional remediation methods, has the benefit of being both economically and environmentally sustainable (Hasan et al., 2019). Two of the most often applied phytoremediation techniques for heavy metal-contaminated soils are phytoextraction and phytostabilization (Yan et al., 2020). Fastly growing plants that can withstand high metal concentrations in their aboveground tissues are employed in phytoextraction. Plants with a strong potential to decrease metal mobility in the soil are utilised in phytostabilization (Wei et al., 2021). In contrast to phytostabilization, which keeps metals underground, phytoextraction is thought to be a permanent solution for the uptake of heavy metals (assuming it involves the final disposal of avoveground biomass) (Yan et al., 2020). For phytoextraction to be successful, a plant must have high aboveground biomass output, high tolerance, and the capacity to extract, transmit, and accumulate metals. Hyperaccumulator plants, which are accumulator plants with high biomass production, are the most suitable for phytoremediation in this regard. Although they may have low production, hyperaccumulator plants can accumulate over hundred times the typical amounts of accumulated metals or metalloids in their aboveground biomass without displaying any symptoms of phytotoxicity (Chamba-Eras et al., 2022). The prevailing consensus is that species utilised in phytoremediation with high biomass production capacity can compensate their comparatively low metal accumulation capability (Ali et al., 2013). The adoption of species that are not just tolerant but also capable of showing quick development, large biomass yield, and the capacity to concentrate the toxic element is essential to the success of this technique (Cheng et al., 2016).

The improper disposal of industrial and municipal waste, the use of phosphate fertilisers, and the application of sewage sludge, among other things, have all contributed to an increase in the concentration of cadmium in the environment over the past several decades. Given that Cadmium (Cd) is hazardous to plants, animals, and people, this fact poses a serious socioeconomic issue (Stritsis and Claassen, 2013). Because of this, a number of methods to lower the amount of Cd in the environment were researched, most notably phytoextraction (Sheoran et al., 2016). But, there are currently only a few types of plants known to be Cd hyperaccumulators, which encourages research on other plants, such as forage grasses. In phytoremediation, the grasses (ex: *Panicum maximum*, *Urochola maxima*, *Chromolaena odorata*, *Lolium multiflorum*, *Zea mays* and *Mirabilis Jalapa*) have been tested with favorable results (Yavari et al., 2015). Plant growth may be hampered by soil pollution brought on by inappropriate waste disposal. Tropical fodder plants grow quickly, produce considerable amounts of biomass, and grow up strongly (Gonçalves & Monteiro 2023).

When grown in soils with metal contamination, hyperaccumulators concentrate trace and heavy metals in their shoots; these trace metal-loaded plants can be eliminated by harvesting the fields. The invention of phytoextraction is a result of studies examining the usefulness of these hyperaccumulators for environmental cleanup (Sheoran et al., 2016). There are, however, only a few known plant species that are Cd hyperaccumulators as of right now, which encourages research on other plants such forage grasses. The increased biomass of these plants, when grown with an appropriate supply of sulphur (S), can compensate the lower proportional Cd accumulation (Rabêlo et al., 2017a). Sulphur of amino acids reduced phytochelatins (PCs) and glutathione (GSH) that work to chelate and prevent harm from Cd, and an appropriate application of this nutrient can raise the Cd extraction capacity (Seth et al., 2012).

Utilising bioenergy crops to remove excess soil P is a contemporary alternative technique to alleviate environmental issues caused by P transport from agricultural soils. The expense of plant-based P remediation solutions can be mitigated in addition to the positive effects of P mitigation when harvested biomass is used as a renewable energy source (Silveira et al., 2013). Significant levels of P can be removed from P-enriched soils through phosphorus remediation utilising forage crops, according to findings (Newman et al., 2009). Due to their persistent nature, relatively high dry matter yields, and lengthy growth season, perennial warm-season grasses offer a potential alternative to reduce excess soil P. Additionally, the properties of their roots and growth help reduce surface runoff and soil erosion (Delorme et al., 2000, Surmen et al., 2018).

Since most commercially grown crops only remove small amounts of phosphorus, it will take decades for plant-based remediation solutions to bring phosphorus levels down to levels that are safe for the environment. The disposal of the harvested plant biomass and the high expense of crop establishment, care, and production are two additional drawbacks of using phytoremediation technologies to reduce excess soil P. A more modern alternative to phytoremediation is the production of bioenergy from plants. Even though the synergies between phytoremediation and bioenergy production have not been thoroughly examined, particularly for the phytoremediation of P, previous researches have shown that metal-accumulating plants can be used for bioenergy generation (Van Ginneken et al., 2007). Some perennial bioenergy crops, as opposed to annual crops, may require less N fertiliser to maintain yields (McLaughlin & Kszos, 2005), adding to the viability of plant-based P remediation solutions (Silveira et al., 2013).

Nano-bioremediation is removing or decreasing environmental contaminants from contaminated locations, such as heavy metals, e-waste, inorganic, and organic pollutants, using nanoparticles formed by bacteria, fungi, and algae with the use of nanotechnology. It is referred to as nano-phytoremediation when such environmental toxins are reduced or eliminated using nanoparticles made by or involving higher plants. Nanoparticles are extremely small atomic or molecule aggregates that range in size between 1-100 nm and can dramatically alter the physico-chemical characteristics of a substance as compared to bulk material. Some types of nanoparticles are: natural nanoparticles (volcanic dusts), and mineral composites; incidental nanoparticles (welding fumes), coal combustion, diesel exhaust; and engineered nanoparticles (nanogold, nanozinc, titanium dioxide and nanoaluminium). Similar to phytoremediation, nano-phytoremediation uses a variety of processes. Accordingly, depending on the processes involved, there may be nano-phytostabilization, nano-phytodegradation, nano-phytovolatilization, nano-rhizofilteration, nano-phytoaccumulation, and nano-phytohydraulics. By enabling access to previously inaccessible locations and encouraging in-situ repair, among other things, nanotechnology improves phytoremediation efficiency. By combining the functions of microorganisms and plants and enhancing them with nanoencapsulated enzymes, nano-phytoremediation makes it easier to break down complex organic chemicals that are resistant to degradation into simpler ones. Nanoparticles with high affinity for metal/metalliod absorption include nanosized zero valent iron (nZVI), titanium oxides, manganese oxides, cerium oxides, and zinc oxides. They are effective for remediation of various contaminants, including 2,4,6-trinitrotoluene (TNT explosive), e-wastes (electronic wastes), heavy metals, polychlorinated biphenyls, endosulfan, and others due to this affinity, their many active surface sites, and high surface area (Nwadinigwe & Ugwu, 2018).

3. Phytoremediation by Guinea grass (*Panicum maximum*)

In addition to their high biomass production (often greater than 20 t DW ha-1 year-1), forage grasses typically have a deeper root system, low requirements for soil fertility, higher adaptation to soil and climatic adversities (Rabêlo et al., 2018a). These traits make them perfect for phytoextraction (Vangronsveld et al., 2009). As a result, numerous studies using forage grasses have been carried out to evaluate its ability for accumulating heavy metals and its potential for phytoextraction (Marzban et al., 2017; Rabêlo et al., 2017b, c, 2018c, d).

Recent studies has shown that *Panicum maximum* has the capacity to clean up sites that are contaminated with copper, cadmium, and barium (Monteiro et al., 2011; Gilabel et al., 2014; Silva et al., 2016). Because of its ability to regenerate, tolerance to biotic and abiotic stressors, and favourable response to fertilisation, this grass is simple to produce and has a high production potential (Silva et al., 2016).

Fakayode and Onianwa (2002) conducted research on Guinea grass (Panicum maximum) in the area of Ikeja Industrial Estate in Lagos, Nigeria. They found highly significant relationships between the soil and grass levels of Mn (0.94), Cd (0.83), Ni (0.90), and Pb (0.73). Cr (23), Cd (34.1), Ni (23.4), and Mn (12.3) had greater accumulation factors (indicating the ratio of average metal concentrations at the contaminated site to that of the control site) than Pb (9.8), Zn (7.2) and Cu (8.7) in the panicum maximum.

According to Paquin et al. (2004), *Panicum maximum* was a successful species for the elimination of RDX (an explosive) (1,3,5-trinitro-1,3,5-triazinane) in Hawaii. According to Lamichhane et al. (2012), the phytoremediation of "RDX explosive" by Panicum maximum was accelerated in the presence of molass and led to RDX disappearance mostly in the root zone.

A possible energy crop that needs additional research is the tropical forage Panicum maximum, which has high biomass, rapid growth, and low humidity content (Ram, 2009). Maximum CV for panicum. Massai (Massai grass) has demonstrated exceptional resilience in surviving at concentrations of 0.1 mmol L-1 Cd in the nutrient solution, even at Cd concentrations in their shoot exceeding 100 mg kg1 DW. This shows that this species may be used for Cadmium phytoextraction (Rabêlo et al., 2018b, c, d). The Massai grass can be used as a model plant in this regard to determine the main plant processes that lead to cadmium accumulation in fodder grasses. According to Gallego et al. (2012), a number of factors, including the plant's nutritional status and its ability to transfer Cadmium from roots to shoots, synthesise Cadmium chelators like glutathione and phytochelatins, and reduce the oxidative stress caused by Cadmium are linked to Cadmium accumulation. However, according to Rabêlo et al. (2018a), we are unsure which of these plant responses is in fact more connected to Cadmium accumulation in fodder grasses. In order to choose forage grasses with a true capacity for Cadmium phytoextraction, it is imperative to establish the primary plant responses connected to Cd accumulation (Rabêlo et al., 2019).

Malondialdehyde levels in tissues was shown to rise when P. maximum Jacq. cv. Massai was exposed to cadmium, according to Rabêlo et al. (2018). Malondialdehyde is a naturally occurring chemical molecule and a sign of oxidative stress with the molecular formula CH2(CHO).

Trinitrotoluene (the explosive used in TNT explosives) can be removed from polluted soil through a novel technique called nanophytoremediation, which was developed by Jiamjitrpanich et al. (2012). This technique combines phytoremediation with nanoscale zero valent Fe (iron) (nZVI). In this study, the purple guinea grass was employed for nano-phytoremediation of soil contaminated with a TNT/nZVI ratio of 100 mg/kg TNT concentration, and it was shown that the remediation of the TNT had been finished in 60 days.

4. Effect of plant nutrition level on phytoremedition

According to de Souza Cardoso and Monteiro (2002), sulphur (S) can play crucial roles in defending plants against abiotic stresses, such as the toxicity of heavy metals. A promising strategy in phytoremediation is the assessment of the impacts of S supply since S can reduce the phytotoxicity brought on by heavy metals (Rabelo et al., 2017).

The simultaneous uptake of NO3 (nitrate) and $NH4^{+}$ (ammonium) by plants is advantageous because it can affect heavy metal bioaccumulation (de Sousa Leite & Monteiro, 2019).

It has been demonstrated that the beneficial element silicon (Si) increases plants' ability to tolerate excess metal in a particular growing media. The effectiveness of Si in reducing Cu toxicity in plants may, however, differ depending on the plant types and the Cu concentration in the soil or other media. Supplying Si to Tanzanian guinea grass can counteract the negative effects of Cu excess. In both growth periods, plant yields increased by Si supplies and decreased with an increase in Cu rates. In contrast to other combinations, plants subjected to Cu at a concentration of 750 mol L-1 without Si treatment had higher copper concentrations in diagnostic leaves (DL), roots, and shoots, as well as increased copper content in these tissues. The primary role of Si was to inhibit the movement of copper (Cu) from roots to shoots, allowing for successive harvesting and reducing the level of Cu in plant tissues (Vieira Filho & Monteiro, 2020).

High amount of potassium supply to Cd exposed plants promoted high levels of shoot drymass production, which decreased the concentrations of this metal in the photosynthetic tissue (indicating remarkable plant tolerance) and harvestable shoots. Thus, K makes Tanzanian guinea grass more capable of phytoextracting Cd (de Anicésio & Monteiro, 2019).

5. Conclusions

A new remediation technique called phytoremediation uses plants and bacteria to purify contaminated air, soil, and water. Long plant growing seasons and higher soil temperatures in tropical and subtropical regions might speed up phytoremediation processes. The selection of promising plants is critical to success of phytoremediation. In addition to their high biomass production, forage grasses typically have a deep root system, low requirements for soil fertility, adaptation to soil and climatic adversities, and successive emissions of shoot apical meristem after the harvest of shoots. Recent studies have shown that Panicum maximum has the capacity to effectively clean-up sites that are contaminated with copper, cadmium, barium, RDX and TNT explosives. Sulphur supply can reduce the phytotoxicity stress sourced from heavy metals during the soil clean up.

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Research

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Solar Drying of Agrobiomass for Biopellets Production

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The paper presents the results of a study on solar drying of agrobiomass waste for the production of biopellets. The tests were conducted under open sun drying conditions during the summer in a Mediterranean climate, specifically in the Aydin province of Turkey. Drying tests were performed for two types of mixtures, i.e., sewage sludge and olive mill waste (OMW30), and sewage sludge and animal waste (DMC30). To ascertain the optimal conditions for the process the mixtures were dried under different thicknesses: 5, 10, and 20 cm and varied mixing intensities: no mixing and 6 times a day. It was observed that mixing of biowaste reduces time of drying, and the tests indicated a preference for drying the mixture with a thickness of 10 cm. The dried mixtures can be utilized in the production of pellets for energy applications.

1. Introduction

Solar drying is widely recognized as a sustainable and environmentally friendly alternative to conventional drying techniques, and it has become a well-established practice in agriculture. In agricultural sector drying process, is applied to remove moisture from crops, fruits, and vegetables, preserving their quality. A high level of moisture can promote the growth of microorganisms, bacterial activity, and mold proliferation, ultimately leading to material spoilage (Lingayat et al., 2021; Udomkun et al., 2020). The reduction of moisture can be achieved using solar or thermal energy in the drying process. This reduction is necessary to prolong the lifespan of the product and has a positive impact on transportation and storage. Solar drying is a method that can be particularly useful in areas with high sun radiation. It is stated that using solar drying can reduce the consumption of non-renewable sources for this process by up to 27% to 80% (Prakash et al., 2016).

The drying rate depends on several factors, including solar radiation intensity, the temperature and relative humidity of the air, the air circulation and thickness of the drying material layer (Wzorek, 2021). During the drying process, where heat and mass transfer occur simultaneously, moisture evaporates near the surface through various mechanisms, including liquid and vapor diffusion, capillary and gravity flows, as well as flow driven by shrinkage and pressure gradients (Ortiz-Rodríguez et al., 2022).

Solar dryers can be divided into two main types: direct and indirect solar dryers (Lingayat et al., 2021). Direct solar dryers expose the products to be dried directly to sunlight in an open field (a method known as open sun drying), and it is the most common and oldest method used in rural areas of developing countries.

Solar dryers can be categorized also according to their system design and the method of utilizing solar energy. For example, they can be classified such as passive, active, and hybrid solar dryers, which are distinguished by their approach to air

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circulation (natural or forced convection) and heat transfer mode (direct or indirect) (Lingayat et al., 2021; Udomkun et al., 2020).

Instead of main products the agricultural sector produces a substantial volume of by-products i.e., sludge, fibrous waste, crop residues, animal, and food processing waste.

The main problem with their reuse is high moisture content. Solar drying can be beneficial in transforming these by-products into valuable resources for various purposes, such as animal feed, energy production, composting, and other value-added products.

Agbede et al. (2023) investigated among others open sun drying of banana stalk chips which were untreated in 5, 10 and 15 mm thick. Solar drying of oil palm empty fruit bunches (EFB), a solid waste product from the palm oil industry, was studied in a hybrid solar dryer integrated with a thermal backup unit. It was determined that the time required to dry 2.5 kg of EFB is 4.21 days under open sun drying conditions. This can be reduced to 1.33 days by using the thermal backup (Al-Kayiem and Yunus, 2013). Maragkaki et al. (2016) examined the effect of greenhouse solar drying of various olive oil by-products among others three-phase and two-phase pomace as well as pomace with leaves and biomass from pruning. The study was conducted from January to April in Crete, Greece and wastes are dried in 10 cm layer. Results showed that for example moisture content for three-phase pomace decreased from 47 to 9.6% after 64 days and for two-phase pomace from 59 to 7.2 after 75 days of solar drying.

Wzorek (2021) conducted tests on drying biofuels made from sewage sludge and other waste in a solar greenhouse dryer equipped with a specially designed mixing system during the Polish summer and autumn conditions. The performed experiments demonstrated that it is beneficial to dry biofuels in 10 cm thick layer.

Türkiye has significant solar energy potential, making it one of the key renewable energy sources. The yearly average solar radiation is 1,311 kWh/m^2 per year and 3.6 kWh/m^2 per day. The total yearly insulation period is approximately 2,460 hours per year and 7.2 hours per day. Turkey was among the top markets for solar air heating and drying in 2021, along with countries like Canada, Spain, the USA, and Austria (Solar Thermal Energy, 2021).

The use of solar energy can be the initial step in biomass processing, either before or after pelletization, depending on the properties of agricultural materials. This preparation is essential for their application in energy processes (Kumar et al., 2022). Pelletization are frequently employed with various types of biomasses to enhance factors such as handling properties, increase its volumetric calorific value, and lower transportation costs (Whittaker and Shield, 2017; Yilmaz et al., 2018).

Therefore, it is crucial to research the solar drying of agricultural materials in regions with high solar radiation to optimize the solar drying processes.

2. Material and Methods

2.1. Materials

Agricultural biowastes: olive mill waste and animal waste as well as sewage sludge from municipal wastewater treatment were used in this study. The selection of biowastes was primarily based on their availability and, notably, the challenge of their utilization within the same region.

Samples of solid olive mill waste (OMW) were gathered from small-scale olive plants situated in the Aydin region. This region is known for its traditional cultivation of Olea europaea L olive tree, used for both oil and table olive production. The OMW material originated from the three-phase decanting method, which involved a combination of olive fruit kernels and pulp and water.

Cow manure originated from a local dairy farm (DCM) that manages 112 cows. The manure is stored there in an open space in the form of a midden.

Sewage sludge (MSS) originated from a mechanical-biological wastewater treatment plant serving 115,000 PE. The sludge had undergone a mechanical dewatering process.

Mixtures with various proportions were prepared using these biowastes, including a mixture with 70% sewage sludge and 30% olive mill waste (OMW30), as well as a mixture of sewage sludge and cow manure with 30% moisture (DCM30). The properties of biofuel components are detailed in Table 1.

The biofuel compositions OMW30 and DCM30 were subjected to solar drying.

Table 1. Parameters of components of biofuels

Materials	Moisture, % w.b.	Ash, % d.b	Volatile Matter,% d.b	HHV kJ/kg
OWM	84.24	22.29	48.65	18 860
AW	79.90	20.16	24.84	9 960
MSS	85.10	41.02	32.19	15 180

w.b. – wet basis; d.m. - dry basis

2.2. Methods

Solar drying test was conducted in the summer in August in Aydin, city at the Aegean province in Turkey (geographic coordinates of 37°50′53″ N latitude and 27°50′43″E longitude). The climate in this region is categorized as a Mediterranean climate, exhibiting characteristics of warm and arid summers alongside cool and wet winters.

In Fig. 1 is presented the total annual solar irradiance for the city of Aydın.

During the test, a meteorological station situated near the test stand continuously monitored ambient temperature, relative humidity, precipitation, and total global solar radiation.

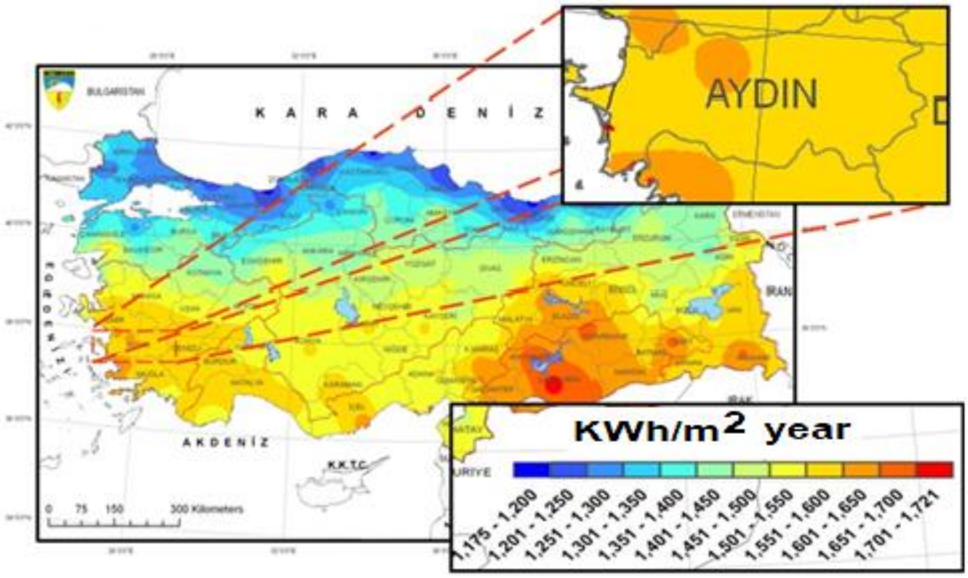

Figure 1. Total annual solar irradiance of Aydın (Anonymous, 2017).

Procedure of solar drying

The study was conducted in the research application area of the Biosystems Engineering Department, Faculty of Agriculture at Aydın Adnan Menderes University.

Biowaste was tested in an open sun drying system and exposed to the entire spectrum of outdoor environmental conditions. Biowaste, mixed in appropriate proportions, was placed in polypropylene containers, which were positioned on a wooden platform in the field to prevent stray radiation and heat transfer from the ground.

To enhance the process, screw-shaped vertical mixers, which moved along containers at a rational frequency ranging from 120 to 360 1/min, were also used for material mixing.

In order to determine the optimal process conditions and conduct a kinetic analysis of solar biowaste drying, a comprehensive set of tests was performed with variable parameters. These parameters encompassed different materials thicknesses (5, 15, and 20 cm) and various mixing intensities (no mixing and 6 times a day).

In the biowaste, the initial moisture content was determined, and then the daily moisture loss in the material samples was measured using the oven-dry method in accordance with the EN 12880:2000 standard.

The moisture content (MC) was calculated using the following equation:

$$MC (\%) = (m_1 - m_2 / m_1) \times 100 \quad (1)$$

where: m_1 is the initial weight of sample and m_2 is the weight of the dry sample.

Pellets production

After the drying process, biomass materials with moisture levels below 20% were subjected to a pelletizing process using a pressure pellet mill equipped with two movable rollers and a variable flat die with Ø6 mm and Ø8 mm holes. Pellets with diameters 6 and 8 mm were produced.

Properties of pellets

In the produced pellets, energy properties were determined:

- Higher calorific value (HHV) was measured by using Oxygen Bomb Calorimeter, model 1341 according to EN 14918:2010 and ISO 1928 standards,
- Ash content was tested according to EN ISO 18122 standard,
- Voltaire matter was carried out according to EN ISO 18123 standard,
- Fixed carbon (FC) content was calculated by difference using following equation:

$$FC = 100 - VM - A \quad (2)$$

where: VM is Voltaire matter, % and A is Ash content %.

3. Results and Discussion

The test was conducted under summer conditions. The average daily temperature during the testing period was 29.3°C, with an average maximum temperature of 33.2°C and an average minimum temperature of 26.5 °C. The average air humidity for this period was 55.65%, while the average total global solar radiation was 1.48 kWh/m².

Fig. 2 shows the temperature and relative humidity of the air during the test, while Fig. 3 illustrates the global solar radiation.

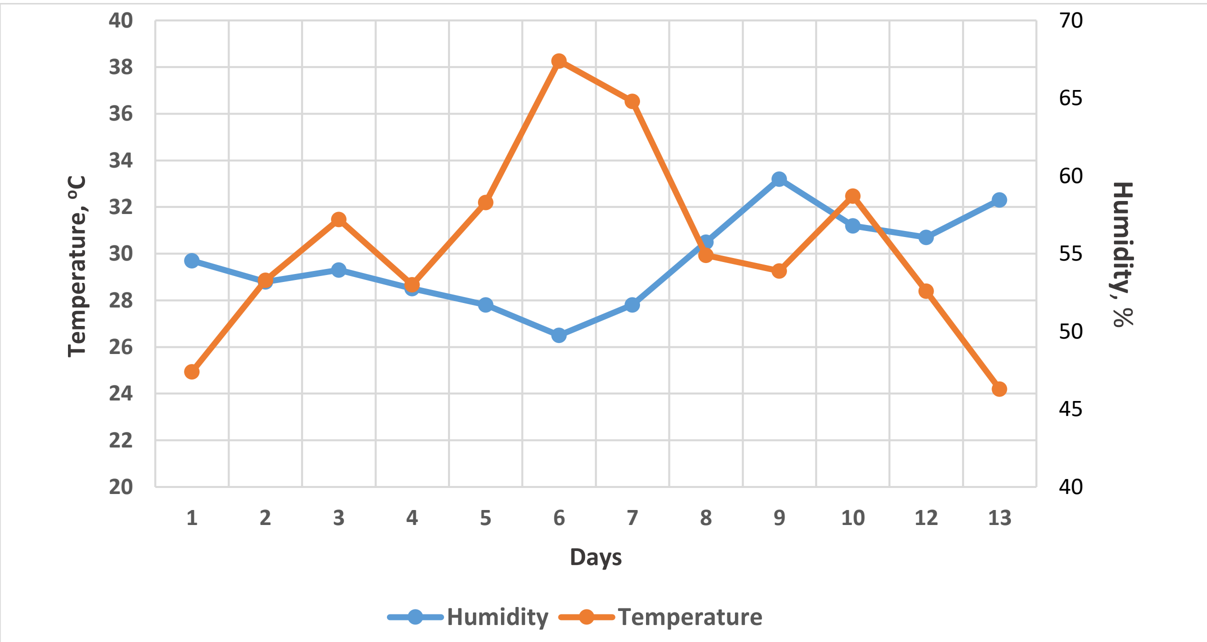

Figure 2. Air temperature and humidity during the test.

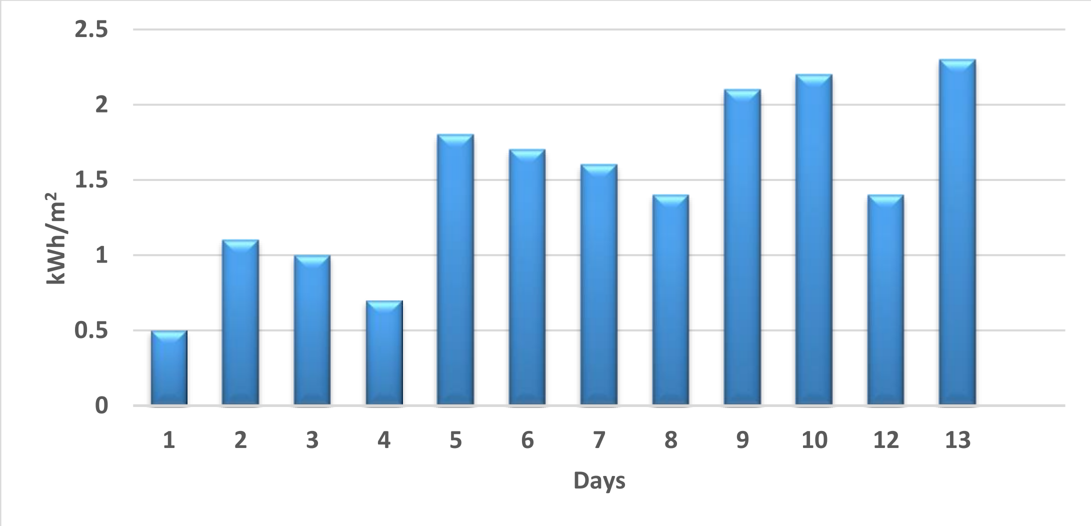

Figure 3. Solar radiation during the test.

In Figs 4 - 6 changes in moisture content in function of time for the tested mixtures of biowaste under open sun drying conditions are presented.

Based on the obtained research results, it can be concluded that mixing has an impact on the drying rate. In the case of drying without mixing, a slower moisture loss is observed compared to the variant with mixing, which is due to the transport of moisture from the interior of the dried material layer. Mixing led to the elevation of the material from the interior to the surface of the layer, facilitating contact with the drying agent. By drying biowaste mixtures in a layer with a thickness of 5 cm and applying mixing, a moisture content of 20% was achieved after 5 days. For solar drying in a 10 cm layer, the time extended by 3 days, and for drying in a 20 cm layer, it increased by 6 days compared to drying in a 5 cm layer. A slight difference in drying rate can be observed among the investigated mixtures, with DCM30 exhibiting a superior drying rate.

Similar results were observed by Yilmaz and Wzorek (2015) in the same climate conditions achieved for solar drying pure sewage sludge. Other authors, for example, Wzorek (2021) obtained a reduction below 10% in moisture content for a mixture of sewage sludge and sawdust after 15 days, and for the mixture of sewage sludge and meat and bone meal, after 8 days in Polish climatic conditions using a greenhouse solar dryer. According to Velis et al. (2009), 20% moisture content in the sludge is achieved during biological drying within 7 to 15 days.

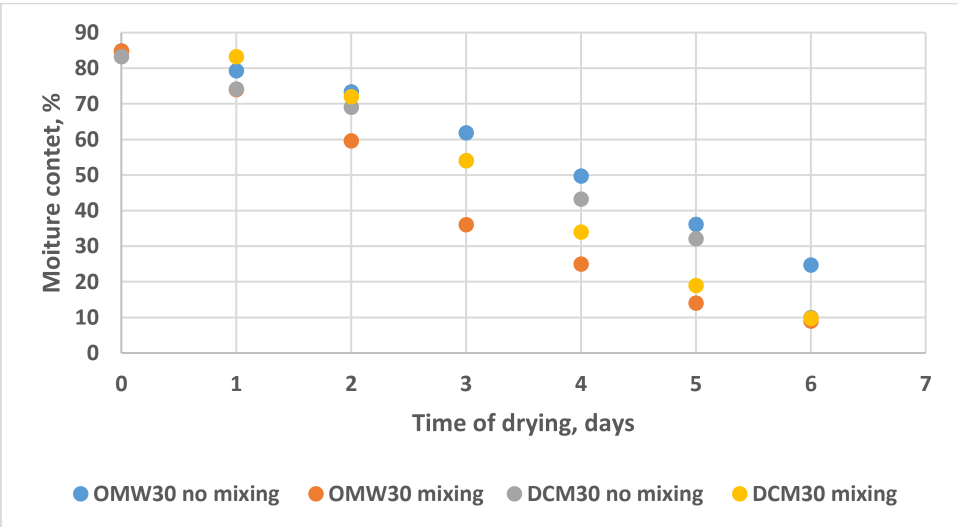

Figure 4. Changes in moisture content of biomaterials in function of time in open sun drying conditions; solar drying in 5 cm layer.

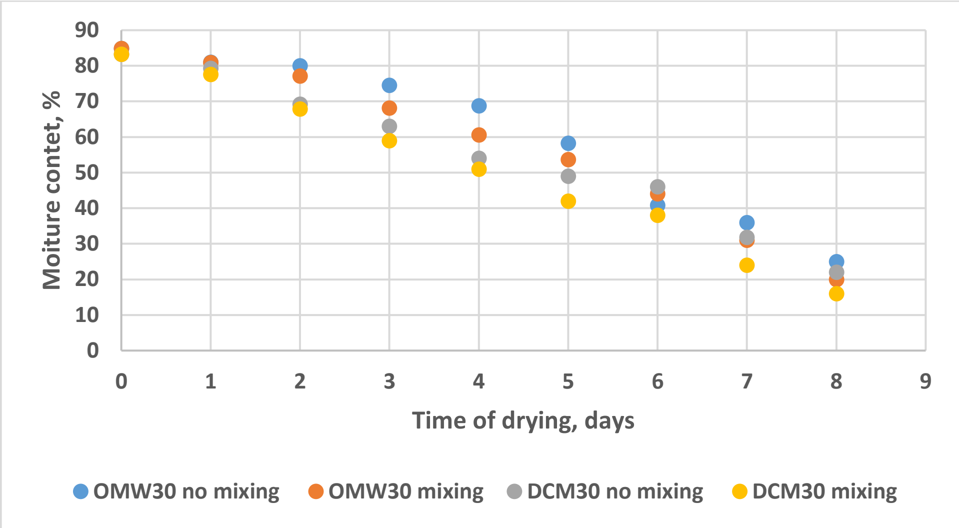

Figure 5. Changes in moisture content of biomaterials in function of time in open sun drying conditions; solar drying in 10 cm layer.

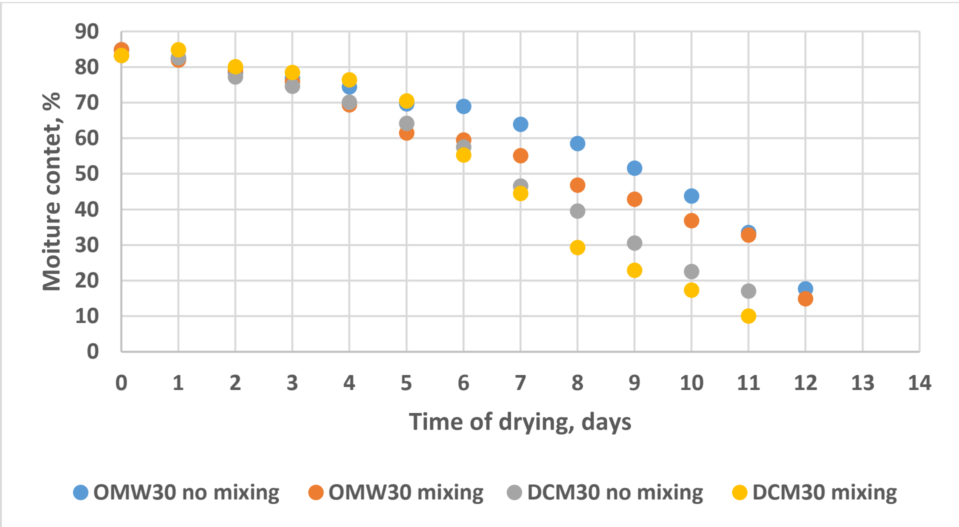

Figure 6. Changes in moisture content of biomaterials in function of time in open sun drying conditions; solar drying in 20 cm layer.

The dried mixtures of biofuel components underwent the pelletization process. In the study (Yilmaz et al., 2018), the pellets were produced using a specially designed system, which initially involved mixing the components and then forming them in special devices equipped with sieves and knives. In this arrangement, the mixtures were expected to have a moisture content in the range of 30-40%. However, in this experiment was decided to pelletize the biomaterials using a pressure pellet mill at lower moisture levels in the material.

The energy properties of the produced biopellets are presented in Table 2.

The addition of sewage sludge raised the Higher Heating Value of the DCM30 biopellets, which initially stood at 16.5 MJ/kg. HHV of DCM30 biopellets are significantly higher, with a value of 18.6 MJ/kg, and are highly recommended for energy generation. The calorific values of the produced bio-pellets fall within the range typical of plant and agrobiomass (Dinesha et al., 2019).

Table 2. Energy parameters of biopellets.

Biopellets	Proximate Analysis (wt %)				HHV kJ/kg
	Analytical moisture w.b.	Ash d.b.	Volatile Matter d.b.	Fixed Carbon d.b.	
OMW30	6.56	30.40	33.28	39.61	16 491
DCM30	5.57	39.61	29.74	30.64	18 633

w.b. – wet basis; d.m. - dry basis

4. Conclusion

The experiments yielded insights into the open air drying of biowaste in the summer conditions of the Aydin province. The study identified the key factors influencing the drying process, including the layer thickness, and mixing intensity, which have a positive impact on process. It was observed that the rate of solar drying is primarily contingent on the mixing of biowaste during the process, aside from weather conditions. Tests revealed a preference for drying the mixture in a 10 cm layer thickness.

It was observed a subtle disparity in drying rates between the OMW30 and DCM30 mixtures, with DCM30 demonstrating a more efficient drying rate.

The method involving solar drying followed by pelletization, can also find broader applications for agrobiomass utilization, such as for agricultural purposes like fertilizers. Pelletizing waste materials makes it easier to transport and store them.

The use solar energy for drying and application of agrobiomass for energy purpose can contribute to achieving sustainable development goals, reducing greenhouse gas emissions, and enhancing energy independence, provided that it is done responsibly and in an environmentally friendly manner.

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Research

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The Effects of Improvement Practices on Vegetation in Barren Pasture: The Case of Kastamonu

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Soil Values

A B S T R A C T

The research was conducted in the pasture of Alpagut village of Kastamonu center (410 25' 48.52"N, 330 55' 20.54E, altitude 851 m) located in the Western Black Sea Region of Türkiye to determine the changes in pasture vegetation caused by pasture soil improvement and management practices. The study was conducted between 2017 and 2023. According to the pasture soil analysis, fertilization was done with base fertilizer in autumn 2018 and top fertilizer in spring 2019. Shrub clearing and rotational grazing system were applied. Vegetation change in pasture soil was measured by the modified wheeled loop method during the flowering period of the plants in the pre- and post-improvement periods. It was determined that improvement practices increased the proportion of legumes, other families and perennial plants and contributed to the formation of a balanced vegetation. The proportions of declining, spreading, invasive and annual species were 11.50%, 5.10%, 46.75% and 33%, respectively, before pasture topsoil reclamation, while there was a decrease in annual species in the post-reclamation period. There was an increase in declining, reproductive and invasive species. It was found to be 26.66%, 15.39%, 55.86% and 17.00%, respectively. While *Bromus sp., Sanguisorba minor, Fumana arabica, Festuca ovina species* were dominant in the pasture area in the pre-improvement period, *Bothriochloa ischaemum, Teucrium chamaedrys, Festuca ovina* and *Astragalus frickii* species became dominant after the improvement. It was determined that improvement and management practices increased the area covered with vegetation from 74.00% to 98.00%, the proportion of legumes from 1% to 12%, and the pasture condition and health classification from poor-healthy to moderate-healthy category. It is recommended that the grazing plan for pasture sustainability be maintained.

1. Introduction

The meadow and pasture land areas in Türkiye, which were 44.20 million ha in 1940, decreased drastically to 12.30 million ha until 1991, and increased to 14.60 million ha today as a result of the studies started with the Pasture Law (Anonymous, 2022). The total pasture land area of Kastamonu province, where the research was conducted, increased to 28,302 ha. When the districts of Kastamonu are calculated, Devrekani, Centre and Taşköprü districts have the highest pasture land area respectively. The calculated pasture land areas of these areas are 8099 ha, 8876 ha and 2796 ha, respectively (Anonymous, 2023a; Gürel and İnan, 2022b).

Our pasture areas are our natural resources where the production of quality roughage required for animals is the cheapest. Due to irregular and excessive grazing in pasture areas, there is a

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decrease in the proportion covered with plants over time. Erosion and landslides occur on sloping lands as the botanical composition is disrupted, the plant species that animals love to eat are reduced and replaced by invasive species (Tosun, 1996; Gökkuş and Koç, 2001; Sürmen and Kara, 2022). For this reason, pastures should be grazed in accordance with the grazing systems and if necessary, it is necessary to carry out reclamation studies using appropriate reclamation methods (Alay et al., 2016; İspirli et al., 2016).

Pasture vegetations as an organic asset climate, topography, soil and other organisms is under the constant influence of the conditions it affects (Sürmen and Kara, 2018). As it is not possible to apply or develop any improvement method without knowing the vegetation structure of pastures, it is also necessary to examine the vegetation characteristics in detail before starting improvement, to identify pasture sections that differ in terms of yield and quality due to changes in soil and vegetation cover, and to carry out improvement and management practices specific to these areas (Yavuz et. al., 2022; Alay et al., 2016; Özyazıcı and Yıldız, 2017; Yavuz and İspirli., 2021). Fertilization is one of the most applied methods in pasture soil improvement. It is possible to increase the yield of pasture 2-3 times with an appropriate fertilization considering the species composition of vegetation and rainfall (Altın et al., 2007). Nitrogen and phosphorus are the nutrients that are most deficient in the soils of our country and therefore affect the yield the most. The effectiveness of fertilizers varies according to the application time and amount of rainfall fertilizer (Çomaklı et al., 2005).

Nitrogen and phosphorus are the nutrients that are most deficient in Turkish soils and therefore affect the yield the most (Çomaklı et al., 2005). The effectiveness of fertilizers varies according to rainfall, time and amount of fertilizer application. When the effects of fertilization on botanical composition are examined; nitrogen increases the proportion of grasses, while phosphorus and sulfur increase the proportion of legumes (Hatipoğlu et al., 2001). Therefore, botanical composition should be taken into consideration in pasture fertilization. Phosphorus fertilizers not only increase pasture yield in pasture but also increase the efficiency of nitrogen when applied together with nitrogen (Black, 1968). In some studies on nitrogen and phosphorus fertilization in different ecological conditions in Türkiye, Büyükburç (1999) reported the most suitable doses for yield and quality as 5 kg/da N, 5 kg/da P_2O_5, Altın et al. (2010) reported 4 kg/da N, 4 kg/da P_2O_5.

In this study, it was tried to determine the effectiveness of the applied reclamation methods through the changes in the botanical composition and pasture condition class of the pasture caused by reclamation practices such as fertilization, brush clearing and regulation of grazing in accordance with soil analysis.

2. Materials and Methods

2.1 General Soil Characteristics of Pasture

In 2017, soil samples taken from 0-20 cm soil depth according to the sampling method with soil auger tool from pasture soil were analyzed at Kastamonu Special Administration Directorate. Fertilization was done according to soil analysis. The soil is salt-free and poor in organic matter. The soil structure of the pasture area is in the neutral class with a pH value of 7.4. Pasture soil, which has a medium calcareous structure, does not have sufficient values in terms of phosphorus (1.71 kg/da) (Aydeniz and Brohi, 1993) (Table 1.).

Table 1. Some chemical and organic matter contents of soil samples taken from pasture

Province	Village	Pasture Parcel	Pasture Area (da)	Analysis type	Conclusion	Status
The Center	Alpagut	118/149	481,674	Potassium (K_2O) kg/ha	29,76	Middle
				Phosphorus (P_2O_5) kg/ha	1,71	Very little
				Lime (%)	14,75	Medium Calcareous
				Organic Matter (%)	1,93	Less
				Total Salt (%)	0,01	No Salt
				pH	7,4	Neutral
				Pasture parcel	69	Clay loam

2.2. Description of the Research Area and Vegetation Characteristics

The study was carried out in a pasture area of approximately 481 ha located at an altitude of 851 (410 25' 48.52"N, 330 55' 20.54"E) in Alpagut village of Kastamonu province. The study area is sloping and 11 km away from Kastamonu province (Figure 1). The average temperature of Kastamonu province for many years is 10.30 °C and the average annual precipitation is 667 mm (Anonymous, 2023b).

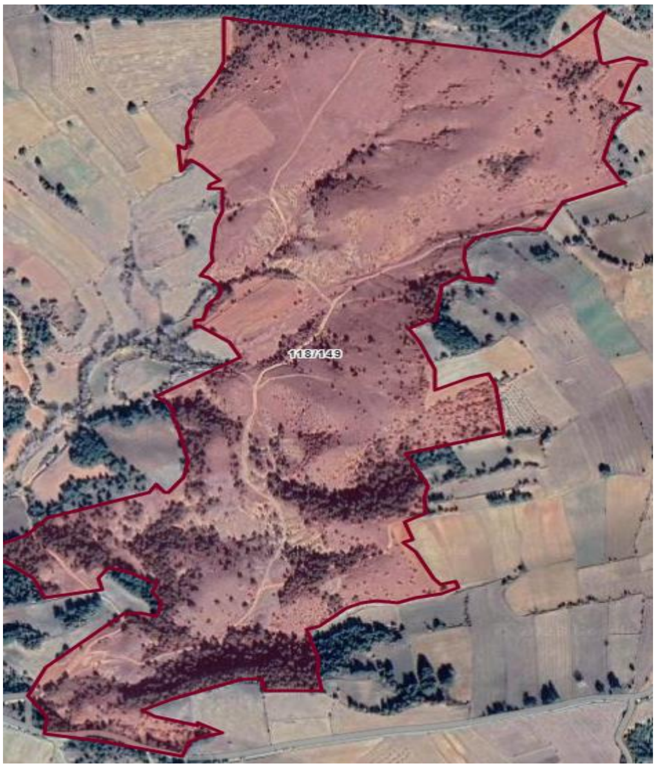

Figure 1. Test Location

The Black Sea Agricultural Research Institute Directorate and Ondokuz Mayıs University, Faculty of Agriculture conducted vegetation surveys of the pasture and determined the botanical composition and pasture condition class one year before starting the rehabilitation in the pasture area. Improvement recommendations were made according to the results of the vegetation report. Vegetation survey was carried out in 2017 by reading plant species during the flowering period based on the east, west, north and south directions of the pasture at a total of 400 points in 4 lines of the pasture (Gürel and İnan 2022a). Vegetation survey was carried out in pastures according to the modified wheeled point method. In the pre-improvement vegetation survey, the area covered with plants was determined as 79%. In the vegetation survey we conducted, 18 different species were identified, 1 from leguminous, 3 from grass and 14 from other families.

2.3. Vegetation Studies

Within the scope of the pasture improvement and management project implemented in Alpagut village, fertilizer doses recommended by Kastamonu Special Administration Directorate were used in fertilization application. In this context, in 2018, 20.20.0 compound fertilizer was applied with 5 kg da^{-1} P_2O_5 and 5 kg da^{-1} N (nitrogen) calculation in autumn with pure matter calculation. In the spring of 2019, Ammonium Sulphate (21%) N fertilization was applied at the rate of 5 kg da^{-1} N (nitrogen).

In the first year of the improvement program, in August 2008, the spreading juniper tree, thorny blackthorn and blackberry bushes, which were not preferred by the animals in the pasture soil area, were removed from the pasture by removing the roots with the excavator machine.

In Alpagut village pasture, a free grazing system was applied for 195 days starting in early April and continuing until October 15 before the pasture improvement project, while a rotational grazing system was applied for 150 days between May 15 and October 15 for the improvement program and after.

3. Results and Discussion

As a result of the vegetation survey of Alpagut village pasture before the improvement program, 18 species were identified and their soil coverage rate was 62.90%. The vegetation measurements of the pastures were carried out using the modified wheeled loop method and were determined at the flowering stage of the dominant plants in the pastures as described by Koç and Çakal (2004). Plant species in the field are divided into 3 classes as decliners, multipliers and invaders. Pasture condition classification was made in the pastures studied by taking into account all of the decliners and 20% of the multipliers among the plants identified. The proportion of vegetation covering the soil was determined by the ratio of the number of points where vegetation was found to the total number of points measured during the vegetation survey (Gökkuş et al., 2000). According to the results of the vegetation surveys conducted after the improvement, the number of species identified was 29, while the soil coverage rate of the species increased to 73.86%. While *Bromus sp. Sanguisorba minor, Fumana Arabica, Festuca ovina* were the dominant species in the pasture before improvement, *Bothriochloa ischaemum, Teucrium chamaedrys, Festuca ovina* and *Astragalus frickii* were the dominant species in the vegetation after improvement (Table 2, 3 and 4.).

Of the 18 species identified in 2017, 1 legume, 3 grass and 14 other species belonged to other families. Of the 29 species identified in the vegetation survey conducted after 5 years of alternate grazing, 5 were leguminous, 5 were grass and 19 were species belonging to other families (Table 2 and 3).

Table 2. Decreasing and increasing species in pasture composition, SCR (%) and PCR (%)

Pre-improvement Declining Plant Species					**Declining Plant Species after Improvement**				
Species	Family	Life span	SCR(%)[1]	PCR(%)[2]	Species	Family	Life span	SCR(%)	PCR(%)
Chrysopogon gryllus	Rosasea	Perennial	0.85	1.00	*Bothriochloa ischaemum*	Poaceae	Perennial	24.89	25.40
Sanguisorba minor	Poaceae	Perennial	10.20	12.00	*Koeleria cristata*	Poaceae	Perennial	0.88	0.90
					Onobrychis armena	Fabaceae	Perennial	0.88	0.90
Total			**11.05**	**13.00**				**26.66**	**27.20**
Pre-improvement Reproductive Plant Species					**Post-improvement Reproductive Plant Species**				
Species	Family	Life span	SCR(%)	PCR(%)	Species	Family	Life span	SCR(%)	PCR(%)
Festuca ovina	Rosasea	Perennial	3.4	4.00	*Festuca ovina*	Rosasea	Perennial	10.58	10.80
Teucrium polium	Lamiaceae	Perennial	1.7	2.00	*Plantago holosteum*	Plantaginaceae	Perennial	0.98	1.00
					Poa bulbosa	Poaceae	Perennial	0.98	1.00
					Teucrium polium	Lamiaceae	Perennial	2.84	2.90
Total			**5.10**	**6.00**				**15.39**	**15.70**

[1]SCR: Soil Coverage Rate (%), [2]PCR: Plan Covered Rate (%)

Table 3. Invasive species in pasture composition, SCR(%) and PCR(%)

Invasive Plant Species before Improvement					**Invasive Plant Species after Improvement**				
Species	**Family**	**Life span**	**SCR(%)**	**PCR(%)**	**Species**	**Family**	**Life span**	**SCR(%)**	**PCR(%)**
Astragalus bicolor	Fabaceae	Perennial	0.85	1.00	*Anthemis cretica*	Asteraceae	One-year	0.88	0.90
Allium scorodoprasum	Liliaceae	Perennial	0.85	1.00	*Astragalus frickii*	Fabaceae	Perennial	4.70	4.80
Bromus sp.	Poaceae	One-year	28.05	33.00	*Brachypodium distachyon*	Poaceae	One-year	1.96	2.00
Eryngium campestre	Umbelliferae	Perennial	0.85	1.00	*Calamintha grandiflora*	Lamiaceae	Perennial	1.18	1.20
Fumana Arabica	Cistaceae	Perennial	6.80	8.00	*Eryngium campestre*	Umbelliferae	Perennial	2.06	2.10
Globularia orientalis	Globulariaceae	Perennial	0.85	1.00	*Euphrasia pectinata*	Scrophulariaceae	One-year	3.82	3.90
Koeleria cristata	Poaceae	Perennial	0.85	1.00	*Fritillaria acmopetala*	Liliaceae	Perennial	1.96	2.00
Minuartia Circassica	Caryophyllaceae	Perennial	0.85	1.00	*Galium aparine*	Rubiaceae	One-year	1.27	1.30
Muscari sp.	Liliaceae	Perennial	0.85	1.00	*Globularia orientalis*	Globulariaceae	Perennial	2.25	2.30
Noaea mucronata	Chenopodiaceae	Perennial	0.85	1.00	*Helianthemum nummularium*	Cistaceae	Perennial	3.72	3.80
Paronychia chionaea	Illecebraceae	Perennial	0.85	1.00	*Herniaria incana*	Caryophyllaceae	One-year	0.98	1.00
Potentilla crinita	Rosaceae	Perennial	0.85	1.00	*Linum hirsutum*	Linaceae	Perennial	0.98	1.00
Teucrium chamaedrys	Lamiaceae	Perennial	2.55	3.00	*Medicago minima*	Fabaceae	One-year	1.18	1.20
Thymus comptus	Lamiaceae	Perennial	0.85	1.00	*Minuartia anatolica*	Caryophyllaceae	Perennial	2.84	2.90
					Ornithogalum orthophyllum	Liliaceae	Perennial	1.27	1.30
					Poa annua	Poaceae	One-year	1.96	2.00
					Potentilla recta	Rosaceae	Perennial	0.98	1.00
					Taraxacum scaturiginosum	Asteraceae	Perennial	2.06	2.10
					Teucrium chamaedrys	Lamiaceae	Perennial	13.43	13.70
					Tragopogon aureus	Asteraceae	Perennial	1.18	1.20
					Trifolium arvense	Fabaceae	One-year	1.37	1.40
					Trifolium dubium	Fabaceae	One-year	3.82	3.90
Total			**46.75**	**55.00**				**55.86**	**57.10**

The applied pasture improvement program caused significant changes in pasture vegetation and vegetated area. While increasing the vegetated area in the pasture, it also ensured that important declining species became the dominant species in the vegetation (Table 2 and 3.). Foreign plant clearing, control of animal grazing and fertilization were effective in making these species dominant. Unfortunately, pasture vegetation is degraded by grazing in violation of management rules (Holechek et al., 2010). If grazing pressure is controlled, the chance of survival of declining species in vegetation increases. As a matter of fact, according to Uzun and Ocak (2019), declining species had higher proportional values in low-intensity grazing systems than in high-intensity grazing systems. The number of desirable species decreases with heavy grazing in pastures. In grazed areas, the proportion of species belonging to other families was approximately two times higher than in ungrazed areas (Bakoğlu et al., 2009).

According to the results of the vegetation surveys conducted by the Black Sea Agricultural Research Institute Directorate and Ondokuz Mayıs University Faculty of Agriculture in the spring of 2023, it was determined that the proportion of legumes in the botanical composition of the pasture increased from 1% to 12.20%, the proportion of species belonging to other families increased from 27% to 56.50%, and the proportion of grass decreased from 46% to 31.30% (Table 4.). In the improvement study conducted by Yavuz and İspirli (2021) in the grassland, the proportion of legumes and grass increased while the proportion of other families decreased. Generally, fertilizer phosphorus increases the proportion of legumes, but decreases the proportion of grass and other families (Çomaklı et al., 2005). In soils where grasses are dense and legumes are low, the amount of symbiotic nitrogen that plants can utilize is low, and swelling may occur in animals grazing on pasture at high legume and pasture rates below 40% (Vough et al., 1995).

Table 4. Effects of improvement practices and fertilization on families, annual and perennial species distribution, pasture condition and pasture health class

	Pastue Status	Pasture Health Classroom	Legume plants (%)	Grass plants (%)	Other Family (%)	Anunal (%)	Perennial (%)
Before reclamation	Healthy	Weak	1,00	46,00	27,00	33,00	41,00
After Reclamation	Healthy	Middle	12,20	31,30	56,50	17,60	82,40

In general, fertilizer phosphorus increases the proportion of legumes and decreases the proportion of other families (Çomaklı et al., 2005). A one-way increase in vegetation cover in favor of grass or legumes is not desirable in pasture management. In soils where grasses are dense and legumes are low, the amount of symbiotic nitrogen that plants can utilize is low, and swelling may occur in grazing animals at high legume and grass rates below 40% (Vough et al., 1995).

The decrease in the proportion of grass was due to the increase in the proportion of area covered by vegetation. As a matter of fact, fertilization and vegetation clearing, clearing form and controlled grazing have a positive effect on the botanical composition of the pasture (Altın et al., 2010 Aydın and Uzun, 2000). Pasture fertilization is an effective improvement method and is effective on the change in botanical composition (Aygün et al., 2017). In order to obtain quality forage from pastures, they should be fertilized sufficiently and should be supported by fertilization under suitable ecological conditions (Aydın and Uzun, 2000). There may be a significant change in the botanical composition of the pasture depending on the type and dose of fertilizer applied (Algan and Aydın, 2017; Gürel and İnan, 2022a: Gürel and İnan, 2022 b.).

While the pre-improvement pasture condition was determined as poor and the pasture health class was determined as healthy, as a result of the activities carried out within the scope of the improvement program, the pasture condition and health class were determined as medium and healthy.

4. Conclusion

As a result, pasture improvement and fertilization significantly increased pasture yields and significantly affected botanical compositions in Alpagut pasture area. İmprovement practices positively affected the botanical composition of the pasture and resulted in a more balanced vegetation. The significant increase in the proportion of perennial declining species and perennial increasing species led to an improvement in pasture condition and health class.

With both the applied improvement methods and the determined grazing season, the pasture condition health classification increased from poor-healthy to medium-healthy. The main reason for this development is the positive changes in botanical composition caused by improvement practices and fertilization.

In order to maintain sustainability in pasture land, it should be taken into consideration that firstly, grazing should be planned correctly, and then some maintenance and improvement processes, especially fertilization and weed control, should be carried out on time.

Conflict of Interest

The author declares that there is no conflict of interest.

Author Contribution

As the author, he/she declares that he/she has made his/her own contribution to the article.

Ethics Committee Decision

This article does not require Ethics Committee Decision.

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Research

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Germination and Seedling Development Performances of Some Soybean [*Glycine max* (L.) Merrill] Cultivars Under Salinity Stress

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Soybean

A B S T R A C T

The aim of the study was to determine the effects of different salt concentrations on the germination and seedling development parameters of some grain and forage soybean [*Glycine max* (L.) Merrill] cultivars. The study was conducted under controlled conditions at the Field Crops Laboratory of the Faculty of Agriculture in Siirt University. The subject of the research consists of different salt concentrations (S_0= 0, S_1= 50, S_2= 100, S_3= 150, and S_4= 200 mM NaCl) applied to four different soybean cultivars (Adasoy, Nazlıcan, Yeşilsoy, and Anp-2018). The laboratory experiment was set up in Petri dishes according to the randomized complete design with 4 replications. In the study, germination parameters such as germination percentage (%), mean germination time (days), germination index, germination uniformity coefficient, and germination energy, and some seedling parameters such as radicle and stem length (cm), seedling fresh and dry weight (mg) and seedling vigor index were examined. Significant differences have been found among the examined cultivars in terms of all the parameters considered in the evaluations. While Adasoy cultivar came to the fore front for germination parameters, Adasoy, Anp-2018, and Yeşilsoy cultivars came to the fore front in seedling development characteristics. In the study, the effect of salt concentrations on germination and seedling development parameters (except seedling dry weight) was statistically significant ($p<0.01$). Increasing salt concentrations negatively affected germination and seedling development. The research results indicate that soybean plants are tolerant up to a salt concentration of 50 mM during germination and seedling development stages. It was concluded that the cultivation of suitable cultivars is important in areas affected by salt stress, and in this regard, the Adasoy cultivar was identified as a cultivar that can be evaluated under 50-100 mM NaCl conditions.

1. Introduction

Soybean [*Glycine max* (L.) Merrill], a highly nutritious legume, is commonly used as a food source for both humans and farm animals due to its rich nutritional content, including proteins, sugars, fats, fatty acids, amino acids, and vitamins (Zhang et al., 2015; Bayraklı et al., 2017; Valliyodan et al., 2017; Lin et al., 2021). Additionally, soybean contributes to soil fertility due to its high biological nitrogen fixation capacity (Rahman et al., 2023). Worldwide, soybean accounts for the highest proportion of total oilseed production at 53% (Pratap et al., 2016). Soybean oil is used in various industrial sectors, including pharmaceuticals, plastics, paper, ink, paint, varnish, cosmetics, and pesticide production (Pratap et al., 2012).

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Soybean, despite its outstanding agricultural characteristics on a global scale, exhibits sensitivity to soil salinity (Papiernik et al., 2005). In this sense, soybean is classified as moderately sensitive to salt (Munns and Tester, 2008). Globally, approximately 932 million hectares of land are affected by salinity (Fagodiya et al., 2022). In Türkiye, there is a salinity problem in 1.7% of the total production area (1.5 million hectares) (Kaplan and Kara, 2014; Çakmakcı et al., 2016). Salinity negatively impacts soil microbial diversity, enzymatic activities, and, consequently, carbon and nitrogen dynamics, as well as greenhouse gas emissions from the soil (Fagodiya et al., 2022). Furthermore, excessive soluble salts in the soil can generally limit crop productivity (Munns and Tester, 2008). The soybean plant is particularly susceptible to abiotic stresses such as drought and salinity during its growth and yield (Chen et al., 2023). In a study, soybean production decreased by 40% with the increasing salinity stress (Papiernik et al., 2005). Butcher et al. (2016), have reported that soybean is sensitive to salt, with yields decreasing by 20% per dS/m above 5.0 dS/m salinity levels. In this regard, soybean is classified as moderately salt-sensitive with a salinity threshold of 5.0 dS/m (Pavli et al., 2021). However, it has also been demonstrated that the soybean gene pool exhibits a spectrum of salt-tolerant phenotypes (Phang et al., 2008).

Salinity is one of the most significant limiting factors for crop production in arid and semi-arid regions. Although 90% of soybean production in Türkiye takes place in the Mediterranean Region; in recent years, its cultivation has started in provinces such as Diyarbakır, Şırnak, Konya and Muş, where arid and semi-arid climates prevail (TÜİK, 2023). Seed germination and early seedling growth, in particular, are critical stages in plant development. In this sense, the germination stage is the most sensitive to salinity among plants (Acikbas et al., 2021; Açıkbaş and Özyazıcı, 2022a). Numerous studies have reported that high salt concentrations inhibit seed germination and reduce the percentage of germinated seeds (Shannon and Grieve, 1999; Khan and Weber, 2008; Ceritoğlu and Erman, 2020; Özyazıcı, 2021a and b, 2022a and b; Özyazıcı and Açıkbaş, 2021a). On the other hand, salt damage is not only depend on the growth stage, environmental factors, and the structure of salts but is also significantly influenced by the plant species and variety, as well as the quantity of salt. Recognizing genotypic differences, especially in the responses of genotypes to salinity during germination and seedling growth stages, is crucial for identifying salt-tolerant varieties (Özyazıcı and Açıkbaş, 2021b). Some morphological indicators such as germination rate, germination potential, and shoot length during the germination stage are easy and quick to measure. These indicators can better reflect the true salt tolerance level of soybean (Zhou et al., 2023). Therefore, this stage is commonly used to assess salt tolerance (Ali and Elozeiri, 2017; Zhang et al., 2019).

The aims of this research was to determine the germination and seedling development of various soybean [*G. max* (L.) Merrill] cultivars under different salt concentrations and to elucidate the salt tolerance potential of these cultivars.

2. Materials and Methods

2.1. Material

The research was conducted at the Field Crops Department Laboratory of Siirt University, Faculty of Agriculture. Grain (Adasoy, Nazlıcan, and Anp-2018) and forage (Yeşilsoy) soybean [*G. max* (L.) Merrill] cultivars (C) were used as plant material. Sodium chloride (NaCl) was used as the salt form.

2.2. Study subject and experimental design

The subject of the study is formed by different salt concentrations (S_0= 0, S_1= 50, S_2= 100, S_3= 150 ve S_4= 200 mM NaCl) applied to four different soybean cultivars. The laboratory experiment was set up with four replicates following a randomized complete design. For each replicate, 25 seeds were used. After sterilizing the seeds in 70% ethyl alcohol for 1 minute and rinsing them three times with sterile water, surface sterilization was performed by covering the seeds with a solution of 10% sodium hypochlorite (NaOCl) and 0.01% Tween20 for 10 minutes to deform any microorganisms on the seed surface. The sterilized seeds were placed between Whatman Grade 2 (Little Chalfont, Buckinghamshire, UK) filter paper (90 mm x 15 mm) in Petri dishes. Salt concentrations prepared in four different levels were applied to each Petri dish separately for each variety, with 5 ml of the solution in each dish. Petri dishes were placed in an oven (BINDER, GmbH, Germany) set at 25±1 °C for germination. Until the end of the study, an additional 5 ml of the appropriate salt dose was added to the Petri dishes every 48 hours (based on the moisture level of the seeds in the Petri dishes). Germination checks were performed every 24 hours throughout the experiment, and the germination experiment was completed on the 10th day. The emergence of at least a 2 mm radicle as the germination criterion was used to determine seed germination (Scott et al., 1984; Soleymani and Shahrajabian, 2018).

2.3. Evolution of germination and seedling growth

Measurements were obtained from ten randomly selected plants within each Petri dish. In cases where inadequate germination occurred due to salt-induced stress, measurements were instead taken from the germinated plants.

Germination percentage (GP) (%): Seeds germinating every 24 hours were counted and Equation 1 used for the determination of the GP (Scott et al., 1984).

$$GP= (NGS/TS)x100 \qquad (1)$$

In the equation, *NGS* is the number of normal germinated seeds, *TS* is the total number of utilized seeds.

Mean germination time (MGT) (day): MGT is generally used to determine the germination day of seeds and was calculated using Equation 2 (Ellis and Roberts, 1981).

$$MGT= \Sigma(N_iT_i / N_i) \qquad (2)$$

N_i is the number of seeds germinated on the T_i day; T_i refers to the number of days from the beginning of germination.

Germination index (GI): It was calculated with the help of Equation 3 reported by Wang et al. (2004).

$$GI= \Sigma(G_i/T_t) \qquad (3)$$

G_i is the germination percentage at the i^{th} day, and T_t is the days of germination test duration.

Coefficient of uniformity of germination (CUG): It was calculated with the help of Equation 4 reported by Bewley and Black (1994).

$$CUG= \Sigma n / \Sigma[(MGT-t)^2n] \qquad (4)$$

t is the time in days starting from day 0, the day of sowing, and *n* is the number of seeds completing germination on day *t*.

Germination energy (GE): It was calculated with the help of Equation 5 reported by Li et al. (2020).

$$GE= (T_1/N) \times 100 \qquad (5)$$

In the equation, T_1 represents the number of seeds germinated on the first day, and *N* represents the total number of seeds.

Root length (RL) and shoot length (SL) (cm): At the end of the study, the lengths of root and shoots were scanned in color with a random selection using an Iscan Color Mini Portable Scanner with a resolution of 600 dpi. The RL and SL parameters were precisely and meticulously measured using (Acikbas et al., 2021) the ImageJ image analysis software (Rueden et al., 2017).

Seedling fresh weight (SFW) and dry weight (SDW) (mg): The SFW was determined at the end of the study by weighing ten randomly selected seedlings from each Petri dish and calculating the average fresh weight of seedlings. Following that, the fresh seedlings were dried in an oven at 70 ^oC for 48 hours to determine the average SDW.

Seedling vigor index (SVI): It was calculated using Equation 6 as reported by Kalsa and Abebie (2012).

$$SVI= GPxSDW \qquad (6)$$

2.4. Statistical assessment

Before performing the analysis of variance, ArcSin transformation was applied to the germination percentage values, following the method described by Zar (1996). The obtained data was subjected to analysis of variance using the randomized complete design, and differences between means were assessed using the TUKEYS HSD multiple comparison test (Açıkgöz and Açıkgöz, 2001).

3. Results

3.1. Germination parameters

Data on germination parameters of soybean cultivars at different salt concentrations are given in Table 1. The statistical analysis revealed that the effects of applied salt concentrations and cultivars on all examined germination parameters were highly significant based on the evaluations ($p<0.01$) (Table 1).

Table 1. Germination parameter results of soybean cultivars at different salt concentrations*

Cultivars	NaCl concentration (mM)					
	S_0	S_1	S_2	S_3	S_4	Average
Germination percentage (GP) (%)						
Adasoy	98.3 a	95.0 ab	81.7 bcd	73.3 de	30.0 jk	75.7 A
Nazlıcan	65.0 efg	56.7 fgh	46.7 hı	28.3 jk	6.7 l	40.7 D
Yeşilsoy	90.0 abc	83.3 a-d	71.7 def	63.3 efg	21.7 kl	66.0 B
Anp-2018	81.7 bcd	78.3 cde	51.7 ghı	38.3 ıj	8.3 l	51.7 C
Average	83.8 A	78.3 A	62.9 B	50.8 C	16.7 D	
Mean germination time (MGT) (day)						
Adasoy	3.34 ef	3.08 f	3.61 def	3.78 c-f	4.70 c	3.70 C
Nazlıcan	3.94 c-f	4.11 c-f	4.26 cde	6.47 ab	7.17 a	5.19 A
Yeşilsoy	3.06 f	3.14 f	3.20 ef	4.57 cd	5.82 b	3.96 C
Anp-2018	3.57 def	3.17 f	4.01 c-f	4.57 cd	6.67 ab	4.40 B
Average	3.48 C	3.38 C	3.77 C	4.85 B	6.09 A	
Germination index (GI)						
Adasoy	6.32 ab	6.46 a	4.84 cd	4.02 def	1.32 ıjk	4.59 A
Nazlıcan	3.48 efg	2.87 fgh	2.46 ghı	0.90 jk	0.19 k	1.98 D
Yeşilsoy	6.45 a	5.53 abc	4.74 cde	2.89 fgh	0.76 jk	4.07 B
Anp-2018	4.99 cd	5.12 bcd	2.68 gh	1.76 hıj	0.26 k	2.96 C
Average	5.31 A	4.99 A	3.68 B	2.39 C	0.63 D	
Coefficient of uniformity of germination (CUG)						
Adasoy	29.5 ab	31.1 a	22.7 cd	19.5 def	6.4 ıjk	21.8 A
Nazlıcan	16.5 efg	13.8 fgh	11.0 ghı	4.4 jk	1.0 k	9.3 D
Yeşilsoy	29.6 ab	26.5 abc	22.4 cde	14.0 fgh	3.7 jk	19.3 B
Anp-2018	22.9 cd	24.7 bcd	13.0 gh	8.5 hıj	1.3 k	14.1 C
Average	24.6 A	24.0 A	17.3 B	11.6 C	3.1 D	
Germination energy (GE)						
Adasoy	60.0 ab	63.3 a	36.7 bcd	5.0 e	3.7 e	36.7 A
Nazlıcan	26.7 cde	15.0 de	10.0 e	5.0 e	2.3 e	23.2 B
Yeşilsoy	43.3 abc	60.0 ab	43.3 abc	10.0 e	1.0 e	31.5 A
Anp-2018	43.3 abc	53.3 ab	13.3 de	5.0 e	1.0 e	11.8 C
Average	43.3 A	47.9 A	25.8 B	10.0 C	2.0 C	

Significance level (P)	NaCl	Cultivar (C)	NaClxC
GP	0.0001**	0.0001**	0.0065**
MGT	0.0001**	0.0001**	0.0001**
GI	0.0001**	0.0001**	0.0001**
CUG	0.0001**	0.0001**	0.0001**
GE	0.0001**	0.0001**	0.0002**

*: The difference between the means indicated by the same letter in the same group is not statistically significant, **: Significant at the level of $p<0.01$

As a result of the study, GP, GI, CUG, and GE values all decreased significantly as salt concentrations increased; however, this decrease was not significant at 0 and 50 mM salt concentrations. In other words, there was no statistical difference between the control treatment and the 50 mM salt dose, and the highest values for these four germination parameters were obtained at 0 and 50 mM doses. The lowest values for the same germination parameters occurred at the highest salt concentration. The application of salt to soybean seeds extended the MGT, the MGT at 0, 50, and 100 mM salt doses ranged between 3.38 and 3.77 days, statistically in the same group for the varieties. In the study, the highest salt dose (200 mM) resulted in the longest MGT of 6.09 days (Table 1).

When the average performance of the cultivars was examined, the Adasoy cv. had the highest results for the average GP (75.7%), GI (4.59), and CUG (21.8) as the mean of salt concentrations. Adasoy (3.70 days) and Yeşilsoy (3.96 days) cultivars developed faster under the effect of salt, making them the varieties with the shortest MGT. These same cultivars also showed the highest performance in terms of GE values (36.7 and 31.5, respectively) (Table 1). In terms of GP, MGT, GI, and CUG, the cultivar with the poorest germination performance as the mean of salt concentrations was Nazlıcan, while the Anp-2018 cv. had the lowest GE (Table 1).

The C x S interaction was found to be significant ($p<0.01$) for all examined germination parameters in the study. In terms of GP, values decreased in all cultivars in general as salt concentrations increased. However, the cultivars varied considerably at the same salt concentrations. In addition, although the MGT generally increased with the increase in salt doses, for example, at a dose of 50 mM, the germination time was shortened in Adasoy and Anp-2018 cultivars, which were in a statistically different group. In terms of the GI, CUG, and GE parameters, it is noteworthy that while the overall trend among varieties inversely correlated with increasing salt doses, certain cultivars displayed deviations from this pattern at some doses. For instance, Adasoy and Anp-2018 cultivars exhibited such a deviation at 50 mM salt concentration. The reasons listed above were effective in making the interaction significant (Table 1).

3.2. Seedling growth parameters

The results of some seedling growth parameters of soybean cultivars at different salt concentrations are presented in Table 2. The effect of applied salt concentrations on seedling growth parameters was statistically significant ($p<0.01$). The values of the examined seedling growth parameters decreased with increasing salt concentrations on mean for the cultivars (especially for SDW, beyond 50 mM). Except for SDW, the highest values for all other parameters were observed in the control treatment without salt application, and the lowest values were found at 200 mM dose for all seedling growth parameters. In terms of SDW, the highest values were obtained at 50 mM salt concentration with 48.8 mg. However, SDW was not adversely affected by salt doses other than 200 mM, and the difference between 0, 50, 100, and 150 mM doses was statistically insignificant (Table 2).

When the average performance of the cultivars was evaluated, the highest values as the mean of salt concentrations were determined as follows: RL for Adasoy (5.59 cm) and Anp-2018 (5.55 cm), SL for Anp-2018 (4.96 cm), SFW for Adasoy (244.0 mg), Yeşilsoy (259.2 mg), and Anp-2018 (220.2 mg), and SVI for Adasoy (22.2) and Yeşilsoy (21.5). The lowest values for these parameters were found in the Nazlıcan cultivar. The difference between cultivars in terms of RL, SL, SFW, and SVI was statistically significant at $p<0.01$. The difference between cultivars in terms of SDW was statistically insignificant, and the SDW values of the cultivars varied between 11.8-37.4 mg as the average salt concentrations (Table 2).

Except for SDW, the C x S interaction was found to be statistically significant at $p<0.01$ for all other seedling growth parameters. It is thought that the interaction for these seedling development parameters examined is due to the fact that cultivars are affected by salt concentrations at different rates and some cultivars are more resistant to salt (Table 2).

4. Discussion

4.1. Effect of salt concentrations on germination and seedling growth parameters

Salinity is one of the most significant stress factors that have adverse effects on seed germination, plant development, and crop productivity, limiting the productivity of agricultural crops. The toxic effect of salts begins with the initiation of the germination process, leading to a decrease in water potential and hindering the water uptake by the seeds (Shanko et al., 2017). As Zapata et al. (2004) have also pointed out, high salt concentrations in the soil or growth medium negatively affect the germination process in almost all species, with a few exceptions.

Salinity is one of the major obstacles to increasing soybean production in cultivation areas (Kandil et al., 2015). High salinity adversely affects the entire life cycle of soybeans (Abel and MacKenzie, 1964). The germination stage in soybean, like many other crop plants, is the most sensitive to salinity. Abel and MacKenzie (1964) reported that the germination of soybean seeds was delayed under low salt conditions (0.05% and 0.1% NaCl) and that higher salt concentrations led to a significant reduction in germination percentage. In the current study, all germination and seedling characteristics were negatively affected due to increasing salt concentrations, both within the cultivars and according to the average results. Sudden declines in germination and seedling development were observed at high salt concentrations (Table 1 and 2). In studies conducted with soybean, salinity stress has been reported to have a negative impact on various aspects, including seed germination, plant height, shoot dry weight (Essa, 2002), seedling fresh weight (Farhoudi and Tafti, 2011), germination percentage (Neves et al., 2005; Ahmadvand et al., 2012; Ndifon, 2013; Ahmed et al., 2023), plant height, and root length (Ahmed et al., 2023). High salt concentration (100 mM NaCl) has been shown to reduce shoot dry weight (Le et al., 2021) and increase the mean germination time (Farhoudi and Tafti, 2011; Ahmed et al., 2023). Based on the findings of Neves et al. (2005), the germination percentage within the control group averaged at 61%, but at higher salt concentrations (200 mM), this rate significantly declined to 5%.

The exact mechanisms by which salt affects germination are not fully elucidated. However, it has been suggested that osmotic (Kingsbury and Epstein, 1986; Kumar and Sharma, 1990) and/or toxic effects (Cramer et al., 1994) may be responsible for salt injury (Essa, 2002). Additionally, Munns (2002) has proposed that soluble salts induce osmotic stress, leading to specific ion toxicity and ionic imbalance, with potential consequences that could ultimately result in plant mortality.

Table 2. The seedling development parameter results of soybean varieties at different salt concentrations*

Cultivars	NaCl concentration (mM)					
	S_0	S_1	S_2	S_3	S_4	Average
			Root length (RL) (cm)			
Adasoy	11.40 ab	9.59 bc	4.86 e	1.61 fg	0.47 g	5.59 A
Nazlıcan	7.02 d	3.97 e	1.37 g	0.86 g	0.26 g	2.69 C
Yeşilsoy	11.36 b	4.68 e	1.54 g	1.48 g	0.32 g	3.88 B
Anp-2018	13.37 a	8.56 cd	3.55 ef	1.51 g	0.75 g	5.55 A
Average	10.89 A	6.70 B	2.83 C	1.37 D	0.45 E	
			Shoot length (SL) (cm)			
Adasoy	8.90 b	6.25 de	2.75 f	1.62 g	0.56 ı	4.02 BC
Nazlıcan	9.08 b	5.73 e	2.61 f	1.42 gh	0.54 ı	3.88 C
Yeşilsoy	9.64 b	6.65 cd	2.61 f	1.67 g	0.75 hı	4.27 B
Anp-2018	12.23 a	7.19 c	2.88 f	1.56 gh	0.92 ghı	4.96 A
Average	9.97 A	6.45 B	2.71 C	1.57 D	0.69 E	
			Seedling fresh weight (SFW) (mg)			
Adasoy	479.8 abc	389.4 bc	227.4 efg	98.3 ghı	25.3 hı	244.0 A
Nazlıcan	340.2 cde	228.9 efg	127.2 ghı	85.3 ghı	9.8 ı	158.3 B
Yeşilsoy	613.8 a	429.7 bcd	142.9 ghı	82.6 ghı	27.1 hı	259.2 A
Anp-2018	534.2 ab	311.6 def	163.1 fgh	72.2 hı	20.0 hı	220.2 A
Average	492.0 A	340.0 B	165.1 C	84.6 D	20.5 E	
			Seedling dry weight (SDW) (mg)			
Adasoy	34.4	118.3	21.3	10.7	2.0	37.4
Nazlıcan	20.8	16.1	12.6	8.9	0.8	11.8
Yeşilsoy	42.3	37.4	16.3	9.9	3.1	21.8
Anp-2018	61.5	23.1	14.4	6.5	1.1	21.3
Average	39.8 AB	48.8 A	16.1 AB	9.0 AB	1.7 B	
			Seedling vigor index (SVI)			
Adasoy	47.4 ab	37.0 bc	10.3 d-g	7.3 efg	0.8 g	22.2 A
Nazlıcan	22.2 cde	13.0 d-g	5.9 fg	2.4 g	0.1 g	8.7 C
Yeşilsoy	55.3 a	35.9 bc	5.3 fg	5.3 fg	0.6 g	21.5 A
Anp-2018	43.8 ab	24.5 cd	8.4 efg	2.8 g	0.2 g	15.9 B
Average	42.2 A	27.6 B	10.8 C	4.4 D	0.4 D	

Significance level (P)			
	NaCl	Cultivar (C)	NaClxC
RL	0.0001**	0.0001**	0.0001**
SL	0.0001**	0.0001**	0.0001**
SFW	0.0001**	0.0001**	0.0004**
SDW	0.0082**	0.2696ns	0.3131ns
SVI	0.0001**	0.0001**	0.0001**

*: The difference between the means indicated by the same letter in the same group is not statistically significant, **: Significant at the level of $p<0.01$, ns: not significant

In the study, it can be argued that soybean seeds are more tolerant to salt stress during the germination stage, but become more sensitive during the seedling growth stage. When the results were examined, it was discovered that the negative effects of salt stress on germination began at a concentration of 100 mM, whereas seedling growth parameters (except SDW) showed a decreasing trend after a dose of 50 mM (Table 1 and 2). Similar findings were also reported by Ahmed et al. (2023), the researchers found that germination rate values at 0 and 50 mM NaCl concentrations (90.74% and 79.63%, respectively) were statistically in the same group, and germination rate significantly decreased at the 100 mM dose. Conversely, plant height and root length characteristics were adversely affected starting from the 50 mM NaCl dose. Islam et al. (2019) suggested that salt concentrations up to 80 mM are tolerable for soybeans, but concentrations higher than that would have a negative impact on germination.

In some studies conducted with different legume species, the adverse effects of salinity stress on germination and seedling development stages have been reported to occur at a 50 mM salt concentration for bitter vetch (Açıkbaş and Özyazıcı, 2022b), chickpea (Ceritoglu et al., 2020), and hairy fruit vetch (Özyazıcı and Açıkbaş, 2022). In a study with Hungarian vetch, the germination rate significantly decreased at a 125 mM NaCl dose, root length at 75 mM, and root fresh and dry weight at 100 mM (Önal Aşçı and Üney, 2016). Another study involving forage pea genotypes (Demirkol et al., 2019) found that salt doses less than 90 mM NaCl had no effect on germination and seedling development.

4.2. Cultivar performance

In terms of the characteristics examined in the study, it was observed that cultivars were differently affected by salt concentrations. Additionally, cultivars that exhibited high salt tolerance during the germination stage did not demonstrate a similar tolerance at more advanced developmental stages. For instance, the Adasoy cv. was identified as a prominent cultivar in terms of germination parameters. However, in the same cultivar, the detrimental effect of salt on shoot length was higher compared to some other varieties. While some cultivars are very affected by salt during the germination stage, it has been observed that the same cultivars become more tolerant to salt during the seedling development stages. Similar distinctions among cultivars have also been emphasized by Essa (2002). Furthermore, some research results have reported variability in salt tolerance among soybean cultivars during the germination and seedling development stages. For instance, Kondetti et al. (2012) reported that increasing salinity levels reduced all examined traits in all cultivars. Ahmadvand et al. (2012) noted differences among cultivars in terms of germination and emergence percentages, while Ndifon (2013) found that salt stress significantly reduced the germination percentage of the TGX849-313D cultivar. Several other studies (Wang and Shannon, 1999; Xu et al., 2011; Ramana et al., 2012; Kandil et al., 2015; Ahmed et al., 2023) have also reported that soybean cultivars exhibit different responses to salinity stress during germination and seedling development stages. Differences between varieties in terms of salt tolerance can be attributed to differences in water-holding capacity, membrane permeability, osmoprotection, and/or genetic and morphological factors. Thanh Le et al. (2023) reported that the genetic diversity in salt tolerance in soybeans is attributed to differences, particularly in the 'exclusion' of ions from shoots in photosynthetically active mesophyll cells. The degree of salt tolerance conferred by soybean genes varies between different developmental stages (Phang et al., 2008).

5. Conclusion

According to the research findings, soybean is generally very sensitive to salinity stress at the seedling stage compared to the germination stage. Salt stress is a significant abiotic stress factor for soybean and have adverse effects on plant growth. Therefore, although soybean is tolerant to salt concentrations up to 100 mM during germination, considering that this dose can inhibit post-germination growth, it may negatively affect nodulation and other agricultural characteristics in the later stages of plant development, potentially leading to reduce soybean yield. Among the factors that limit soybean production, especially under salt stress, achieving high and uniform germination and emergence in the field is essential. In this regard, a salt concentration of 50 mM NaCl can be considered as a threshold value for soybean during germination and seedling growth. However, understanding the responses of varieties to the stress caused by salt is also crucial. Based on the research results, considering both germination and seedling growth parameters, it is recommended to cultivate the Adasoy cv. under salt stress. As a result, in today's environment, where salinity is becoming an increasing issue, defining the performance of salt-tolerant soybean varieties under field conditions is critical.

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Determination of Some Characteristics of Tall Fescue (*Festuca arundinaceae* Schreb.) Populations Collected from Natural Flora and Selection of Grass Type Genotypes

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The aim of this study was to determine the identification criteria (phenological, morphological and some agricultural) and select the ones suitable for turfgrass. Agricultural studies in Black Sea Agricultural Research Institute Ambarköprü Station were carried out. Identification studies was done according to IBPGR with 900 genotypes in 2015 and 2016. Some parameters determined in the study as follows. Average plant height 65–177 cm, main stem thickness 2.0–6.1 mm, internode length 11–53 cm, flag leaf length 10–42 cm, flag leaf width 3–14 mm, days to heading 208–246, lodging ratio 1.5–5.0 (1=erect; 5= prostrate), tillering potential 9–330, spring growth 1.5–5.0 (1- early; 5- late), herbage forage yield 101–2330 g/plant. End of the morphological and technological measuring and observations, 49 genotypes were selected for turfgrass with using relative rating method. According to the analysis, the genotypes were first divided into two main groups. It was determined that the genotypes FA 06-07, FA 31-02, FA 09-08 and FA 05-13 in the first group were collected from Samsun and Tokat locations, and all of the genotypes in the second group were collected from the Tokat location.

1. Introduction

Today, while the population is decreasing due to migration from rural areas to cities, it is increasing in cities. As cities grow geographically and humanly, natural areas disappear and people's need and longing for green spaces increases. Rapid population growth, migration and unplanned urbanization, social, economic, political and cultural conditions cause the deterioration of the physical environment of the people living in the city and a decrease in the quality of life (Kır et al., 2010; Özköse, 2012; Alay, 2020).

In cities where green areas are sufficient, the quality of life and productivity of individuals are also high. Therefore, a great deal of importance is given to green areas in the establishment of cities. Today, green areas are needed in many sports and playgrounds such as parks, gardens, football-golf fields, horse races, as well as on railway sides, airports, around buildings, hospitals and schools. (Kuşvuran, 2009; Özköse, 2012).

Turfgrass areas, in addition to their aesthetic contribution to urban spaces, create a green cover that allows them to play and rest. They absorb sunlight during the day and affect the environment positively by not giving back the

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radiation they collect during the night. By absorbing the dust in the air, they eliminate the dust problem. They also consume carbon dioxide in the atmosphere as they are a natural oxygen producer. Green areas also remove other atmospheric pollutants such as ozone, sulfur dioxide, nitrogen dioxide, ammonia, carbon monoxide, volatile organic compounds and lead (Stier et al., 2013). They ensure that rain and snow waters are transformed into groundwater on a regular basis. They lose water by transpiration, thereby reducing the ambient temperature up to 5 ˚C. By forming approximately 4000 shoots in an area of 1 m^2, they function like an air conditioner due to their energy absorption properties (Uzun, 1992; Avcıoğlu, 1997; Oral and Açıkgöz, 1998, Nick et al., 2016).

Although our country has a great genetic potential in terms of grass breeding, all purchased grass species are varieties obtained from breeding studies of foreign countries. These varieties cannot show the desired characteristics in our country's conditions (such as climate, soil, resistance to diseases and pests) and the plant life is short. This situation necessitates more fertilization, irrigation and other maintenance works in lawn areas and requires the facility to be renewed in a short time (Özköse, 2012; Alay, 2020). Thus, the construction and maintenance costs of lawn fields increase significantly. We need to breed new varieties by using the grass plants found in our natural flora and use our potential to produce grass seeds. Developing a domestic grass variety will not only contribute to meeting the seed needs of our country, but also contribute to meeting the grass needs of countries with similar ecologies and improving export opportunities. Scientific studies on this subject will gain momentum and the number of trained people, information and resources will increase.

This study was carried out to determine the morphological and agricultural characteristics of tall fescue (*Festuca arundinaceae* Schreb.) populations collected from the natural flora of the Central Black Sea Region and to select genotypes that could be turf type.

2. Materials and Methods

2.1. General characteristics of the research area

The research was carried out in Samsun Black Sea Agricultural Research Institute, Çarşamba Ambarköprü trial station (41°29' 11 N - 36° 401 06 E) between 2014-2016. Its height above sea level is 17 meters.

2.2. Soil and climate characteristics of the research area

The pH value of the soil of the research area is 7.35, and it is slightly alkaline, clay loam, organic matter is medium, phosphorus is very low, lime is medium, salt free and potassium is insufficient.

The average temperature of the province of Samsun 1980-2016 for many years is 15.0 °C and the total precipitation is 992.4 mm. According to the long-term average, the highest temperature value was 24.9 °C in August, and the lowest temperature value was 6.5 °C in January. The highest total precipitation was in January with 154.4 mm and the lowest precipitation was in July with 22.8 mm. When the average temperature and total precipitation values for many years are examined, it is seen that the dry period begins in late June and continues until mid-October (Table 1).

When the climate data of the years of the experiment were compared, the lowest monthly total precipitation was in April with 16.8 mm in the first year of the experiment, in November with 18.5 mm in the second year and in July with 31.5 mm in the third year. In March 2014, the total precipitation amount in March, April and May, when the seedlings were planted and the cool season plants made a significant part of their development, was lower than the average of 2015-2016 and many years. While the average relative humidity for many years was 77.2%, this value was 78.5% in 2014, 79.0% in 2015 and 78.1% in 2016 (Table 1).

Within the scope of TAGEM /TA/00/11/01/009 and "Black Sea Region Forage Crops Research Project", seeds of a total of 64 populations, 9 from Samsun, 53 from Tokat and 2 from Sinop, were collected. While collecting, features such as collection place, latitude, longitude, altitude were recorded, and the seeds were taken from different places at a distance of at least 1 km.

Table 1. The average temperature, average relative humidity and total precipitation values of the county of Çarşamba, 2014, 2015 and 2016 and the long-term average (U.Y.O.) (1980-2016) (Anon., 2018)

Location	**Çarşamba**											
	Total Precipitation (mm)				**Average Temperature (°C)**					**Average Relative Humidity (%)**		
Months	**Long-Term Average**	**2014**	**2015**	**2016**	**Long-Term Average**	**2014**	**2015**	**2016**	**Long-Term Average**	**2014**	**2015**	**2016**
January	154.4	-	128.5	199.9	6.5	-	6.9	6.3	69.8	-	68.8	100.0
February	52.2	-	103.0	37.4	8.7	-	8.0	10.9	71.9	-	76.0	70.3
March	81.5	41.5	112.9	103.8	9.6	9.8	8.6	10.3	77.1	77.3	81.4	73.2
April	68.5	16.8	106.0	50.6	12.1	12.2	10.7	14.4	76.8	75.2	74.8	75.6
May	100.2	48.6	20.4	267.7	16.6	16.8	16.7	16.7	80.2	79.5	79.3	79.6
June	103.7	115.4	106.8	33.6	21.2	20.5	20.7	22.2	78.4	79.6	82.2	77.0
July	22.8	46.4	29.5	31.5	23.8	23.9	23.0	23.9	76.5	78.4	80.4	76.3
August	69.7	95.8	179.6	37.4	24.9	24.7	24.6	25.2	79.9	79.8	80.7	78.9
September	59.1	101.2	42.5	108.1	21.1	20.4	22.4	20.0	80.5	81.6	86.8	76.4
October	69.6	103.9	76.0	38.9	15.6	15.8	16.6	14.9	84.7	86.9	90.3	83.4
November	73.1	116.2	18.5	79.6	11.8	10.4	13.0	11.2	75.0	71.6	72.0	71.2
December	137.7	93.8	125.6	162.8	8.2	10.0	7.4	4.9	75.3	75.3	74.8	75.7
Mean	**82.7**	**77.9**	**87.4**	**95.9**	**15.0**	**16.4**	**14.9**	**15.1**	**77.2**	**78.5**	**79.0**	**78.1**
Total	**992.4**	**779.6**	**1049.3**	**1151.3**	–	--	–	–	–	--	–	–

Seeds belonging to the populations were sown in one row on the land of the Black Sea Agricultural Research Institute, Ambarköprü trial station in October 2013. Sowing was done manually in rows of 5 m in length. From these rows, 20 randomly selected genotypes (per plant) for each population were planted in the observation garden with 20 plants (genotypes) from each population in March 2014. Considering the soil analysis results, fertilization was made at the stage of planting the seedlings in the field at 5 kg N (nitrogen) and 8 kg P (phosphorus) per decare. In the years of 2015 and 2016 of the experiment, a total of 10 kg of nitrogen fertilization, 5 kg per decare in the early spring and 5 kg after the first cutting, was applied. In general, irrigation was not done in the experiment. It has been sprayed twice a year against Melolontha ssp. with the drug whose active ingredient is Lambda-cyhalothrin. Weed control was done when necessary. The total number of plants in the experiment was 1280, and later on, some genotypes were damaged by (*Melolontha* ssp.) and lost during mechanization studies. For this reason, observations and measurements were made in 900 genotypes. In 2015, the cutting was done on May 6, and in 2016, on May 15. In both years, the second cutting was not done because the plants showed little development after cutting. Cleaning was carried out at the end of October in the establishment year, 2015 and 2016 years.

In this study, turf type genotypes were determined according to the weighted scaling method among 900 genotypes, with agricultural and morphological identification lasting two years, excluding the establishment year. The averages of two-year data were used to determine the superior tall fescue genotypes, which are candidates for turf type. The minimum (by subtracting the extreme ones) and the maximum (by subtracting the extreme ones) values were obtained from the values obtained. The difference between the maximum and minimum values is divided by 3, and the result is added to the minimum value and added to the maximum values to form 3 groups. Average values were obtained by multiplying the scale score of the genotypes with the feature of being a turf type and the % importance level. Genotypes above the mean were selected (Gebeyahou et al, 1982; Yazgan, 1989; İslam and Deligöz, 2012). Descriptive statistics of the data of each feature obtained from this study were made. At the end of the calculations, the minimum and maximum value, mean, standard deviation and coefficient of variation results were obtained. Since the data obtained will only show the characteristics of the group to which it is related, “mean±standard deviation” is given together (Özbek and Keskin, 2007).

3. Results and Discussion

3.1. Spring growth (1-5)

When the average of 2015 and 2016 in terms of spring growth is examined, the lowest group value was 1 (early), the highest group value was 5 (late), and the average group value was 3 (medium). It was determined that 140 of the genotypes were early, 697 of them were medium and 63 of them were late. The standard deviation value determined between genotypes was calculated as 3±0.84. Looking at the average of both years, it is seen that the standard deviation is low. This shows that the variation between the observation values given to the genotypes in terms of spring growth is close. The coefficient of variation was calculated as 30.7% on average (Table 2). This shows that the variability between genotypes is high. This is an expected result since the studied populations were collected from nature.

If tall fescue is grown for forage grass, it gives more green grass and comes to grazing maturity early, if it is grown for turf grass, it stays green for a longer time and provides the expected benefits as green area. Late maturing genotypes were selected for turf type.

Arslan and Orak (2011) reported the spring growth rate of of tall fescue with turf type grass characteristics and some species as 3 (1-5) in Tekirdağ coastal belt. Also, Alagöz and Türk (2017) reported the spring growth rate of 1.7-4.3 (1-5) in five turf grass crops (*Lolium perenne* L., *Poa pratensis*, *Festuca arundinacea*, Festuca rubra var. rubra, Festuca rubra var. commutata) in Isparta ecological conditions. Moreover, Varoğlu (2010) reported the spring growth of *Festuca arundinacea* as 3.5 (1-5) in its mixtures with pure stand and *Lolium perenne* in İzmir conditions, while Varoğlu et al. (2015) reported that the spring growth of tall fescue (*Festuca arundinaceae*) and red fescue (*Festuca rubra*) varieties in Bornova conditions between 2-4 (1-5). In another study, Erdoğan and Sürmen (2019), spring growth of *Festuca rubra var. rubra* in Aydın conditions was measured as 4.5 (1-5) while *Festuca rubra var. commutata*'s was 2.0 (1-5) and *Festuca arundinacea*'s spring growth was 2.5 (1-5). In addition, Özkan and Avcıoğlu (2013) determined the spring growth rate in Mediterranean conditions between 1.38-3.32 (1-5) in the mixtures of *Festuca arundinacea* with pure stand and *Lolium perenne*, while Eraşık and Soya (2014) were reported as 2.57 (1-5), and Balekoğlu (2015) reported as 6.52 (1-9) in Mediterranean conditions.

These results are in general agreement with our study. Spring growth is closely related to the climate. How long the winter season lasts, the severity and duration of the cold, the snow cover, the number of days when the temperature is below zero, the number of hot days, etc. factors directly affect spring growth. In addition, the genetic diversity of tall fescue turf type genotypes is also important.

Table 2. Frequency distribution and descriptive statistics values of spring growth of tall fescue genotypes

Observation Value		Mean	
	Group Value (1-5)	Number	%
1-2*	1 (early)	140	15.56
3*	3 (medium)	697	77.44
4-5*	5 (late)	63	7.00
Minimum		1	
Maximum		5	
Average		3	
Standard Deviation		3±0.84	
Coefficient of Variation (CV) (%)		30.7	

*1-Too fast growth *2-Fast growth *3-Moderate growth * 4-Slow growth *5-Too slow growth DK- Coefficient of Variatio

3.2. Tillering potential (number/genotype)

When the average of the years 2015 and 2016 was analyzed in terms of tilling potential, the minimum number of tillering was 9 (less-infrequent), the maximum number of tillering was 330 (frequent-high), the mean of genotypes was 84.87 (near medium), and the standard deviation value was 84.87±51.6. Looking at the average of both years, it is seen that the standard deviation is high. This shows that genotypes have wide variation in terms of tillering potential. It was determined that 551 genotypes were in the 1st (less-rare) group, 276 were in the moderate and 73 were in the 5th (frequent-high) group. The coefficient of variation was calculated as 60.7% on average (Table 3). This shows that the variability between genotypes is high. Grass density can be measured by counting the amount of stems or leaves per unit area. However, it can be determined more easily and accurately by stem counting.

It is desirable that the density (tillering potential) value, which expresses the number of shoots per unit area, is high in grass areas. Therefore, over tillering is important in terms of suppressing foreign plants, completely covering the area and creating a good green plant (Beart, 1973; Avcıoğlu, 1997). Genotypes that have over tillering potential were selected for turf purposes.

Varoğlu (2010) found tillering potential of some species (*Festuca rubra* (Engina, Franklin, Pernille), *Festuca arundunaceae* (Eldorado, Finelawn, Apache), *Poa pratensis* (Enprima, Geronimo, Connni)) used in green areas and to be 4.3 (1=seldom, 5=dense), while Özkan and Avcıoğlu (2013) reported between 3.67-4.56 (1-5) for *Festuca arundinacea*, *Lolium perenne*, *Festuca rubra var. rubra*, *Festuca rubra var. commutata*, *Festuca ovina* and *Poa pratensis* in Mediterranean conditions. Also, Eraşık and Soya (2014), reported as 4.61 (1-5) in Mediterranean conditions. On the other hand, Balekoğlu (2015) investigated the tillering potential of some *Festuca arundinacea* cultivars (Eldorado, Millenium, Rebel Pro, Regiment-2, Tahoe, Tomat, Turbo RZ) in Mediterranean conditions on a scale of 1-9 (1=rare, 9=frequent), and reported it as 7.36. Whihe Erdoğan ve Sürmen (2019), stated the tillering potential in tall fescue as 3.25 (1-5) in Aydın province conditions, Varoğlu et al., (2015), found it between 2.8-4.8 (1= sparse, 5= dense) of *Lolium* sp., *Poa* sp., *Festuca* sp. turf type grass crops, in Bornova conditions. Saygın and Ayan (2019) found that the number of tillering varies between 3.5-5 (1-5) in pure stand tall fescue sowing, in which a total of 6 cuttings were made and 4 sowing rates were applied (30, 40, 50 and 60 g/m^2) in Samsun – Çarşamba conditions. Okkaoğlu (2006), who measures tillering condition as a number instead of a scale, reported 104.60 in İzmir conditions, while Ayan et al. (2011) reported it as 17-220 in Samsun-Çarşamba conditions.

There is a general similarity between the results of this study and the results of other researchers. In tall fescue turf type genotypes, besides the genetic differences of plants in terms of tillering number, environmental factors (climate, soil moisture, etc.) such as cutting tool type, cutting height, cutting frequency, amount of nutrients in the soil, light exposure of the bottom parts of the plant, plant age and development also are factors affecting.

Table 3. Frequency distribution and descriptive statistics values of tillering potential of tall fescue genotypes

Observation/Measurement Value (number/genotype)		Mean	
	Group Value (1-5)	**Number**	**%**
[5-85]	1 (seldom)	551	61.22
[86-165]	3 (moderate)	276	30.67
165<	5 (dense)	73	8.11
Minimum		9	
Maximum		330	
Average		84.87	
Standard Deviation		84.87±51.6	
Coefficient of Variation (CV) (%)		60.7	

3.3. Lodging ratio (1-5)

When the average of the years 2015 and 2016 is examined in terms of lodging ratio, the lowest group value was 1 (erect), the highest group value was 5 (prostrate) and the average group value was 2.23 (semi-erect). It was determined that 448 genotypes were in the 1st (erect) group, 403 were in the 3rd (moderate) group and 49 were in the 5th (prostrate) group. The standard deviation value determined between genotypes was calculated as 2.23±0.89. Looking at the average of both years, it is seen that the standard deviation is very high. This shows that the genotypes have high variation. The coefficient of variation was calculated as an average of 52% (Table 4). As a result of the scoring, 49 genotypes can be evaluated as turf type, which develops erect, semi-erect, covers the soil surface better and gets 50 score (highest) in terms of lodging ratio.

Lodging ratio in tall fescue and some species in some species, while Ayan et al. (2011) were determined as 1-3 in *Festuca arundinacea* Schreb., *Festuca ovina* L., *Festuca pratensis* Huds., *Festuca rubra* L., *Festuca drymeja* Koch., *Festuca amethystina* L., *Festuca woronowii* Hackel. and *Festuca lazistanica subsp. giresunica* Alex. in Samsun conditions, Özköse (2012) was determined that it varies between 1-8 (1=erect, 9=prostrate) in Ankara conditions.

In our study, the growth pattern of genotypes varied between 1 and 5. There is a general similarity between the study and the results of the researchers. The differences may be caused by many factors such as the type of plants, genetic structure, temperature, soil and air humidity, nitrogen fertilization.

Table 4 Frequency distribution and descriptive statistical values of tall fescue genotypes of lodging ratio

Observation Value	Group Value (1-5)	Mean Number	Mean %
1*	1 (erect)	448	49.78
2-3*	3 (semi-erect)	403	44.78
4-5*	5 (prostrate)	49	5.44
Minimum		1	
Maximum		5	
Average		2.23	
Standard Deviation		2.23±0.89	
Coefficient of Variation (CV) (%)		52	

*1- Erect *2- Semi-erect *3- Moderate *4- Semi-prostrate *5- Prostrate

3.4. Days to heading

When the average of the years 2015 and 2016 in terms of days to heading is examined, the lowest number of days was 207, the highest number of days was 242 and the average number of days was 232. 163 genotypes were in the 1st (early) group, 672 were in the 3rd (medium) group and 65 were in the 5th (late) group. The standard deviation value determined between genotypes was calculated as 232±11.2. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the genotypes are somewhat far from each other in terms of days to heading. The coefficient of variation was calculated as an average of 5.6% (Table 5). This shows that the variability between genotypes is high. This result is an expected result since the studied populations are collected from nature.

Early stem elongation and flowering are undesirable in turf grass (Açıkgöz, 1994). Controlling the entry of turf type grasses into the booting stage means controlling the quality of the grass. Because when the turf grass enter the seed creation period, the desired continuous uniform green cover is disrupted due to the stem elongation (Avcıoğlu, 1997). As stated by the researchers, 65 genotypes, which were determined grass having late maturity in terms of the number of days of stem elongation, can be considered as grass type.

The number of days of stem elongation in tall fescue genotypes varied between 207 and 242, as the average of two years. Since the reactions of plants to the common effects of photoperiod and temperature factors are different, there are significant differences in terms of maturation time between genotypes in the species (Tosun, 1973). Grass plants are generally long day plants and can flowering in very wide photoperiods (Açıkgöz, 1994; Avcıoğlu, 1997).

Oliveira and Charmet (1989) found the between 6 May and 7 June in 50 perennial ryegrass population collected from North West Spain, while while Romani et al (2002) found 52 genotypes of perennial ryegrass (*Lolium perenne*) collected from different regions of Italy reported the heading date between 5 and 25 May. Also, Mirjalili and Bennet (2006), in their study in Iran, reported the average heading date of 11 perennial ryegrass lines to be 6 May. Shipway et al (2010) reported that in the UK conditions, when there is 50% stem elongation in grass species or varieties, it is determined as the stem elongation date; for example, if it happened after 20 days from 1 May, it expressed as REE20 (Relative Ear Emergence). They are divided into three groups as early, medium and late, since the duration of stem elongation differs in tall fescue, and they report that each group covers a period of 12 days or more. They report that the heading dates of the perennial ryegrass varieties they are working on vary between 18 May and 29 June. Sokolovic et al. (2011) recorded the heading dates of populations collected from different parts of the country between 13-20 May for perennial ryegrass breeding suitable for Serbian conditions.

The number of days of stem elongation or dates values obtained from this study are generally in agreement with the results of other researchers. Differences may be caused by many environmental factors such as climate and soil characteristics, as well as genetic and variety differences in the materials used.

Table 5. Frequency distribution and descriptive statistics values for the number of days to heading of tall fescue genotypes

Observation/Measurement Value (day)		**Mean**	
	Group Value (1-5)	**Number**	**%**
[206-220]	1 (early)	163	18.11
[221-232]	3 (medium)	672	74.67
232<	5 (late)	65	7.22
Minimum		207	
Maximum		242	
Average		232	
Standard Deviation		232±11.2	
Coefficient of Variation (CV) (%)		5.6	

3.5. Plant height (cm)

When the average plant height of 2015 and 2016 is examined, the lowest plant height was 65 cm, the highest plant height was 184 cm and the average plant height was 129.5 cm. It was determined that 114 of the genotypes were in the 1st (long) group, 703 in the 3rd (medium) group and 83 in the 5th (short) group. The standard deviation value determined between genotypes was calculated as 129.5±17.42. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes in terms of plant height is high. The coefficient of variation was calculated as 18.5% on average (Table 6). This shows that the variability between genotypes is high. Since the studied populations are populations collected from nature, this result is expected. 83 short-grown genotypes can be evaluated with 50 points (the highest) as turf type grass in terms of plant height.

Table 6. Frequency distribution and descriptive statistics values of plant height of tall fescue genotypes

Observation/Measurement Value (cm)		**Mean**	
	Group Value (1-5)	**Number**	**%**
136<	1 (long)	114	12.67
[95-136]	3 (medium)	703	78.11
[51-94]	5 (short)	83	9.22
Minimum		65	
Maximum		184	
Average		129.5	
Standard Deviation		129.5±17.42	
Coefficient of Variation (CV) (%)		18.5	

Desired plant height varies according to the purpose of growing in tall fescue. Tall fescue plants to be used as turf grass should be short in length, slowly developing after the cutting, narrower leaf blade width, etc. features are required. In this study, the average plant height of two years varied between 65-184 cm.

Watkins and Meyer (2004) measured the plant height of *Festuca arundinaceae* between 71.7-104 cm in American conditions, while Edward (1993) reported it as 122 cm. Also, Dzyubenko and Dzyubenko (2011), stated it between 100-160 cm in Russian conditions. While Gençkan (1983) found the plant height of Festuca arundinaceae between 30-200 cm in İzmir conditions, Davis (1985) reported that he measured the plant height between 30-150 cm in Turkey conditions, just two years later. Öztan and Okatan (1985) found the plant height of *Festuca arundinaceae* to be between 100-150 cm in the climatic conditions of Trabzon province located in the humid Black Sea Region, while Ayan and Acar (2009) measured it between 120-150 cm in Samsun conditions, and again Ayan et al., (2011) reported that they found it between 63-170 cm in Samsun conditions. Moreover, Serin and Tan (1998) reported that the plant height of tall fescue varies between 100-150 cm in Erzurum cold climate conditions. Başer and Kaplan (2015) reported that the plant height of tall fescue varies between 69.1-97.3 cm Kayseri conditions, while Kaya and Avcı (2019) reported that they determined it as 20-95 cm Konya conditions in the continental climate.

Although there is a general similarity in terms of plant height, there are some differences as well. These differences may be caused by environmental and genetic factors.

3.6. Main stem thickness

When the average of the years 2015 and 2016 is analyzed in terms of main stem thickness, the lowest main stem thickness was 1.9 mm, the highest main stem thickness was 6.1 mm and the average main stem thickness was 3.1 mm. It was determined that 235 of the genotypes were in the 1st (thick) group, 538 in the 3rd (medium) group and 127 in the 5th (thin) group. The standard deviation value determined between genotypes was calculated as 3.1±0.64. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes is high in terms of main stem thickness. The coefficient of variation was calculated as an average of 23.7% (Table 7). This shows that the variability between genotypes is high. Since the studied populations are populations collected from nature, this result is expected. 127 genotypes with 50 points (highest) in terms of main stem thickness can be evaluated.

Desired main stem thickness varies according to the purpose of cultivation. There is a close relationship between main stem thickness and yield-yield components in tall fescue. There is a very important relationship between plant height and main stem thickness in tall fescue plant. As the main stem thickness increases, the plant height also increases (Ayan et al., 2011). It is desirable that the main stem of tall fescue plant to be used as turf type is thin, the herbage yield is low and it develops slowly.

Table 7. Frequency distribution and descriptive statistics values of main stem thickness of tall fescue genotypes

Observation/Measurement Value (mm)		Mean	
	Group Value (1-5)	Number	%
3.8<	1 (thick)	235	26.11
[2.8-3.8]	3 (medium)	538	59.78
[1.7-2.7]	5 (thin)	127	14.11
Minimum		1.9	
Maximum		6.1	
Average		3.1	
Standard Deviation		3.1±0.64	
Coefficient of Variation (CV) (%)		23.7	

In this study, main stem thickness in tall fescue genotypes varied between 1.9–6.1 mm. The main stem thickness was found as 2.29 mm by Yazgan et al. (1992), while it was reported as 2.66 mm by Ekiz et al. (1995) in Ankara conditions. While Arslan and Orak (2011) were stated as 2.10 mm of stem thickness in Tekirdağ coastal belt, Ayan et al. (2011) were reported between 2.22-6.77 mm in Samsun conditions.

Although there is a general similarity between the main stem thickness determined in the research and the results of the researchers mentioned above, there are also differences with some of them. Among the reasons for this; It may also be caused by the genetic structure of the studied genotypes, such as the different climate and soil conditions of the research location.

3.7. Internode length

In terms of internode length, the lowest internode length was 11 cm, the highest internode length was 53 cm, and the average internode length was 25.25 cm, according to the average of 2015 and 2016. It was determined that 154 of the genotypes were in the 1st (long) group, 720 in the 3rd (middle) group and 26 in the 5th (short) group. The standard deviation value determined between genotypes was calculated as 25.25±4.81. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes is high in terms of internode length. The coefficient of variation was calculated as 19.9% on average (Table 8). This shows that the variability between genotypes is high. Since the studied populations are populations collected from nature, this result is expected. The above 26 genotypes with 50 points (the highest) in terms of internode length were selected. Internode length plays an important role in determining the height of the plant in tall fescue. It is not a desirable situation because turf type tall fescue plant to be used in the green area is tall in height, has a high herbage yield and grows rapidly, as it will require more care (irrigation, mowing, fertilization) both in terms of aesthetics. The large number of genotypes (900 genotypes) used in this study and the fact that these genotypes were collected from different ecological regions and altitudes may cause a wide variation in internode length.

In this study, it was determined that the internode length varies between 11 and 53 cm in tall fescue genotypes. While Watkins and Meyer (2004) found the internode length between 13.1-20.9 cm in American conditions, Okkaoğlu (2006) stated as 13.3 cm in İzmir conditions, and Ayan et al. (2011) reported between 3.2-37 cm in Samsun conditions.

Although there is a general similarity between the research conducted and the results of the researchers mentioned above, there are differences. These differences are due to the differences in the research location, climate and soil conditions, and the genotypes studied.

Table 8. Frequency distribution and descriptive statistics values of internode length of tall fescue genotypes

Observation/Measurement Value (cm)		**Mean**	
	Group Value (1-5)	**Number**	**%**
36<	1 (long)	154	17.11
[22-36]	3 (medium)	720	80.00
[6-21]	5 (short)	26	2.89
Minimum		11	
Maximum		53	
Average		25.25	
Standard Deviation		25.25±4.81	
Coefficient of Variation (CV) (%)		19.9	

3.8. Flag leaf length (cm)

When the average of the years 2015 and 2016 is examined in terms of flag leaf length, the lowest flag leaf length is 10 cm, the highest flag leaf length is 42 cm, and the average flag leaf length is 19.94 cm. It was determined that 443 genotypes were in the 1st (long) group, 383 in the 3rd (middle) group and 74 in the 5th (short) group. The standard deviation value determined between genotypes was calculated as 19.94±5.06. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes is high in terms of flag leaf length. The coefficient of variation was calculated as an average of 25.5% (Table 9). This shows that the variability between genotypes is high. Since the studied populations are populations collected from nature, this result is expected.

Many researchers have reported that flag leaf length of tall fescue (*Festuca arundinacea* Schreb.) varies between 4-61 cm in different ecologies (Gençkan, 1983; Davis, 1965-1985; Öztan and Okatan, 1985; Edward, 1993; Serin and Tan, 1998; Hannaway et al., 1999; Okkaoğlu, 2006; Salman et al., 2008; Ayan and Acar, 2009; Dzyubenko and Dzyubenko, 2011; Kaya and Avcı, 2019). The flag leaf length values (10-42 cm) determined in this study are among the values obtained in the studies.

Although there is a general similarity between the research conducted and the results of the researchers mentioned above, it also differs with some others. The reasons for this may be due to the different research location, climate, soil conditions and genotypes.

Table 9. Frequency distribution and descriptive statistics values of flag leaf length of tall fescue genotypes

		Mean	
Observation/Measurement Value (cm)	**Group Vlaue (1-5)**	**Number**	**%**
29<	1 (long)	443	49.22
[18-29]	3 (medium)	383	42.56
[6-17]	5 (short)	74	8.22
Minimum		10	
Maximum		42	
Average		19.94	
Standard Deviation		19.94±5.06	
Coefficient of Variation (CV) (%)		25.5	

3.9. Flag leaf width (mm)

When the average of the years 2015 and 2016 in terms of flag leaf width is examined, the lowest flag leaf width was 3 mm, the highest flag leaf width was 14 mm and the average flag leaf width was 8.06 mm. It was determined that 764 of the genotypes were in the 1st (very rough) group, 86 in the 3rd (rough) group and 50 in the 5th (moderate) group. The standard deviation value determined between genotypes was calculated as 8.06±2.89. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes is high in terms of flag leaf width. The coefficient of variation was calculated as 35.5% on average (Table 10). This shows that the variability between genotypes is high. Since the studied populations are populations collected from nature, this result is expected.

If the leaf width is less than 1 mm, it is described as very fine, between 1-2 mm as fine, between 2-3 mm as moderate, between 3-4 mm as rough and if larger than 4 mm as very rough. It is ideal for grass plants to have a flag leaf width between 1.5-3 mm (Beard 1973; Avcıoğlu 1997).

In order to determine the turf type grass characteristics in tall fescue, Edward (1993) reported that the flag leaf width changed between 0.3-1.27 mm in American conditions, while Hannaway et al. (1999) reported that it changed between 3-12 mm in American conditions. Also, Davis (1985) calculated the width of the flag leaf in tall fescue as 5-10 mm in the natural flora of Turkey. While Okkaoğlu (2006) reported the flag leaf width as 6.75 mm in tall fescue in İzmir conditions, Varoğlu (2010) reported it as 3.6 mm in the same conditions. Again in the same province, Salman and Avcıoğlu (2008) reported that they calculated the flag leaf width between 2-6 mm in Lolium perenne and *Festuca arundinacea*. While Avcıoğlu (1997) reported the flag leaf width between 5.2-6.2 mm (very rough) in Bornova conditions, Uyaroğlu (1999) reported it as 4.77 mm (very rough) in the same conditions. While Alagöz and Türk (2017) found the flag leaf width in tall fescue to be 3.28 mm in Isparta conditions, it was reported by Kılıç and Türk (2017) that it changed between 3.1-3.4 mm, Starlet, Debussy and Rebel cultivars in the same province in the same year. On the other hand, Karaca and Akgün (2005) measured it in LoliumxFestuca hybrids between 5-8.5 mm in the same conditions. While Erdoğan and Sürmen (2019) found it in tall fescue to be 4.08 mm in humid Aydın climatic conditions, Arslan and Acar (2019) reported that it was 3.3 mm (rough) in humid Samsun conditions. In the continental climate conditions, while Ekiz et al. (1995) measured it in tall fescue as 6.58 mm in Ankara, Kaya and Avcı (2019) measured it between 0.6-10 mm in Konya, and Yılmaz and Avcıoğlu (2000) measured it as 4.71 mm (very rough) in Tokat and Demiroğlu et al (2011) reported that 2.9-4.4 mm in İzmir conditions.

Edward (1993) reported the flag leaf width between 0.3-1.27 mm in order to determine the grass area characteristics in tall fescue, while Hannaway et al. (1999) reported that they found it between 3-12 mm in American conditions. Davis (1985), in the natural flora of Turkey, measured the flag leaf width between 5-10 mm in tall fescue. While Avcıoğlu (1997) measured the flag leaf width between 5.2-6.2 mm in Bornova conditions as very rough, Uyaroğlu (1999) found it as 4.77 mm in Bornova conditions as very rough. In continental climate, Yılmaz and Avcıoğlu (2000) reported the flag leaf width as 4.71 mm (very rough) in Tokat conditions, Kaya and Avcı (2019) reported it as 0.6-10 mm in Konya conditions, and Ekiz et al. (1995) stated it as 6.58 mm in Ankara conditions. Moreover, Alagöz and Türk (2017) calculated the flag leaf width of tall fescue as 3.28 mm in Isparta conditions. While Karaca and Akgün (2005) found the flag leaf width of 5-8.5 mm in LoliumxFestuca hybrids in Isparta conditions, Kılıç and Türk (2017) reported it as 3.1-3.4 mm in Starlet, Debussy and Rebel cultivars in same conditions. In Izmir climate conditions, Okkaoğlu (2006) reported the flag leaf width of tall fescue to be 6.75 mm, while Salman and Avcıoğlu (2008) calculated it to be 2–6 mm in Lolium perenne and *Festuca arundinacea*, and Varoğlu (2010) found it 3.6 mm in same climatic conditions. While Erdoğan and Sürmen (2019) calculated it to be 4.08 mm in Aydın conditions, Arslan and Acar (2019) found it to be 3.3 mm (rough texture) in Samsun conditions.

In this study, it was determined that flag leaf width varies between 3-14 mm or between 1-5 group values in tall fescue genotypes. Although there is a general similarity between the flag leaf width found in the study and the results of the researchers mentioned above, there are also differences with some of them. The reasons for the differences may be due to the different genotypes in terms of research location, climate and soil conditions, cultural practices, cutting height, fertilization, variety and species.

Table 10. Frequency distribution and descriptive statistics values of flag leaf width of tall fescue genotypes

Observation/Measurement Value (mm)		**Mean**	
	Group Value (1-5)	**Number**	**%**
4<	1 (very rough)	764	84.89
4	3 (rough)	86	9.44
3	5 (moderate)	50	5.67
Mimimum		3	
Maximum		14	
Average		8.06	
Standard Deviation		8.06±2.89	
Coefficient of Variation (CV) (%)		35.5	

3.10. Herbage yield (g/genotype)

When the average of the years 2015 and 2016 in terms of herbage yield is examined, the lowest herbage yield was 101 g, the highest herbage yield was 2330 g and the average herbage yield was 629.1 g. In terms of herbage yield it was determined that 267 of the genotypes were in the 1st (high) group, 337 in the 3rd (medium) group and 296 in the 5th (low) group. The standard deviation between genotypes was calculated as 629.1±370.7. Looking at the average of both years, it is seen that the standard deviation is high. This shows that the variation between genotypes in terms of herbage yield is very high. The coefficient of variation was calculated as 57.8% on average (Table 11). As can be seen from the variation limits, the variability between genotypes is very high. Since the studied populations are populations collected from nature, this result is expected. It is important for the turf type grass to stay green as long as possible, to be short, to have low herbage yield and to grow slowly, both in terms of aesthetics and the sustainability of the grass. In the study, herbage yield in tall fescue genotypes varied between 101-2330 g/genotype.

Many factors such as genotype, climate, season, soil moisture, cutting tool, cutting height, cutting frequency affect the herbage yield (Beart, 1973; Avcıoğlu, 1997).

Avcıoğlu et al. (1999) calculated the herbage yield per plant as 24.6 g in Kentucky bluegrass in İzmir conditions. Yılmaz and Avcıoğlu (2000), found the average herbage yield values as 1932.6-2486.5 kg/da, 2277.1 kg/da, 4107.6-4410.7 kg/da, 1684.1-2054.6 kg/da, 2148.4-2326.8 kg/da, 1859.5-2196.6 kg/da and 5053.5 kg/da of creeping bentgrass (*Agrostis stolonifera* L.), bent grass (*Agrostis capillaris*), perennial ryegrass (*Lolium perenne*), kentucky bluegrass (*Poa pratensis*), creeping red fescue (*Festuca rubra var. rubra*), chewings fescue (*Festuca rubra var. commutata*) and tall fescue (*Festuca arundinaceae* Schreb.) in Tokat conditions, respectively. Moreover, Okkaoğlu (2006) reported that herbage yields per plant were found as 953 g for smooth brome (*Bromus inermis*), as 925 g for intermediate wheatgrass (*Elymus hispidus*), as 617 g for reed canary grass (*Phalaris arundinacea*), as 585 g for tall fescue (*Festuca arundinacea* Schreb.), as 453.50 g for orchard grass (*Dactylis glomerata*), as 379.5 g for tall meadow oat (*Arrhenatherum elatius*), and as 197 g for perennial ryegrass (*Lolium perenne*) in İzmir conditions. Also, Kuşvuran (2009) reported that he measured herbage yield values between 153.2-651.4 g/m^2 in tall fescue and bent grass species in Çukurova conditions. Saygın and Ayan (2019), in their study conducted in Samsun – Çarşamba conditions (in pure stand tall fescue), determined the herbage yield between 281-460 g at 30 g/m^2 sowing rate, between 218-670 g at 40 g/m^2 sowing rate, between 248-525 g 50 g/m^2 sowing rate, and between 258-1071 g 60 g/m^2.

While the data obtained from the study and the results reported by some researchers overlap, there are differences with some of them. The herbage yield values obtained from some non-overlapping researchers are yield values per decare, m^2. There is a general similarity with the others, although the plant variety and species are different.

Table 3.11. Frequency distribution and descriptive statistical values of herbage yield of tall fescue genotypes

Observation/Measurement Value (g/genotip)		**Mean**	
	Group Value (1-5)	**Number**	**%**
[100-400]	5 (low)	296	32.89
[401-800]	3 (medium)	337	37.44
800<	1 (high)	267	29.67
Minimum		101	
Maximum		2330	
Average		629.1	
Standard Deviation		629.1±370.7	
Coefficient of Variation (CV) (%)		57.8	

3.11. Genotypes selected as turf type and their characteristics

Among 900 genotypes, 49 turf type genotypes were selected by weighted scaling method and 49 selected genotypes were subjected to cluster analysis. According to the results of the analysis, 5 groups were formed.

1. GROUP (FA 26-10, FA 29-07, FA 49-02, FA 23-17, FA33-12, FA26-02, FA28-08, FA21-07, FA11-12, FA24-03, FA25-03, FA27-01, FA28-20,

FA22-01, FA36-09, FA20-02, FA20-07, FA23-02, FA07-03, FA28-13, FA34-14, FA44-17)

2. GROUP (FA06-07, FA31-02, FA09-08, FA05-13)

3. GROUP (FA43-14, FA37-15, FA09-13, FA25-15, FA36-12, FA58-10)

4. GROUP (FA11-15)

5. GROUP (FA22-18, FA24-08, FA49-16, FA09-19, FA23-16, FA28-03, FA32-06, FA37-02, FA31-19, FA36-13, FA32-14, FA32-17, FA37-12, FA35-19, FA07-13, FA24-18) it has been found. Only FA11-15 genotype was included in the fourth group. According to the analysis, it was determined that FA 26-10 in the 1st group and FA 06-07 in the 2nd group had the farthest degree of relationship in terms of relationship level. FA 26-10 in group 1 and FA 43-14 in group 3, FA 26-10 in group 1 and FA 11-15 in group 4, FA 26-10 in group 1 and FA 22-18 in group 5, respectively are first four genotypes far from each other, as can be seen from the dendogram in Figure 1. It was determined that FA 32-06 in the 3rd group and FA 37-02 in the 5th group had the closest relationship degree in terms of relationship level. FA 32-14 in group 5, FA 32-17 in group 5, FA 20-07 in group 1, FA23-02 in group 1, FA 25-03 in group 1 and FA 27-01 in group 1, respectively are the first four genotypes close to each other, as can be seen from the dendogram in Figure 1. Looking at Figure 1, we can see that the genotypes were first divided into two main groups (1 and 2). Group 1 includes FA 06-07, FA 31-02, FA 09-08 and FA 05-13. These genotypes have the same lodging ratio, spring growth and internode length (except FA 05-13) while also having similar number of days to heading, herbage yield, main stem thickness and flag leaf length (except FA 05-13). These genotypes were collected from Samsun and Tokat locations. The large group 2 is the group with the most differentiation and is clearly divided into two groups as 2a and 2b. Group 2a is less than group 2b in terms of genotype number and includes FA 43-14, FA 37-15, FA 09-13, FA 25-15, FA 36-12, FA 58-10 genotypes. All of these genotypes were collected from Tokat location. These genotypes have the same lodging ratio and spring growth. Group 2b is the group with the most sub-branching and all genotypes were collected from the Tokat location (except FA 07-13 and FA 07-03). Of these genotypes, FA11-15 alone differed from other groups in terms of lodging ratio.

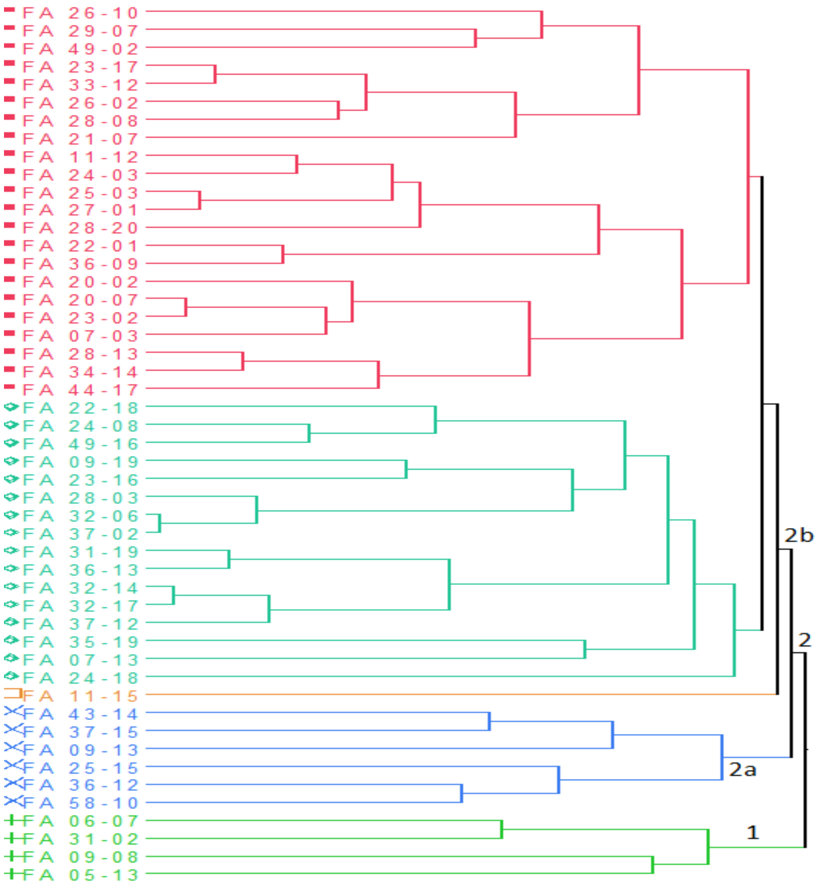

Figure 1. Grouped version of 49 selected grass genotypes

4. Conclusion

According to the analysis, it was determined that FA 26-10 in the 1st group and FA 06-07 in the 2nd group had the farthest relationship degree in terms of relationship level. FA 26-10 in group 1 and FA 43-14 in group 3, FA 26-10 in group 1 and FA 11-15 in group 4, FA 26-10 in group 1 and FA 22-18 in group 5, respectively are the first four genotypes far from each other. It was determined that FA 32-06 in the 3th group and FA 37-02 in the 5th group had the closest relationship degree in terms of relationship level. FA 32-14 in group 5, FA 32-17 in group 5, FA 20-07 in group 1, FA23-02 in group 1, FA 25-03 in group 1 and FA 27-01 in group 1, respectively are the first four genotypes close to each other, as can be seen from the dendogram in Figure 1.

Among 900 genotypes collected from Samsun, Sinop and Tokat provinces, 49 turf type genotypes with broad genetic pool were selected according to their morphological and agricultural characteristics. This genetic material, whose basic data are known, will make a significant contribution to the breeding studies that will be carried out later.

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