GRASSES

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PREFACE

Grasses can own a considerable, economic effect on crops. The grasses performance and production are the outcomes of genotypic expression as modulated by continuous interaction with the environment to succeed to maximize productivity. Annual and perennial grasses utilizes as cover crops and the grass species farthest valued for using as cover crops. Perennial grass are generality often used in forage crop production to minimize soil erosion and facilitate machinery passage during high soil moisture conditions. we are preferred fast germinating species, even though for cropping systems with multiple season production of the primary crop, even slower fixing crops are appropriate. The book presents a recent literature on the influence of grasses to various environment at the level of physiological processes and the possibility of productive.

Prof. Dr. Yaşar KARADAĞ
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CHAPTER 1

Annual Ryegrass (*Lolium multiflorum* Lam.)

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INTRODUCTION

Generally known as Italian ryegrass, *Lolium multiflorum* Lam. or *Lolium perenne L*. ssp. *multiflorum* (Lam.) Husnot is a cool-season annual grass native to southern Europe. North and South America, Europe, New Zealand, and Australia are among the countries where it has spread extensively. Annual ryegrass is one of the most important forage and turf grasses, having extensive use worldwide. As a cool-season annual bunchgrass with good yield, ornamental characteristics, and palatability (Vieira et al., 2004), annual ryegrass is regarded as a sustainable grass species for livestock systems, ecosystem services, and landscaping (Castanheira et al., 2014).

Annual ryegrass is an outcrossing plant that is commonly observed as a diploid taxon with the chromosomal structure 2n = 2x = 14. It is native to northern Italy's Po Valley, where it has been the dominant grass component of irrigated permanent meadows since the 13th century. It ranges from Central and Southern Europe to North Africa and SW Asia. It was introduced in the majority of temperate zones, from the lowlands to around 800 meters in the Alps (Lopes et al., 2009).

Plant Morphology

Annual ryegrass is typically annual to biennial, but varieties that can last up to two years have been created (Figure 1). Leaf blades are green to dark green, hairless, flat, Upper surface is equally ribbed, while the below side is smooth and lustrous. Up to 40 cm in length, 5-12 mm in width. The bud has young leaves rolled in it. The auricles are small and narrow. White, transparent ligule that is shorter than wide. Leaf sheath is hairless, with fine longitudinal ribs similar to leaf blades, and is rounder towards the rear.

Inflorescence is a spike up to 30 cm long. Spikelets are made up of 10-20 florets that are laterally flattened, green, and 15-25 mm long. One glume per spikelet, lanceolate, about 10 mm long, outer surface ribbed like the upper surface of the blade, 5 nerved, covers less than the lower half of the spikelet. The lemma is lanceolate, 5-8 mm length, and 5 nerved. Awn is virtually terminal, fine, and straight, measuring around 10 mm in length. Palea is shaped and sized similarly to the lemma, and it has two nerves with small hairs running along them. Anthers 3, yellow or purple (Lamp et al., 2001; Ibrahim and Peterson, 2014).

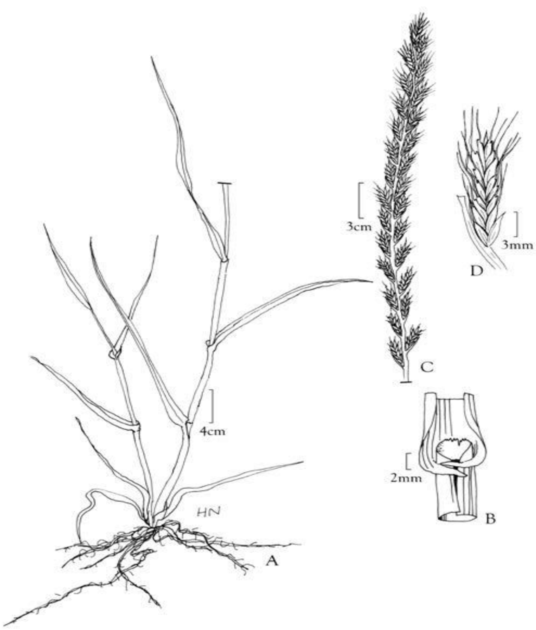

Figure 1. *Lolium multiflorum*. Base of culm. B. Sheath, ligule, and blade. C. Spike. D. Spikelet. A−C drawn from *Kanal 260* (US- 3214594); D modified from Hitchcock (1951). (Anonimous, 2022).

Establishment

Annual ryegrass requires a rich, healthy soil to thrive. It is distinguished by its quick establishment. It grows best in the fall, winter, and spring, although it may still thrive in the summer if there is enough moisture. It is especially recognized for its faster winter growth than perennial ryegrass (Lamp et al., 2001). It is tolerant of acidic to alkaline soils and has a wide range of soil adaptation (pH 5.0 to 7.8). Aluminum toxicity may be an issue below pH 5.0, while higher pH can produce chlorosis owing to iron and manganese deficits. The optimum growth happens when the pH of the soil is kept between 5.5 and 7.5 (Hannaway et al., 1999).

The most appropriate row spacing was found to be 30 cm for both forage and seed yields in the study conducted with 8 different row spacings (15, 20, 25, 30, 35, 40 and 45 cm) in Adana- Turkey (Kusvuran and Tansi, 2011). Seeding rates for annual ryegrass vary greatly and can range from 22,4 kg ha^{-1} to 39,2 kg ha^{-1} (Bryn et al., 1991; Chambliss, 1999). When over-seeding warm season perennial ryegrass, Evers et al. (1992) recommended that annual ryegrass be sown at a rate of 23-34 kg ha^{-1}. They determined that increasing seeding rates from 56 to 112 kg ha^{-1} boosted early season yield but would not be economically feasible in most cases. Minimum planting rates for acceptable annual ryegrass stands should be sufficient to yield a minimum of 600 seedlings per m^2 (Evers and Nelson, 1994). Only the first-harvest yields of annual ryegrass have been observed to increase when the sowing rate is increased (Evers, 1995).

Simic et al. (2009) found that a high seeding rate (15-20 kg ha^{-1}) was optimal for maximizing seed yield in the first producing year, and that medium row spacing (40 cm) was the least risky.

Annual ryegrass is not drought resistant. Therefore, it did not survive two years of drought without irrigation (Garwood and Sinclair, 1979). Irrigated annual ryegrass may provide very high forage yields with good nutritional qualities (Dovrat, 1993). For Eckard's (1989) experimental study, different dry matter yields of ryegrass were produced over two growth seasons with four different water stress treatments. The results of the dry matter yields were 13.5 t ha^{-1} and 9.5 t ha^{-1} for the control treatment; 7.7 t ha^{-1} and 8.2 t ha^{-1} for the control's 75 % water availability; 6.1 t ha^{-1} and 6.2 t ha^{-1} for the control's 50 %; and 5.6 t ha^{-1} and 4.1 t ha^{-1} for the control's 25 %, respectively.

Annual ryegrass has a high nutritional content that may be stored for three or more months before its digestibility falls (Lippke and Elis, 1997). The water soluble carbohydrate ratio in annual ryegrass leaves is fairly high, and in the early stages of growth, dry matter digestibility can reach up to 80% (Balasko et al 1995; Sandrin et al., 2006).

Fertilization

Under nitrogen conditions, annual ryegrass has a high production capacity and feed quality. Nitrogen concentration is the most important individual nutrition component influencing annual ryegrass fertilization growth and development (Rechitean et al., 2018).

According to Kesiktas (2010), the application of 150 kg ha-1 N resulted in the greatest values of dry matter yield, ratio, and crude protein yield. Kusvuran and Tansi (2005) the highest dry matter yield has been obtained from the 200 kg ha^{-1} N dose. Akdeniz et al. (2019) reported that 60 and 80 kg N ha^{-1} may be recommended for higher forage and dry matter yields and also for improving the quality content of annual ryegrass under the condition of Iğdır-Turkey. According to Simic et al. (2014), 50 kg ha^{-1} of N treatment was shown to be the best amount for seed production, whereas greater doses of N treathment (100 to 150 kg ha^{-1}) had either no effect on seed yield or decreased seed yield due to ryegrass lodging following seed shedding.

Forage Yield and Quality

Due to its high production and fodder quality, annual ryegrass has been one of the most significant forage grass species produced in many regions of the world (Pivoriene and Pasakinskiene, 2007; Simic et al., 2009). It is very adaptable to a variety of climatic and soil conditions, as well as to heavy and frequent grazing (Evers et al., 1997; Lemus 2009). Due to its ease of establishment and lengthy production period, annual ryegrass may be used for grazing and as a source of forage or silage. It has high productivity, good nutritional properties, digestibility, high palatability, protein, minerals, and metabolisable energy. This trait is critical in giving higher-quality material between winter and summer grazing (Hannaway et al., 1999; Abraha, 2011).

Previous studies show that dry matter yields of annual ryegrass were ranged from 4.5 to 15.6 t ha^{-1} (Kusvuran and Tansi, 2005; Redfearn et al., 2005; Butler et al., 2007; Baytekin et al., 2009; Yavuz et al., 2017). These inconsistencies were likely caused by environmental factors and genetics.

Forage yield was found to be 30670 kg ha^{-1} in Çukurova (Türemen,1988), 6835 kg ha^{-1} in Kırşehir (Şimşek, 2015), 31192 kg ha^{-1} in Aydın (Kara, 2016), 29168 kg ha^{-1} in Tokat (Çetin, 2017) in the studies carried out with annual grass in different locations of Turkey. In the same studies, dry matter yields were found to be 7833, 2053, 4587 and 7819 kg ha^{-1}, respectively. The total amount of forage produced and distributed during the growing season is determined by location, climate, and management strategies such as seedbed type, planting timing, and fertilizer (Evers and Smith, 1995).

Seed Yield

There is little information available on appropriate management strategies and operations for annual ryegrass seed crop. Harvesting for seed production can be done by swathing and collecting up later with a combine, or by combining directly. At harvest, climates with hot and dry summer months are good for sowing annual grass (Young, 1997). Ryegrasses are cut and windrowed at roughly 40% seed moisture, then allowed to dry in the field to 12% moisture before being threshed (Silberstein et al., 2005).

Nitrogen is the most important mineral element influencing grass crop seed production, principally through its impact on tillering and fertile tiller number. The seed yield of first-year annual ryegrass harvested by hand in Serbia averaged 1035 kg ha^{-1}. (Simic et al., 2012). In two field trials in New Zealand, Rolston et al. (2012) observed seed yields more than 3500 kg ha^{-1} at a N fertilization rate of 180 kg ha^{-1}. In Oregon's Willamette Valley, where temperate, moist winters and dry summers provide an ideal climate for turfgrass seed production, seed outputs exceeding 2000 kg ha^{-1} are common (Young, 1997).

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CHAPTER 2

Bermudagrass *(Cynodon dactylon* L.*)*

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General Characteristics and Adaptation

The genus *Cynodon* L. C. Rich, tribe Chlorideae is comprised of nine species and ten varieties (Harlan et al., 1970). The only member of the genus with world-wide distribution is *C. dactylon* var. dactylon. It is a sod-forming, warm-season perennial grass that is extremely variable, ranging from very small, turfy types to robust forage types.

Bermudagrass (*Cynodon dactylon*) is a warm-season perennial grass that grows throughout the warmer regions of both hemispheres. It is native to Africa but occurs throughout the world in tropical to warm temperate climates between 45 degrees north and 45 degrees South latitude (Carey, Jennifer H. 1995), and was introduced from Africa into the United States in 1751 (Funderburg, 2017). In the Turkey Bermudagrass is most common in the subtropical regions from southern Anatolia to the Egean region.

In areas of low rainfall it commonly grows along irrigation ditches and streambeds (Crampton 1974, Humphrey 1977, Burton and Hanna 1985). Bermudagrass is a plant that is grown for pasture and forage for livestock, turfgrass for lawns athletic fields and golf courses, but it also can be an invasive weed in fields (Ahring at al., 1982; Chessmore, 1973, Yavuz, 2019; Açıkgöz, 2021). It is found in most areas of world and is common in gardens, landscapes, turf areas, orchards, roadsides, vineyards, and industrial areas. It also has many other common names including couchgrass, devilgrass, or dogtooth grass. Warm temperatures are necessary for the plants to thrive, and long periods of freezing weather or short durations of extremely low temperatures are detrimental to the plants. Average daily temperatures above 24 ºC are necessary for substantial growth and temperatures of 38 ºC result in maximum growth rates (Burton and Hanna 1985) and grows very little when the night temperature falls below 16 ºC. In addition to high temperatures, Bermudagrass requires high light intensities and it is not tolerant to shading. It needs direct sunlight in order to grow and dies out with increased levels of shade.

Bermudagrass tolerates a wide range of soil types and conditions but is best suited to a well-drained site. It is drought tolerant, although production and yield decreases during drought conditions. Growth is greater on heavy clay soils than on light sandy soils in dry regions; this may be due to the greater water holding capacity of the clay. It can survive long periods of flooding, but little to no growth occurs without adequate soil aeration (Burton and Hanna 1985). It grows on soils with a wide range of pH values, however alkaline soils are tolerated more than acidic ones. Growth is promoted by the addition of lime to soils with a pH of 5.5, the ideal range from 5.8 to 6.0. Site selection is important to optimize production potential and stand life (Tiffanee Conrad-Acuna at al. 2014).

Botanical characteristics of bermudagrass are quite variable among cultivars. In general, leaf blades are gray-green in color with a hairy ligule at the base. The plants produce both rhizomes and stolons. Stem diameter is variable, ranging from slender to stout, and from short as in common bermudagrass to relatively long as in Tifton 85 internodes. Seedheads form a digitally arranged cluster of 3 to 5 thin spikelets (2.5–

7.5 cm long). Only a few of the available cultivars produce seed as common and Coastal. Hybrid cultivar, Tifton 85, do not produce viable seeds. Plants are normally short, ranging from 30 to 60 cm (Taliferro et al. 2004).

Bermudagrass Varieties

There are many bermudagrass cultivars developd in USA. The cultivars are Common, Coastal, Midland, Hardie, Oklan, Coastcross-1, Tifton 44, Greenfield, Callie, Alicia,Tifton 85, Suwannee, Florakirk, Mislevy 2000 and Jiggs (Chessmore, 1973; Wallau et al., 2020). Their adaptability to soils and climatic conditions is different, therefore farmer should select the one best suited to the conditions on their own farm. A small increase in production of a better adapted variety could mean extra profits since bermuda will remain productive for many years (Chessmore, 1973). Common bermudagrass was first introduced to the U.S. over 150 years ago from Africa. It has very aggressive growth characteristics and is often a major weed in cultivated crops of the Southeast due to viable seed production. It has relatively low nutritive value and productivity and not winter hardy. Coastal was the first improved forage bermudagrass. This hybrid variety was selected by Dr. Gelenn W.Burton. It is a cross between Tift, a common bermuda, and a tall-growing bermuda from Sout Africa. It grows uprigth and respons better to nitrogen fertilization. Tifton 85 is a hybrid between a bermudagrass and a stargrass developed and released by Dr. Glenn Burton’s breeding program at the Coastal Plain Station in Tifton, Georgia. It is more digestible and has produced greater hay yield and animal weight gain than Coastal across the Southeast. Tifton 85 is superior to bermudagrass under continuous stocking in northern Florida because of its greater herbage accumulation, herbage in vitro digestible organic matter, average stocking rate, animal gain ha^{-1}, and persistence (Pedreira at al. 2016).

Bermudagrass Establishment

Failures in establishment are generally caused by: Poorly prepared or weedy seedbeds, lack of moisture at planting and poor planting material, failure to firm the soil to ensure soil contact with planting material, excessive or inadequate depth of planting material with sustained soil moisture, and inadequate fertility. Bermudagrass can be established in three to four months and proper for the first hay harvest or light grazing. Late plantings should not be harvested, but allowed to go through the winter with plenty of top growth. Successful establishment of a bermudagrass variety requires a few important steps. Start ahead of time, so that proper weed control, soil pH, and soil fertility are accounted for before planting.

Site Selection and Land Preparation

It is recomended to choose a reasonably well-drained soil. Destroying existing vegetation by spraying a broad-spectrum herbicide (e.g., glyphosate) and cultivating the soil recommended. If reestablishing bermudagrass over an existing field, it might be a good practice to plant a cycle of annual crops to make sure the old variety is completely killed and will not contaminate the new planting (Wallau at al., 2020).

Fertilization

The ideal soil pH for bermudagrass is between 5.5 and 6.0, or up to 6.5 if the pasture will be overseeded with legumes (e.g., alfalfa or clovers) in the future. For sandy soils, apply soil test-recommended rates of phosphorus (P) and potassium (K), along with 30-40 kg of nitrogen per hectare as soon as the bermudagrass plants start to grow. It is recommended to apply an additional 80 kg of nitrogen per hectare and one-half of the recommended potassium when stolons begin to develop. Bermudagrasses, especially the newer, improved varieties, have high nutrient requirements and are very responsive to nitrogen fertilization. A complete fertilization (N, P, K, S, and Mg) is essential not only to enhance productivity, but also to sustain persistence, especially in poor, sandy soils. Low rates of N (<200 kg/ha annually) are generally insufficient to maintain a good stand and encourage weed encroachment (Burton, 1954). Potassium is commonly overlooked in fertilization for perennial forages. However, it is an essential nutrient for stand persistence and disease resistance, and it is associated with increased uptake of P and N. After three years of clipping treatments, pastures that did not receive K fertilization had only 34% bermudagrass cover (Silveira et al. 2017). In a literature review of fertilization for bermudagrass, Taliaferro et al. (2004) suggested maintaining a ratio of 4-1-3 to 4-1-4 of N-P_2O_5-K_2O.

Planting Time

The improved hybrid bermudagrasses do not produce sufficient seed and must be established from vegetative plant parts, either tops (stems) or sprigs (rhizomes). The best time to plant when using sprigs is in late winter when bermudagrass is dormant, but before spring green-up. This will ensure maximum carbohydrate reserves in the planting material. It is important to use well-fertilized and mature stems to ensure maximum concentration of reserves. If possible, all plantings should be completed no later than mid-August. Fall plantings have been successful in some years, but as a general rule, fall planting is not recommended because of the possibility of damage from drought or an early freeze in the fall. Young plants should be allowed three months to develop a strong root system before the onset of cold weather (Wallau at all.2020).

Sowing Rate and Planting Method

Bermudagrass can be produced or established by runners, rhizomes and seeds. In addition to the use of seeds in establishment, it is also widely and practically established with the vegetative part of the plant. Although some varieties of bermudagrass are propagated by seed, many varieties are propagated vegetatively by shoots (Açıkgöz 2021). For stand establishment sprigs used approximately 5000–7000 kg of per hectare. Higher planting rates can be used to ensure rapid development of a good stand if planting material is readily available or low in cost. Sprigs can be planted with commercial sprig planters that place the sprigs 5 to 7 cm deep. Both sprigs can be broadcasted on the surface with a spinner-type grass planter. The planting material should be immediately covered with a disk harrow to a depth of 5–7 cm. Pack the soil with a heavy roller so that soil capillarity can be established, which will keep the soil moist around the planting material.

A well-prepared seedbed is critical to successfully establish bermudagrass from seed. A good seedbed should be uniformly firm, smooth, weed-free, and free of clods, holes and ridges. A firm seedbed is essential with seeded bermudagrass varieties because the seed are very small and seeding depth is critical. If the seedbed is too flufy, it is easy to plant seeded varieties too deep. A cultipacker or drag harrow is very helpful in establishing bermudagrass from seed. An excellent way to plant seeded bermudagrass varieties is to: 1. Disk and harrow the field until the seedbed is prepared. 2. Cultipack the field to firm the seedbed. 3. Broadcast the seed. 4. Cultipack again to press seed into the ground. Some seeders, such as a Brillion, combine steps 2-4 and save two trips across the field. Bermudagrass seed may be coated or uncoated. The coatings usually contain a combination of fertilizers and fungicides. The coatings usually double the weight of the seed, so the seeding rate must be doubled when using coated seeds to get the same amount of pure live seed as with uncoated seed. The seeding rate for hulled bermudagrass is usually 5-10kg of pure live seed per hectare; for unhulled seed, it is 15-20 kg of seed per hectare. Seeds usually germinate when temperatures are above 20 °C and begin to grow within three weeks if temperature and soil moisture are sufcient. Growth can be very rapid if conditions are optimum, and one plant has been observed to cover an area of 2.5 square meter within 150 days after germinating (Funderburg, 2017).

Forage yield and Nutritive Value

In general, bermudagrass forage production ranges from 4 to 25 tons of dry matter per hectare, It is harvested 3-5 times a year and in good conditions, its yield can exceed 20 tons per hectare (Açıkgöz, 2021). Studies carried out with bermudagrass in different years and locations, dry matter yields were determined as ton/ha by Burton, (1954). 4.25-24.06; Franzluebbers at al. (2004), 6.92-8.28; Çınar et al. (2014), 7.24; Conrad-Acuna at al. (2014), 1.5-13.5; Overman at al. (2000), 6.25-26.5; Ugiansky, (2020), 6.96-11.96; Yılmaz at al. (2018), 1.19. The main factors responsible for the variation in production are cultivar, fertilization management, and harvesting/grazing intervals. Bermudagrasses are very responsive to N fertilization; the increase in forage production and nutritive value due to different N fertilization levels, Burton, 1954; Overman at al. 2000. A large amount of available nitrogen is required for maximal above-ground growth; this element is often the limiting factor for bermudagrass. Nitrogen fertilizers are routinely used in order to increase the forage and turf value of bermudagrass (Humphrey 1977; Açıkgöz, 2021).

A common practice to increase total forage production is to overseed bermudagrass fields with cool-season forages. Those can be drilled or broadcast (annual ryegrass) after the last cut of hay in October, if weather conditions are favorable. In the spring, prior to the onset of growth of bermudagrass, it is important to remove the excessive biomass of the winter annuals (via grazing or cutting) to reduce competition for the bermudagrass during green-up. Interseeding alfalfa into bermudagrass pastures has been proposed as a way to increase productivity and nutritive value of the pasture and the potential to increase farm profitability especially with fluctuations in Nitrogen prices (Rushing et al. 2022).

The main factors responsible for the variation in nutritive value are cultivar, fertilization management, and harvesting intervals (maturity). Bermudagrass hay yield and quality are maximized when nitrogen is applied frequently at levels 400 kg ha in growing year (Overman et al., 1992). Protein and energy are highest in young plants. As plants mature, lignin, which is mostly indigestible, is deposited into the cell walls. The higher the lignin content, the lower the digestibility of the plant. The decline in digestible nutrients is most pronounced in tissue of warm-season perennials, such as bermudagrass. Nitrogen fertilizer influences crude protein and total digestible nutrient content of bermudagrass, but to a lesser degree than plant maturity. A research showed that crude protein increased 1-2 percent and total digestible nutrients increased 0.5-0.9 percent per 110 kg/ha N applied, depending on variety (Funderburg, 2017). In general, bermudagrass has 47–60% in vitro digestibility and 12–19% crude protein. In tests at the Georgia Coastal Plain Experiment Station, nitrogen increased hay yields and protein content from 7.12% to 16.09% up to rates of 908 kg of actual nitrogen per hectare. However the most profitable rate was 454 kg per hectare (Burton, 1954).

Harvesing Stage and Grazing Management

Much research has been conducted to determine when bermudagrass should be harvested for the best compromise between yield and quality.

Plant maturity (clipping interval) and seasonal rainfall can influence yield and protein content. As a rule of thumb, bermudagrass recommend to cut at four- to five-week intervals or when it is 30-40 cm to tall, whichever comes first. When the forage is 30 to 40 tall, a delay of two weeks or more can result in the loss of regrowth and quality (Tiffanee Conrad-Acuna et al. 2014).

Bermudagrass is one of the most important warm-season perennial grasses used for livestock grazing and hay production (Taliaferro at al. 2004). Grazing germudagrass is well adapted to close, frequent defoliation because of its low-growing, creeping growth pattern. During the active growing season, pastures often regrow rapidly enough to regraze at 10- to 21-day intervals bermudagrass, especially the common types, can withstand severe grazing pressure and trampling. (Tiffanee Conrad-Acuna at al. 2014). Long regrowth intervals or understocking will result in mature forage with low nutritive value and decreases in average daily gain (Bransby 1983). For bermudagrass to thrive, sufcient leaf area must remain after grazing for plants to recover. If too much leaf area is removed, the plants cannot produce enough photosynthates to maintain good root growth. Heavy grazing can reduce forage production, increase weed pressure, and reduce animal performance. Cultivars respond differently to grazing management. In general, it is ideal to maintain a 10-12 cm stubble height during the growing season to avoid overgrazing, especially on more upright-growing cultivars. Overgrazing can result in slow regrowth, weed encroachment, and loss of stand. The growing season for bermudagrass generally ranges from early spring to mid-fall, depending on weather conditions, but is more concentrated during the summer months (Wallau at al. 2020).

Peak bermudagrass production occurs during the summer, and that can present a challenge for determining the required stocking rate to maintain a proper grazing pressure throughout the year. Early fertilization will help increase production in the spring. As forage growth increases in the summer, a section of the pasture can be closed off while animals are concentrated in the remaining area to improve forage utilization. That will help maintain proper grazing pressure in the grazed area. Excess growth can be stockpiled for later use in the fall or harvested for hay.

Bermudagrass for Seed Production

Most bermudagrass cultivars produce few or no seed and must be propagated vegetatively. This greatly limits the versatility of bermudagrass because establishment technology (equipment) cannot be used efficiently in confined areas such as home sites, or on steep embankments such as dam faces or roadbanks. There has been little research aimed at characterizing the effects of cultural and management practices on bermudagrass seed production. Understanding the influence of these practices on seed yield is fundamental to establishing efficient seed production systems. Bermudagrass for seed production is best on medium- to heavy-textured fertile soils with soil pH values of 6.5 to 8.0. Seed production fields, whether established from seed or sprigs, require good weed control and fertilization programs. Seed fields should be fertilized with phosphorus and potassium according to soil test recommendations prior to planting. Nitrogen fertilization of 35 to 70 kg N/ha) should be applied after the sprigs germinate and begin to spread (Ahring, at al.1982).

Daytime temperatures of 30 to 38 °C and intermittent rainfall patterns are near optimum for bermudagrass seed production. However, severe temperatures> 38° C for an extended number of days, as well as too much rainfall during May, June, and July, can be detrimental to seed production. Bermudagrass seed production differs from certain other grasses in that plant competition for light, nutrients, and moisture is uniformly distributed and yield is more dependent on water management for a particular cultural practice. The value and utilization of nitrogen fertilization depends on water management and the distribution of rainfall. Alternate wet and dry cycles are needed in the production of bermudagrass seed to first promote, and then to slightly stress plant growth. These alternate wet-dry cycles stimulate seedstalk production and flowering. Three or four such growth-stress cycles during May, June, and July are needed to produce an accumulated seedstalk (head) mass, good seed set, and a good seed crop in August.

A major problem in producing certain grass seed is that of seed harvesting. Heading and flowering of many range and pasture grasses take place over a long period. Some grasses, after reaching a certain physiological stage, produce seedheads continuously for periods of one to three months during the growing season. As a result, at harvest some seedheads are ripe, early heads have shattered, and later heads are immature. Judgement, and a certain degree of guesswork, is involved in selecting optimum harvest dates in these species, and accounts for a large part of the amount of treatment and year to year variability in studies dealing with such species. Grass seed retention, or shatter resistance, on the inflorescense appears to be genetically controlled. Some grass species shatter readily soon after reaching physiological maturity, but Bermudagrass retain seed for long periods after maturity. This characteristic is one of the reasons high seed yields are possible, with proper management. However, bermudagrass is a reasonably low-growing sod-forming species, and one must handle the vegetative growth to remove the seed in the harvesting operation. Seed fields of bermudagrass are normally swathed and allowed to cure for several days before combining. For grower use, the chemical-cure and combined direct method appears to have advantages over the conventional harvest method in that: 1) it requires no initial swathing operation, 2) it requires less time to cure, 3) it increases harvesting efficiency, and 4) it reduces the number of rethresh tailing operations needed.

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CHAPTER 3

Crested Wheatgrass (*Agropyron cristatum* (L). Gaertn)

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INTRODUCTION

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn), is one of the common perennial grass of the genus Agropyron. It is a cross-pollinated, long-lived, cool-season grass with extensive root systems. It is native to Europe and Asia,and was introduced to the North America in the early 1900s. This species exhibits tolerance to drought and extreme winter temperatures and has wide adaptability to abiotic stresses . Three main ploidy forms exist within crested wheatgrass complex which are diploid (2n = 14), tetraploid (2n = 28) and hexaploid (2n = 42) (Asay and Jensen 1996).

Cool season, long-lived, drought tolerant, perennial bunch grass. May be weakly rhizomatous. Adapted to a wide range of sites but is most productive on well-drained, medium textured soils. Good palatability to livestock when green (Anonymous, 2022).

Crested wheatgrass begins to grow very early in the spring and reaches grazing maturity earlier than natural ranges. It produces delicious nutritious grass in rainy periods and goes dormant in dry periods. It is resistant to overgrazing and trampling. It competes well with other species in mixtures. It is a good soil holder. It can be used to combat erosion. 20-25 years of yield can be obtained. Since it is resistant to drought, cold and trampling, it can be used in green field plant in arid regions (Açıkgöz, 2021).

DESCRIPTION OF PLANT

The homeland of the crested wheatgrass Central Asia, Western Siberia and cold arid Eastern Russia. It can grow up to 2600-2800 m altitude.

Plant height varies between 60–90 cm. Lots of siblings. The stems develop semi-horizontally until the first node and then continue to grow by making elbows. The plant is foreign fertile. Therefore, it differs in terms of leafiness (Manga et al., 1994; Çınar et al., 2016).

Table 1. Mean plant height in crested wheatgrass genotypes (cm)

Genotypes	Tokat Location		
	2014	2015	Mean
Sivas population	71.9	44.5	58.2
Variety candidate	80.6	53.3	67.0
Erzurum breeding population	76.0	42.2	59.1
Mean	76.1	46.7	61.4
			Sivas Location
Sivas population	60.0	61.6	61.8
Variety candidate	80.1	89.0	84.5
Erzurum breeding population	73.4	74.4	72.4
Mean	71.2	75.0	73.1

Leaves, blades 2–9 mm wide, often open but becoming inrolled upon drying, leaf sheaths and collar hairless. Inflorescence 2.5–7 cm long, rachis continuous, the internodes 0.5–2.5 mm long. Spikelets 6–11 mm long, widely divergent from the main rachis; florets mostly 2 to 8 per spikelet, glumes shorter than florets, narrow and tapering to an awn-tip. Lemmas hairless, awn-tipped or with awns to 5 mm long (Anonymous, 2022).

It is a plant with thin stems and sometimes rhizomes. Leaf blades are straight, fringed rooted, roots go deep. Inflorescences are spikes. The spikelets are connected at right angles to the spike axis. There are 4-10 flowers in a spikelet. The lower spikelets contain more flowers than the upper ones. Seeds are awnless. Thousand grain weight is 1.4-3 g. There are 551 seeds in 1 gram (Figure 1) (Karadağ ve ark. 2017).

Figure 1. Spike and seeds

Climate And Soil Requirements

Crested wheatgrass, which is resistant to drought and cold, grows well in regions with a total annual precipitation of 250-450 mm. It has spread to areas close to the North Pole. Therefore, no cold damage was observed.

Crested wheatgrass grows in almost any type of soil. High yields are obtained in well-drained soils. It is drought resistant, very poor tolerant to water ponding. Being under water for 7-10 days reduces the yield a lot. It has low tolerance to acidic and alkaline soils. It is moderately resistant to salinity. This resistance differs according to the cultivars.

Sowing and Growing

The most well-known variety of crested wheatgrass is the Fairway variety, which was registered in Canada in 1927. This variety is cultivated in large areas in Canada and the USA. Many varieties have been registered in recent years. In Turkey, the varieties of Geçit-1 of Tokat Central Black Sea Transition Zone Agricultural Research Institute and Kıraç of Ankara Field Crops Central Research Institute were registered in 2021.

Crested wheatgrass seeds are small, so the field soil must be well prepared. Plant emergence does not do well from loose, unpressed, loamy soils. Weeds should be controlled in the area to be planted.

Crested wheatgrass seedlings develop well in the cool period. Better results are obtained from autumn planting. Sowing should be done in the middle of summer in mountainous and high altitude lands, since the growing season is short. Fields with maize or grain stubble cut from the soil surface make a good seedbed for early spring.

For grazing purposes, planting is done with a row spacing of 40-60 cm in arid areas and 20-30 cm in moist areas. For seed production, the spacing between rows varies between 60-90 cm. Weeds can be a problem between wide rows and they should be dealt with.

The amount of seeds to be planted per decare varies between 0.5-1 kg. Sowing is done at a depth of 1 cm in well-prepared soils. Sowing is done with crested wheatgrass pure or with other grass and leguminous forage crops. It mixes well with alfa alfa and sainfoin. When planted as a mixture, higher yield is obtained than pure sowing. In mixtures, plantings can be mixed and planted in the same rows, or sowing can be done in alternate rows. During dry periods, higher yields can be obtained from alternative rows (Figure 2).

Figure 2. Crested wheatgrass

The effect of phosphorus fertilizers on crested wheatgrass is not seen much. The effect of nitrogen fertilization is very evident. In sowing, 3-5 kg/da of pure nitrogen increases seedling growth and yield in the first year. In the following years, 5-10 kg/da pure nitrogen fertilization increases grass and seed yield (Açıkgöz, 2021).

Due to the excess fertilizer given in dry periods, the rate of weeds increases. Perennial weeds rather than annual weeds are a problem in areas where crested wheatgrass are cultivated, and they should be dealt with by mowing or using appropriate herbicides.

Hay Production

For a good hay yield and quality, it should be mowed at the beginning of the spike. After spike, the quality decreases. Since the stems are thin after shaping, they are easy to dry and can be stored.

In the USA and Canada, the average yield for many years varies between 150-500 kg/da (Açıkgöz, 2021). In studies conducted in Turkey, hay yields were obtained between 550-600 kg/da in in Sivas (Çınar et al. 2016).

Table 2. Dry matter yields (kg/da), 1000 seed weights (g) and seed yields (kg/da), crude protein (%) of crestedwheatgrass genotypes

Genotypes	Dry matter yield	1000 seed weights	Seed yield	Crude Protein	Crude Protein Yield	ADF	NDF
Variety candidate 1	554.2	1.43	76.7	10.7	59.2	37.6	53.5
Variety candidate 2	601.4	2.99	30.8	10.9	65.6	38.8	56.0
Erzurumbreeding population	577.3	2.10	72.0	12.3	71.3	38.9	58.9

In the researches carried out, it was determined that the crude protein ratios were 10.7-12.3%, the crude protein yield was 59.2-71.3 kg/da, the ADF ratios were 37.6-38.9%, and the NDF ratios were 53.5-58.9% in the hay grass (Karadağ al.2016).

The yield decreases after 3-4 years in purely grown crested wheatgrass. With the appropriate amount of nitrogen fertilizer (3-4 kg/da), the decreased yield can be increased again. In studies carried out in Erzurum arid conditions in Turkey, it was determined that nitrogen fertilization increased forage yield and hay quality (Serin 1989).

Crested wheatgrass can be planted in a mixture with legumes for grass production. For this purpose, mostly alfalfa is used in the mixture. In many studies, the yield and quality of forage increased in mixtures made with alfalfa. (Yavuz and Karadağ, 2016)

Use As A Rangeland Plant

Crested wheatgrass is planted for grazing rather than grass production. It starts growing earlier than most range plants in the spring. It reaches grazing maturity 2-4 weeks earlier than other plants in natural rangeland. This has made crested wheatgrass a good range plant for arid regions. Crude protein ratio varies between 20-30% in the early period of the plant. In the early period, animals love to grass, in this period the rate of digestion is high. Crested wheatgrass range can be heavily grazed. The yields of crested wheatgrass range are at least 2 times higher than the yield of natural rangeland.

It creates a good mixture with alfalfa in pastures established for grazing. However, it is necessary to keep the ratio of alfalfa in the mixture low so that it does not swell. After the establishment year, alfalfa may become dominant in the botanical composition, so the botanical composition should be followed carefully.

Although crested wheatgrass grazes very well in the early period, its palatability decreases in the later periods. Therefore, it is not overgrazed by animals during the stem and flowering periods. Animals do not eat plants that dry up in summer. The higher the leaf rate, the more it grazes. After the spike period, the rate of digestion also decreases. Cultivation of grazinggrass with legumes and nitrogen fertilization increase its palatability (Figure 3).

Figure 3. Grazing in the crested wheatgrass

Seed Production

Crested wheatgrass is a good seed producer. Seed yield depends on many factors such as the age of the plant, rainfall, row spacing, fertilization. Generally, higher seed yield is obtained from plants planted in wide row spacing (60-90 cm). 300-350 g/da of seed is sufficient for sowing intended for seed production. After planting, weeds growing between rows are combated mechanically or chemically.

Crested wheatgrass sheds seeds easily. Therefore, the harvest time should be well adjusted. Seeds mature from the tip to the bottom. If a few seeds are spilled when the plant, which is held by the stem, is hit somewhere, seed harvesting should be started. 30-80 kg/da of seeds can be taken from the crested wheatgrass in arid conditions and 110 kg/da of irrigated conditions (Çınar et al., 2016). Harvesting can be done with a combine harvester (Figure 4).

Figure 4. Harvest (by Sezai Gökalp)

Diseases and Pests

No diseases or pests are seen in hay production, but a fungal disease called silvertop is seen in seed production. In this disease caused by fusarium species, the ears turn white and dry. In some years, this disease can cause great damage. It can be effectively combated with stubble burning and some chemical drugs.

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CHAPTER 4

Dallisgrass (*Paspalum dilatatum* Poir.)

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INTRODUCTION

Forage plants are low-cost source of calories and protein, as well as a source of fiber for the ruminal function. The major criterion for sustainable grass pastures has been seasonal and total forage mass characteristics. Planting tropical forages and improving their performance can have a significant impact on social, economic, and environmental conditions. To improve the resilience of seeded pastures, among other agricultural systems, the current increase in climate variability necessitates new techniques and germplasm sources. Dallisgrass is a South American grass that is commonly used as feed in tropical, subtropical, and warm temperate climates around the world. It has a higher forage quality than other C_4 forage grasses and is cold and drought tolerant. This plant is primarily grown in apomictic monocultures. Forage plants play an important part in ruminant nutrition. In comparison to other concentrate feeds, it is a low-cost source of calories and protein, as well as a source of fiber for the ruminal function (Moncao et al., 2016). Over the next few decades, the global population is expected to grow and become wealthier, necessitating a greater demand for animal products such as milk and meat. Tropical regions, where pasturelands play a key role in sustaining greater animal production, offer a lot of potential to meet this expanding global need. In order to improve sustainability, better feed sources are essential. The planted area should not increase, and greater areas cultivated with one or a few forage species should be avoided. Despite the fact that traditional tropical forage breeding has succeeded in releasing well-adapted and high-yielding cultivars over the previous few decades, genetic benefits from these initiatives have been modest in light of the expanding global food demand (Simeao et al., 2021).

Planting tropical forages and improving their performance can have a significant impact on social, economic, and environmental landscapes (White et al., 2019). Annual and perennial grasses, herbaceous and dual-purpose legumes, and multipurpose trees and shrubs are all examples of tropical forages (Paul et al., 2020). Despite being some of the world's most essential crops, forages have received less attention than cereals, fruits, and vegetables (Capstaff & Miller, 2018). Plant collection and study on the diversity and usage of grasses and legumes did not gain substantial global momentum until the 1950s and 1960s, despite previous interest in the potential of tropical and subtropical feed germplasm for increased livestock productivity. Tropical and subtropical forages were recognized in Latin America, Australia, Southeast Asia, South Asia, and Africa as contributing to a variety of commercial and smallholder livestock production systems by 1990–2000. However, because of perceived environmental risks, questions about whether past achievements could be improved, and the high costs of maintaining genebanks, their use, the value of further research, and the need to maintain the very large and diverse collections held in international and national genebanks were challenged at this time. Since then, the decline in investment and the quality of conservation and curation has been a relatively rapid process and reached the crisis point of today in just 20–25 years (Maass & Pengelly, 2019).

The major criterion for sustainable grass pastures has been seasonal and total forage mass characteristics. To optimal gain per unit land area, forage bulk influences grazing intensity and stocking rates. The nutritional value of forage determines the maximum gain per animal. Although both forage bulk and nutritional value are uniquely linked to animal performance, the primary role for C_3 versus C_4 forages differs due to significant variances in protein % and digestible DM (Rouquette Jr, 2016).

Dallisgrass

Dallisgrass (*Paspalum dilatatum* Poir.) is a South American grass that is commonly used for feed in tropical, subtropical, and warm temperate climates around the world (Giordano et al., 2014a). Throughout many of the warmer climates, including the southern United States, common dallisgrass is an important fodder grass (Burson, 2019). Paspalum is a perennial bunchgrass that supplies summer feed in several of Australia's higher-rainfall subtropical coastal areas, including New South Wales and Queensland, as well as the southeast United States (Campbell, 1999). In southern New South Wales, Western Australia (Callow et al., 2006), and northern Victoria, it has also become a component of irrigated pastures (Lawson and Kelly, 2007).

To improve the resilience of seeded pastures, among other agricultural systems, the current increase in climate variability necessitates new techniques and germplasm sources. It is vital to gain a detailed understanding of the structure of the germplasm of potentially relevant wild species in order to effectively use wild germplasm in domestication and breeding (Sandro et al., 2019).

Dallisgrass is a South American native grass of particular relevance to dairy and red meat production. It has a higher forage quality than other C_4 forage grasses and is cold and drought tolerant. This plant is primarily grown in apomictic monocultures (Giordano et al., 2014a). Dallisgrass is prized for its vigor, producing up to 15 tons of dry matter per hectare (Cook et al., 2005) and crude protein concentrations of up to 18.6%. (Barea et al., 2007).

Morphology & Genetics & Breeding

Dallisgrass is a warm-season perennial grass belonging to the *Poaceae* family and the *Panicoideae* subfamily. Southern Brazil, eastern Argentina, and Uruguay are the origins of this species (Brown, 2020). There are around 400 species in the genus *Paspalum* L. Paspalum is divided into twenty-five informal groups, with the Dilatata group being of particular significance because its members are good pasture grasses (Miz & de Souza-Chies, 2006).

The plant is an erect or bent perennial tufted grass with short rhizomes. Grows up to 1,5 m high. Leaf blades are flat. Rachis are flat with the midrib raised on one side. Inflorescence is loose and flexible with 4-5 one-sided racemes. It has tufts of white hairs where the racemes join the central axis. Flowers between November - February. Dallis grass is susceptible to Claviceps paspali infestation; a dark coloured poisonous fungus that thrives on the spikelets and form hard, brownish bodies known as sclerotia or ergots. The staggers syndrome occurs predominantly in cattle. Clinical signs usually appear 2 to 7 days after grazing on infected grass (Botha & Venter, 2002). *Paspalum dilatatum* is a C_4 monocotyledonous species (Soares et al., 2008).

Fig 1. *Paspalum dilatatum* Poir. (Bilgin and Tansı, 2019-2021).

In warm, humid areas, C_4 grasses are preferred as pasture crops. Because the tropical belt is extending owing to global climate change, the usage of C_4 grasses in pastures is expected to rise. While dallisgrass has a greater fodder quality than other C_4 forage grass species, warm-season grasses have lower digestibility than temperate grasses in general. In C_4 forage grasses, the presence of thick-walled parenchyma bundle-sheath cells around the vascular bundles is linked to the deposition of lignin polymers in cell walls. A high ratio of syringyl to guaiacyl lignin subunits reduces digestibility, which is further lowered by high lignin concentration (Giordano et al., 2014b).

In the subtropics, *Paspalum dilatatum* is an excellent forage grass. There are various sexual (tetraploid) and apomict (penta- and hexaploid) biotypes in this species. Apomixis in penta- and hexaploid biotypes is thought to be caused by the presence of an undiscovered origin genome, the X genome (Casa et al., 2002). *Paspalum dilatatum* subsp. *flavescens* Roseng., Arrill. & Izag. is a sexual, autogamous member of the species complex that includes the highly prized apomictic forms of *Paspalum dilatatum* (Dilatata group) (Sandro et al., 2019). The genome formula of common dallisgrass is IIJJX, and it is an apomictic pentaploid (2n=5x=50) of hybrid origin with irregular meiosis. The I and J genomes are identical to those of diploid *P. intermedium* and *P. jurgensii*, but the X genome's origin is unknown. X-chromosome members may have genes with unique biological significance, such as those that control apomixis (Espinoza & Quarin, 2000).

Fig. 2. *Paspalum dilatatum* with ergot symptoms (Bilgin and Tansı, 2019-2021).

Apomixis has played a significant role in the evolution and survival of this species. It's a 50-chromosome natural hybrid with three genomes that pair up at meiosis as 20 bivalents and 10 univalents. Plant breeders have been unsuccessful in developing the species because it is a pentaploid obligate apomict. Radiation or interspecific hybridization have had little effect on the apomictic barrier (Burson, 2019).

Several polyploid biotypes have been identified, including sexual tetraploids, apomictic pentaploids, and hexaploids (Casa et al., 2002). Increased feeding value, extended grazing season, and improved pasture persistence have all resulted from genetic enhancement of grasses through breeding (Wilkins and Humphreys, 2003). However, breeding programs aimed at domesticating perennial warm-season grasses have had less success than breeding programs aimed at temperate grasses. Managing their development cycle, flowering asynchrony, and seed harvesting are all major issues in developing warm-season grasses (Miles, 2001).

Agronomy

Temperate grasslands are dominated by warm-season grasses (Gonzalez Barrios et al., 2016). Dallisgrass thrives in deep, moist, fertile alluvial and basaltic clay soil, as well as sandy soil, with ideal annual rainfall ranging from 900 to 1250 mm. It has a limited tolerance for salinity, is particularly tolerant of poor drainage, and is drought-resistant once established due to its deep root structure (Evers & Burson, 2004). Dallisgrass is native to environments ranging from sea level to 1800 m elevation and latitude approximately 28 N to 35 S, and it is naturalized in areas up to 2100 m elevation and below latitude 35N. It is indigenous to environments ranging from sea level to 1800 m elevation and latitude approximately 28 N to 35 S, and it is naturalized in areas up to 2100 m elevation and below latitude 35N. Dallisgrass is well adapted to the Black Belt physiographic region of Alabama for these reasons, where it starts producing early in the spring and is generally ready for grazing earlier than other pasture grasses (Venuto et al., 2003). It thrives in damp areas with clay and loam soil (Botha & Venter, 2002). Dallisgrass can handle up to 134 kg N/ha of commercial fertilizer, as well as P and K. (Bungenstab, 2009). Bermudagrass (Cynodon spp.) is frequently used alone or in conjunction with it (Bungenstab et al., 2011).

In many humid grassland ecosystems, flooding and grazing are substantial disturbances that impair plant performance at the same time (Striker et al., 2008). Individual responses to flooding in the perennial grass *Paspalum dilatatum* were examined using plants cultivated in species-diverse grassland microcosms by Insausti et al. (2001). The impacts of flooding on root and leaf sheath structure, as well as shoot morphological features, were studied. Flooding enhanced root porosity and aerenchyma in the leaf sheath. In flooded plants, leaf extension rates and tiller height were both higher, resulting in a considerable portion of the shoot architecture protruding above the water level. Flooding increased stomatal conductance, leaf water potential, and net photosynthesis, especially when air-vapour pressure deficits were present. Even in the presence of natural competitors, *P. dilatatum* displayed tight management of water and carbon relations under severe soil-oxygen shortage. The range of adaptive responses described here could assist to explain why this species' population increases amid large floods.

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CHAPTER 5

Foxtail Millet (*Panicum italicum* L. *Seteria italica* L.)

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INTRODUCTION

Panicum italicum L. (Syn. *Seteria italica* (L.) P. Beauv.), which is called as Foxtail millet or Italian millet, is one of the most widely cultivated millet species in the world. An annual foxtail millet is a warm season herb. Its homeland is considered to be the Far East, India and Central Asia. Since ancient times, its grains have been used in human nutrition as bread and porridge. Today, it is a cultivated plant widely grown in subtropical and temperate regions of the world. This plant, which can mature in 60-70 days, can be grown very easily in places with short summers. It can be used in grain forage and green grass production and in the establishment of temporary rotation pastures (Serin and Tan, 2014).

In our country, millets (P. italicum and P. miliaceum L.), which this plant is included in, have a cultivation area of 2.691 ha (Anonymous, 2015). Millets are grown in the western regions of our country as a second crop after the wheat harvest. They are used as a second crop in the fields after the grain harvest in the summer months. They have a short development time. They produce high quality roughage in a short time with rapid development in hot summer months. However, in this aquaculture in summer, if irrigation is done and fertilized with nitrogen, the yield increases even more (Aghtape et al., 2012; Serin and Tan, 2014).

Foxtail millet has been the most important plant of dry agriculture and arid areas from past to present. In order to develop high-yielding varieties, increase production and increase consumption, and improve product processing technologies, it is necessary to collect and evaluate gene resources and to use gene resources and genomic resources. In this way, significant added value and profit will be achieved with high-yielding varieties offered to the use of the public and private sectors and farmers.

Foxtail millet, which has many uses, is also a very nutritious plant. However, it is a very important source of livelihood for poor farmers as it adapts to marginal lands (Morris et al., 2013). There are more than 37000 gene sources of foxtail millet, whose gene center is India and China. There are significant differences in the plant's various biotic and abiotic stresses and quality involving important agricultural applications. The entire genetic diversity of these plants has been identified as a collection of major and minor centers and has been used in genetic and genomic studies to identify various new sources. Genetic and genomic resources are of great importance in the development of new varieties of these plants (Dwivedi et al., 2012).

1. Classıfıcatıon And Taxonomy

1.1.Millet (*Panicum* L.)

Panicum genus, which is one of the most important genera of the Grain family, has about 600 species that are common especially in the warm and temperate regions of the world. The name *Panicum* derives from the Latin word öpanisö, which means bread. Among the 600 species in this genus, the most important ones in terms of agriculture are proso millet and switch grass (Gençkan, 1983).

1.2. Foxtail or Italian Millet (*Seteria italica* (L.) Beauv. = *Panicum italicum* L.)

The genus *Seteria* has about 125 species common in tropical and continental temperate regions of Africa. *S. italica* is the most well-known and cultivated of these species. The homeland of *S. italica* is a large region encompassing India, Central Asia, China, and Japan. The cultivation of this warm climate grain, whose grains were used to make bread and porridge in prehistoric times, first began in the BC. It started in China around 2700 BC. It was later taken to Europe and from there to America in the 1800s. Today, it is common in all subtropical and temperate regions of the world and is cultivated in large areas. The wild form of *Setaria italica* is *Setaria viridis*, which was found in northern China 8700 years ago.

The evolution of *Setaria viridis* resulted in *Setaria italica* (Lu et al., 2009). *Setaria italica* is a very important cereal due to its high nutritional value, climate resistance and low-input cultivation and is grown in many arid and semi-arid regions of Asia, Southern Europe, India, South America and North Africa (Goron and Raizada, 2015; Pant et al. , 2016). In addition, with their relatively short life cycles and small diploid genomes (approximately 500 Mb), *S. italica* and *S. viridis* have become model species for food and bioenergy plants (Doust et al., 2009; Bennetzen et al., 2012; Huang et al., 2016).

1.2.1. Scientific Classification

Foxtail millet

Immature seedhead

Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Monocots
Clade:	Commelinids
Order:	Poales
Family:	Poaceae
Subfamily:	Panicoideae
Genus:	Setaria
Species:	*S. italica*

2. Genetic Structure And Breeding Of Foxtail Millet

2.1. Genetıc structure of foxtaıl mıllet

Foxtail millet (*Setaria italica* (L.) P. Beauv.) is of the subfamily *Panicoideae* and has a chromosome number of 2n = 2x = 18 (AA) and belongs to the *Paniceae* family. It is an important ancient plant of dry agriculture, cultivated in China since 10,500 years ago (Yang et al., 2012).

The wild form of the cultivated plant foxtail millet is *Setaria viridis* (2n = 2x = 18, AA). The genus *Setaria* emerged from 3 gene pools based mainly on interspecies hybridization and observations of hybrid fertile pollen. The first gene pool consists of cultivated foxtail (*S. italica*) and its wild form, *S. viridis* (Harlan and de Wet, 1971). The second gene pool consists of *Setaria adhaerans* (2n = 2x = 18), two allotetraploids *Setaria verticillata* and *Setaria faberi* (2n = 4x = 36) (Benabdelmouna et al., 2001). The third gene pool includes *Setaria glauca* (or *Setaria pumila*, 4x to 8x) and many wild species. Morphological and molecular studies of cultivated millet have shown that its genetic diversity is quite large (Reddy et al., 2006; Upadhyaya et al., 2008; Vetriventhan et al., 2012; Wang et al., 2012; Jia et al., 2013). Many hypotheses have been proposed regarding the origin and cultivation of foxtail millet, and the hypothesis of multiculturation is the most accepted among them (Li et al., 1996). Li et al. (1996) proposed a multiple evolution hypothesis in three centers: China, Europe and Afghanistan-Lebanon. Hirano et al. (2011) in a study of the geographic genetic makeup of 425 foxtail native strains and 12 green foxtail entries with a large genome marker transposon (TD) showed that there are two clear genetic boundaries: 1) Starting from East Asia, Central, Southern or between other regions, including Southeast Asia and the Middle East, 2) between Western Europe and Eastern Europe, where strong regional variation exists and there is evidence that gin millet evolved and was cultivated in each region. Foxtail millet has abundant interspecies diversity. Prasada Rao et al. (1987), comparing the morphologies of cultivated foxtail, noted that there are three foxtail strains: (1) the *moharia* race is common in Europe, southeastern Russia, Afghanistan, and Pakistan; (2) the *maxima* race is common in eastern China, Georgia (Eurasia), Japan, Korea, Nepal, and northern India (it has also been introduced in the USA); and (3) the *indica* race is found in the rest of India and Sri Lanka. These races can be further divided into 10 subraces (*aristata*, *fusiformi*s, and *glabra* in *moharia*; *compacta*, *spongios*a, and *assamense* in *maxima*; and *erecta*, *glabra*, *nana*, and *profusa* in indica). Later, Li et al. (1996) added *maxima*, *moharia* and *indica* races together with the *nana* race and stated that these plants have very short, delicate many siblings similar to wild green millet, have very short bunches with low yield performance and mature early unlike the *nana* race.

2.2. Breeding Of Foxtail Millet

Foxtail millet originates from the region of China and was first cultivated between 7000 and 8000 years ago. In Germany, foxtail was grown in the Rhineland and eastern Germany. At the beginning of the twentieth century, foxtail millet completely displaced it. In the twenty-first century, China has become the most important producer of foxtail. Since foxtail millet is not homogeneous, germination time was longer when compared to other millet species in the malt making stage. On the other hand, foxtail millet showed similar characteristics with proso millet.

In the early days, the most widely used breeding method was pure line selection breeding method to increase the grain yield of foxtail millet. In this method, single plant selections are made from local and registered varieties and superior plants are tested in multiple locations and promising plants are determined as varieties. However, sorghum and millets are self-pollinating, have small flower structures and are difficult to cross. Therefore, recombination breeding method cannot be used in sorghum and millet. A very low degree of foreign pollination was observed in foxtail millet. A high and sufficient level of parental heterosis can be seen in grain yield in foxtail millet. Thus, approximately 60-70% higher average yield can be obtained from the F_{1S} generation compared to the parents. Although highly significant heterotic effects were observed, more additive effects were used. The significant correlations between the heterosis effects of cultivars and the measured additive effects of traits led to the understanding that some genes affecting grain yield, plant height and spike length were in the same linked genes (Siles, 2004).

As a result of the studies carried out to improve the genetics of foxtail millet, varieties were defined in the early 1940s and varieties such as Co1, Co2, Co3 were introduced in 1943. About 32 varieties have been launched in India by 2015. In India, short-term cultivars such as SiA3085, SiA3088 and SiA 3156 with yield potential of up to 2500 kg/ha have been widely grown (Hariprasanna, 2017). Apart from India, significant success has been achieved in the development of new varieties that have been bred in China. At the beginning of the 1950s, many regional stations were established. Within the scope of the breeding program implemented since 1920, local varieties were collected and selections were made, as a result of this program; Yanjing No. 811, Huanong No. 4 and Biangu No. 1 variants were developed (Jaiju, 1989). In the 1950s and 60s, pedigree selection method was used to develop new varieties. In the 1950s, the hot water emasculation technique was developed and widely used for crossbreeding. A normal dominant marker character was used to identify true F_{1S}'s. Subsequently, rapid generational evolution and improvement of selection were followed widely (Jaiju, 1989). In 1959, the first variety "Xinnongdong No. 2" was developed by hybridization method. Following this, about 50% of the currently cultivated cultivars were developed by the hybridization breeding method, which is the main method of breeding foxtail millet in China. Mutagenesis breeding method was started in 1970s. In 1949-79, about 150 varieties developed by breeding were grown on a total area of 4.5 million hectares (Jaiju, 1989). In China, large-scale cultivation of improved gin varieties has greatly helped increase its productivity. Improved cultivars were grown in all areas except the hill regions. In the improved varieties, besides grain yield, lodging tolerance, resistance to diseases, insects and various stresses were also increased. However, early maturing cultivars have been developed in Japan and China (Liu et al., 2006).

To exploit heterosis, male sterile lines have been developed in China, such as dominant and recessive genetic male sterile lines and photosensitive nuclear lines gene interaction male sterile lines cytoplasmic male sterility and cytoplasmic genetic male sterility (Zhi et al., 2007). Although several male sterile lines have been developed, the partial genetic male sterile line (PAGMS) has been successfully used in hybrid production (Diao and Jia, 2017). With the use of genetic male sterile lines and the utilization of heterosis, the yield of foxtail in China has increased significantly. Yields of up to 4.5–6 t/ha were obtained from traditional cultivars, while yields of up to 12 t/ha were obtained from Zhangzagu5, a high-yielding hybrid. However, Chang 10A, whose cytoplasm was contributed by Qinyuanmujizui, was used as the source for most current advanced male sterility (Liu et al., 2014). Most of the summer foxtail lines were developed from Huangmi 1A with cytoplasm from Dahuanggu (Liu et al., 1996, 2006).

3. The Origin, Distribution And Adaptation Of Foxtail Millet

The wild form of foxtail millet has been identified as *Setaria viridis*, which is interfertile, and there are also other wild forms of foxtail. It has been explained that the main difference of Zohary and Hopf, which are wild forms of foxtail millet, from the cultivated varieties is the dispersal biology of their seeds. While the seeds of wild forms deteriorate, the seeds of cultivated varieties do not deteriorate (Zohary and Hopf, 2000). The reference genome of foxtail millet was completed in 2021 (Zhang et al., 2012). Genetic comparisons have also proven that *S. viridis* is the ancestor of *S.italica* (Diao and Jia, 2017). Recent research has revealed that the Cishan culture of China is the earliest culture to cultivate foxtail millet around 6500-5500 BC (Purugganan and Fuller, 2009). Around 4000 BC, the earliest evidence for cultivation of gin outside of its native distribution was found at Chengtoushan in the Middle Yangtze River region. In Japan, the first findings with foxtail millet were found around 4000 BC in the Jōmon region of Usujiri in Hokkaido (Diao and Jia, 2017). Foxtail millet came to Europe later. The charred seeds of foxtail millet first appeared in central Europe in the 2nd millennium BC. In the Near East, the first evidence of millet cultivation was found in TilleHöyük in Turkey, around 600 BC, the Iron Age (Zohary and Hopf, 2000).

The grassy genus *Setaria* is generally common in warm regions of the world. This species was not found in ancient Egyptian monuments as a grain. However, during the excavations in El Lahum dating back to the 12th dynasty, clusters of S. verticillata were found in a wreath (Dixon, 1969). *Setaria* species were also a very important wild grain among the Australian aborigines (Bulmer, 1964) and some wild species were harvested in India, especially during times of famine (Bor, 1960). In the Philippines, Setaria palmifolia (Coen.) Stapf was often harvested by forest tribes and used as a rice substitute (Monsalud et al., 1966). *Setaria* species were also propagated vegetatively and used as green vegetables in New Guinea (Barrau, 1958). *Setaria* species were also an important source of starch among various tribes in Mexico. However, an unidentified *Setaria* species was used as a wild grain in the Tehuacan Valley in prehistoric times (Smith, 1968) but lost its importance with the introduction of native maize. During the 2000 years when it was widely used, seed size increased regularly as a result of natural selection made by selectively planting large seeds while planting (de Wet, 1975).

However, since these species have the ability to spread seeds naturally, large-seeded *S. geniculata* (Lam.) Beauv. There are still wild forms in northwest Mexico. Two species of *Setaria* are grown as cereals. Both species lost their natural seed spreading abilities and became completely cultivated plants. (Harlan, de Wet and Price, 1973; de Wet and Harlan, 1975). This species is also wild-collected as a grain and differs morphologically from its cultivated species in that spontaneously occurring *S. glauca* only in the maturation stage the spikelets are more or less persistent during flowering. Yellow Foxtail millet is more common in warmer parts of the world and is a favorite wild grain due to its fruit size of 2-3 mm. However, foxtail millet *Setaria italica* (L.) Beauv. It is an important grain in Southeast Europe, South and Central Asia and the Far East. These species are also cultivated as fodder for caged birds in parts of North and South America, Australia and Africa, as they are a small grain. The closest wild form is wild 5. viridis (L.) Beauv. (green foxtail millet) is distributed in warmer parts of the world. In Afghanistan, *S. viridis* and *S. italica* are morphologically intermixed, and cultivars cultivated differ from cultivars that usually form spontaneously only with the degree of fertile natural seed dispersal. Species cultivated in temperate Eurasia are highly variable in inflorescence morphology and are distinctly divided into races.

4. Cultivation Of Foxtail Millet

In India, foxtail is an important crop grown in arid and semi-arid regions (Xianmin and Guanqing, 2017). In South India, it has been a staple food among people since the Sangam period. In China, de foxtail millet is the most widely grown millet and is a staple food especially among the poor in the arid northern part of the country. In Southeast Asia, foxtail is grown mainly on dry, highlands (Cristina, 2010). In Europe and North America, it is grown mainly for hay and silage, and to a limited extent for bird feed. In the northern Philippines, foxtail was once an important food crop, but was later replaced by rice and sweet potatoes.

A warm season herb, usually planted in late spring, foxtail is grown for hay and silage. 15,000-20,000 kg/ha of green grass yield, 3,000-4.000 kg/ha of hay and 800-900 kg/ha of grain yield are obtained. However, green grass harvesting takes place in 65-70 days while grain harvesting takes place in 75-90 days. As can be seen, it is suitable to be grown in dry agricultural areas due to its early maturation and efficient use of available water.

4.1. Diseases and Pests of Foxtail Millet

Diseases of foxtail millet include leaf and head blast disease caused by *Magnaporthe grisea*, smut disease caused by *Ustilagocrameri*, and green ear diseases caused by Sclerospora graminicola. If the foxtail millet harvest is delayed, birds and rodents will damage the plant.

The main pests of foxtail millet are: 1) Firefly: *Atherigona atripalpis Atherigona approximata*, *Atherigona pulla*, *Atherigonapunctata* and *Atherigona biseta* 2) Lizard: *Agrotis ipsilon* 3) Stem borer: *Chilo partellus* 4) Pink worm: *Sesamia inferens* 5) Corn worm: *Ostrinia furnacalis* 6) Worms: *Mythimna separata*, *Spodoptera frugiperda* and

Spodoptera litura 7) Leaf bug: *Oulema melanopus* 8) Aphid: *Chaetocnema basalis* etc. (Kalaisekar, 2017).

5. Morphology Of Foxtail Millet

The cultivated millet varieties were identified by Linnaeas (1753) as *Panicum italicum*. Later, *Panicum germanicum* Miller was identified as a second species, differing from other cultivars in having short panicle branches. Both taxa were transferred to *Setaria* and merged as *S. italica* (L.) Beauv by Beauvois (1812), who transferred *Panicum viride* L. to *Setaria*. It is classified morphologically into *S. italica* cultivated in the spontaneous 5th virus, and Li, Pao and Li (1942) stated that these two species interbred to produce fertile hybrids. Green foxtail and *S. viridis* are wild forms of gin and this naturally occurring taxonomy was defined by classifying it as a subspecies of *S. italica*, as stated by Harlan and de Wet (1971). *Setaria italica* subsp. viridis (L.) Thellung, Mem. Soc. sci. Nat. Cherbourg 38:85 (1912), *S. viridis* (L.) Beauv. Ess. agrost. 51: 171-178 (1812). This subspecies is an annual herbaceous plant commonly known as green foxtail. It is also native to temperate Eurasia, but is widely available as a weed in all temperate regions of the world. It is common in cultivated fields, vacant lots, and natural habitats in the New World. The characteristic feature of the subspecies of Viridis; It is 1,5 m long, small, and has erect or slanting stems (Figure 1).

Figure 1. *Setaria italica* subsp. viridis, common wild green foxtail.

Leaf margins are lanceolate with stripes, 29 cm long and generally shorter and glabrous. Its spike-like panicles are densely flowered, erect or swaying slightly when mature, and are usually less than 10 cm long. The branches of the panicles are usually less than 1 cm and bear clusters of spikelets, each 2,0-2,5 mm long, with 1 to 3 hairs around them. The spikelets are elliptical, the lower glume is about one-third the length of the spikelet, and the upper glume is equal in length to the lemma. When the spikelets mature, they separate from under the husks. The only fruit produced in each spikelet is wrinkled and consists of a tightly closed berry with hardened lemma and palea. There is *Setaria viridis*, a resistant strain of green foxtail major (Gaudin) Pospichal) occurs throughout Eurasia (Rominger, 1962) and has recently become a difficult weed to control in American cornfields (Pohl, 1966). This breed is 1,5-2,5 m tall and is more robust than the common green foxtail. The inflorescences are lobed and larger (20 cm) and the panicle branches are usually 4 cm long (Figure 2).

Figure 2. *Setaria italica* subsp. viridis, weedy giant green foxtail.

Pohl (1951) stated that giant foxtail millet emerged by combining the cultivated foxtail millet genes. Hybrids between green foxtail and foxtail are easily produced, although both taxa are highly self-pollinated. Derivatives of these hybrids (Fig. 3) are morphologically similar to giant foxtail millet.

Figure 3. Hybrid between *Setaria italica* subsp. italica (female) and viridis (male).

Foxtail millet was once widely cultivated as a minor grain. Giant foxtail millet appears to have evolved in maize-growing regions. Native foxtail, which has the ability to spread its seeds naturally, has survived by competing with wild green foxtail in natural habitats. In field trials, up to 3% outcrossing was observed in trial plots where subspecies viridis and subspecies italica were grown together.

Setaria italica subsp. italica (L.) Beauv., Ess. agrost. 51.169-178 (1812); this subspecies has lost its fertile natural seed dispersal ability, therefore it is quite different from self-growing foxtail. It has been cultivated and the propagation of its seeds is done by humans. The morphologies of the cultivated foxtail millets are variable. Primitive strains are similar to the giant green foxtail that develops spontaneously in inflorescence morphology, while advanced strains are characterized by their gigantic panicles. The two races are commonly identified by fundamental variations in cluster structure (Scheibe, 1943). The *Moharia* genus is characterized by small (4-15 cm long) erect or slightly swaying inflorescences with short (1-3 cm long) branches on which the spikelets are arranged in clusters (Figure 4, 5). The bristles are usually well developed, changing from straw to purple when ripe, and the color of the fruit from white to yellow to black. This breed is quite different from self-evolving varieties, which have persistent spikelets in their maturing panicles. This race includes primitive varieties derived from the phylogenetically more advanced *maxima* race.

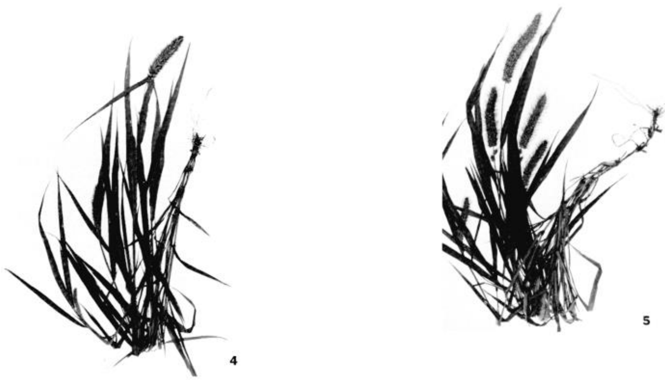

Figure 4, 5. *Setaria italica* subsp. italica race moharia from Afghanistan.

The *maxima* are characterized by clusters of lobed flower-forming spikelets and elongated secondary branches, and broad panicles that droop when mature (Figure 6, 7).

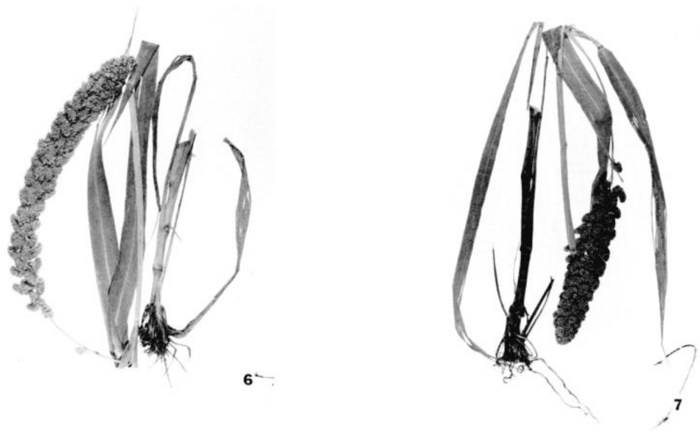

Figure 6, 7. *Setaria italica* subsp. italica race maxima from China.

The panicles are 35 cm long and 8 cm wide. The panicle branches are stiff and spreading, usually 2-6 cm long, with crowded cluster-shaped spikelets on the short secondary branch. In some species, the panicle branches are longer and drooping, with each branch resembling a thorn (Gritzenko, 1960). Their hair varies from short to long and from straw to dark purple. *Maxima* grains are used in the same way as moharia grains.

6. Usage Areas Of Foxtail Millet

Foxtail millet is a warm season annual herb. Due to its tolerance to harsh growing conditions, it can be grown in areas where other grain crops such as maize or wheat cannot survive. Foxtail millet is a cereal plant and is rich in energy, protein, iron, zinc and numerous antioxidants (Nambiar et al., 2011). 100 g of foxtail millet; It contains 351 calories, 11.2 g protein, 4 g total fat, 63.2 g carbohydrates. Therefore, it is very beneficial to be fit for a healthy life. In addition, it is very important to control diseases such as tumor treatment, blood pressure, cholesterol level and diabetes in the body (Nambiar et al., 2012). Compared to other grains, foxtail millet has a lower protein content but a higher percentage of fat and mineral content and indigestible fiber. Production of foxtail millet in general has declined significantly over the past few decades. Millet production was almost completely replaced by wheat in Europe, maize and wheat in Transcaucasian Russia. It is still an important crop only in parts of India, Afghanistan, Central Asia, Manchuria, Korea and Soviet Georgia. However, foxtail millet is part of the staple diet in northern China. In China, it is usually mixed with legumes or mixed with other grains to prepare flour, dough for bread or noodles. In addition, the sprouts of foxtail millet are used in nutrition. In India, shelled gin is cooked like rice, ground into flour or mash, and sometimes used as unleavened bread. In addition, the green part can be used as green and dry grass as well as used as silage. In Russia and Europe, *Setaria* is grown primarily as grain fodder for domestic poultry and caged songbirds. In Southeastern Europe, it is mixed with wheat flour and used in bread making. However, it is used to make alcohol in Russia and Georgia (Sher et al., 2021).

In Central Asian countries such as Tatarstan, Tajikistan, Turkmenistan, Uzbekistan, and Kazakhstan, foxtail millet has been grown mixed with amaranth (Amarantus L.) species in recent years. Then, this mixed planting is mowed at the appropriate time and silage is made. Foxtail millet grass is rich in carbohydrates, while cockscomb grass is rich in protein so that they complement each other and a quality green fodder is obtained. Foxtail millet can also be included in silage mixtures and it increases the quality of silage by enabling the silage to mature in a shorter time and with minimum loss. It is also used in grass production and in the establishment of temporary rotation pastures (Sher et al., 2021).

RESULT

Panicum italicum L. (Syn. *Seteria italica* (L.) P. Beauv.), which is called as foxtail millet or Italian millet, is one of the most widely cultivated millet species in the world. An annual foxtail millet is a warm season herb. Its homeland is considered to be the Far East, India and Central Asia.

Foxtail millet (*Setaria italica* (L.) Beauv.) is widely cultivated in Eurasia as a small grain. Primitive varieties of foxtail millet belonging to the *moharia* race are cultivated in Southeast Europe, parts of the Near East, and especially Afghanistan. In terms of flowering morphology, *S. italica* subsp. viridis (L.) Thellung (green millet) is similar and its hybrids between wild and cultivated varieties are very productive. Such natural hybrids gave rise to the weed known as giant green foxtail in Eurasia and temperate North America. The *maxima* race of foxtail millet is also highly modified and is an important grain in Central Asia and the Far East. Foxtail millet has been cultivated in China since the fifth millennium BC and in Europe since the third millennium BC.

Since ancient times, its grains have been used in human nutrition as bread and porridge, as grain fodder for domestic poultry and songbirds in cages, and to make alcohol. In addition, the green part can be used as green and dry grass as well as used as silage. Today, it is a cultivated plant widely grown in subtropical and temperate regions of the world.

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CHAPTER 6

Intermediate Wheatgrass (*Agropyron intermedium*) (Syn: *Thinopyrum intermedium*)

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INTRODUCTION

Intermediate wheatgrass is a perennial forage, grain, and biofuel crop with high biomass and grain yield with resistance to pests and diseases. Its extensive root system help reducing soil erosion. Mixtures of this grass with legumes may increase forage yield, nutritive value and economic benefits. Development of intermediate wheatgrass as a grain crop is still in its infancy. Intermediate wheatgrass is one of several perennial crops available for potential food use. Harvesting intermediate wheatgrass for grain results with a straw harvest. Additionally, vegetative biomass can be cut in spring, fall, or both for hay production. Direct domestication of intermediate wheatgrass as a perennial grain crop is underway. One of the major challenges for adoption of this dual-use forage and grain crop is the decline in grain yield in subsequent harvest years.

In an era of depleted natural resources, perennial grains may provide sustainable food production with reduced erosion and increased atmospheric carbon capture (Crain et al., 2021). Perennial crops have fewer environmental impacts compared to annual crops (Jungers et al., 2017). The wheat tribe *Poaceae* (*Triticeae*) is a diverse group of grasses. Apart from important grain crops, there are also wild grasses with great practical value (Mahelka et al., 2011). Intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv) [Synonym: "*Elytrigia intermedia* (host) Nevski"] (Khan, 2000); [Synonym: "*Thinopyrum intermedium* (Host) Barkworth & Dewey"] (Sibikeev et al., 2017) is a segmental autoallohexaploid ($2n = 6x = 42$) plant species

(Wang et al., 2015). It is a perennial crop with high biomass and grain yield, long seeds, and resistance to pests and diseases. It also reduces soil erosion, nitrate and mineral leaching into underground water tables, and sequesters carbon in its roots (Bajgain et al., 2019). Its extensive root system help reducing soil erosion (Sakiroglu et al., 2020). Intermediate wheatgrass provides high quality forage for hay and pasture in the Great Plains of North America but lacks persistence under grazing. Time of grazing and cultivar selection influence the persistence of tillers of intermediate wheatgrass primarily through their effect on tiller recruitment (Hendrickson et al., 2005).

GRAIN FEED

Efforts to domesticate intermediate wheatgrass as a perennial grain crop roots in 1980's. Currently, there are several breeding programs within North America and Europe working toward developing it into a viable crop (Crain et al., 2020). Breeding for increased seed weight is one of the primary goals for improving grain yield of intermediate wheatgrass (Zhang et al., 2017). Direct domestication of intermediate wheatgrass as a perennial grain crop is underway, and selection has focused primarily on improving seed size and grain yield. Correlation analyses revealed that when yield was measured on a yield per spike basis, floret site utilization was the primary contributor to yield, and when measured on a per-plant basis, reproductive tiller number was the primary contributor. The indirect effects of biomass and maturity traits on both measures of yield were limited. Future work should investigate the predictive ability of reproductive tiller counts in spaced plant and sward environments to inform how breeders assess and select for yield (Altendorf et al., 2021).

“Kernza” branded intermediate wheatgrass is the first perennial grain crop in the world and has been developed with conventional breeding to increase seed yield of forage intermediate wheatgrass. When managed for dual-use (grain and forage), Kernza intermediate wheatgrass can produce grain, crop residue (straw) in the summer, and green forage in the spring and fall. Mixtures of this grass with legumes could increase forage yield and nutritive value and provide other environmental and economic benefits (Favre et al., 2019). It is the first perennial grain crop in the United States, commercialized as Kernza since 2015 (Zimbric et al., 2020). Harvesting intermediate wheatgrass for grain results with a straw harvest. Additionally, vegetative biomass can be cut in spring, fall, or both for hay production (Hunter et al., 2020). Growers utilized and valued Kernza as a dual-use crop (grain and forage), sometimes not harvesting grain but almost always grazing or harvesting hay and straw for bedding (Lanker et al., 2020).

One of the major challenges for adoption of this dual-use forage and grain crop is the decline in grain yield in subsequent harvest years. Post-harvest management practices (such as chopping, burning, chemical, and mechanical thinning) could reduce the intraspecific competition for light and maintain Intermediate wheatgrass grain yields over time (Pinto et al., 2021). Grain yield from Kernza is lower than comparable annual cereal crops such as wheat and oats. Also, although Kernza is a long-lived perennial that can persist for decades, grain yield tends to decline over time as Kernza stands age leading most farmers to replant or rotate to a different crop after 3–5 yrs. Increased intraspecific competition as stand density increases with age has been reported to cause grain yield declines (Law et al., 2021). Grain yield declines >75% are often observed after second year of the perennial stand. Intercropping Intermediate wheatgrass with a perennial legume such as alfalfa (*Medicago sativa*) can benefit nutrient cycling while increasing agroecological diversity (Tautges et al., 2018). Because the development of intermediate wheatgrass as a grain crop is still in its infancy, basic agronomic management practices needed to maximize grain yield and profitability remain unclear (Fernandez et al., 2020).

AGRONOMY

Fernandez et al., (2020) conducted an experiment to see the effect of N fertilizer rate and type (organic vs. synthetic) and planting density on grain and forage yield of intermediate wheatgrass over three years. N application was not effective for grain yield in first year but increased yields in second and third years. Reducing planting density from 145 seeds/m2 to 36 seeds/m2 reduced grain yield in first year, but increased grain yield in subsequent years when inorganic N fertilizer applied at 80 kg N /ha. A high ratio of fertile tillers was the best predictor of high intermediate wheatgrass grain yield. This suggest that, shifts toward vegetative growth over sexual reproduction in the following years are associated with grain yield declines. Biomass yield responded positively to increasing N application rates and planting density across all years.

Researches on perennial grasses was shown that seed yield can be increased by 1) mechanically defoliating the stand for hay production; 2) increasing row spacing. Hunter et al., (2020) evaluated effects of row spacing and defoliation across four years of an intermediate wheatgrass stand. Overall, grain yield declined substantially over time, from a mean of 880 kg/ha in 2015 to 276 kg/ha in 2018. Wider row spacings increased grain yields. Defoliation increased grain yield in the first two years, but may have decreased stand vigor in following years. Main cause of yield decline was the reduction in grain number per high-yielding spike, which dropped by roughly half after the first year. The proportion of spikes that were high yielding also declined over time. Increasing competition among reproductive units likely contributed to yield decline, but there was also evidence that resource allocation to reproduction declined over time. Future research in intermediate wheatgrass breeding and management should focus on maintaining high grain number, reducing intra-stand competition, and increasing resource allocation to reproduction.

Perennial grain crops intercropped with legumes are expected to use nitrogen resources efficiently (Li et al., 2021). Intermediate wheatgrass produced 519 kg/ha and 446 kg/ha seed yield in first and second years after establishment, repectively. Autumn grazing increased seed yield compared with post-harvest residue removal or chopping. Inter-seeding alfalfa (*Medicago sativa*), sweet clover (*Melilotus officinalis*), and white clover (*Trifolium repens*) did not affect intermediate wheatgrass seed production (Dick et al., 2018).

Trinexapac-ethyl reduces height and lodging in wheatgrass. It increases grain yield when lodging risk was high (Frahm et al., 2018). Expansion of perennial grain and forage Kernza intermediate wheatgrass to temperate regions may be limited by its vernalization requirements. there is potential for selection for reduced vernalization requirements in Kernza populations (Ivancic et al., 2021).

FOOD & BIOFUEL CROP

Allohexaploid intermediate wheatgrass possesses many desirable agronomic traits which make it a source of genetic material useful in wheat improvement. Identification of its genomic components is the object of considerable investigations. But complete genomic constitution and its potential variability are still being unravelled (Mahelka et al., 2011). Intermediate wheatgrass has edible and nutritious grain and desirable agronomic traits, including large seed size, high grain yield, and biomass (Zhang et al., 2016). The high protein and fiber content of intermediate wheatgrass, together with its interesting agronomic traits and environment related benefits, make this crop attractive also for human consumption (Marti et al., 2016).

Progress in breeding of intermediate wheatgrass has enabled bran removal (Tyl et al., 2019). Intermediate wheatgrass is one of several perennial crops available for potential food use. The potential of intermediate wheatgrass for food use was investigated by Rahardjo et al., (2018). They determined that grains of intermediate wheatgrass were high in protein and fiber, but low in starch compared to wheat. Intermediate wheatgrass proteins were deficient in glutenins, which are needed for dough elasticity. Paste from intermediate wheatgrass flour had lower viscosity during heating/cooling compared to wheat. Intermediate wheatgrass whole-grain flour produced weaker dough and low loaf volume compared to wheat.

Perenniality would be valuable option for grain production, but attempts to introgress this complex trait from wheat-Thinopyrum hybrids have not been commercially successful (Larson et al., 2019). Intermediate wheatgrass is identified as a candidate for domestication and improvement as a perennial grain, forage, and biofuel crop and is actively being improved by several breeding programs. To accelerate this process using genomics-assisted breeding, efficient genotyping methods and genetic marker reference maps are needed. Genomic tools can help lead to rapid improvement of intermediate wheatgrass and development of high-yielding cultivars of this perennial grain that would facilitate the sustainable intensification of agricultural systems (Kantarski et al., 2017).

CONCLUSIONS

Intermediate wheatgrass is a perennial forage, grain, and biofuel crop with high biomass and grain yield with resistance to pests and diseases. Biomass yield responded positively to increasing N application rates and planting density during consecutive years. Grain yield declines >75% are often observed after second year of the perennial stand. Intercropping Intermediate wheatgrass with a perennial legume such as alfalfa can benefit nutrient cycling. Development of intermediate wheatgrass as a grain crop is still in its infancy. Harvesting intermediate wheatgrass for grain results with a straw harvest. Also, vegetative biomass can be cut in spring, fall, or both for hay production. Direct domestication of intermediate wheatgrass as a perennial grain crop is underway.

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CHAPTER 7

Kentucky Bluegrass (*Poa pratensis* L.)

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INTRODUCTION

There are about 250 species in the genus *Poa*. Among these species, *Poa pratensis*, *Poa trivialis*, *Poa palustris*, *Poa nemoralis* and *Poa annua* come to the fore. *Poa pratensis*, which is the most important of these species, is a perennial and long-lived (25-30 years) species that grows naturally in the meadow pasture areas of our country. *Poa pratensis* is a good pasture plant because it is resistant to grazing, a good green field plant because it is resistant to mowing, and a good soil protection plant because it forms a tight lawn (Soya et al., 2004).

Poa pratensis is also widely available in Europe and is a delicious pasture plant that grows very early in the spring. It is a dominant species in old pastures (Bender et al., 2006). *Poa pratensis* is widely used in the establishment of green areas, due to the fact that it forms a good cover layer, is resistant to mowing, and its leaves are thin and shiny (Açıkgöz, 2001; Kir et al., 2010; Açıkgöz, 2013;Varoğlu et al., 2015).

Poa pratensis has rhizomes, has abundant leaves and leaf surfaces are folded in a "V" shape. The tip of the leaf surface shows a boat-shaped fold. It grows in meadows and where water is plentiful. The plant is classified as increaser (Serin et al., 2008). *Poa pratensis* thrives well in cool areas with regular rainfall, going dormant in hot summers (Açıkgöz, 2001). *Poa pratensis* is a species with high output power and good winter and drought resistance (Karakurt, 2004).

Poa pratensis is a cool season grass forage crop that can be used against the negative effects of erosion in pasture areas. In a study conducted under laboratory conditions, it was reported that *Poa pratensis* reduced soil erosion by 95% (Geren & Yönter, 2007).

1. Cultivation of *Poa pratensis*

Poa pratensis is the most cultivated species among the *Poa* species. It grows naturally in the entire northern hemisphere. It is not known exactly when it started *Poa* farming. It has been reported that *Poa pratensis* is not of great importance as a forage plant in Turkey and almost all of the seeds offered to the market are used in the establishment of green areas (Açıkgöz, 2001, 2021). However, when look at the studies conducted in recent years, it has been seen that *Poa prantensis* is included in rangeland improvement programs and has been successfully evaluated (Genç Lermi et al., 2016; Palta & Alagöz Altındaş, 2018).

Sowing depth of *Poa pratensis* should be 2-3 cm. 1.5-2 kg/da of seed should be used in row sowing and 2.5-3.0 kg/da in scatter sowing. For seed production, 35-90 cm row spacing and 0.3-1.2 kg/da seeds are used. It gives seeds between 10-20 kg per decare. It is considered as a meadow pasture plant rather than grass production (Soya et al., 2004). In case of cultivation for grass production, the ideal row spacing is 20 cm (Yılmaz & Avcıoğlu, 2002). The highest green grass yield, coverage rate, grass color and grass quality are obtained from the areas where 25 g seeds per square meter are used (Akdeniz et al., 2018).

2. Use of *Poa pratensis* in Mixtures

Poa pratensis is a good mix plant. In the study carried out for three years in Erzurum conditions, while the dry matter yield of *Poa pratensis* in pure form was 495 kg/da, increased to 1472 kg/da in the mixture with red clover and to 1509 kg/da in the mixture with alfalfa. While the crude protein ratio in pure form was 10.83%, it increased to 16.47% in the mixture with red clover and 16.36% in the mixture with alfalfa. While pure crude protein yield was 68.8 kg/da, it increased to 239.6 kg/da in the mixture with red clover and 247.9 kg/da in the mixture with alfalfa (Serin et al., 1998).

Likewise, the dry matter yield of *Poa pratensis*, which was 495 kg/da, increased to 1227 kg/da when mixed with white clover, and to 1239 kg/da when mixed with bird's-foot trefoil. While the crude protein ratio was 10.69%, it increased to 14.74% in the mixture with white clover and 15.31% in the mixture with bird's-foot trefoil. While the crude protein yield was 52.7 kg/da, it increased to 147.4 kg/da in the mixture with white clover and to 150.9 kg/da in the mixture with bird's-foot trefoil (Serin et al., 1997).

These studies clearly show that *Poa pratensis* is a good mix plant and when sowed with legumes it gives good results in terms of yield and quality.

3. Yield and Quality Characteristics of *Poa pratensis*

Although *Poa pratensis* is an excellent cold season plant, its yield decreases in arid conditions (Zhang et al., 2021) and is affected by competition (Bender et al., 2006). Yield and quality characteristics of *Poa pratensis* were given in Table 1.

In terms of yield characteristics; it seen that the average plant height of *Poa pratensis* was 11.4-71.3 cm, biological yield 257.2-384.0 kg/da, green forage yield 493 kg/da, dry matter yield 197 kg/da, seed yield per plant 6.2-10.1 g, seed yield per decare 7.7-20.4 kg, thousand seed weight 0.278-0.404 g and hectoliter weight varies between 27.27-32.17 kg (Table 1).

In terms of quality characteristics; It seen that the average crude protein ratio of *Poa pratensis* was 11.07-13.50%, crude ash ratio 5.77%, crude oil ratio 1.40%, NDF ratio 51.5-59.66%, ADF ratio 26.7-32.3%, ADL ratio 0.60-4.47%, DDM ratio 63.5-65.65%, DMI ratio 2.01-2.12% and relative feed value varies between 102.2-123.9 (Table 1).

Table 1. Some yield and quality characteristics of *Poa pratensis*

Yield characteristics (*)		**Quality characteristics (**)**	
Plant height (cm)	11.4-71.3	Crude protein (%)	11.07-13.50
Biological yield (kg/da)	257.2-384.0	Crude ash (%)	5.77
Green forage yield (kg/da)	493	Crude oil (%)	1.40
Dry matter yield (kg/da)	197	NDF (%)	51.5-59.66
Seed yield per plant (g/plant)	6.2-10.1	ADF (%)	26.7-32.3
Seed yield per decare (kg)	7.7-20.4	ADL (%)	0.60-4.47
Germination rate (%)	65.9-66.8	DDM (%)	63.5-65.65
Thousand seed weight (g)	0.278-0.404	DMI (%)	2.01-2.12
Hectoliter weight (kg)	27.27-32.17	RFV	102.2-123.9

(*): (Yılmaz & Avcıoğlu, 2002), (Karakurt, 2004), (Tamkoç et al., 2007), (Ek et al., 2021) (Özaydın et al., 2021)
(**)(Bender et al., 2006), (Gürsoy & Macit, 2017a), (Başbağ et al., 2018)

According to the quality classification method determined by Lacefield (1988), *Poa pratesis* was determined to have third class feed quality

(Başbağ et al., 2018). Forage crops belonging to the grass family, including *Poa pratensis,* have the potential to meet the quality roughage needs of farm animals in general and give satisfactory results in terms of relative feed value (Gürsoy & Macit, 2017a).

4. Nutrient Content of *Poa pratensis* and Evaluation as a Green Field Plant

Poa prantensis can be used in the germination of fields such as playgrounds, parks, golf courses all over the world (Elçi, 2005). The element content of *Poa pratensis* and its properties as a green field plant were given in Table 2.

It has been observed that the nutrient contents of *Poa pratensis* are close to the optimal values of macro and micro element contents determined by Motsara & Roy (2008). When *Poa pratensis* is evaluated as a green field plant, it is understood that it has medium grass quality, especially when the scale between 1-9 is taken into account.

Table 2. Nutrient content of *Poa pratensis* and its properties as a green field plant

Nutrient content (*)				Green field plant (**)	
N (%)	1.05-1.76	Zn (ppm)	33.8-	General view (1-9)	4.00-7.70
P (%)	0.41-1.17	Mn (ppm)	95-215	Leaf clour (1-9)	5.40-7.19
K (%)	2.09-2.55	Ni (ppm)	19.89	Leaf texture (1-9)	1.60-3.01
Ca (%)	0.27-0.32	Al (ppm)	0.22	Covering degree (1-9)	3.90-5.70
Mg (%)	0.19-0.22	Co (ppm)	1.27	Sparseness (1-9)	2.30-4.70
S (%)	0.32	As (ppm)	2.12	Density (1-9)	5.39-5.80
Fe (ppm)	0.33-273.5	Cr (ppm)	3.36	Autumn growth (1-9)	3.88
Cu (ppm)	9.84-68.84	B (ppm)	0.35	Spring growth (1-9)	4.55

(*)(Bender et al., 2006), (Gürsoy & Macit, 2017b) (Başbağ et al., 2018) (Ek et al., 2021),
(**)(Gül, 2015) (Akdeniz et al., 2018) (Koyuncu & Avcı, 2018), (Varoğlu et al., 2015), (Alagöz & Türk, 2017), (Yilmaz et al., 2018).

It has also been reported that because *Poa pratensis* creates green grass cover in spring, summer, autumn and winter, it should be included in the green field mixtures that growers will use (Gül, 2015).

CONCLUSION

Poa pratensis, in addition to being a plant that grows and develops spontaneously in natural areas, is also cultivated in the world and in our country. *Poa pratensis*, which has been largely used in grass fields in the past years, has been successfully used in the improvement of pasture fields as well as grass fields in our country. *Poa pratensis*; It is a species that can give satisfactory results in terms of yield and quality, in terms of performance in mixtures with legumes, in terms of the nutrient content it contains and its properties as a green field plant. As a result, *Poa pratensis* is a valuable forage plant that can be considered as a good pasture improvement plant, a good mix plant, a good soil protection plant and a good green field plant.

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CHAPTER 8

Orchardgrass *(Dactylis glomerata)*

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INTRODUCTION

Orchardgrass *(Dactylis glomerata)* is a perennial grass that is accepted as a natural plant of Eurasia, but introduced to many temperate countries of the world as a valuable pasture plant, continues to live in the climate and natural conditions of many countries, and is widely spread within these countries.In many places, it is known as an aggressive and persistent low-growing grass, Orchardgrass has been described by Cal-IPC (2015) as an aggressive perennial grass that grows in all types of soil, is drought-resistant and invades some pastures.This plant is grazed year-round by wildlife, including deer. It has been reported to be invasive in shrubs, open woodlands, riparian habitats, freshwater wetlands and coastal environments, suppressing native plants and inhibiting their growth and regeneration, and forming dense grazing areas (Muyt 2001; Weeds of Australia 2015).

Taxonomy

Although ITIS (2015) lists several subspecies and cultivars, on Orchardgrass only two subspecies, *Dactylis glomerata* ssp. *glomerata* and ssp. *lobata* (Drejer) H. Lindb. is declared it accepted.The Plant List (2013) and USDA-ARS (2015) reported that there are many subspecies in addition to the two mentioned. Some of those species are *Dactylis glomerata* L. ssp. *aschersoniana* (Graebn.) Thell., *Dactylis glomerata* L. ssp. *glomerata*, *Dactylis glomerata* L. ssp. *himalayensis* Domin, *Dactylis glomerata* L. ssp. *hispanica* (Roth) Nyman, Dactylis glomerata L. ssp. *lobata* (Drejer) H. Lindb, *Dactylis glomerata* L. ssp.

polygama (Horv.) Domin, *Dactylis glomerata* L. ssp. *smithii* (Link) Stebbins and D. Zohary, *Dactylis glomerata* L. ssp. *woronowii* (Ovcz.) Stebbins and D. Zohary, *Dactylis glomerata* L. var. *detonsa* Fr., *Dactylis glomerata* L., var. *vivipara* Parl.

Beddows (1959) claimed that at least 200 names dispersed in the European botanical literatureapplied to taxa under *Dactylis glomerata* (sensu lato). It is clear that there is a wide variety of forms within the species, some flat-growing, others sprawling and upright-growing, with a wide variety of leaf colours. Some of these species are used as ornamental plants, some have yellow or golden leaves and others are variegated.

Description

Orchardgrass is a perennial herbaceous plant, 15-140 cm long, with straight or elbowed, cluster-shaped with flowering stems. The plants have an extensive fibrous, fringe root system but no stolons and rarely have short rhizomes.The leaf sheaths are flat and keeled, the collar is membranous. The leaf blade is flat and V-shaped in cross section, glabrous, flat, folded between the midline, and the leaf length is 10-45 cm long, 2-14 mm wide.The stance of the flowers on the stem is imaginatively resembling a rooster's foot, the flower head is 7-20 cm long, unilateral, erect, branches close together and spike-like, and the lowest branch is well below the others and all branches terminate in a few tight clusters of spikelets.The spikelets in the panicle are solitary and consist of 2-5 fertile flowers, oblong or wedge-shaped, laterally compressed, 5-9 mm long, that divide under each fertile flower when mature.Their glumes are different and shorter than the spikes. The lower glume is lanceolate, 3/4 of the length of the upper glume, membranous, vertebrate and veined. The lower glume is oval with a sharp tip, keeled and veined.The lemma surrounding the flower gradually tapers to a point with an awn 0.5-1.5 mm long in total. Karyopsis is tightly surrounded by lemma and palea (Anonymous 2022).

Figure 1. Vegetative growth, spike and flower structure

Adaptation

Orchardgrass *(Dactylis glomerata)* is native to Europe, North Africa, and some regions of Asia and it is produced in most parts of the world, including Northwest Europe, Australia, New Zealand, Japan, and the northeastern part of the United States and the Pacific Northwest. Turkey is an important gene center and there are 11 species belonging to the genus Dactylis (Davis 1985).

Orchardgrass is generally adapted to mild winters, mild summers, relatively high rainy or irrigeable regions. It is moderately resistant to cold, heat and drought, but more shade-tolerant than other forage crops. Therefore, it is suitable to be grown under fruit trees.It is adapted to drained or irrigated conditions in fertile soils of medium texture, well-drained, calcareous, neutral or moderately acidic. It does not growth well in salty soils and high ground water levels in the rooting zone. It can only tolerate moderate salinity or less.

Although Western Mediterranean ecotypes withstand long, hot, dry summer, Orchardgrass is a cool season plant and 22/12°C (Day/Night) temperature values are ideal for growth (Altin *et al*. 2005; Acikgoz 2021).

Figure 2. Flowering and seed maturity period (AYFAM Orchardgrass)

Cultivation and Management

Orchardgrass is suitable for autumn cultivation in temperate regions of our country and in spring in cold winters regions. The plant is suitable for planting alone or mixed with legumes. It can be grown mixed with alfalfa and meadow clover for hay production, and with large-leaved ladino type alfalfa for grazing (Avcioglu *et al*. 2009). The most suitable planting method is with a seeder, and the germination rate should be at least 80% and the pure seed rate should be at least 90% according to the seed standard. The seedbed should be clean, suppressed and weed-free for cultivation. Pasture and erosion control plantings should be done in late autumn or very early spring. Planting failure may occur due to drought and hot summer conditions before well established in sowing after the loss of spring moisture. Sowing depth should be between 0.6-1.25 cm. Row spacing should be 20-40 cm for grass production, and 70-100 cmwith 720-960 g da^{-1} sowing norm for seed production. When Orchardgrass is grown alone, 1-3 tons of yield can be obtained per decare, 3-5 tons of yield can be obtained when grown with alfalfa or meadow clover. The seed yield can be varied between 120-144 kg da^{-1}. To store seeds, they should be dried upto 12% moisture in boxes and 15% in sacks (NRCS 2012; USDA 2017). In summer drought, it becomes dormant and can survive long drought periods. Three harvests are possible, depending on irrigation levels.

It is a suitable plant in legume mixtures for feed production. The palatability is highest during the autumn and spring active growth periods, the forage quality decreases as it matures.Harvesting should be done before flowering and when the cluster is fully formed. It is one of the most sensitive pasture plants to nitrogen applications. As a strategy to equalize feed production after the first and second harvest or grazing period and to increase late spring and summer production fertilizing is necessary (USDA 2017). Nitrogen application is not recommended in orchardgrass-legume mixes for turfgrass becauese it increases competition of grasses with legumes.

Depending on the age of the planting, pure or mixed cultivation, soil fertility, precipitation and irrigation, 5-10 kg da^{-1} nitrogen application in early spring and after each harvest is sufficient for grass production (Acikgoz 2021).

In the study carried out at Bridger Plant Materials Center in 2004-2006 under irrigated conditions, 648.8 kg da-1 dry hay yield was obtained when Orchardgrass was sown alone and 1.186,3 kg da-1 when mixed with alfalfa. In the study, it was stated that two harvest were taken in 2005 and three harvest in 2006 (NRCS 2012).

Orchardgrass is also preferred in pastures due to its early spring growth and rapid growth after grazing. The highest yield in orchardgrass-legume pastures is obtained from the grazing starts when the above-ground biomass levels at a height of 20-23 cm and then closed for grazing when the stubble height is reduced to 10 cm (NRCS 2012).

Within the scope of plant breeding studies carried out in Turkey, three varieties, Taya, Ayfam and Doğu Yıldızı developed by Erzurum East Anatolian Agricultural Research Institute according to the synthetic variety breeding method were registered in 2015 and started to be used in plant production.

Yavuz and Karadag (2016) In the province of Tokat, which is located in the transition climate zone of the Black Sea Region, the highest dry matter yield was obtained from the sainfoin + salad burnet + orchardgrass mixture (1.188,9 kg da^{-1}), the lowest dry matter yield was obtained from lean sown orchardgrass alone (562,1 kg). da^{-1}) have been obtained.

Based on the results of the study carried out in Sivas Ecological Conditions to determine some agronomic and quality characteristics of five different origins *Dactylis glomerata* cultivars (Lucullus, Lidaglo, Lidacta, Ayfam and Doğu Yıldızı), Our national varieties, Ayfam and Doğu Yıldızı were able to compete with foreign varieties with its 1.102,6-1,161.2 kg da^{-1} hay yield and gave high values (10.65-11.23%) in terms of crude protein (Karakoy *et al*. 2019). In Erzurum irrigated conditions, Kharazmi and Tan (2021) reported that the hay yield was 882.1 kg and 712.9 kg, respectively, in 15 kg da^{-1} nitrogen and 150 kg da^{-1} zeolite applications

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CHAPTER 9

Reed Canary Grass (*Phalaris arundinacea* L.)

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INTRODUCTION

Reed canary grass is a perennial grass forage crop with rhizome (Apfelbaum and Sams, 1987). It grows practically everywhere in the world, despite its natural distribution in Northern Africa, North America, Asia, and Europe (Magee and Ahles, 2007). It's a perennial herbaceous plant that grows in rivers and lakes all around the world. *Phalaris arundinacea* L. is also known as reed canary grass, canary grass, speargrass, ribbon grass, and gardener's gaiters.

Reed canary grass has grown in popularity as a means of creating permanent pasture and obtaining dry grass in areas where other forage crops cannot grow. Aside from being used as fodder, it is also used as an ornamental plant, in paper manufacturing, biofuel, and medicine (Finell, 2003; Wrobel et al. 2009; Anderson et al. 2016). Because of its dense and rhizome root structure, as well as its dense grass cover, it provides excellent erosion control in stream ponds and coastal strips. Furthermore, it provides a habitat for wild animals, and its spilled seeds provide food for many bird species (Semere and Slater, 2007; Tansı, 2009).

Reed canary grass grows upright and has a plant height ranging from 60 cm to 150 cm (Fernald, 1950). It is a vigorous plant that can grow to be 1 m in diameter by forming a strong ball. Typically, the leaves are green or bluish in color (Welsh et al. 1987). The leaves are 8-20 mm wide and quite hard. Auricles are not formed. The collar is well developed and has a slight hairiness to it. The spikelet assemblage is a spike-like cluster type. There is one fertile flower at the spike tip and two sterile flowers below it. Seeds mature downwards, beginning at the top of the cluster, and the maturing seeds are poured immediately. Its seeds are gray or gray-black in color, and 1000 seeds weight 0.75 g (Tansı, 2009).

Reed canary grass is a plant of humid and cool climates. However, they can also tolerate cold, drought and cold conditions to a certain extent. It is moderately drought resistant and requires 450-650 mm of annual precipitation or irrigation for its cultivation. It is very resistant to flooding. With this feature, it allows animals grazing on wet pastures to wander without sinking. Studies show that mature plants can survive for 49 days or more, seedlings for 35-49 days, and seeds for 35-56 days in flooded areas (McKenzie, R.E., 1951). It can be grown in soils with a pH of 5.5-8.0. Salinity tolerance is moderate. It adapts well to soils ranging from moderately acidic to slightly salty-alkaline soils.

Figure 1. Reed canary grass (*P. arundinacea* L.) (Anonymous 2022)

Since the seeds of reed canary grass are very small, good seedbed preparation is required. However, it is not possible to prepare a good seedbed because the areas where reed canary grass is grown are moist, poorly drained areas (Krol et al., 2019). Therefore, it is necessary to increase the quantity of seeds. While the quantity of seed to be planted in a good seed bed is 600-900 g/da of pure and live seed, if the seed bed is not well prepared, 1500-2500 g/da of seed should be planted and the planting depth should be 1-2 cm. Reed canary grass is a rhizome-reproducing plant, and its rhizomes are used in the reed canary grass facility as well as for seed planting (Harrington, 1964). When using rhizomes, there is no need to prepare a good seedbed. It is sufficient for the rhizome nodes to remain in the moist soil. The rhizomes can be mixed into the soil by scattering them in the pasture, or they can be covered by opening incisions.

Planting of reed canary grass should be done in autumn. Seedling development is quite slow. However, once the seedlings are well rooted, they show strong growth (Hoffman et al. 1980).

The competition of reed canary grass is high, so it does not allow the development of foreign plants. The plant should not be grazed until it develops well. It would be better to harvest 1-2 times for dry grass before grazing. In order for the plant to maintain its vitality, 15 cm of stubble should be left in the forms. In good conditions, it can be harvested 2 or 3 times. Reed canary grass can withstand low and frequent harvests, but its yield is greatly reduced in this way. Reed canary grass is suitable for lamb and calf farming areas due to its resistance to heavy grazing conditions.

Since reed canary grass is a rough plant, grazing should be started when the plants reach 25-30 cm. Since it is a rhizome plant, its resistance to grazing is high. In the production of hay, harvest should be done when the spikes start to appear. The total hay yield is 1.0-1.2 t/da and can reach 2 t/da. Seed yield is 20-25 kg/da.

In cold regions, silage makes a significant contribution to the diets of ruminants compared to hay (Wilkinson & Rinne, 2018). The use of reed canary grass as silage in the winter months when grazing is not possible ensures that the feed requirement is met (Chen et al. 2020).

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CHAPTER 10

Rhodes Grass (*Chloris gayana* L. Kunth)

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INTRODUCTION

Fodder crops are the most important and affordable food source for animals. In livestock production, producing high-dry-matter feed is critical. Rhodes grass (*Chloris gayana* L. Kunth) is an valuable forage species well accepted to pastures with saline soils in subtropical and warm-temperate zones. This grass uses C_4 photosynthesis to efficiently utilise solar energy and available soil moisture to rapidly accumulate a large quantity of biomass. It is a leafy grass, 1-2 m in height and highly variable in habit. Additionally, it has fair forage nutritional quality and palatability, fits well to pasture and hay production and has good drought, salinity and fire resistance. It also represents large intraspecific variation.

Tropical and subtropical climates are ideal for Rhodes grass. When cultivated on grassland, the yearly rainfall ranges from 600 to 1600 mm. It can be found up to 2000 m altitude in open grassland or grassland with scattered bush or trees, lake edges in native zone (Africa). Tropical C_4 grasses have the potential to boost forage production in temperate and subtropical areas throughout the summer, when growing conditions are not favorable for C_3 temperate grasses. This review is summerising informations produced during the last two decade on Rhodos grass.

Fodder production contributes significantly to agricultural economic growth. Fodder crops are the most important and affordable food source for animals that require a lot of metabolizable energy as well as other nutrients like carbohydrates and protein. In order to keep cattle, a consistent supply of high-quality feed is a must (Bakhashwain, 2010).

In livestock production, producing high-dry-matter feed is very critical. Large volumes of fodder can be produced by subtropical pasture management, but the nutritional quality of the forage is often poor, lowering animal performance and, as a result, the overall system productivity (Da Silva, 2004). The advancement of information and understanding about the existing worldwide diversity of plant species is required to improve the conservation and use of genetic resources (Negawo et al., 2021).

Given its good adaptation to drought, salt, and mild freezing, Rhodes grass (*Chloris gayana* L. Kunth) is an valuable forage species well accepted to pastures with saline soils in subtropical and warm-temperate zones. Its tolerance, however, varies according on the cultivar. Significant yield losses have been seen in tetraploid varieties (Ceccoli et al., 2011).

Fig. 1. Rhodes grass at vegetative stage (Bilgin and Tansı, 2019-2021)

Rhodes grass, like corn and sugarcane, is a tropical grass that uses C_4 photosynthesis to efficiently utilise solar energy and available soil moisture to rapidly accumulate a large quantity of biomass. The crop is great for erosion management and weed suppression, and it is well adapted for rapid development, however it may take a while to establish. Fair forage production, nutritional quality, and palatability are additional merits (Valenzuela and Smith, 2002). It is useful forage for pasture and hay, drought-resistant and very productive, of high quality when young (Feyissa, 2000).

Rhodes grass grows wild throughout most of Africa's tropical and subtropical regions. It can be found up to 2000 m altitude in open grassland or grassland with scattered bush or trees, lake edges, or periodically flooded plains. Around 1900, Rhodes grass was introduced to Australia and the United States. It is now widely sown and naturalized in Queensland's coastal and sub-coastal districts. Rhodes grass is now primarily seeded in Florida and Texas' southern regions. Most other tropical and subtropical countries, as well as several warm temperate countries, have been introduced to Rhodes grass. It is particularly important in the Middle East, as well as Japan and Argentina to a lesser extent (Elnazier, 2010).

Taxonomy & Morphology

Chloris gayana is a gramineous perennial species native to Africa (South Africa, Kenya, and Zimbabwe) (Ponsens et al., 2010). It belongs to the family *Poaceae* and sub tribe *Chloridoideae*. (Luna et al. 2002). It is in the sub-family *Chloridoideae* (Arshad et al., 2019).

Rhodes grass is a perennial or annual tropical grass. It is a leafy grass, 1-2 m in height, highly variable in habit. The culms are tufted or creeping, erect or decumbent, sometimes rooting from the nodes. The leaves are linear, with flat or folded glabrous blades, 12-50 cm long x 10-20 mm wide, tapering at the apex (Valenzuela et al., 2002). The seed head has an open hand shape and encompasses 2-10 one-sided or double-sided racemes, 4-15 cm long. The inflorescences are light greenish brown (rarely yellow) in colour, and turn darker brown as they mature. The spikelets (over 32) are densely imbricated and have two awns. The fruit is a caryopsis, longitudinally grooved (Cook et al., 2005).

Agriculture

The establishment, persistence, and forage production of new forage species in grassland ecosystems or managed pasture systems are all important factors in their success (Baron and Belanger, 2007). Tropical C_4 grasses have the potential to boost forage production in temperate and subtropical areas throughout the summer, when growing conditions are not favorable for C_3 temperate grasses. Temperate grasses, on the other hand, showed little persistence (Crush and Rowarth, 2007). The critical daily mean temperature for growth of Chloris gayana is 8 degrees Celsius (Imaz et al., 2017).

Tropical and subtropical climates are ideal for Rhodes grass. When cultivated on grassland, the yearly rainfall ranges from 600 to 1600mm. The crop can be produced in a variety of soil types, ranging from clay to sandy loam. It struggles with very heavy clays. Rhodes grass grows best in soil with a pH of 5 to 8.3. This pasture crop responds well to irrigation and is flood tolerant to a degree, although it does not tolerate shade. Rhodes grass is produced under irrigation in desert locations (such as the Middle East). It thrives in a variety of fertile loams, from sandy-textured to red volcanic soils to clay loams. Rhodes grass is a fire-resistant grass. In irrigated agriculture, Rhodes grass is extensively planted as a pure stand or in a mixture with legumes on rangeland and irrigated pastures. If harvested just as it starts to flower or a bit sooner, the crop yields excellent hay. The hay from the old stand is of poor grade. Silage has been successfully produced in Nigeria, Zambia, and Northern Australia, but it is generally unsatisfactory. Rhodes grass alone produced 58 DM t/ha in Zambia. In Texas, a dry matter yield of 15.8 t/ha was obtained under irrigation. An irrigated Rhodes grass pasture treated with three fertilizer dressings at eight weeks throughout Summer in South-West Australia yielded 23.6 t/ha (November to April). Each dressing provided 56 kg/ha of nitrogen, 22 kg/ha of phosphorus, and 45 kg/ha of potassium, respectively. In Florida, U.S.A., annual dry matter yields ranged from 15.5–17.2 MT/ha, with better yields reported when planted in 25cm rows and treated with 150 kg N/ha (Elnazier, 2010). Pastures grown on low-phosphorus soils (less than 10ppm or 10 mg/kg) were shown to be deficient in P for beef production, implying that the animals would suffer from P insufficiency unless P supplements were given or the pasture was fertilized (Cook, 2014).

Rhodes grass's natural distribution across Africa, as well as its natural stands, demonstrate its tolerance to a variety of environments. It also represents the large intraspecific variation, resulting in a variety of morphologies that may exploit various settings. With an average water intake of 600 mm to 1200 mm, Rhodes grass has a high protein content (9-12%). More than three years of sowing Rhodes grass results in development (Arshad et al., 2016). It's a high-yielding, high-quality forage grass that's also utilized as a cover crop to increase soil fertility and nematode control. Rhodes grass is a highly polymorphic forage grass species that is mostly cross-pollinated diploid or tetraploid (with a basic chromosomal number of x = 10) and is primarily cross-pollinated (Cook et al., 2020).

Fig. 2. Rhodes grass at generative stage (Bilgin and Tansı, 2019-2021)

The growing demand for animal and animal-related products can be fulfilled by using enhanced pasture species to meet the dietary needs of animals. In tropical and subtropical areas, Rhodes grass is one of the best grasses for rotating land and for establishing pasture lays. It's good for silage and hay, and it's enjoyed by all kinds of livestock (Mabu et al., 2019). Crude protein 4-13 percent, crude fiber 30-40 percent, ether extract 0.8-1.5 percent, nitrogen-free extract 4-46 percent, and digestibility 40-60 percent of dry matter are typical organic components. As a result, the crop is extremely appealing to animals. Dissertation (Brima, 2007).

Abiotic Stress Tolerance

In the tropics and subtropics of east and southern Africa, Australia, and Central America, Rhodes grass (*Chloris gayana* L. Kunth) has long been a popular perennial grass. Eastern and southern Africa are the origins of the crop. It's known for its capacity to cover ground, drought endurance, light frost resistance, soil salinity tolerance, and compatibility for growing with a variety of tropical legumes (Elnazier, 2010). It grows in a wide range of ecologies and soil types, has a deep root system, and can endure long periods of drought. Several cultivars have been generated and commercialized with better performance, particularly in drought and low temperature prone locations. Frost tolerance has also been reported in a few cultivars (Cook et al., 2020). It isn't tolerant to standing water. On very acidic soils, Rhodes grass has some difficulties establishing (Abebe et al., 2015).

Information on available variety and drought tolerance among *Chloris gayana* accessions could be used to choose genotypes that could help ease the feed scarcity that limits cattle productivity in dry tropical environments (Ponsens et al., 2010). Drought, salt, low temperatures, pests, and diseases have all been observed to be more resistant/tolerant in diploid cultivars than in tetraploid cultivars. Tetraploids, for example, are more vulnerable to root-knot nematode than diploids (York, 1990). Rhodes grass (*Chloris gayana* Kunth) is one of the most widely cultivated subtropical grasses in the semiarid region, with the tetraploid cultivar Epica INTA-Peman being one of the most popular. This cultivar is derived from Boma and has a photoperiodic response to short days, thus flowering comes at the end of summer, allowing you to extend your grazing season while still keeping a high nutritional value. Furthermore, it has a better primary output than diploid cultivars (Perez et al., 2009).

Under salinity conditions, some salt-tolerant Poaceae plants deposit salts to the leaf surfaces, and the bicellular glands on their leaf surfaces have been hypothesized to excrete salt (Oi et al., 2013). Under salinity, Oi et al. (2012) investigated the morphology, location, and ultrastructure of the salt glands of Rhodes grass (*Chloris gayana* Kunth), Poaceae. On the adaxial surface, salt glands were found above the tiny veins and between the veins on the abaxial surface. The salt glands were scattered along the same lines as the macrohairs. With increasing NaCl treatment concentrations, salt gland density increased, implying acclimation to improve salt excretion under high salinity. The basal cell and the cap cell were the two cells that made up a salt gland. At the apical portion of the basal cell, distinct membranes ran longitudinally from the plasma membrane and existed as bended sheets.

The sheets were inflated in the basal cell's bottom area, but they were not attached to the plasma membrane there. The presence of many mitochondria in gland cells indicates that salt transport is an energy-intensive operation. According to a study conducted by Al Khalasi et al. (2010), sorghum fodder cultivated under high saline levels can be fed to Omani sheep without causing harm to their health or performance.

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CHAPTER 11

Smooth Bromegrass (*Bromus inermis* Leyss.)

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INTRODUCTION

Bromus (L.) is one of the most important genus of forage grasses including more than 100 C3 grass species. The genus is widely distributed in Asia, Europe, Africa, and the America (Williams *et al*., 2011). A few perennial species of *Bromus* are widely cultivated for their attributed agricultural characteristics as forage species while few others are very effective in soil conservation.

Smooth bromegrass (*Bromus inermis* Leyss.) is the most widely cultivated species of genus *Bromus* (Tuna *et al*., 2001). It is a long-lived perennial and rhizomes forming cool-season grass. Smooth bromegrass is widely used for pasture and hay in semiarid regions which are important species of the Genus (Han et al., 2016). It is generally considered to be a species for hay production because of its uniform leaf arrangement, upright tillering and high dry matter yield. The forage quality of smooth bromegrass is higher than that of most other cool-season grasses such as orchardgrass (*Dactylis glomerata* L.) or tall fescue (*Festuca arundinacea*) (Türk et al., 2015). It is a cool-season grass that grows best during months with cooler weather, and becomes semidormant during the hot and dry summer months. Smooth bromegrass also provides excellent permanent cover for sites such as waterways, eroded areas, rocky areas, and farm lanes (Ray et al., 1992). Its rhizomes and tough root network also make it worthwhile for ground cover and erosion control (Türk et al., 2015). Smooth bromegrass remains the most dominant cool-season grass in pastures due to high palatability for all livestock classes, excellent competitiveness, and high forage and livestock production (Schick, 2016). But, it is poorly adapted to management-intensive rotational grazing because of slow and limited regrowth potential.

The smooth bromegrass is indigenous to Central Asia, Afghanistan, Turkiye and Iran. The cultivated species is distributed to the World from Hungary and Russia. It grows naturally in cool season pastures from France to Eastern Siberia and China. It is common in Turkiye, especially in Eastern Anatolia region (Serin and Gökkuş, 1993). Turkiye is located in the gene centers of many plant species, and also fairly richness in diversity of smooth bromegrass (Unal and Mutlu, 2015).

Systematics and Morphology

The genus *Bromus* is nested in the tribe Bromeae, subfamily Pooideae, and the family Poaceae. Bromeae contains only a single genus but *Bromus* is further broken into six sections. *B. inermis* is a member of the section Bromopsis (Preister, 2018).

The base chromosome number of *Bromus* species is n= 7. Chromosome numbers for smooth bromegrass are 2*n* = 28, 42, and 56. The commonly grown form of smooth bromegrass is an autoallooctaploid with a chromosome number of 2n= 8x= 56, while the tetraploid (2n = 4x = 28) is an allotetraploid (Tuna et al., 2001). Nizam et al. (2020) reported that according to the results of the flow cytometric analysis, the mean 2C nuclear DNA content varied between 11.43 pg with 22.77 pg on tetraploid and octaploid smooth bromegrass accessions (Figure 1 and 2).

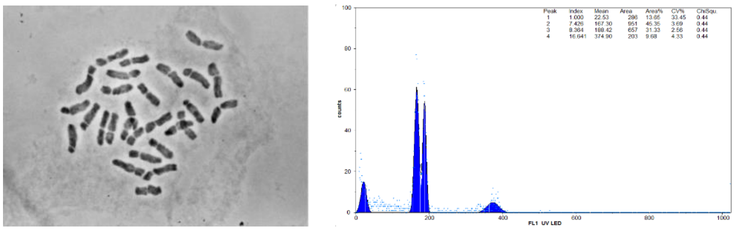

Figure 1. Tetraploid *Bromus inermis* L. somatic chromosomes (2n=4x=28) and flow cytometry histograms

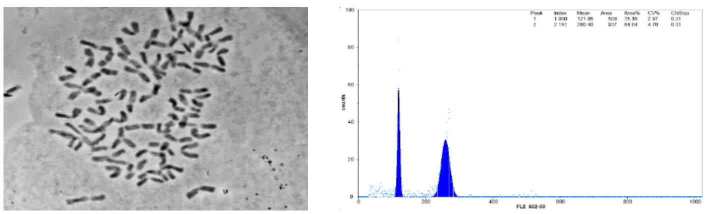

Figure 2. Octaploid *Bromus inermis* L. somatic chromosomes (2n=8x=56) and flow cytometry histograms

Smooth bromegrass has strong rhizomes and forms grass cover. It is deep rooted and fills the soil with numerous roots and rhizomes (Figure 3). The rhizomes emerging from the root crown can grown up to 1.5 m. Its roots extend to a depth of 1.5 m. However, the roots are dense in the top 10-15 cm soil layer of the soil (Açıkgöz, 2021).

Figure 3. Smooth bromegrass rhizomes and roots (https://weedid.missouri.edu/weedinfo.cfm?weed_id=430)

Stem is a culm, erect to nodding above, round, hollow, glabrous, 2–5 mm wide at the brown base. The stem can grow up to 50-100 cm (Reaume, 2011; Altın, 1991).

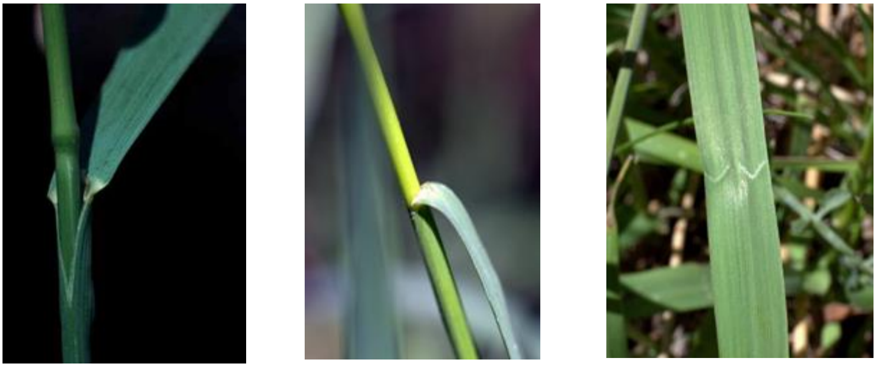

Figure 4. Leaves of smooth bromegrass (https://mpgnorth.com/field-guide/poaceae/smooth-brome)

The leaves are round in shoot. Leaf blade is narrow, 5–38 cm long by 3–16 mm wide, scabrous along the edges and below, glabrous above.

There is a W-shape mark on the middle part of the blade (Figure 4). Sheaths are glabrous and round. Ligules are 1–3 mm long, membranous, and lacerate. Auricles are absent or rarely shrunken (Bakır, 1959; Serin and Tan, 2009; Reaume, 2011).

Inflorescence is a loosely contracted panicle that only moderately open (Figure 5). Panicles 6.5–22 cm long, 3.5–14 cm wide, open; branches erect to ascending, often nodding at maturity, scabrous, usually longer than spikelet, 1–5 spikelets; lowest inflorescence node with 3–7 branches. Spikelet stems are attached in panicle to nodes on the axis of the panicle. Spikelets 1.7–3.2 cm long (including awns); florets 7–10 (Saarela, 2008). Spikelets are cylindrical in the pre-flowering stage. Anthers are linear, orange-yellow in color. Plant is mostly foreign polinated by the wind. The thousand seed weight is 3.18 (Elçi and Açıkgöz, 1976; Serin and Gökkuş, 1993).

Figure 5. Panicle of smooth bromegrass (POWO, 2022)

Smooth bromegrass has two ecological-geographical groups: the meadow group (northern climatype) and steppe group (southern climatype). The Southern types, which grows in drier conditions, is deep rooted and taller. Its leaves are short, narrow and erect. Northern types, which grows mostly in humid places, has less competitive power and spreading (Vogel et al., 1996). General characteristics of northern and southern types of smooth bromegrass are given in Table 1 (Wasser and Dittberner, 1986).

Table 1. General characteristics of northern and southern types of smooth bromegrass

Northern types	**Southern types**
Symmetrical open panicle	One-sided, drooping panicle
Weakly rhizomatous	Strongly rhizomatous
Better seed producer	Poorer seed producer
Slower sod binding	Rapid sod binding
More recovery after cutting	Less recovery after cutting
Less drought resistance	More drought resistance
Less seedling vigor	More seedling vigor
Later spring grower	Earlier spring and later fall grower

Adaptation

Smooth bromegrass is widely adapted because of the ecotypic variation that exists in the species in its native range (Vogel et al., 1996). It is highly resistant to drought and heat. In arid conditions, it is more productive than orchardgrass and timothy (*Phleum pretense* L.), although not as much as *Agropyron* sp. It grows well in area with an annual precipitation of more than 400 mm. Smooth bromegrass is dormant during the dry and hot summer months. It goes to rest during the extremely long drought period and starts to develop again after the drought period. It starts to grow again with return of autumn rains and cool and short day conditions. Optimum growth temperatures are between 18-25 °C, growth slows down at temperatures above 35 °C. Cold resistance is good (Açıkgöz, 2021). Smooth bromegrass can survive extreme winter temperatures down to -28°C, allowing it to survive above 40°N latitude (Schick, 2016). Although it is generally adapted to cool seasons, there are also types that can adapt to hot climates. The southern types, which spread to the world from the Volga coasts, North Caucasus, Eastern Ukraine and Southern Altai regions, are more resistant to heat and drought. The southern type is more resistant to drought and heat (Serin and Tan, 2009).

Smooth bromegrass, which can adapt to different soil types, can grow in all soil types from sandy-loamy soils to heavy-clay soils. However, it grows best in clay-loamy, well-drained, deep and fertile soils (Serin and Tan, 2009). It grows very well in very fertile and heavy soils. However, due to the excessive development of rhizomes in these soils, the yield of smooth bromegrass decreases within a few years (Açıkgöz, 2021). This situation occurs under conditions of high light, heavy rainfall, low soil fertility and especially insufficient nitrogen. It is based on alkalinity. The most suitable soil pH is 6.0-7.0, although it is adapted to slightly alkaline or acid soils. It is moderately resistant to salty soils (Serin and Tan, 2009).

Figure 6. Smooth bromegrass affected by low temperature

Agronomy and Yield

Planting

Fall and early spring planting of smooth bromegrass is preferred. In cold climatic regions, spring planting should be prefered in mixtures of smooth bromegrass with legumes. Autumn planting can be done in temperate climatic regions (Tekeli, 1988). In regions where both autumn and spring planting can be done, autumn planting is preferred due to the lack of weed competition and resistance to summer heat and drought (Açıkgöz, 2021). Since the smooth bromegrass planted in autumn provides the need for cooling, the product can be obtained in same year.

Smooth bromegrass planting should be done in deep, moist, fertile and well-pressed seed bed. A moist and pressed seedbed is esential for emergence. Since it seeds are light, sowing should be done with a seed drill to adjust the sowing depth. Seeds can also be broadcast in places that are not suitable for machine planting. Seed should not be planted deeper than 1-2 cm. Planting depth may be deeper in coarse soils, shallow in fine textured soils. Smooth bromegrass can be planted alone or as a mixture with alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.). It is grown in mixtures with sainfoin (*Onobrychis sativa* L.) where rainfall is more limited. In moist pasture, white clover (*Trifolium repens* L.), birdsfoot trefoil (*Lotus corniculatus* L.) or alsike clover (*Trifolium hybridum* L.) are suitable for mixture with smooth bromegrass. Seeding rate varies with seedbed condition, method of seeding, and quality of seed. For suitable plant density in alone planting, 1.5-2.0 kg da^{-1} of seed is sufficient for machine planting, and 3.0 – 4.0 kg da^{-1} is sufficient for broadcast. In the mixtures of smooth bromegrass with alfalfa, 0.75 – 1.25 kg da^{-1} alafalfa and 1.0 kg da^{-1} smooth bromegrass seeds are used. The spacing between rows in planting varies according to environmental conditions. It is desirable that the row spacing is 30 - 60 cm in forage production under irrigated conditions, and 50-100 cm in arid conditions (Tekeli, 1988; Okkaoğlu *et al*., 2007; Serin and Tan, 2009). Although the seedling develops poorly after germination, the plants develop rapidly in the following period.

Fertilizer

Before planting, soil analyzes should be made and the amounts of plant nutrients in the soil should be determined. Smooth bromegrass responds well to nitrogen fertilizers. In arid conditions, 5.0-10.0 kg da^{-1} of N fertilizer is sufficient. The use of phosphorus and potassium together with nitrogen increases the utilization of nitrogen fertilizer. Excess nitrogen application causes lodging. In rainy and nitrogen-poor soils, the amount can be up to 50.0 kg da^{-1} of N (Açıkgöz, 2021).

Weed Control

Smooth bromegrass planted in the spring can be damaged by weeds. The most important maintenance process after emergence is weed control. Fort his reason, herbicides should be applied in the first year in fields where weeds are high. If there are annual grass weeds, cutting should be done in the spring without allowing the seed maturation of the weeds. Tan and Coruh (2021) reported that mixed sowing with companion crop decreased the rate of weeds in the first year from 76.7 % to 7.8 %.

Irrigation

Smooth brommegrass is a drought-resistant plant that can grow in arid conditions. However, the yield increases in soils containing sufficient moisture. The effectiveness of fertilizer increases with irrigation. When irrigation is made after cutting, the plant can well develop again.

Yield

Smooth bromegrass is an important plant for forage production in both arid and irrigated conditions. However, the disadvantages are that it develops slowly after the cutting and forage yield is higher in spring, while the late spring and summer yield is low. For this reason, plants that develop after the first cutting are evaluated by grazing (Açıkgöz, 2021). While one cutting is made in arid regions, two or three cuttings can be made in rainy regions. In general, the first cutting has a higher forage yield. Harvest time for forage production is between panicle emerge and the flowering. While the amount of cellulose increases rapidly towards maturation in stems, the protein content decreases rapidly after flowering. In parallel with the increase in cellulose in the stems, hay yield increases until the beginning of flowering. The hay yield varies depending on region, the climate, especially the annual rainfall and soil fertility.

In areas sown with narrow row spacing, a decrease in yield can be seen as a result of cover by rhizomes a few years after planting. This situation can be reduced by planting with wide row spacing in arid conditions. Killing plants mechanically and fertilizing are other methods that can be used to solve the problem. If smooth brommegrass fields are plowed with cultivator at intervals of 30-40 cm in the 3rd and 4th years, alive of the plants will be extended.

Figure 7. Smooth bromegrass for hay production

In a study conducted Tekirdag conditions, total fresh yield of smooth bromegrass clones were between 839.67 – 4182.00 kg/da and 1673.67 – 6922.67 kg/da for 1st and 2nd years, respectively. Total hay yield was between 216.67 – 1546.33 kg/da and 540.00 – 2279.33 kg/da for 1st and 2nd years, respectively (Nizam and Tuna, 2020). Karadag et al. (2017) found that fresh yields of smooth bromegrass genotypes ranged between 2702.2 - 3129.0 kg da-1 in Tokat condition, and 3156.7 - 3634.8 kg/da in Sivas conditions. In the research, hay yields ranged between 1134.1 – 1233.0 and 1095.1 – 1210.4 kg/da in Tokat and Sivas conditions, respectively.

Use for grazing

Smooth bromegrass is resistant to grazing as it spreads by strong rhizomes (Figure). Therefore, it is a good grassland plant. It is grazed by animals especially in the early stages, because it is delicious. Smooth bromegrass is resistant to grazing, but sensitive to frequent and heavy grazing (Gençkan, 1983). Plant spreads by strong, creeping rhizomes and seed dispersion. Smooth brome provides excellent pasture with a high carrying capacity and excellent hay when properly managed and harvested. Forage yields can be exceptional— 3-4 tons per acre or more—with good management when rainfall is adequate (Ray et al., 1992).

Türk et al. (2015) reported that CP, TDN and RFV values of smooth bromegrass decreased throughout the grazing season, while ADF and NDF contents increased in grazing and non-grazing areas. The ADF and NDF contents of smooth bromegrass in non-grazed areas were higher than the grazed areas, while CP, TDN and RFV values of grazed areas were higher than non-grazed areas. It can be concluded that the harvesting at the late stages caused a reduction in forage quality of smooth bromegrass in grazing and nongrazing areas.

Figure 8. Smooth bromegrass under simulated grazing

In plantings for pasture, smooth bromegrass is grown in a mixture with legumes such as alfalfa, sainfoin and red clover, depending on the climatic and soil conditions.

Quality

The quality values of smooth bromegrass hay vary widely. In general, the protein content of hay varies between 8-12 %, ADF 30 - 45 %, and NDF 50-70 % (Açıkgöz, 2021). Unal and Mutlu (2015) reported crude protein ratio as 17.82 – 21.93 %, ADF ratio as 34.41 – 37.69 %, and NDF ratio as 61.79 – 66.43 %. As grasses mature, forage quality drops rapidly. Crude protein content declines rapidly between boot and mature seed stages. Crude protein levels in hay harvest at early heading range from 10-18 %, but drop rapid after heading. Unlike protein and digestibility, fiber concentrations of smooth bromegrass increase with advancing maturity (Lamond et al., 1992).

Seed Production

Seed production of smooth bromegrass is difficult and yield is low. For seed production, it should be sown alone. Row spacing should be 50-75 cm in arid conditions (Gençkan, 1983). In wet conditions, 30 cm row spacing is sufficient (Serin, 1996). Fertilization positively affects seed yield. Phosphorus fertilizer should be applied as 6-10 kg/da P_2O_5 at planting time. Nitrogen fertilizers are applied in autumn and spring. Nitrogen fertilizer amount between 5 - 9 kg/da is sufficient depending on irrigation conditions in seed production (Tekeli, 1988).

Inflorescences of smooth bromegrass mature from top to bottom. It can be harvested at the full maturity period, as there is no danger of spilling too much seed. Harvesting can be done with a combine harvester after the seeds have matured. It is necessary to harvest from 2.5 cm of stubble height. Seed yield is related to tillering amount, available N amount, temperature, photoperiod and inflorescences formation (Serin and Tan, 2009). In arid conditions, seed yield varies according to the amount and distribution of annual precipitation. There are also differences in seed yield between cultivars. Seed yield is higher in northern smooth bromegrass varieties. In arid regions, the seed yield is 5-30 kg/da (Açıkgöz, 2021). In regions where precipitation is favorable, the seed yield is 30-60 kg/da (Tekeli, 1988).

Burning the stubble or removing the leaves and stems in the fields where seeds are produced increases the yield by 20-30%. Burning can be done in autumn or early spring (Açıkgöz, 2021). Since the rhizomes of the smooth bromegrass cover the interrow, the interrows should be processed with cultivator every few years. After the seed harvested, the stubble and regrowth can be used for hay or grazing, but the quality will be much lower than for early harvested hay (Lamond et al., 1992).

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CHAPTER 12

Sheep Fescue (*Festuca ovina* L.)

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INTRODUCTION

Sheep fescue (*Festuca ovina*) is a competitive erosion-controlling subspecies encountered in pastures and pasture facilities and is rarely favored by cattle or horses, although grazed by sheep. Sheep fescue is a herbaceous plant which is not suitable for grass production due to its short structure and low growth form. Although it provides minimal protection in wildlife, it is ideal for stabilizing degraded soils on account of its dense root system and ensures excellent weed control where grown. Its strong and dense root system makes it one of the indispensable plants in the improvement of arid areas. Sheep fescue is widely used to protect recreational areas such as roadsides, airport landing strips, residential and industrial areas, camping areas, and ski trails from erosion.

Taxonomy

The systematic place of sheep fescue which is a member of the *Festuceae* tribe of the wheat family is as follows:

Family: *Graminea*

Subfamily: *Festucoidea*

Tribe: *Festuceae*

Genus: *Festuca*

Strain: *Festuca ovina*

Sheep fescue (*Festuca ovina*) has many subspecies with different characteristics. *Fetsuca ovina ssp. duriuscula* (L.) Koch. (*Festuca. duriuscula* L.), *Festucaovina ssp. vulgaris* Koch., *Festucaovina ssp. capillata* (Lam.) Hackel:=*Festuca tenuifolia* Sibths), *Festuca ovina ssp. glauca* (Lam.). Hackel is the main strain among these substrains (Avcioglu *et al*. 2009).

Description

Festuca ovina is a perennial plant with an erect stem that can grow up to 10-60 cm, usually has 2 nodes and a large amount of thin leaves forming clusters. Numerous narrow and inwardly curved leaves are stiff, short and semi-erect. It is a short plant that produces many clusters. Its panicles are narrow and short, almost spike-like. The panicles are 4 cm long and each spikelet has 4-5 flowers. The flower community forms dense clusters and is gray in color. The general appearance of the plant is bluish or gray-green in color. The seeds of the plant are very small in structure and their 1000-grain weight weighs around 0.7 g (Genckan 1983; USDA 2022).

Figure 1. Sheep fescue plant

Adaptation

Sheep fescue (*Festuca ovina*) is a perennial cool season herb extensively grown in the northern hemisphere. It is found in temperate regions in Europe, in the mountains of North Africa, Siberia, the Himalayas, North and South America, and Australia. The plant grows in the Channel Islands and Ireland and all over Great Britain at all altitudes, up to the north in the Shetland Islands. Alpine meadows are found at altitudes of 400-2800 m in steppe areas (Davis 1965).

It is one of the dominant species found in the sheep pastures of our country, especially in Central Anatolia and Eastern Anatolia Regions. The plant, which is very common especially in barren pastures, is cold tolerant and also resistant to salinity stress (Elci 2005; Dumlu 2010; Ogle *et al*. 2010; Zhang *et al*. 2013).

Festuca ovina, which is very resistant to cold and drought and can demonstrate moderate resistance to shade, has thin leaves, so it is more suitable to be grown in stony and sandy areas with low grass yields and therefore arid, barren slopes. The plant can be grown in a wide variety of soil conditions. It adapts best to silty loamy or sandy loam soils, but it can also be found in fertile sandy soils and shallow, dry, gravelly soils. It is resistant to autumn fires, but takes 2-3 years to regenerate after burning. Sheep fescue, which is resistant to grazing pressure, continues to exist in pastures where intense grazing is done. It has adapted extensively to open and unprotected areas, mountain slopes, slopes, hills, ridges, meadows and forest areas (USDA 2022).

Cultivation and Management

Sheep fescue (*Festuca ovina*) is used as ornamental grass in urban landscaping and as grass in sports fields in addition to being grown in pastures. It is widely used as mixtures in playgrounds used in winter, greening airports and roadsides, in barren areas where irrigation is insufficient, and in marginal areas that are not suitable for growing other plants, as it is resistant to cold and mowing.

Since the seeds of sheep fescue (*Festuca ovina*) are very small, the most suitable planting method is with a seeder and their maximum planting depth is 1 cm. 1.5-2 kg da^{-1} seed is sufficient for grass production while 1-1.5 da^{-1} per decare of seeds are sufficient for seed production (Tosun 1974; Avcioglu *et al*. 2009). Sheep fescue can be productive for 4-5 years in the field where it is planted. While 300 kg da^{-1} production is realized in arid conditions, 700 kg da^{-1} production can be obtained in wet conditions (Smith *et al*. 1998).

Sheep fescue ecotypes were studied in the breeding studies of grassy forage crops carried out in the Eastern Anatolia Agricultural Research Institute and the plant height of the ecotypes was 55-122 cm, the number of nodes was 2-4, node spacing was 2-39 cm, leaf length was 3-18 cm, leaf width was 1-7 mm in width while cluster length was 7-27 cm, fresh forage yield was 70-216 g $plant^{-1}$, and dry forage yield was 24-75 g $plant^{-1}$ (Tavlas *et al*. 2016).The grass quality of the sheep fescue (*Festuca ovina*) genotypes in a study carried out in Konya province was 6.76 while seasonal color change was 5.33, leaf texture was 2.22, density was 5.49, plant height was 25.12 cm, leaf width was 0.15 cm, leaf length was 6.29 cm, the growth pattern in autumn was 4.78, plant diameter was 12.41 cm, growth time in spring was 4.58, spiking tendency was 3.63, spike length was 5.79 cm, final node length was 18.47 cm and seed yield was measured as 0.57 g (Erkan 2019).

In a study conducted in Giresun focussing on investigating lead (Pb) pollution caused by traffic, Kinalioglu et al. (2009) reported the importance of planting lead-resistant and lead-retaining plants such as *Festuca ovina*, *Agrostis tenois* and *Deschamsia flexuosa* on the roadsides.

In a study in which the nutrient compositions of some grassy forage crops collected from the pasture areas of Erzurum province were determined, the lowest Crude protein (11.01%), NDF (33.41%), ADF (23.29%) value, as well as the highest ADL (7 ,54%) content were detected in *Festuca ovina* (Gursoy and Macit 2014).

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CHAPTER 13

Sorghum Cultivation (*Sorghum vulgare*= *Sorghum bicolor* L.)

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INTRODUCTION

The sorghum plant, which is from the Poacea family, is included in the Andropogonae order. Its wild and cultured species are classified under bicolor (L) Moench (formerly vulgare) (Chopra, 1982). However, sorghum was previously classified in different ways. For example, Harlen and De Wet (1972) classified sorghum as *Sorghum bicolor* var. bicolor in terms of plant cultivation and divided it into five races as durra, kaffir, guinea, bicolour and caudatum. All of these main breeds are of African origin and are widely cultivated in these regions for different purposes. On the other hand, there are three species in the species classification of sorghum: (1) *Sorghum halepense* (L.) Persian. (2n=40) is a rhizome-forming perennial species found in regions covering Southern Asia and Europe. (2) *Sorghum propinquum* (Kunth) hitch (2n=20) forms rhizome, showing a wide distribution covering South India, Srilanka and Southeast Asian Islands. (3) *Sorghum bicolor* (L) Moench (2n=20) are all annual and form a widely cultivated sorghum species (House, 1985). Subspecies bicolor, and subspecies drummondii (steud), a wild African complex, are examples of cultivated sorghum species. Tropical origin sorghum species make up 90% of the sorghum cultivated in the world (Tiryaki 1998). Sorghum, which has historically been cultivated in hot regions; It has also been able to adapt to cool regions with high altitudes, including the hot regions of Ethiopia, East Africa, and China (Tiryaki, 1998). Although sorghum is presumably of African origin, some evidence suggests that it originated in both Africa and India independently (Bennett, 1990).

Wild sorghum species found in the Eastern Region of Central Africa and India are not suitable for cultivation, as they have some undesirable characteristics (for example, small, colored grain and low yield). However, studies on transferring some new and agronomically important genes from wild related species found in these regions to genetic lines currently being cultivated are still ongoing (Bennett, 1990).

Figure 1. General view of sorghum plant

Figure 2. A view from the grain sorghum field

Sorghums show great differences in terms of plant height, the structure of clusters and seed characteristics as well as their intended use. Therefore, it is difficult to classify sorghums. Many classifications have been made according to morphological characteristics, and at the end, the cultivated sorghums have been divided into five main races and many groups, as bicolar, kafir, caudatum, durra and guinea, according to their cluster and flower structure. These breeds have the ability to interbreed and give fertile offspring. Traditionally, sorghums are grouped under four main groups according to their cultivation purposes (Harlen and De Wet, 1972).

Grain Sorghums

In previous years *Sorghum vulgare* Pers. grain sorghum evaluated under the type is grown mainly for seed production, and some varieties for grass production or silo feed production. They are generally short, form-fitting, thick stems and tasteless varieties. Grain sorghum with very large seeds is used in many countries as human food. Grain sorghum is cultivated in Africa, India, some parts of China, and Central and South American countries. In these regions, sorghum is among the most important human food. Grain sorghum produced in the USA is used in animal nutrition. In addition, the excessive amount of stalk produced in grain sorghum production is used as fuel or animal feed (Açıkgöz, 2021).

Sugar Sorghums

Sugar sorghums have a sweet sap in their stems. Sugar sorghums formerly classified as *Sorghum vulgare* var. Saccharum (Moench.) Boerl. dry or green grass are also suitable plants for silage feed production. It is very tasty for animals, especially in the green state. In addition, sugar and syrup are obtained from the juice obtained by squeezing the stems. Its grains are bitter and tasteless. In recent years, bioethanol (=bioethanol) and its wastes have been emphasized for the production of solid fuel (Açıkgöz, 2021).

Forage sorghums

Forage sorghums tall, abundant tillering and many leafy sorghum varieties are grown for fodder production. Sudan grass, which was classified as *Sorghum Sudanese* (Piper) Stapf. in previous years, is a specific example of this group. Typical forage sorghums have high grass yield and low seed yield. The sugar content that can be fermented in the stems is quite high. Sorghum, called sorghum x Sudan hybrid, made with grain sorghums of Sudan grass, is grown for grass production (Açıkgöz, 2021).

Broom sorghums

Broom sorghums formerly named *Sorghum Vulgare* var. Technicum (Koern.) Jav. have been grown for centuries for the production of brooms from their clusters. Broom sorghum, which has lost its importance in recent years, is produced in limited quantities both in Turkey and in many countries (Açıkgöz, 2021).

Sorghums have very different morphological features. It is very difficult and time-consuming to explain all these features in detail according to their breeding purposes and breeds. Sorghum, an annual plant, has a strong root system. Brace roots may also emerge from the above-ground nodes of some plants. The roots of the sorghum plant, which has a root system that goes down to an average of 1.5 m, can grow to a depth of 2.5 m in sandy soils. The roots are distributed in the form of fibrous roots and spread over an area of 30-60 cm in diameter. The reason for the superior durability of sorghum cultivars in arid conditions is that their roots spread over a deep and wide area. In sorghums whose aboveground parts resemble maize, stem thickness can sometimes reach up to 4-5 cm. Tillering takes place from the buds in the lower part of the stem. Especially in sparse planting, excessive tillering is undesirable in terms of grain production, but it is a desirable feature in sorghum grown for grass production and grazing. While the plant height is shortened up to 100 cm in varieties improvement for grain production, it can reach up to 4-6 m in some hybrid varieties breeding for grass production (Açıkgöz, 2021).

Figure 3. General view of the sorghum plant. A: Sudanese grass types, B: Grain sorghum

Sorghum leaves are similar to maize leaves. However, it is narrower and has toothed edges. The fact that the surface of the leaf blade is covered with wax and the suitability of the pores in the leaf makes the plant much more resistant to hot and dry periods. The inflorescence of the plant is a panicle. The glumes of sorghum flowers can be awned or awnless. There is a great variation among the varieties in terms of the shape of the cluster and the position on the stem. The shape of the cluster, which varies from sparse to dense and compact clusters, and the vertical, horizontal or ground-turning shapes of the clusters on the stem are especially important characters in the classification of grain sorghum varieties (Açıkgöz, 2021).

Figure 4. Cluster types of different sorghum types

The colors of sorghum seeds can be white, red, yellow or brown. The seed, which is large in grain types, is smaller in grass types. The 1000-grain weight of the seeds varies between 5-15 g in feed types and 20-30 g in grain types according to varieties.

Figure 5. Different sorghum seed types (Alfieri M. et al 2017)

SORGHUM PRODUCTION IN THE WORLD AND TURKEY

Sorghum is grown extensively in the United States (USA), parts of Africa, Central and South America, and parts of Asia (especially India and China). The production amount of sorghum, which is cultivated on an area of approximately 40 million hectares in the world, is 58 million tons. In terms of production, the USA ranks first with a share of 16.2%, followed by Nigeria, Ethiopia, India and Mexico, respectively (Table 1). In terms of yield, Oman takes the first place, followed by Israel, Jordan, Uzbekistan, Australia, Italy and Turkey, respectively (Table 4). Although the yield in these countries is above the world sorghum average, the average yield is quite low in countries such as Nigeria, Ethiopia and India, which are important sorghum producers.

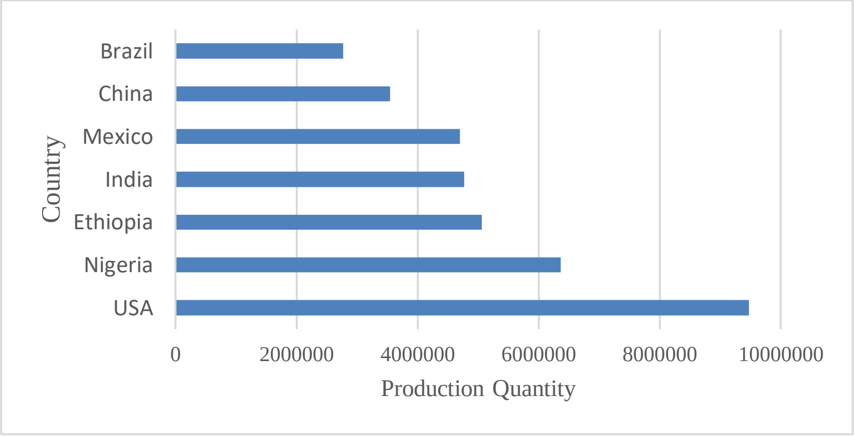

Table 1. Important sorghum producing countries in the world

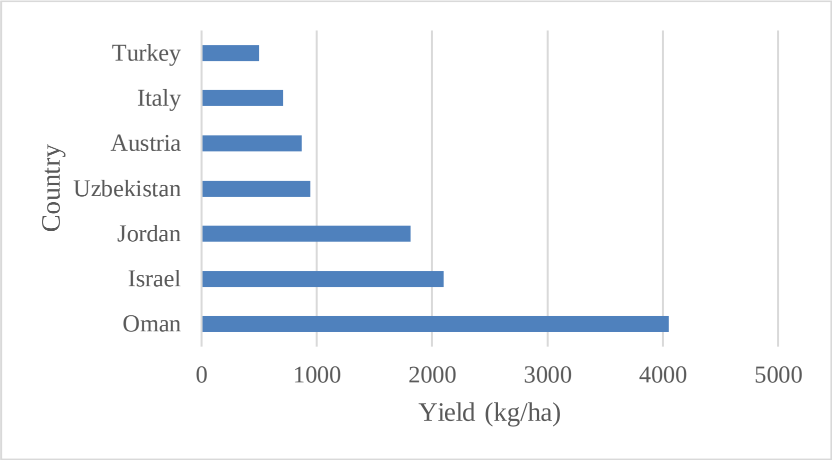

Table 2. Countries with high productivity in the world.

In Turkey, according to FAO data, it is stated that grain sorghum is produced in only 1 ha area. However, in the TÜİK data for 2021 (Anonymous, 2022), it is seen that the production amount and cultivation area of sorghum, especially as a green herb, has increased (Tables 3 and 4).

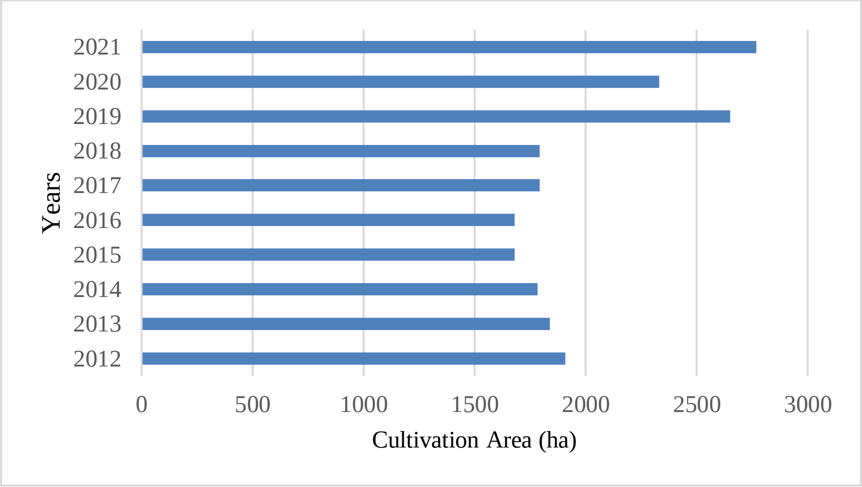

Table 3. Sorghum cultivation area in the last 10 years in Turkey.

When Table 3 is examined, although the cultivation area, which was 1908 ha in 2012, decreased over the years, it increased especially in the last three years and became 2768 ha in 2021. While the production amount was 51.3 tons in 2012, it increased continuously over the years and 113.1 tons of production was realized in 2021 (Table 4). It is seen that the data found in both FAO and TÜİK data covers all sorghum varieties. There is no detailed information. However, this plant, which is used especially for animal nutrition and can be an alternative to maize in arid areas, needs to be investigated further, both as green grass and for silage, and more clear information should be found (Anonymous, 2022).

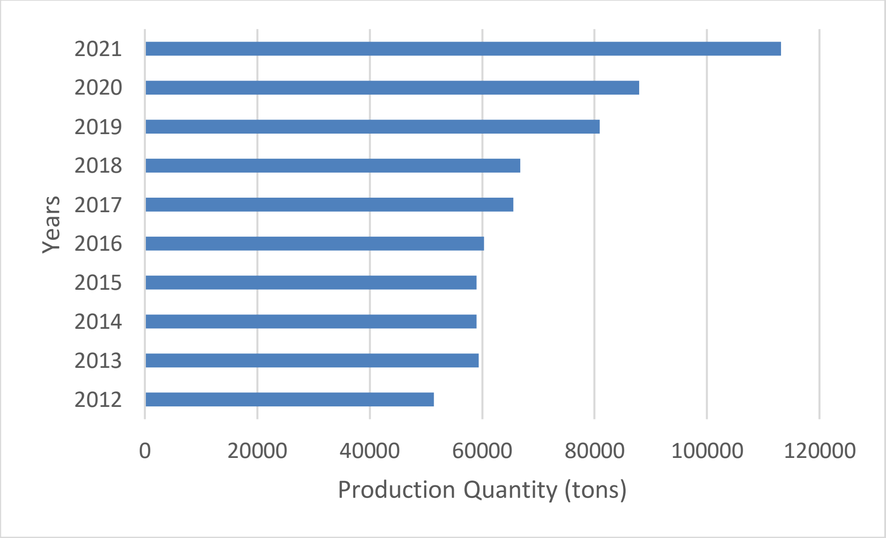

Table 4. Sorghum production quantity in the last 10 years in Turkey.

Use Areas of Sorghum

Bread made from flour obtained by grinding the grain is one of the most common ways of using sorghum in human nutrition (House, 1985). Sorghum grain is widely used as animal feed as well as in human nutrition. Grain sorghum is broken down and fed to animals as a source of cellulose (fiber) (Bennett, 1990). On the other hand, plant stems and leaves are chopped as green or used for feeding animals as straw and silage feed. In some regions, sorghum stalk is used as a building material or energy source (House, 1985).

Figure 6. Sorghum grain and flour

The main structure of sorghum is primarily starch, sugar, protein and oil. On average, the grain contains 10% protein, 3% fat and 70% starch (House, 1985). Grain sorghum also contains many vitamins such as riboflavin, niacin, and pantothenic acid (Bennett, 1990). Although the ratios of these components in the grain are sufficient for animal nutrition, if they are used as a human food source, these ratios are very low and undergo little change with fertilization and other cultural practices (Tiryaki, 2005). Sorghum stands out as an important C4 plant that can be an alternative to maize and used in animal nutrition. Sorghum stalks, which are a good food source for animals, are either silaged or fed directly to animals. Sorghum types;

- wide adaptation ability,
- more resistant to drought and high temperatures,
- resumption after harvest,
- nutrition value is close to maize,
- to be able to give more yield products than maize in the same ecological conditions,
- high water use efficiency,
- producing more digestible nutrients per unit area,
- more resistant to diseases and pests,
- tolerant to waterlogging and salinity,
- low transpiration coefficient (310 lt for 1 kg DM),
- it can be easily grown in regions with annual precipitation varying between 400-750 mm,
- high sugar and biomass production potential
- to be able to grow up to 4.5 m in suitable growing conditions (during a growing period of 4-5 months),
- they are species that can be an alternative to maize with their features such as using less fertilizer than maize and having a biomass yield varying between 4.5-11 t/da (Reddy and Sanjana, 2003; Gnansounou et al., 2005; Tesso et al., 2005; Almodares et al., 2007; Karadağ and Özkurt, 2014; Dweikat, 2020; Kaplan, 2021).

Due to these features, it has the potential to replace maize silage in marginal areas and adverse environmental conditions, especially because it is more resistant to abiotic environmental conditions than maize. Due to these features and potential, it reveals that it is a species that will contribute to closing the roughage deficit by increasing the production of quality roughage (Kaplan, 2021). In addition, sweet sorghum is used in ethanol (Jacques et al., 1999) and animal nutrition (Jafarinia et al. 2005; Kaplan, 2021).

However, in addition to all these positive properties, the cyanite (Prussic acid) found in the green stems of some sorghum species has a toxic effect for animals. The rate of cyanite is highest in the seedling period and this rate decreases gradually with plant growth. For example, at the end of 30 to 40 days of growth after emergence, the rate of cyanide decreases and disappears before the plant shows panicle (Busk and Moller, 2002; Tiryaki, 2005).

Besides, Sweet sorghum plant; It is widely distributed in sugar (Schaffert and Gourley, 1982), fuel and fuel additive to obtain ethanol yield (Lueschen et al., 1993). According to the researches, approximately 700 to 1200 kg of sugar is produced from sweet sorghum in 1 decare area (Grassi, 2000). Thus, the sugar we obtain is fermented, converted into ethyl alcohol and used as energy. While sweet sorghum produces ethanol equivalent to 200 to 300 kg of oil per decare per year, fuel equivalent to 600 to 900 kg of oil can be obtained from the pulp part. Its energy from the pulp part is approximately 15 900 to 18 000 kJ/kg (3 795 to 4 295 kcal/kg) (Avcıoğlu, 2018).

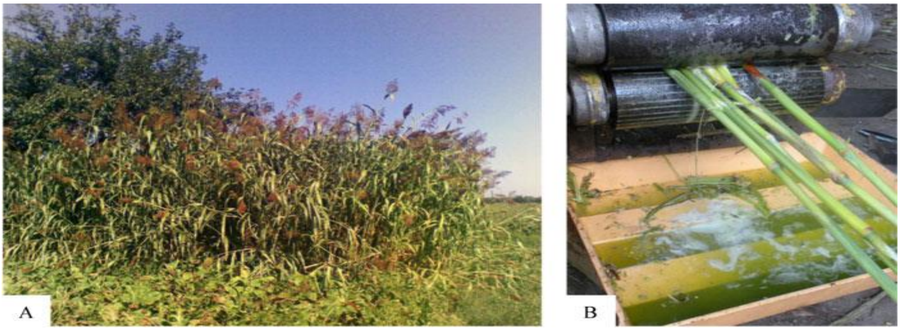

Figure 7. A – grown on the field; B – squeezed on the roller press. (https://benthamopen.com/FULLTEXT/TOASJ-14-235/FIGURE/F1/)

Sweet sorghum with a single stem and a height of 1 to 5 m (Guiying et al., 2003) is described as the camel of the plant kingdom due to its excessive elongation. In addition to being an energy plant, it is also a good source of sugar as a concentrated syrup. The product obtained from the sweet sorghum plant and the usage patterns of these products are given below (Köppen et al, 2009).

Grains: In first-generation bioethanol, nutrition, food

Extracts: In first-generation bioethanol, sugar

Pulps: In bioenergy, compost, second-generation bioethanol, nutrition, manure, pulp

Leaves: fertilizer, bioenergy, second-generation bioethanol, nutrition

The sugar content in sweet sorghum is very high. Most sugar (78.7%) is found in the stem part. It is followed by the clusters (2.99%) and leaves (2.54%). There are over 14 sugar varieties on its stems, this sugar variety is evenly spread overall. Sucrose, glucose, fructose are the most well-known of them (Grassi, 2001). Also from the must obtained from the stalks of sweet sorghum (for ethanol production), from its straw (energy production, plastic production), from grain (for animal feed ethanol production), from its pulp and green leaves; they report that it has a wide range of uses such as an excellent feed, organic fertilizer, cellulosic raw material in industry, food, sugar, and pulp, and its importance is increasing day by day (Almodares and Goli., 2013).

In addition to all these areas of use, sorghum is also successfully used in the reclamation of soils contaminated with cadmium. Mining, metal processing and smelting, industrial emissions, excessive use of chemical products such as fertilizers and pesticides, irrigation with sewage water and heavy metal pollution have become a rapidly increasing serious problem in the world (Vareda, 2019; Shi, 2019).

Cadmium has gained a lot of attention as one of the most toxic heavy metals. One of the viable economic alternatives to a land management strategy for food or feed production is growing suitable metal-tolerant energy crops to remove HM while harvesting valuable energy products for HM-polluted arable land. (Sathya et al. 2016; Pogrzeba et al. 2019; Yang et al. 2017). Moreover, considering that growing energy crops on contaminated soils will positively address the food-fuel issue, the researchers examined the HM tolerance of sweet sorghum and evaluated its HM absorption capacity (Sathya et al. 2016; Marchiol et al. 2007; Zhuang et al. 2009)

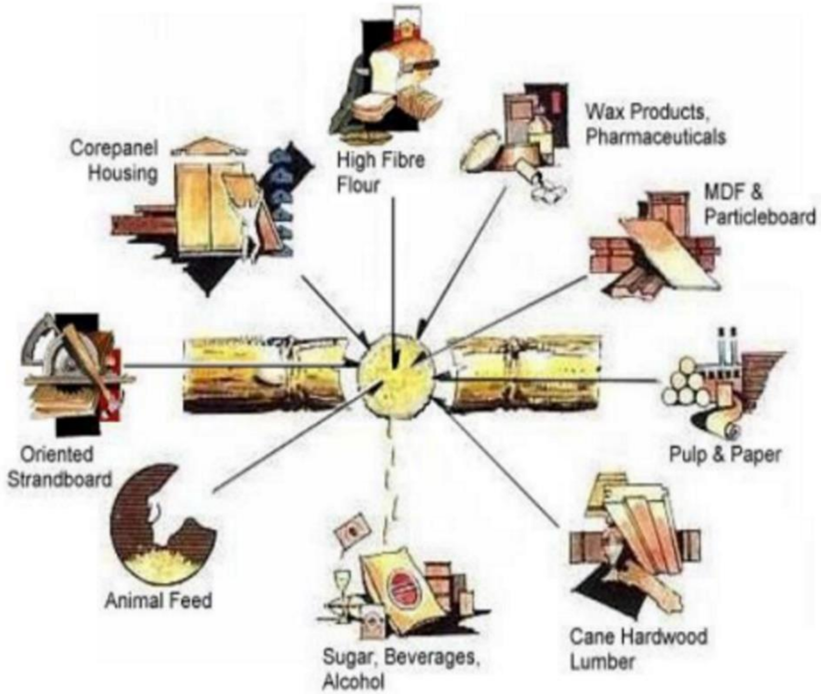

Figure 8. Proposed uses for sorghum stalk by Great Valley Energy, LLC.

Figure 9. Dermal layer (left) and pith (right) of sweet sorghum stalk after processing

Adaptation

The sorghum plant, which can adapt to very different environmental conditions, needs a growth period of 90 to 140 days to mature. The highest yield is obtained from varieties that mature in 100 to 120 days (Dogget, 1988). Soil temperature is one of the most important factors determining the planting date for sorghum, which is a plant of tropical regions. 18-20 ^{o}C soil temperature is the most suitable time for planting (Kırtok, 1987). Sorghum can easily be grown in any type of soil, from the heaviest clay soil to sandy soil, where the pH varies between 5.5 and 8.5. Since sorghum performs better than maize in drought-resistant, arid conditions due to its root structure, it continues to fill areas that maize has left or will leave due to stress in semi-arid conditions (Kaplan, 2021). Sweet sorghum, the pulp remaining after sap removal is used in ethanol (Jacques et al., 1999) and animal nutrition (Jafarinia et al. 2005). It is known that the new sorghum varieties developed for silage in recent years are taller, have a higher biomass yield per unit area, and are close to or equivalent to maize in terms of quality. Sorghum is similar to maize in terms of the photosynthetic pathway (C4), but tissue structure and distribution (stalk, leaf and earing) differ in the two plants. The most suitable ensiling period for sorghum is the middle pulp period of the grains (65-70% of plant moisture), and if it is to be used for cattle, it is harvested a few days later (Undersander et al., 2003).

Sweet sorghum is a short-day plant (Almodares et al., 2000), most of the cultivars require very high temperatures and grow best in these conditions (Reise and Almodares, 2008). The maximum productivity of temperate and tropical species occurs between 25 and 30 °C (temperate) and 30 to 35 °C (tropical) (Cherney et al., 1988). It is accepted that the optimum temperature range of 25-30 °C is needed for the growth of sorghum species (Ketterings et al., 2005).

Hydrocyanic acid (HCN) is a toxic chemical that can cause mild to severe reactions in animals when grazing sorghum. Due to the high HCN content and nitrate content in the sorghum plant, it has the potential to be toxic to animals. The rate of this toxic effect also differs between sorghum genotypes (Luthra et al., 1976). Hydrocyanic acid is less effective when hay or silage is made and 2-3 weeks after silage (Undersander et al., 2003). The nitrate level of 0.51.0% on a dry matter basis in the plant is considered potentially toxic for ruminants. A nitrate level higher than 1% on a DM basis is considered dangerous (Yaremcio, 1991). Sorghum has the potential to release hydrogen cyanide, or hydrocyanic acid (HCN) or prussic acid when consumed by animals as fodder. In recent years, as a result of the development of remarkable low lignin content and highly digestible "BMR" sorghums through breeding programs, the wide gap between forage sorghum and maize in terms of quality has been tried to be closed (Contreras-Govea et al., 2010). Reducing the lignin content increases the overall digestibility of the fibre component in the feed and thus improves the overall quality of the feed. Transferring the BMR trait to some species and cultivars is an important step forward. Because quality is now the main target of sorghum species. The primary goals of improving feed quality are to increase feed intake and digestibility and to reduce anti-nutritional properties (Smith et al., 1997). Sweet sorghum is classified as a high-energy feed because of its high water-soluble carbohydrate (WSC) content (Kaiser et al., 2004). It is reported that this type of sorghum is similar to forage sorghum in terms of DM yield, but it is a good alternative for silage production because it has higher water-soluble carbohydrate (WSC) content (Zhang et al., 2015). Thanks to arid and semi-arid conditions and high elevations, lower requirement for soil fertility, lower production costs, potential for re-mown, high temperature and drought tolerance, Sorghum silage (Sorghum bicolor L. Moench) compares to maize silage as feed for ruminant animals is preferred. Maize and sorghum, high dry matter yield (Fribourg, 1995; Rooney et al., 2007), are tropical plants commonly used for silage due to their low buffer capacity and high WSC (Stuart, 1984; McDonald et al., 1991). They are defined as naturally occurring phenolic compounds that bind to high molecular weights and macromolecules such as tannins, proteins, structural carbohydrates and starches, thereby reducing their ruminal degradation (McSweeney et al., 2001; Silanikove et al., 2001). Tannins are divided into two main groups: hydrolyzable and condensed tannins. The polyphenols found in sorghum are condensed tannins (Jansman, 1993). Reduction in dry matter intake and digestion of protein and fiber is an adverse effect usually associated with tannins (Schofield et al., 2001; Makkar, 2003). However, the presence of moderately concentrated tannins in the rumen is related to the protection of dietary protein from degradation by ruminal microorganisms, increasing the flow of dietary protein to be absorbed in the intestines (Min et al., 2003). More recently, concentrated tannins have also been associated with reductions in ruminal methane emissions (Woodward et al., 2001; Makkar, 2003).

The response of the sorghum plant to fertilizer varies greatly depending on the variety grown and environmental conditions. Although each kg of nitrogen application in sorghum cultivars grown in arid conditions with a low fecundation rate causes an increase in grain production of 6 to 10 kg, this rate varies between 20 and 40 kg in cultivars with high fertilization rate (House, 1985). For example, in the sorghum grain grown as a second crop in Çukurova conditions, the best results were obtained from the application of 18 kg/da nitrogen (Arslangiray et al., 1999). Phosphorus and potassium needs vary between 15-18 kg/da and 13-18 kg/da, respectively, depending on the amount of P and K in the soil (Mitchell and Mask, 1986). Sevimay et al. (2001) in a study carried out in Ankara conditions between 1998 and 1999, different N doses (0-5-10-15 kg/da) in some silage sorghum cultivars (Early, Sumac, Leoti, Rox) grown as the main crop in yield and some characteristics effects have been studied and they determined that the plant height was between 169.3 and 184.9 cm. Acar and Akgün (2009), in the ecological conditions of Konya in 2002-2003, sugar millet (Sorgum bicolor (L.) Moench var. saccharatum) in the study of the effects of four different N levels (7.5-12.0-15.0-18.0 kg/da) on green forage yield and yield components; They found that N doses had significant effects on green grass yield, the number of leaves, stem weight, and dry matter yield. The same researchers determined the green grass yields of 7.20 to 8.08

t/ha, the number of leaves per plant 9.2 to 9.7, the plant stem weights 383 to 478 g, the plant leaf weights 87 to 103 g, the plant weights to 472 to 581 g, and the number of stems per m to 21. They stated that the plant heights varied between 199 and 226 cm, and they suggested a dose of 15 kg/da N for maximum green grass yield. Agung et al. (2013), in their research with different varieties and organic fertilizer doses (0, 10, 20, 30 t/ha) in dry farming conditions in Indonesia, reported that the varieties had a statistically significant effect on the investigated properties of organic fertilizers and interactions were insignificant. The same researchers found that the KCS105 genotype gave the highest biomass yield (2.82 t/da), dry stem weight (907 kg/da), brix value (18.9%), ethanol content (94.1%) and stem sugar yield (260 kg/da) have reported. Girgin (2012), in 2010 Bornova ecological conditions, as a summer second product, in the study carried out to determine the effects of different nitrogen doses (0-7.5-15.0-22.5-30.0-37.5 kg/da N) on some agricultural characteristics related to silage, green grass and grain yields in sweet sorghum; reported that sweet sorghum plants can be grown successfully in local conditions and nitrogen doses have significant effects on green grass and seed yield. The researcher, who stated that he obtained the highest yield of green grass, grain, must and ethanol from 22.5 kg/da N application, in territory conditions, a total biomass yield of more than 6 t/da and a grain yield of more than 200 kg/da can be obtained in two harvests , one for silage and the other for grass, from sweet sorghum plant, that the stalks of sweet sorghum plant, when mechanically squeezed, provide a must yield of close to 2 tons/da, and have a bioethanol production capacity of more than 150 litres, has detremined that silages made from the pulp remaining after removing the sap from both the whole plant and the stems are very good quality silage feed.

Although sorghum is known as a plant of arid regions, it shows significant yield increases in irrigated conditions, as in other cultivated plants. In general terms, the sorghum plant needs 400 mm of water to produce 1 kg of dry matter during the entire growth process (Dogget, 1988). The amount of water that the plant can use in the soil during planting has a great effect on the yield of sorghum grown in arid conditions and causes the grain sorghum yield to be obtained from these areas to be very variable (Unger and Baumhardt, 1999). For example, depending on the amount of water in the soil during planting in arid areas, no product can be obtained, and it is possible to reach high values such as 600 kg/da grain yield (Unger and Baumhardt, 1999). Dündar et al. (2020), in their study to determine the effects of different water levels (full irrigation, 75% full irrigation, 50% full irrigation and 25% full irrigation) on ethanol and biomass yield in Çukurova conditions, have determined the effect of dehydrated straws (pulp) on yield and some silage quality values. M81E sweet sorghum variety was used as the material in the research carried out under Çukurova second crop conditions. As a result of the research, it has been determined that different water levels affect the pulp yield and the yield varies between 6890 and 5050 kg/da, and the yields decrease in parallel with the amount of water. In addition, it was determined that water levels changed the acid detergent lignin (ADL) values of silages made with pulp between 6.89% and 9.36% and had a statistically significant effect, but did not create a statistical difference in terms of other properties. In the same study, it was determined that crude protein (HP) ratio, which is one of the important silage quality features, varied between 2.71-3.95%, acid detergent fibre (ADF) ratio changed between 39.79-43.32% and relative feed value varied between 79.4-84.9%.

Yield

Sorghum, which has a high yield potential, varies greatly in terms of yield depending on the ecological conditions and cultivation techniques in which it is grown. In areas where the average grain yield of sorghum in the world is not a limiting factor, the yield can exceed 5000 kg/ha (Anonymous, 2002). On the other hand, when we look at the countries producing sorghum in general, it is observed that the yield varies between 700 and 5260 kg/ha due to the above-mentioned reason (Anonymous, 2002). In the researches, the researchers have determined that the average yield was determined by Dundar et al. (2020) between 5050-6890 kg/da in Çukurova, Demir (2020) between 7444.5-144433.2 kg/da and biomass yield between 7714.3-16285.7 kg/ha in Şanlıurfa, In the researches, the researchers have determined the average yield was determined by Dundar et al. (2020) between 5050-6890 kg/da in Çukurova, Demir (2020) between 7444.5-144433.2 kg/da and biomass yield between 7714.3-16285.7 kg/ha in Şanlıurfa, Çoban and Acar (2018) found green grass yield between 7038.3-9400.7 kg/da and hay yield between 1794.7-2581.0 kg/da in Konya, Karadağ and Özkurt (2014) The green grass yield between 2128.2-4764.3 kg/ha and the dry matter yield is between 935.0-1924.0 kg/da in Tokat conditions. Both the pulp yield and the green and dry grass yield vary considerably according to the regions. Therefore, it is important to determine the appropriate sorghum genotypes according to the regions.

Soil and Climate Requirements

Sorghum can be grown in almost any type of soil. It gives abundant crops in moderately well-drained, clay loam soils. The most suitable pH is between 6.0-6.5. However, sorghum is also quite resistant to acidity. If the pH goes down to 5.7, it does not affect the yield much. It is moderately resistant to salinity. Although sorghum can be grown in areas where annual precipitation is 400-600 mm, they give very high yields in irrigated areas. It relies on water ponding more than many plants.

For optimum development of sorghum, which is a hot season plant, the average temperature should be 25-30 ^{o}C. The minimum soil temperature for good germination is 15 ^{o}C. It is desirable that the growing season be at least 125 days. Cool and humid regions are not suitable for sorghum cultivation. Low temperature and short growing seasons are important factors hindering sorghum cultivation. Especially when the night temperature drops below 15 ^{o}C, it negatively affects pollination and seed holding. Sorghums yield abundant crops in areas with heavy summer precipitation. However, sorghum is a suitable plant for grain production in barren areas. The emergence of clusters, pollination and seed holding period is quite long. Therefore, short-term droughts do not adversely affect sorghum grain yield. It slows down its growth during periods of limited water, sometimes it stays dormant. It continues to grow with the onset of precipitation. For this reason, seed products can be obtained even in adverse environmental conditions. The waxy structure of the leaves is accepted as the reason for resistance to drought. Sorghums are short-day crops. However, there are differences between the varieties in terms of response to the photoperiod (Fribourg, 1995; Açıkgöz, 2021).

Cultivars

Many cultivars with different morphological and agricultural characteristics have been developed all over the world. Some of them are grain type, some are Sudan grass or sorghum x sudan hybrid grass type sorghum varieties. Although some sorghum varieties are grain types, they are also suitable for grass and silage. Sorghum varieties can be standard or hybrid. Most of the cultivars bred in developed countries in recent years are hybrid cultivars. However, standard varieties are also quite numerous. All these issues should be taken into account when choosing a variety. Grain and grass type standard varieties have been bred and registered in our country. In addition, many standard and hybrid sorghum varieties from abroad were brought for sale by the private sector. Planting should be done after the varieties suitable for the region and cultivation purpose are determined (Açıkgöz, 2021).

Table 5. Sorghum and Sorghum X Sudan Grass Hybrid Varieties Registered in Turkey

Çeşit	Özellik	Tür Adı
Öğretmenoğlu 77	-	Sorghum
Akdarı 80	Darı	Sorghum
Aldarı	Darı	Sorghum
Beydarı	Darı	Sorghum
Jumbo	-	Sorghum
Gülşeker	-	Sorghum
Teide	-	Sorghum
Hay Buster Bmr	Silaj	Sorghum
Master Bmr	Silaj	Sorghum
Uzun	Silaj	Sorghum
Alba	Tane	Sorghum
ES Typhon	Tane	Sorghum
ES Foehn	Tane	Sorghum
Erdurmuş	Silaj	Sorghum
Hayday	-	Sorghum Sudan Grass
Greengo	-	Sorghum Sudan Grass
Sugar Graze II	-	Sorghum Sudan Grass
Nutri Honey	-	Sorghum Sudan Grass
Aneto	-	Sorghum Sudan Grass
BMR Gold II	Silaj	Sorghum Sudan Grass
Nutrima	Silaj	Sorghum Sudan Grass
Tonka	Silaj	Sorghum Sudan Grass
Supergraze 1000	Silaj	Sorghum Sudan Grass
Stella	yem - silaj	Sorghum Sudan Grass

Reference: Anonymous, 2022a

Soil Preparation

Although reduced tillage or direct planting methods are applied in some parts of the USA, sorghum is planted in the seed bed prepared with standard tillage methods in Turkey. In sorghum plantings, timely and proper tillage is necessary for yield. Since sorghum seeds are quite small and slow to develop within 4 weeks after germination, the seedbed should be cleared of weeds. During tillage, previous crop residues should be removed and weeds should be buried in the soil.

According to the pre-plant, after deep tillage in autumn or early spring, the soil surface should be crumbled with different tools and equipment such as cultivator or disc harrow. Since the main product sorghum is planted in April, May or June according to the regions, there is a wide time period for tillage. Especially the spring tillage causes the killing of weeds that develop in the winter months and the disappearance of some diseases and pests with the effect of heat and sunlight (Açıkgöz, 2021).

Fertilization

Sorghum is one of the plants that removes a lot of nutrients from the soil because they produce a lot of above-ground parts. Nitrogen demand is particularly high. Phosphorus and potassium are not very important. In studies conducted in irrigable areas in Turkey, it has been suggested to give a total of 15-30 kg/da N and 8-10 kg/da P_2O_5. In these studies, it is seen that the same amount of nitrogen application is more efficient when the plant is 5-8 kg/da N and the plants are 30-40 cm tall. It is appropriate to give a total of 10-18 kg/da N in the second crop condition. In grain type sorghums, half of the 10-15 kg/da N fertilizer should be applied during planting, and half should be given when the plants are 40-50 cm tall. In arid regions, it is considered sufficient to give 4 kg/da N together with planting (Brohi et al. 2000; Balabanlı and Türk, 2005; Demirhan, 2007; Karataş ,2011; Karadağ and Özkurt; 2014).

Planting Time

The main crops should be planted when the soil temperature reaches 10-15 oC. Practically, sorghum planting can be started 1-2 weeks after maize planting. According to the research, main crop planting can start in mid-April. Sorghum can be cultivated as the main crop, or it can be grown as the second crop in the irrigable areas of our coastal regions with long growing seasons and Central and Southeastern Anatolia. Planting can be done from late May to mid-July with soil preparation after the main crop harvest (Küçüksemerci and Baytekin, 2017; Açıkgöz, 2021).

Planting Depth

In sorghum planting, the seeds must be placed in the moist soil layer. Planting depth is accepted as 10.-1.5 cm in heavy soils and 2-3 cm in light soils. Grain seeders or maize planting machines can be used according to the spacing between rows in planting. After planting, the soil must be tamped. The cream binding of the soil in the main crop plantings prevents the grow up to a great extent. For this reason, the cream layer should be broken or replanted. In the second crop planting, the cream binding problem is not much (Avcıoğlu et al.2009; Açıkgöz, 2021).

Planting Rate

The normal planting rate in sorghum is 2-3 kg/da. A planting rate of 1.0-1.5 kg/da is sufficient for small forage sorghum varieties. Studies on seeding rate in grain type sorghum are very limited. Successful results were obtained from planting in Eskişehir conditions with 60 cm row spacing and 40-60 grains/m^2 planting rate (Başbağ et al. 1999; Avcı et al. 2018). Increasing the sowing rate in forage type sorghums can positively affect the first harvest yield. However, the effect of the planting rate on the total forage yield is not much. The number of siblings and cluster size may vary according to the sowing rate. Sudangrass type sorghums are very tillering after harvest. Tillering is weaker in other forage sorghums and sorghum x Sudan hybrids. In areas where water is scarce, plants that are planted frequently use the water in the soil in the early period, so the plants get stressed in the later stages. For this reason, frequent planting should only be done when a product with a thin stem and high leaf rate is desired (Baytekin and Şılbır, 1996; Baytekin et al. 1996; Açıkgöz, 2021).

Row Spacing

Row spacing to be applied in sorghums; it varies according to the region, soil conditions, available planting machines and cultural practices. In narrow row plantings, plants share moisture, plant nutrients and sunlight better. For this reason, 10-15% more grain yield is obtained from sowing with narrow rows such as 25 cm compared to 100 cm row spacing in grain type sorghum. Cultural operations such as weed control are very difficult in narrow row planting (Carter et al. 1990). For this reason, planting should be done with 70 cm between rows as in maize planting. In our country, different results were obtained in the research made with grass-type sorghum. The most suitable row spacing was found to be 40-60 cm in irrigated areas or in areas with regular rainfall. In some regions, sowing between rows as narrow as 12.5-25.0 cm increased the yield and led to a better quality grass product with fine stems (Karadağ and Özkurt, 2014; Öten, 2017). Since the stems get thinner in frequent planting, it is more suitable for consumption as green and for hay production.

Weed control

In sorghum agriculture, weed control is important in this period as the seedlings develop slowly after emergence. If the seedbed is prepared cleanly before planting, the weed problem can be largely avoided. After the plants are sized a little, weed growth decreases with shading. The use of herbicides against weeds is quite common. Atrazine, Metolachlor ce Benoxacor etc. against broadleaf weeds. Many herbicides can be used before and after emergence. Post-emergence herbicides such as Buctril, Banvel and 2,4-D are effective against broadleaf weeds. Herbicides that can be used against post-emergence weeds are very limited. For this reason, precaution should be taken against these herbs with herbicides containing acetochlor, alachlor, metolachlor, dimethenamide-P or s-metolachlor. Sorghum root outbreaks are known to inhibit the development of some weeds. Sorgoleone, which is the most important of these secretions, was obtained chemically and started to be used for the purpose of fighting against many weeds. Sorgoleone, which is especially effective against small-seeded plants, prevents the germination and shoot development of seeds like herbicides used before planting (Uddin et al. 2014; Açıkgöz, 2021).

Irrigation

The fringe roots of sorghum can go down to 2.0-2.5 m depths of the soil. However, most of the water and plant nutrients are taken from the top 1 m layer of the soil. Thanks to its well-developed root system, sorghum withstands drought much better than corn. It can be grown without irrigation in regions with annual precipitation of 400-850 mm. However, irrigation greatly increases the yield. The period when sorghums are most sensitive to water is between the onset of cluster formation and flowering. Good irrigation before this period increases the yield a lot. In addition, irrigation should be given importance as it reduces HCN formation in plant tissues in grass type sorghums. In sorghum irrigations, drip irrigation systems can be used in flooding, sprinkling and planting with wide row spacing. The number of irrigation and the amount of water to be given varies according to the region and soil structure (Açıkgöz, 2001; Açıkgöz, 2021).

Hay Production

Sorghum and sorghum x Sudan hybrids produce a tasty, juicy and nutritious hay. The high sugar content in the sap of some varieties increases the palatability as well as the energy value of the herb. Sorghums produce in the summer months when they are dormant in cool season grassy forage crops. For this reason, sorghums are considered an ideal plant for the summer season. In the USA, a large part of the daily green feed requirement of cattle, especially beef cattle, is provided from sorghum (Fribourg, 1995). For grass production, pruning is done when the clusters start to appear. Care should be taken to leave at least 10-15 cm of stubble in the harvests. Otherwise, the next harvest will be delayed and the yield will decrease. Sometimes cuttings made too deeply can cause the death of plants. Sometimes cuttings made too deeply can cause the death of plants. Sorghum grass is difficult to dry. Especially the stems take a long time to dry. When it dries, its digestibility decreases. Therefore, sorghum hay should be fed as green or silage. Hay suitable for drying can be obtained from very thin-stemmed sorghum x sudan hybrids with frequent plantings. However, sorghums are not generally considered a good hay plant. The number of harvests; It varies according to the climate and soil structure of the region, irrigation and fertilization conditions, and the type and harvest used. In general, the first harvest can be done 8-10 weeks after planting, then other harvests can be done at intervals of 5-7 weeks depending on the air temperature and irrigation conditions. Generally, the first harvests have high yields. Yields gradually decrease according to the number of harvests. A harvest can be obtained from the drought-resistant sorghums in arid regions. A harvest is taken from the grain sorghum planted for the purpose of grass production. After the harvest, the plants can reapply depending on the moisture condition of the soil. Growing plants can only be valued by grazing. In Turkey, in Central Anatolian conditions such as Ankara, Konya and Karaman, the total green grass yield is generally up to 6-7 tons/da, while this yield has increased up to 19 t/da in some studies (Sevimay et al. 2001; Karadaş, 2008). In the research made especially in Çukurova and Harran plains, green grass yield was obtained from planting the second crop at least as much as the planting of the first crop. Only one form can be obtained harvest sorghum grown in arid regions and the green grass yield is up to 1.5 t/da in these regions. The protein ratio of sorghum, which is a hay, is quite high in the early stages. Crude protein ratio varied between 5-12% in the harvests made during the appearance of the clusters in general. As in almost all forage crops, crude protein ratio decreases in sorghum in the advancing development stages. In sorghum grasses, ADF is 38-48%, NDF is 55-75% and relative feed value is 70-80 (Uzun et al. 2009; Küçüksemerci and Baytekin, 2017).

Using as a Silage Plant

Sorghum plants are more suitable for siloing than hay production. Especially sugar sorghum is very easy to ensilage. Progression of the harvest period may increase the dry matter content and pH value of silages, while lowering the crude protein, ADF, NDF and lactic acid values. Sorghums with high grain yields are more suitable for siloing. The most important factor affecting the quality of these silages is the grain ratio in the silage. In a good sorghum silage, the grain ratio should be 25% (Carter et al 1990). In all sorghum cultivars, attention should be paid to the harvest time since delaying the harvest too long to increase the dry matter will lead to yellowing and shedding of the leaves. More dry matter yield can be obtained from some sorghum varieties, especially in hot and arid regions, than maize. However, since the grain ratios are much lower in silages made from feed type sorghum, their energy values are low. It is generally accepted that the energy values, digestibility and nutritional value of sorghum silage are 15-20%

lower than maize silage (Undersander, 2019). Among the reasons for this; the low amount of grain in silage, the presence of tannin and puricic acid, the low voluntary consumption of animals, the high cellulose content can be counted. However, sorghums stay green longer than maize and retain their moisture content (Açıkgöz, 2001; Açıkgöz, 2021).

BMR (Brown midrib mutant) Sorghum

BMR sorghum is known as brown-grained sorghum. BMR was also detected in sorghum after mutant maize. Studies have shown that at least four different genes play a role in the development of brown blood vessels. Plants carrying this gene show a red-brown color change in the veins in the middle of the leaves. Sometimes similar color changes can be detected in the stem and plant sap. Due to the low lignin concentration in mutant plants, NDF digestibility, protein content and palatability are higher. Plants carrying this gene have poor early development, 10% lower grass yield than normal varieties, and a higher lodging risk. To prevent lodging, a number of new cultivars were developed with short stature, short internode spacing, but the same number of leaves as normal cultivars. These varieties are particularly well suited for regions with short growing seasons or for second-crop plantings. In recent years, many forage sorghum Sudan grass and sorghum-Sudan hybrids carrying these genes have been developed. In the research, it has been determined that the nutritional value of the silages made from sorghum varieties carrying this gene is equivalent to maize silage, and dairy cattle give 13% more milk than normal sorghum varieties. Due to all these advantages, the number of sorghum varieties carrying this gene has been increasing rapidly in recent years (Liu et al. 2017; Undersander, 2019; Açıkgöz, 2021).

Using as a Grazing Plant

Forage sorghums are sometimes used for grazing. In many regions, sorghum has been considered a good grazing plant for the summer months. When the plants are 70-100 cm tall, they are grazed with animals. However, due to the fact that the plants are chewed during grazing and there is a great loss of feed, it is a more appropriate method to give the daily feed requirement to the animals after they are cut and chopped instead of grazing. Chopped green sorghum grass is widely used in dairy cattle in the USA. The ratio of sorghum grass fortified in supplementary feeds in the ration can be up to 50-65% (Fribourg, 1995). New shoots of sorghum harvested for grass are grazed with animals. In grain production, post-harvest plants can re-take. Fallen leaves, clusters and stubble can be grazed with animals. Nitrate poisoning can be seen after drought or low-temperature stress in sorghum pastures grown on fertile soils and excessive nitrogen fertilizer. Care should be taken in this regard (Avcıoğlu, 2009).

Hydrocyanic acid (HCN) Poisonings

Hydrocyanic acid (HCN) poisoning is an important problem in the grazing or fresh consumption of sorghum. There is no prussic acid or hydrocyanic acid in intact plant tissues. Sorghum plants, especially leaves, contain cyanogenetic glucosides called dhurrin (adhurrin).

These glycosides in the tissues turn into hydrocyanic acid (prussic acid) by enzymes when plants are under drought stress or when they are harvested. Hydrocyanic acid taken with the plants that animals eat turns into cyanide in the rumen and mixes with the blood. This substance converts hemoglobin in the blood to methemoglobin, making it difficult to transport oxygen. In animals, breathing becomes difficult, pulse increases, muscle contractions are observed. In animals, these symptoms begin 5 minutes after the consumption of sorghum. If precautions aren't taken, deaths can be seen within 15 minutes (Undersander, 2003; Açıkgöz, 2021). In general, Sudan grasses and grain sorghums have less hydrocyanic acid. On the other hand, hydrocyanic acid poisoning is more common in sorghum x Sudan hybrids. Excessive nitrogen N fertilization in sorghum, insufficient irrigation or rainfall, acid soils, soil phosphorus deficiency and low temperature lead to hydrocyanic acid elevation. Therefore, these factors should be taken into consideration in aquaculture. Sorghum grass should be carefully fed to animals, especially after a prolonged drought or cold weather. Hydrocyanic acid poisoning is closely related to plant circuits. Hydrocyanic acid is more abundant in young plants. As the circuits progress the likelihood of acid formation and poisoning decreases. This danger is minimized in the milk stage. For this reason, the plants should not be grazed before they are 70-100 cm tall, or they should not be given to animals by cutting. If it is to be given to animals during this period, it should be left on the ground for at least 2-3 hours after the plants are cut to allow the hydrocyanic acid to evaporate (Undersander, 2003; Avcıoğlu, 2009; Açıkgöz, 2021).

Seed Production

A different cultivation technique is not applied for seed production in forage sorghums. Fields planted similarly to hay production are left to seed. Completely dried plants can be harvested directly by threshing. In the seed harvesting period of tall forage sorghums, green stems or leaves may prevent harvesting and threshing with the combine. In these cases, various plant desiccants with gramoxone active substances are applied to the plants and the plants are dried completely. Then, harvesting and threshing can be done by removing the combine harvester table.

Seed yield varies between 100-300 kg/da in irrigable coastal areas. In the inner regions of Turkey, the seed yield is lower and the average yield is between 50-150 kg/da according to environmental conditions. In multi harvest forage sorghums and sorghum x Sudan hybrids, seed production can be made from the first harvest, or the second harvest can be left to seed in fields where the first form is taken for grass. In the research, it was determined that more seed yield was obtained by leaving the first harvest to the seed (Akash and Saouub, 2002; Awad et al. 2013). Since grain sorghums are short, the plants dry easily. If the clusters are sparse, the seeds also reach harvest maturity in a short time. In developed countries, almost all of the seed harvesting is done by combine harvesters. Harvest can be started when the moisture content of the seeds decreases to 20-25%. Seed yield is generally high in grain sorghums. The yield of grain type sorghum reaches up to 400-500 kg/da in Central Anatolian irrigated conditions. Bird damage is an important problem in sorghum seed production. In all sorghum varieties, birds do great damage during the seed ripening period. Harvesting a little early reduces the level of damage (Avcı et al. 2018).

Sorghum grains are used successfully in the nutrition of almost all kinds of animals. For example, using 16-32% sorghum grains instead of corn in dairy cow rations positively affected milk yield and quality without changing feed consumption. If white oil is required in broiler farming, sorghum is an ideal feed. In recent years, it has been determined that a mixture of sorghum and maize gives good results (Etuk et al. 2012).

Diseases and Pests

Many different diseases can be seen in sorghum agriculture. After planting, the seeds should be planted after being sprayed with fungicides containing Captan effective substance against seedling blight, slumping and anthracnose factors. Apart from this, leaf diseases such as leaf blight and powdery mildew are also seen in rainy and humid regions. In the fight against these diseases, cultural measures are mostly emphasized. The use of disease-free seeds, cleaning of plant residues in the field and proper rotation can be counted among these measures. In the studies conducted in our country, many pests have been detected in sorghum, but it has been understood that Sesamia species are the most damaging species among them. Medication can be used to combat the aforementioned pest. One of the most important pests in sorghum agriculture is birds. Bird damage is an important problem in sorghum agriculture. Bird damage can reach great proportions, especially if there are no other plants in the environment. To prevent bird damage, sounds, tools, guns and some scents that birds do not like can be used. In addition, varieties resistant to bird damage and high tannin content can be preferred (Açıkgöz,2021).

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CHAPTER 14

Sudangrass Cultivation (*Sorghum sudanense*)

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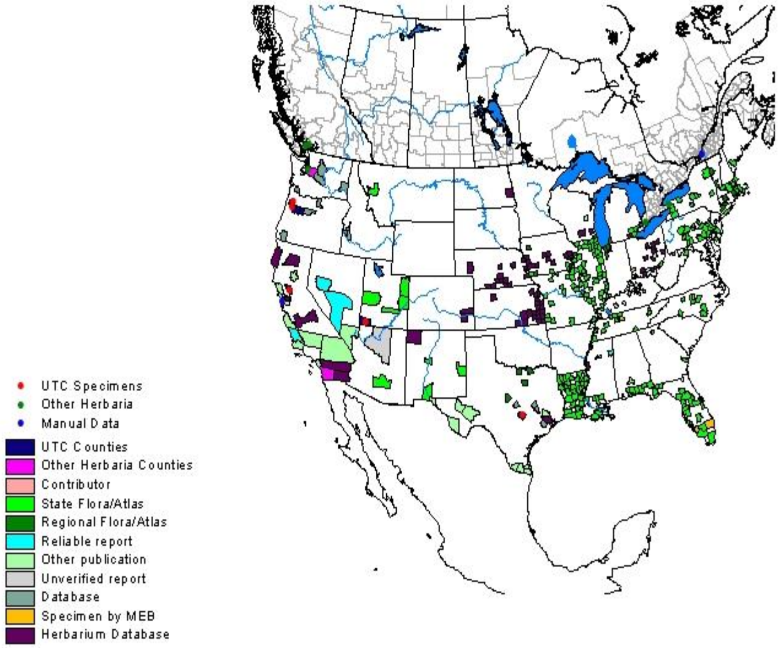
SUDANGRASS ORIGIN AND TAXONOMY

Sudangrass is a short-day plant, usually an annual, that belongs to the Andropogonae tribe of the Poaceae family. The existence of its wild species in different continents such as Africa, Asia and Australia has led to different opinions on the origin of this genus. According to some, sorghum culture started in East India, spread from there to Anatolia and Mesopotamia, and was taken to Europe by the Arabs via North Africa. Opposition to it is based on the richness of forms of wild species with n=10 in Africa, it was determined that the n=10 cultured sorghum admits that it originated in Africa. Information on the origin of the wild species is even less. However, it is thought that the sorghum halepense originated in southeast Asia. B.C. Sorghum culture was made in the Assyria around 700 BC. For hundreds of years, the staple food of Africa has been millet. In this continent your husband There are many types in terms of vegetation period, plant height, cluster and grain structure. Cultivated in Southern Europe, the Near East, Russia, Turkestan, Manchuria, China, Korea, Japan, Pakistan and India, the millets show a wide variety of forms (Bennett, 1990; Tiryaki 1998; Chopra, 1982).

After wheat, rice and corn, it is the most produced grain in the world. There are many varieties bred to produce grain silage, green and hay, skirting board and must. Many sorghum forms spread over all continents show wide differences in terms of morphological and physiological characteristics and ecological demands (Hussain et al. 1991; Merrill et al. 2007; Marsalis et al. 2010; Sowiński and Szydelko 2011).



Picture 1. Sudangrass distribution area (Anonymous, 2022a).

In the Feterita group varieties, the core of the stem is dry and coarse. Seed coat (testa) brown on the other hand; because it is surrounded by a thick mesocarp, this color does not pass into the fruit skin (pericarp); however, it causes the grain to appear chalky (bluish-white). Indigenous varieties of Sudan are collected in this group (Howell et al. 2008).

Sudangrass: Its height is 0.8 -2 m. Due to its tillering and high number of leaves, it is suitable to be used as meadow grass, hay and silage. The flower community is in open clusters (Kiziloglu et al., 2009)

MORPHOLOGY

Root

Found suitable humidity and air temperature, the celandine seed will germinate in 1-2 days. When the root sheath (coleorhiza) grows about 2mm, the rootlet (radicula) begins to appear inside. The rootlet, which continues to elongate with rapid mitotic divisions, contains densely absorbent hairs at the tip. Meanwhile, with the elongation of the first node (mesocotyl) in the embryo, the grass sheath (coleoptile) appears in the opposite direction of the rootlet. In the 5-6day old plant, the first adventitious roots begin to appear from the base of this first node. These roots, which will develop in a plant that is only 10 days old, They form the primary root system. Although these roots, which are short and very uniform in diameter, branch more or less, they form a small part of the root system that will develop later on (Açıkgöz, 2021).

Sudangrass begins to form after this. When the plant is 2 weeks old, adventitious roots begin to emerge from the node to which the grass sheath is attached, and then from the nodes where the first upper leaves emerge. Over time, these adventitious roots surrounding 7-8 nodes form the root of the sudangrass plant. The number and length of roots emerging from a node increase from bottom to top (first to last). The first of these root rings and the one at the bottom (at the base of the grass sheath) are formed in the plant, which is only 2 weeks old. The youngest root ring at the top develops at the time of flowering and fertilization. Since the uppermost roots emerge from the nodes above the ground, the exposed parts of these roots are green with chlorophyll.

The underground parts of this and all other roots form long branching lateral roots that move in all directions through the soil. The number and branching of the lateral roots in waterfowl are more prominent than the root system of corn, and a typical fibrous root system (radix Fibriosa) form. Because of this strong root system, the aquatic plant has a high uptake of nutrients from the soil and moisture. The drought resistance of the sudangrass plant is also related to the strong root system (Joseph et al. 1980; Akash and Saoub 2002).

In sudangrass , the stem consists of a node and an internode, a leaf emerges from each node, and in some varieties, side branches emerge from the middle and upper nodes. The number of knuckles on the main stem can be between 15-30; 8-10 of them are found under the ground in the root zone. The stem nodes are shortened towards the bottom, the nodes under the ground overlap and form root layers. Their knuckles show a corrugated shape and an oval cross-section, as in maize. The internode between the uppermost node carrying the flower community shows a thinner and cylindrical structure. This cluster-bearing upper node is upright in some varieties, and oblique or large in others. Stem thickness varies between 1-5 cm (Caravetta et al., 1990; Taleb-nejat 1995; Bahrani and Ghenateghestani 2004).

Plant height varies between 0.6 -4.5 meters. Plant height depends on the length and number of internodes. In some cultivars, depending on the environmental conditions, more than one sibling and branching in the upper nodes of each sibling are seen. Branches appear after the generative passage of the main stem. It can start at the second node from the top and go down to the lower nodes. The number of branches does not exceed one or two. Branching is more common in sparse sowing and early cultivars (Türk and Çelik 2006; Rafiei 2009; Stevovic et al. 2012).

Leaf

The total number of leaves in the common millet plant is between 15-30. However, as 8-10 of them emerge from the underground nodes in the first period of development, they dry out later. The main photosynthetic leaves are the leaves emerging from the above-ground nodes of the plant, and their number is 7-9 in early varieties and around 15 in late varieties (Arslangiray et al., 1999).

Leaves consist of leaf sheath and leaf blade. Leaf sheath length varies between 20-25 cm; it may wrap the node above the node from which it exits, partially, completely, or in such a way that it overflows the upper node. A leaf emerges from each node. Since the stem, leaf sheath and leaf blade are usually covered with a wax layer, the plant has a hazy appearance (Brohi et al. 2000).

Picture 2. Sudangrass general view (Anonymous, 2022b).

Numerous hygroscopic cells located near the midrib facilitate the folding of leaves in dry weather. The waxiness of the leaf surface and the appropriate structure of the leaf pores (stoma) allow sudangrass to easily survive hot and dry periods. When conditions return to normal, the wilted leaves reach their former turgor. The collar is thin, membranous and short (2-3 mm) and prevents insects, water and dust from entering between the leaf sheath and the stem (Açıkgöz, 2021).

Terms of leaf length and width, sudangrass is the plant that closely resembles corn. In sudangrass, leaf length is from the bottom, 3rd-4th at the top. It increases progressively towards the knuckle, and becomes shorter towards the top. Leaf blade length can be 50-100 cm. The width of the widest leaf in the plant can vary between 5-12 cm depending on the conditions. Generally, leaf sizes are higher in late varieties (Caravetta et al. 1990; Taleb-nejat 1995; Bahrani and Ghenateghestani 2004).

Leaf color can be dark, normal or yellowish green. On the leaves, spots that come from the genotype of the variety or are related to mechanical damage and physiological disturbances and turn red or purple over time can be seen. The color of the coleoptile can be green, light or purple. The leaf sheaths are usually purplish red in plants with purple sprouts (Akash and Saoub 2002).

There is a glycoside called “dhurrin” in the stem and especially in the young leaves of the watermelon. During the breakdown of this glycoside, cyanhydric acid (HCN), which is toxic to humans and animals, is produced. HCN can cause death in animals that eat young and green algae plants. In order to eliminate this risk, it is necessary to give the cut sudangrass to the animals after they are withered in the shade for 1 day, and the new silages should be ventilated (Açıkgöz, 2001; Açıkgöz, 2021).

Flower Pollination and Fertilization

In sudangrass, the flower community is in the form of a mixed bunch (panicula) at the end of the stem. Depending on the variety and environmental conditions, it can be upright, inclined or bent like a cane tip in the uppermost internode (cluster stalk) bearing flower community. Generally, in varieties with large clusters, the cluster trying to come out of the flag leaf is pushed outwards by the leaf sheath. Although the soft cluster stem continues to elongate during this period, it cannot keep the heavy cluster at the end upright and as the cluster gets heavier, the stalk maintains this bent state. Twist of the handle; It is seen in cultivars with narrow leaf sheaths and large clusters, in optimal conditions where panicle stem elongation is very fast, and in sparse plantings. The cluster is cylindrical, ellipsoid, oval or conical, depending on the variety (Harlen and De Wet, 1972).

Cluster density ranges from compact to flagellum; The cluster is 10-50 cm long and 5-15 cm wide. It has a prominent cluster axis (rachis). The length of the axis of release affects the form of the cluster. There are 4-16 branching nodes on the cluster axis, each of which can have 3-9 branches. The length of these branches can be between 1-20 cm. As the branches are long, they can be scattered or drooping. These primary branches branch several times and give twigs bearing spikelets at their ends (Bednarz and Oosterhuis 1999).

Picture 3. İnflorescence of a sudangrass plant (Anonymous, 2022c).

The sessile one is fertile, the stalked one is generally sterile. At the ends of the branches barren and fertile. spikelets are found. a fertile There are two flowers in the spikelet. Of these, the lower one is usually barren and has only one semen (Bennett, 1990).

Sudangrass is highly self- fertile. According to the variety and environmental conditions, foreign pollination and fertilization rate may increase (Açıkgöz, 2021).

Grains

Ellipsoid or laterally flattened, depending on the variety. The weight of a thousand grains varies between 8-11 grams in small-grained varieties, 12-24 grams in medium-grained varieties, and 25-40 grams in coarse-grained varieties. The seed consists of 83% endosperm, 10% embryo and 7% shell (Joseph et al. 1980; Akash and Saoub 2002).

Picture 4. Grains of a sudangrass plant (Anonymous, 2022d).

Grain color can be white, cream, yellow, brown, red, purple or black. It is available in varieties with red or brown spots on white. Grain contains 69-72% starch, 9-14% crude protein, 3% crude oil, 2% crude fiber and 1.5% ash. It is similar to the corn kernel content (Saoub 2002).

Climate Requests

Sudangrass, which is a native plant of the warm climate, is also successfully grown in temperate climates. Minimum germination temperature is 10-12 ˚C, germination and seedling development are accelerated at 18-20 ˚C. It is slow in the initial growth period. The optimum temperature for growth and development is between 24-27 ˚C. It is more resistant to high temperatures than corn. Extreme temperatures during flowering reduce fertilization and grain retention. There are very early varieties with a vegetation period of less than 90 days and very late varieties with a vegetation period of more than 125 days. The sowing date is the date when the soil temperature exceeds 10 ˚C (Açıkgöz, 2021).

Sudangrass is one of the economical plants that use water economically. The amount of dry matter it creates is higher than the unit of water it consumes. It shows great resistance to drought. Its annual precipitation is 450-600 mm. can be grown in regions with It can be easily cultivated in regions with low summer precipitation and high temperatures (López-Bellido et al. 2005).

Sudangrass to grow in arid conditions and its drought resistance are due to its morphological and anatomical features. The number of adventitious roots and the depth they can descend are high. The number of leaves and their surface area less than that of corn. Transpiration is low because the leaves are covered with a waxy layer. The plant passes the temporary extremely hot and dry periods stagnant, when the conditions improve, it resumes its normal and growth development. Sudangrass can withstand even weeks of drought. However, the longer this stagnation period that the plant will enter, the less dry matter and yield it will produce in a unit area. In addition, increasing humidity with temperature increases the yield of sudangrass. It can be grown as a second crop in places where the temperature and humidity are suitable. The biggest problem in the cultivation of celandine in dry agricultural regions is that the soil moisture is not sufficient for the germination of the seed (Açıkgöz, 2021).

Soil Requirements

Sudangrass, which does not have soil selectivity, can be successfully grown in different types of soils. However, the highest efficiency; It provides moisture and nutrients in abundance and in soils with favorable temperatures. It is a plant that can be yielded even under limited environmental conditions. It can also adapt well to fertile soil conditions. In very clayey, heavy soils, there is a serious decrease in yield in dry years. It adapts well to salty and alkaline soils. Yield cannot be obtained in heavy soils with drainage problems (Bisson et al. 1994; Bednarz and Oosterhuis 1999; Sangakkara et al. 2000).

Soil Preparation

The tillage that will be applied to the field where Sudangrass will be grown varies according to the region. Since it is usually grown in arid areas, it is very important to maintain soil moisture. In dry farming areas, the soil is tilled in spring. Soil tillage, which removes weeds, preserves soil water and prevents erosion, is recommended just before planting. Yield is directly proportional to the moisture in the soil. Moisture protection can be maintained with tools that work from the bottom without overturning the soil (Carter et al. 1990).

In moist agricultural areas, the soil is deeply cultivated. Before sowing, trimming is done with a harrow or a disc harrow. A good seed bed should be prepared by breaking up the coarse soil particles on the field surface. Otherwise, germination and emergence will not be equal. Sudangrass grows slowly during the first 3-4 weeks. It is important that weeds are well cleaned at this stage.

Sowing Time

Sudangrass is slow at temperatures below 20 ˚C. It cannot compete with weeds, so planting should be done when the soil temperature reaches 20 ˚C. Since Sudangrass is a winter day plant, if it completes its generative period in the short days of autumn, it gives abundant crops. However, if planting is done earlier than necessary, grain yield will decrease as fertilization and grain setting will coincide with the hottest and driest days of summer. For these reasons, the climatic characteristics and variety characteristics of the region should be taken into account in determining the planting date.

In our country, sowing of sudangrass is carried out in a few months from April to June. Sowing is done earlier in our Southeast region, where the spring precipitation starts early and the soil moisture reaches the appropriate level quickly. From our coastal areas to our inner regions, the planting date is gradually delayed (Küçüksemerci and Baytekin, 2017; Açıkgöz, 2021).

Sowing Method

The planting method of Sudangrass varies according to the purpose of cultivation, the climate and soil characteristics of the region and the possibilities of the enterprise. It can be planted with a scattering or grain seeder for green hay purposes. Fine and quality feed can be obtained if the plant is planted frequently (Başbağ et al. 1999; Avcı et al. 2018).

According to the regions and planting methods, the spacing of the rows varies between 30-100 cm, and the rows vary between 5-25 cm. The number of plants per square meter varies between 25-40 in soils with high humidity and fertility, and 5-15 in arid regions. Sowing depth is recommended to be between 2-4 cm. 1000 grain weight is between 20-30 g. The amount of seed to be planted per unit area is calculated according to the region and variety characteristics and the purpose of cultivation. This amount varies between 1-5 kg/da. It is recommended to plant less seeds per unit area in grain-purpose planting and more seeds in forage production (Küçüksemerci and Baytekin, 2017; Açıkgöz, 2021).

Care

The maintenance works to be applied to Sudangrass should be hoeing, thinning, irrigation and fertilization. In the days following sowing, if the soil surface binds cream before emergence, the cream should be broken with a light rake or brush broom. If sowing is done by hand or if the plants are dense on the row, 10-15 cm. When the dye arrives, the dilution is done. Sudangrass, like corn, cannot fight weeds in the first development period. For this reason, hoeing should be done before weeds develop, especially in this first period. Dilution can also be done with the first anchor. Hoeing can be repeated depending on soil moisture. After the plants are able to shade the rows in full, there is no need for hoeing. If dilution is necessary, it should be done until the plants are 10 cm tall (Uddin et al. 2014; Açıkgöz, 2021).

In regions where irrigation facilities are available, the growth and development of sudangrass is accelerated by irrigation under suitable temperature conditions, and its yield increases significantly. The amount of water to be given to the sudangrass during the growing period is around 400 mm. This amount of water should be given in 3-5 irrigations depending on soil and weather conditions. It makes a serious contribution to the irrigation and yield at the beginning of the clustering (Akash and Saouub, 2002; Awad et al. 2013).

Fertilization

Fertilization is often not economical for sudangrass grown in arid regions. In the irrigated areas, the plant's uptake of nutrients and its response to fertilizer increases, and its yield increases. A high amount of biomass is obtained from the unit area if there is suitable temperature, humidity and fertilizer. In this case, the importance of fertilization increases. Fertilization in irrigated conditions is similar to maize. Which fertilizer should be given in what amount depends on the nutrients in the soil. ecological and economic conditions determine (Brohi et al. 2000; Balabanlı and Türk, 2005; Demirhan, 2007; Karataş, 2011; Karadağ and Özkurt; 2014).

Harvest

Harvest time and method vary according to the purpose of growing sudangrass, regional conditions and the possibilities of the enterprise. It is recommended to harvest the grain with a combine harvester. The clusters are expected to dry well in the field. It is desirable that the moisture content of the grain be around 12-13%. Otherwise, heating and deterioration will occur. Harvested grains should be laid and dried. The number of revolutions should be paid attention to in order not to break the grains during the blending (Karadaş, 2008).

Sudangrass, which is grown as hay, is dried together with its stem and bunch, in bunches or individually, with sickle, scythe, mower or harvester ties during the yellow maturity period. Especially the varieties with thick or musty stems need to be dried for a long time in order to be stored safely. Harvesting of reagents is not recommended in humid areas as it may cause rutting of the bunches. Harvesting of sudangrass, which will be considered as silage, should be done after the death of the grain but before the stems become lignified. Depending on the growing conditions, 3 -10 tons of biomass can be obtained per decare (Undersander, 2019).

Diseases and Pests

Sudangrass are millet closed smut (*Sphacelotheca sorghi*), millet open smut and millet head smut (*Sphacelotheca reilianum*) are smut species (Açıkgöz, 2021).

Picture 3. Plant disease of *Sphacelotheca* (Anonymous, 2022e)

Millet indoor smut is the most common disease of sudangrass. In the infected plant, spores are formed instead of grains. The spore masses that replace each grain are surrounded by a thin membrane. The spores scattered by the rupture of this membrane during death infect the healthy grains in the field and threshing. If such grains are planted as seeds, the fungus will germinate along with the seed and continue to grow in the stem. Micelles reaching up to the cluster replace the grains with brown-black spores. This disease, which is very harmful for the grain crop, is does not affect the yield of vegetative mass; however, it is recognized by its symptoms in the cluster (Egbe, 2005).

Millet open smut also fills the grains with spores. In this type of smut, the membrane surrounding the spores ruptures earlier and the spores spread to the environment and nearby healthy plants. Plants caught in millet open smut are weak and short. Since the infection in these two types of smut is by seed, spraying the seed with fungicides is an effective way. There are cultivars that are resistant to some biotypes of the disease (Sarrantonio, 1994).

Millet head pillow is a rare but occasionally very damaging disease in sudangrass. In the infected plant, a large tumor forms in place of the cluster. Surrounded by a thin membrane from the outside, this product is filled with spores inside. With the rupture of the membrane of the ur soon after, the spores spread to other plants and the soil. The spores, which spend the winter on the soil, plant residues or polluted algae grains, germinate with the seed and extend their mycelium in the stem of the algae plant. In the infected plant, the appearance is normal until it produces clusters. Since the disease is mostly transmitted by soil, it cannot be effectively prevented by seed spraying. Seed and field should not be contaminated with spores, and as soon as tumors appear on the plants, they should be collected and burned before they disperse (Ngongoni et al., 2007).

Apart from these, there are leaf diseases such as root and stem rot , rust, leaf spot and blight. Cultural measures should be taken against diseases for which seed spraying is not effective, and cultivars that are resistant or can overcome the disease with little damage should be cultivated (Terao et al., 1997).

With abundant trees and sparse and small aquamarine fields, birds cause significant grain loss during death. However, there are varieties of aquawort that are resistant because their husks are thorny or disliked by birds (Ouma, 2010).

Picture 4. Bird damage (Anonymous, 2022f).

Bird damage is an important factor limiting the production of calendula in many regions. Different bird species cause significant grain loss, starting from the period of milk production in the sodagrass fields. The rate of damage varies according to the variety, year and the possibility of birds to find other food in the environment. The rate of damage varies according to the variety, year and the usual way birds find other food in the environment. In areas grown for grain, 50% damage may occur (Waniska et al., 1989).

Success in various measures to be taken is quite limited. Precautions can be taken, such as frightening birds with noise vehicles, disrupting nearby accommodation, planting other plants that they love to eat as bumper strips, and spraying chemicals on the field (Bullard and York, 1996).

Most of the insects that cause damage to corn can also damage watermelon. However, it is not as obvious damage as in corn. The important pests of Sudanese are aphids. Aphids live mostly in the flag leaf palm and sheath of sudangrass and reproduce rapidly. Due to the direct or indirect damage to the leaves by the sticky substances and dirt they produce, the inflorescences cannot take their normal form and grain binding is disrupted. Grain quality decreases as it matures. One or more of the measures such as combating with pesticides, crop rotation, shifting the planting time, proper soil cultivation can be applied against different types of aphids and other pests (Kiruba et al., 2006).

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CHAPTER 15

Switchgrass (*Panicum virgatum* L.)

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INTRODUCTION

Switchgrass (*Panicum virgatum* L.), which can grow up to 2 m in height, is a perennial warm season plant with short rhizomes. Switchgrass, which is a very important lice plant of North American pastures, is loved and consumed by animals because it is a delicious plant in early spring (Açıkgöz, 2021). It is an perennial C4 plant, which switchgrass has a high quality and high herb yield, is used as a bioenergy plant, increases the quality of the soil thanks to its developed and deep profiled roots, reduces carbon emissions, does not require tillage every year, can produce biomass in arid conditions, has low production costs and can be grown in marginal areas (Gönülal, 2018).

Figure 1. General view of the switchgrass plant

There are two different ecotypes of switchgrass, as lowland and upland, according to its morphological characteristics and environmental conditions. Lowland ecotypes that develop vertically are tall, hairless, high tillering, rapid growth and thickening plants (Figure 1). Varieties belonging to this ecotype are generally seen at the edges of wetlands, meadows and flooded areas. Plants in the lowland ecotype are mostly used as energy plants. Upland ecotypes with short stature are hairy, have thin stems and are more suitable for grass production. These ecotypes are distributed in arid areas where precipitation is low and at high altitudes (Porter, 1996). Upland ecotypes are mostly used for animal feeding (Gönülal, 2018). Chromosome numbers vary between 2n=2x=18 and 108 in switchgrass, and lowland ecotypes generally have 2n=4x=36 and upland ecotypes have 2n=8x=72 chromosome numbers (Williams and Auer, 2014).

Switchgrass, which can be grown in many different soil types, is moderately resistant to water ponds, salinity and acidity in the spring months. It is generally propagated by seed. It can be sown from mid-April to the end of May. The amount of seed to be used in sowing varies depending on the viability of the seed and the germination rate. Before planting, the germination rate of the seeds should be checked and the amount of seed should be calculated according to the data obtained (Figure 2). The amount of seed to be used is stated as 0.6-0.9 kg/da in some sources (Açıkgöz, 2021), and as 1-2 kg/da in some sources (Soylu, 2012). Sowing depth should be between 1.0-1.5 cm. According to the studies conducted in our country, it is reported that the most appropriate row spacing in planting varies between 15 and 30 cm (Soylu et al., 2009).

Figure 2. Sowing frequency in swihgrass plant

Soil analysis must be done before fertilizing in switchgrass. For switchgrass, 3-4 kg/da of nitrogen and 10 kg/da of phosphorus fertilizer should be given with planting. After the plants emerge, the nitrogen amount should be completed up to 10 kg/da. In the second year of switchgrass, around 15 kg of nitrogen fertilizer should be used per decare, provided that it is divided into two equal parts (Soylu, 2012). In a study conducted in Italy, it was reported that the highest dry matter yields were obtained from 7.5 kg/da nitrogen application and 15 kg/da nitrogen application in Greece (Alexopolou et al., 2002). In a study on the fertilization of switchgrass in the USA, it was revealed that at least 16.8 kg/da of nitrogen fertilizer application should be made per year (Muir et al., 2001). In the study conducted in our country, it was determined that 10-15 kg/da of nitrogen and 10 kg/da of phosphorus application gave good results in switchgrass (Soylu, 2012).

AGRONOMY and YIELD

Switchgrass should be harvested at the beginning of clustering for herbage production. Delaying the form until the full flowering period causes an increase in herbage yield and a decrease in quality (Figure 3). The dry herbage yield in switchgrass varies greatly depending on the varieties and irrigation (Açıkgöz, 2021).

Picture 3. Harvest time for herbage and seeds in the switchgrass plant

It was reported that the dry herbage yields of switchgrass genotypes ranged between 350-2500 kg/da in a study conducted in Hatay (Çeliktaş et al., 2017), and between 350-1800 kg/da in a study conducted in Kırşehir conditions (Doğuş, 2017). In the study conducted in Konya under irrigated conditions, the dry herbage yields of switchgrass ranged between 350-1800 kg/da (Soylu, 2012), while the dry herbage yield was 3 t/ha and the green herbage yield was 5.5 t/ha by some researchers (Filikci, 2018).

In a study conducted in England, the Netherlands and Germany by Elbersen et al. (2002a); it was reported that the biomass yields of switchgrass cultivars decreased in the first year, reached the maximum level in the third year, and the cultivars gave different values in each location. In the study; It was determined that Blackwell variety in the 1st, 2nd and 3rd years gave biomass yield of 0.5, 5.3 and 8.8 t/ha in the Netherlands, 0.9, 9.2 and 13.6 t/ha in England, and 1.6, 2.1 and 6.4 t/ha in Germany, respectively.

In the study conducted by Fike et al. (2006) to determine the biomass yields of lowland and upland ecotypes of switchgrass in 5 different states of the United States (North Carolina, Kentucky, Tennessee, Virginia and West Virginia) and 8 different locations, it was reported that an average of 12.6 t/ha dry matter yield was obtained from upland ecotypes and 15.8 t/ha dry matter yield from lowland ecotypes. On the other hand, in the study carried out in 3 different locations of the Illinois region of the USA, namely the north, south and center, it was reported that the dry matter yield of the switchgrass type was between 7.8-8.1 t/ha in the north, 13.0-19.8 t/ha in the center, and 6.7-8.7 t/ha in the south, on an average of 3 years (Heaton et al., 2008).

In the study carried out to investigate the possibilities of growing switchgrass as an alternative bioenergy and silage crop for Turkey; yield and yield components of 9 different switchgrass cultivars in the second year were investigated. As a result of the study; It has been reported that the flowering dates of the cultivars were between 18 June-22 August, plant height 66-173 cm, stem weight 1.0-9.4 g, green biomass yield 959-5755 kg/da, dry matter ratio 31.9-43.0% and dry biomass yield 342-1818 kg (Soylu et al., 2009).

In the study conducted by Soylu et al. (2010) in order to determine the cultivation possibilities of the branched millet plant in our country conditions in 2007, 2008 and 2009, 9 different branched millet varieties (Blackwell, Shawnee, Kanlow, Carthage, Forestburg, Cave in Rock, Shelter, Alamo, Dacotah) were used. In the results of working; parameters in the second and third years of switchgrass, which is a perennial plant, were taken into account. It was reported that total green biomass yields varied between 8.59-57.55 t/ha and 33.62-64.93 t/ha, dry biomass yields between 3.42-18.18 t/ha and 11.00-25.82 t/ha in 2008 and 2009, respectively. When the green and dry biomass yields were examined among the 9 cultivars studied, it was determined that Kanlow, Blackwell, Carthage, Shawnee, Cave in Rock and Alamo cultivars came to the fore.

In the study conducted in Konya conditions in 2008 and 2009, some characteristics of switchgrass in the second year were examined. In the results of working; it has been determined that the plant height of switchgrass varies between 156 cm (Blackwell) - 203 cm (Kanlow), biomass yields between 4839 kg/da (Blackwell) - 8814 kg/da (Kanlow), and dry matter yields between 1682 kg/da (Blackwell) - 3142 kg/da (Kanlow) (Şeflek, 2010).

In the study carried out to determine the biomass yield and some properties of 5 different switchgrass cultivars (Cloud nine, Dacotah, Cave in Rock, Alamo, Kanlow) in Bornova ecological conditions between 2012 and 2014; properties such as plant height, number of stems, dry biomass yield and crude ash content were investigated. In the results of working; it was reported that the highest plant height was obtained from the Cave in Rock variety with 176.3 cm, and the lowest plant height was obtained from the Dacotah variety with 116.3 cm in 2013. In terms of dry biomass yield, it was reported that there was an increase from the first year to the third year, the yield of all cultivars increased in the third year, and a yield of 1596, 1567, 1562, 1503 and 1344 g/m^2 was obtained from Cave in Rock, Cloud nine, Alamo, Kanlow and Dacotah cultivars in the third year, respectively (Geren et al., 2016).

In the study carried out by Giannoulis et al. (2016) in two locations in 2009-2010 in Greek conditions; it was reported that the plant height was 131 cm under dry conditions, 193 cm in irrigated conditions in Velestino location; 231 cm under dry conditions and 247 cm in irrigated conditions in Palamas location. In the study, dry biomass yield was determined as 9.2 t/ha in rain-free conditions and 14.3 t/ha in irrigated conditions in Velestiona location; 19.7 t/ha in dry conditions and 22.8 t/ha in irrigated conditions in Palamas location.

In the study carried out to determine the responses of some switchgrass cultivars to different harvest times in Konya ecological conditions, it was reported that green biomass yields ranged from 2437 kg/da (Cave in Rock) to 5290 kg/da (Alamo) (Çiçek, 2017). On the other hand, in another study carried out for 2 years between 2016 and 2017 in the Karapınar district of Konya; irrigation issues were used in the main plots, and 6 switchgrass varieties (Shelter, Alamo, Cave in Rock, Shawnee, Kanlow and Trailblazer) were used in the sub-topics. After two years of research; it has been determined that total dry biomass yields ranged from 1247.9 kg/da (Cave in Rock) to 1903.7 kg/da (Alamo), irrigation water use efficiencies between 4.4 kg/da/mm (Cave in Rock) - 7.0 kg/da/mm (Kanlow), and Trailblazer, Alamo and Kanlow varieties stand out as the varieties that use water most effectively in all water stress applications (Gönülal, 2018).

In the study carried out by Gönülal and Soylu (2020) in order to determine the effect of restricted irrigation on grain yield and some properties of branched millet varieties in Konya Karapınar conditions; the average grain yield per unit area in terms of cultivars was determined in the range of 5.7 kg/da (Alamo)-52.7 kg/da (Cave in rock), thousand grain weight was ranged between 0.82 g (Alamo)-1.66 g (Cave in rock) and the harvest index was ranged between 0.21% (Alamo)-3.57% (Cave in rock). In the results of working; It was reported that the cultivars in the lowland ecotype had low grain yield per unit area, thousand grain weight and harvest index value, and the cultivars in the upland ecotype had higher grain yield and grain size per unit area, and irrigation was effective on the investigated parameters.

In a study conducted by Kesen and Geren (2020) in İzmir-Bornova in order to determine the effect of different cutting frequencies on feed yield in switchgrass; it has been reported that plant height varies between 53.5-230 cm, green herbage yield between 7263-17921 kg/da, dry matter yield between 2439-7421 kg/da. On the other hand, in a study conducted in Van ecological conditions to determine the biomass and feed quality of swichgrass cultivars harvested at different maturation periods, it was reported that the wet biomass yield ranged between 800-4877 kg/da (Zorer Çelebi and Ekin, 2020).

In the study carried out in Konya conditions in order to determine the biomass yield and agricultural characteristics of 6 different branched millet varieties in dry conditions due to precipitation; It has been reported that the green biomass yield varies between 734 kg/da (Cave in rock)-1499 kg/da (Alamo), the dry biomass yield varies between 343 kg/da (Cave in rock)-774 kg/da (Trailblazer), the plant height varies between 47.8 cm (Cave in rock)-70 cm (Alamo), the number of stems per square meter varies between 229.8 adet (Cave in rock)-448.5 adet (Trailblazer) and the stem weight varies between 0.78 g (Trailblazer)-1.24 g (Kanlow) (Gönülal and Soylu, 2021).

In the study carried out to determine the cultivation potential of branched millet varieties as a bioenergy plant in the ecological conditions of the Eastern Anatolia region; 5 different branched millet cultivars (Alamo, Cave in Rock, Cloud Nine, Kanlow and Shawnee) were used as plant material. In the results of working; it has been reported that the plant height of switchgrass varies between 157.3-200.1 cm and biomass yields between 845-1756 kg/da (Tutar, 2021).

Quality

Switchgrass, which has a very high herbage yield but low herbage quality, has the potential to find cultivation areas in our country. It is an important advantage of cool climate forage crops to produce in the summer months when their yield decreases. It is possible to evaluate the herbage, which is not very high quality, as silage. Crude protein ratios in switchgrass are between 5-6%. In some genotypes, this rate can be as high as 16%. ADF ratios of switchgrass vary between 30-50%, NDF ratios between 50-70% and digestible dry matter ratios between 55-60% (Çeliktaş et al., 2017; Doğuş, 2017; Baz, 2018).

As a result of the study carried out with 12 different varieties of switchgrass planted in the spring of 1998 within the scope of the European Union project in the Netherlands; it was determined that the dry biomass yield was obtained as 0.93 t/ha, 6.7 t/ha and 12.8 t/ha, crude ash ratios as 34.9, 21.3 and 21.5 g/kg, nitrogen amounts as 16.63, 5.01 and 7.46 g/kg, phosphorus ratios as 1.55, 0.64 and 0.92 g/kg, calcium ratios as 3.25, 3.80 and 2.92 g/kg, potassium ratios as 2.10, 2.55 and 2.54 g/kg, sodium ratios as 85, 107 and 83 g/kg, magnesium ratios as 1.14, 1.17 and 1.15 g/kg, respectively, in the 1st, 2nd and 3rd year harvests (Elbersen et al., 2002b).

In a study conducted by Lemus et al. (2002) on 20 different switchgrass ecotypes in the south of the USA; it has been reported that the biomass yield was 9.0 t/ha, plant height was 140 cm, NDF ratio was 73.1%, ADF ratio was 42.1%, lignin ratio was 6.1%, hemicellulose ratio was 31.6%, cellulose ratio was 36.1%, crude ash ratio was 6.1% and total nitrogen ratio was 0.54%.

In the research conducted to investigate the biomass quality of switchgrass species; it was determined that the volatile matter rate was

71.5%, the ash ratio was 3.7%, the lignin ratio was 6.1%, the hemicellulose ratio was 36.0%, the cellulose ratio was 31.6%, the nitrogen ratio was 0.6% and the sulfur ratio was 0.04% (Karp and Shield, 2008).

In a study conducted by Xiong et al. (2008) in a semi-arid region of North China, to investigate whether delayed harvesting improves the quality of fuel in 5 potential energy crops; it was determined that the calorific value of the switchgrass species was between 16.50-17.42 MJ/kg, the ash ratio was between 3.48-5.69%, the carbon ratio was between 46.51-46.88%, the hydrogen ratio was between 6.03-6.07% and the nitrogen ratio was between 0.24-0.60%.

In the study conducted by Gupta and Demirbaş (2010); it has been reported that the calorific value of the switchgrass species was 18.3 MJ/kg, the ash content was 4.5-5.8%, the sulfur content was 0.12%, the cellulose content was 45.0%, the hemicellulose ratio was 31.4% and the lignin ratio was 12.0%, and these values obtained from the switchgrass were superior to many species used for bioenergy purposes.

In a study using the Alamo variety of the switchgrass plant, it was reported that the biomass yield was 15.4 t/ha, the bioethanol yield was 2172 kg/ha, the cellulose ratio was 30.3%, the hemicellulose ratio was 19.8%, the lignin ratio was 19.6%, and the ash ratio was 4.0%. In addition, it was reported that the chemical composition contents (C, H, N, O) were determined as 44.0%, 6.01%, 0.67%, 45.3%, respectively, and the upper calorific value was 17.7 MJ/kg. (Hu et al., 2017).

In a study conducted in Izmir-Bornova in order to determine the effect of different cutting frequencies on feed yield and quality in switchgrass; it has been reported that the crude protein ratio varies between 5.7-12.7%, the metabolic energy varies between 1220-2178 kcal/kg, and the relative feed value varies between 62-123 (Kesen and Geren, 2020). On the other hand, in the study conducted in Van ecological conditions in order to determine the biomass and feed quality of switchgrass cultivars harvested at different maturation periods; it has been reported that the protein content varies between 1.06%-8.67%, dry matter content varies between 36-92%, NDF content varies between 63-88%, ADF content varies between 34-55%, crude ash rate varies between 5.96-10.09%, cellulose content varies between 27-46% (Zorer Çelebi and Ekin, 2020).

An Alternative Biofuel Plant

Alternative and renewable energy sources consist of wind, water, solar, geothermal and biomass (Kavruk and Atalay, 2007). Biomass; It is a renewable energy source that is obtained from plants and agricultural wastes, has very important advantages such as clean, easily obtainable, sustainable and environmentally friendly (Kapluhan, 2014). Among the alternative energy sources, biofuels produced mostly from biomass are at the forefront (Gross et al., 2003). Looking at the 2018 data; It is seen that 14.0% of the world's energy supply is obtained from renewable energy sources, and 67.5% of this rate consists of biomass. In Turkey, it is reported that 13.4% of the energy supply is obtained from renewable energy sources and 15.5% of this rate consists of biomass (IEA, 2020).

Energy crops are environmentally friendly, renewable and energy sources that can grow under different ecological conditions. Perennial grasses such as switchgrass and miscanthus are preferred primarily in biomass energy because they have higher biomass, low input requirements and long-term life form compared to annual plants (Wrobel et al. 2009).

Switchgrass (*Panicum virgatum* L.) was selected as a model species among 37 plants by the American Bioenergy Program for cellulosic ethanol production due to its high biomass yield, wide adaptability and ability to make good use of marginal areas (Wright and Turhollow, 2010). On the other hand; other superior agricultural characteristics such as being drought and flood resistant, low pesticide and fertilizer requirement, easy planting and high biomass yield for many years, increasing soil organic matter and being a good erosion control plant with its strong root system have brought this species to the fore. 1 ton of switchgrass biomass has the capacity to produce 380 liters of bioethanol. In addition to being a biofuel plant, switchgrass has become an important biomass plant for different energy usage areas due to its high energy content. The fact that the heating values of biomass are equivalent to many solid fuel sources, ease of production, ability to use marginal areas have brought the switchgrass plant to an advantageous position. However, switchgrass has the potential to be an important raw material source for the paper industry, thanks to the high cellulose in its cell wall (Ekmekçi, 2017).

In a study conducted by McKendry (2002) on switchgrass, it was reported that the lignin ratio was 5-20%, the cellulose ratio was between 30-50%, the hemicellulose ratio was between 10-40% and the upper calorific value was 17.4 MJ/kg.

In the study carried out to determine the cultivation possibilities of branched millet in our country, 9 varieties of switchgrass (Blackwell, Shawnee, Kanlow, Carthage, Forestburg, Cave in Rock, Shelter, Alamo, Dacotah) were used; reported that the second and third year performances of switchgrass varieties, which is a perennial plant, were evaluated. In the study, it was stated that the energy values varied between 18.062-18.740 Mj/kg and 17.840-19.059 Mj/kg, respectively, in 2008 and 2009 (Soylu et al., 2010).

In the study conducted by Vamvuka et al. (2010) to determine the effect of different irrigation and fertilization on the biomass yield of the switchgrass plant in the ecological conditions of Greece, it was reported that irrigation levels had a significant effect on the dry matter yield, while fertilization did not have a significant effect. As a result of the research; it was determined that the dry matter yield was similar (15.4-24.0 t/ha) in the 2nd and 3rd years, the volatile matter rate was between 70-85%, the calorific value was between 24-26 MJ/kg, and the ash content was between 1.8-10.0%. In addition, according to the results of elemental analysis; it has been reported that the carbon ratio is 41.1-46.0%, the hydrogen ratio was 6.3%-6.6%, the nitrogen ratio was between 0.10-0.69%, the sulfur ratio was between 0.02-0.07% and the oxygen ratio was between 41.4-45.8%.

In the study conducted by Mitchell and Schmer (2012) with two different switchgrass ecotypes; It has been reported that a single harvest at the end of the season is suitable for production for energy purposes, and the shape is suitable for production to be made for herbage or silage purposes, depending on the variety, twice at the end of July and at the end of October, leaving 10-15 cm of stubble.

In a study conducted by Başar et al. (2020) to determine the effect of enzyme dose on bioethanol production from switchgrass biomass, in Shawne cultivar; It has been reported that 34.76% of hemicellulose, 33.13% of cellulose, 5.57% of lignin, 40.13% of carbon, 5.75% of hydrogen and 0.87% of nitrogen were obtained, and the sulfur content could not be determined. It was reported that hemicellulose ratio was 36.24%, cellulose ratio was 35.94%, lignin ratio was 5.42%, carbon ratio was 41.95%, hydrogen ratio was 6.14%, nitrogen ratio was 0.35%, and sulfur ratio could not be determined in Kanlow variety.

In the study conducted by Tang et al. (2020) to determine the response of switchgrass grown for feed and energy in semi-arid marginal land to nitrogen, phosphorus and potassium; it has been reported that nitrogen is the most determining factor in the production of switchgrass, and potassium and phosphorus should be taken into account in the quality of feed and bioenergy products to be obtained from switchgrass. In addition, it has been reported that ethanol yields in Nitrogen-

Phosphorus-Potassium application were determined as 2532 l/ha in 2015 and 2797 l/ha in 2016.

In the study carried out to determine the cultivation potential of switchgrass varieties as a bioenergy plant in the ecological conditions of the Eastern Anatolia Region; it has been reported that the calorific value of switchgrass varies between 17.02-17.99 MJ/kg, and the bioethanol yield varies between 147.2-409.7 l/da, the C, H, N, S and O_2 contents were between 42.66%-45.21%, 5.55%-5.92%, 0.71-1.11%, 0.019-0.025%, and 47.83-51.06%, respectively (Tutar, 2021).

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CHAPTER 16

Perennıal Ryegrass (*Lolium perenne* L.)

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INTRODUCTION

Perennial ryegrass is the most widely used grass in both Turkey and the World. It originated from Southern Europe, Southwest Asia, and North Africa. Perennial ryegrass is the one of earliest forage crops to be domesticated around the 17th century. It has a vast range of adaptation and wide distribution in the temperate climate zone of the northern hemisphere. *Lolium perenne* is a short-lived perennial grass with a bunch-type growth habit.

Perennial ryegrass is utilized in many purposes thanks to its resistance to heavy grazing, ability to continue development in temperate and humid regions for a long time, palatability and glory leaf structure. It is often used for grazing pasture in mixtures, but is also used for hay, silage soil conservation and turf.-Perennial ryegrass can be grazed as both summer and winter pasture in temperate climates in mixtures. It is grown as pure stand or in mixtures with forage grasses and legumes. It produces high yield of very quality forage. It is a perennial grass that preferred for hay production because of its ability to maintain palatability in the later stages of maturity and the high fiber digestibility (Açıkgöz, 2021, Baytekin et al, 2009; Manga et al, 2002).

Perennial ryegrass is also utilized for turf grass in recreation areas, sports turf, golf courses and so on (Açıkgöz, 1994). It is most widely used amenity grass in the world thanks to its ability for easy establishment, rapid covering soil surface, high mowing and wear tolerance. In recent years many varieties have been developed with many functions including growth characteristics such as plant form, shoot and root density, fineness of leaf and cleanness of cutting and the more complex traits such as mowing, wear, disease tolerance and colour.

The overall breeding objective of grasses is to improve the plant species for forage and turf. For forages, breeding objectives include higher yield, higher quality of crude protein, carbohydrate and water-soluble carbohydrate, greater vigor and persistence, resistance to pests, and greater tolerance to soil and climatic conditions, while for turf, breeding objectives include plant form, shoot root density, fineness of leaf, cleanness of cutting, wear tolerance and disease resistance and colour (Frame, 1994; Hannaway et al, 1999; Van Huylenbroeck, J. M. 1999; Arslan and Çakmakcı, 2004; Orr et al, 2004; Simit et al, 2005a; Simit et al, 2005b).

Perennial ryegrass has a vast range of adaptation and wide distribution in Turkey's natural flora (Elçi, 2005). However, breeding and agronomy studies on perennial ryegrasses in Turkey have generally been carried out using varieties imported from abroad. There are also a limited number of breeding works with genotypes collected from the natural flora of Turkey.

Distribution, Taxonomy and Plant Characteristic

Perennial ryegrass (*Lolium perenne* L.), a native of southern Europe, the Middle East, North Africa, and eastwards to central Asia, was introduced to the United States, South Africa, and Australia (Fig. 1). Today, it is cultivated in many countries of the world.

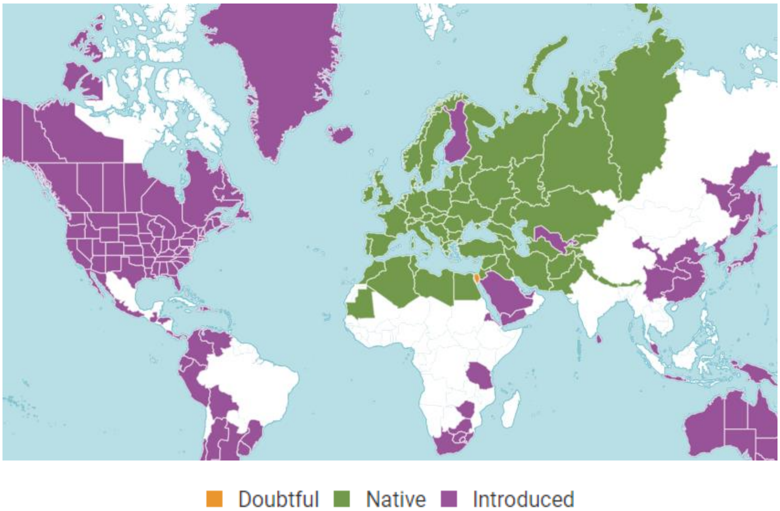

Fig. 1. Origin and Distribution of Grasses (Anonymus 1)

Taxonomy of perennial ryegrass

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Monocotyledonae

Family: Poaceae

Genus: Loli

Species: Lolium perenne L.

Perennial ryegrass has many subspecies such as *subsp. perenne*, *subsp. multiflorum*, *subsp. remotum* and *var. cristatum* althoug the cultivated species is *Lolium perenne L.* subspecies. *Lolium perenne L.* has 2n=14 chromosome number that is capable to cross with *Lolium multiflorum L.*

The species resulting from this hybridization is generally identified as *Lolium hybridum.* There are many varieties available commercially as a result of this crossing. Also, many cultivars have been developed from the hybrids of *Lolium perenne L.* with *Festuca arundinacea schreb.* and *Festuca pratensis L.*. The species that developed by crossing between *Lolium perenne L.* with *Festuca arundinacea* Schreb. is called Festulolium and many studies are being conducted on it.

Root: Perennial ryegrass has a shallow fibrous root system. The primary root that emerges after the germination of the seed loses its function with the presence of the adventitious roots. Densely adventitious roots emerge from the nodes of the stem close to the ground.

Stem: Perennial ryegrass is bunch-type growth habit with abundant tiller. It has short rhizomes. The stems are erect and consist of nodes and internodes. Each node produces a leaf. Stems can reach height of 100 cm. The color is the stem base is red that is a identification feature in early development stage (Serin and Tan, 1998; Peeters, 2011; Sanford,2011).

Figure 2. Development status of single plants in perennial ryegrass (Samsun)

Leave: The leaf consists of a leaf sheath and leaf blade. The leaf sheath wraps around the stem and folds over in perennial ryegrass, unlike annual grass. The leaf blade is 2-6 mm wide, 5-15 cm long, and ends with a sharp edge. The back surface of the leaf is smooth, shiny and hairless. The leaf sheath covers the stem and is hairless and is cylindrical. The junction of the leaf sheath and stem is reddish. A ligule and auricles are located at the joint of the leaf blade and leaf sheath. The ligule is a membrane-like and has short hair rarely. The auricles remind is claw-like.

a b c

Figure 3. Tillage in perennial ryegrass (a and b), leaf parts (c) (Anonymus 2)

Inflorescence: The inflorescence is narrow spike with flattened spikelets. It is up to 30 cm and each spike has 5-40 spikelets attached edgewise directly to the spike axis. Each spikelet contains 3-10 florets. Only two spikelets at the tip of the spike contain glume. It is a cross-pollinated species with three male (pollen grain) and one female (stigma) organs in each floret (Serin and Tan, 1998; Sanford,2011).

Seed: The seed structure is a caryopsis wrapped with inner glumes. Seeds are 5-8 mm long, 1-1.5 cm wide, and the average thousand-grain weight is 1.8-2 grams (Serin and Tan, 1998; Peeters, 2011; Sanford,2011).

a b c

Figure 4. Generative parts in perennial ryegrass. flower(a), spike (b) and seed(c) (Anonymus 3)

Climate and Soil Requirements

Perennial ryegrass is common in Turkey's natural flora. It is preferred in sheep and cattle grazing systems thanks to its tolerance to heavy grazing (Jung at all, 1996). It has adapted to temperate climatic regions with regular precipitation and high relative humidity. It has poor tolerance to shade, drought, and high and low temperatures. It grows rapidly in spring and autumn in contrast it is dormant in hot summer with a lack of moisture in the soil. Perennial ryegrass is best grown in the soil with well-drained, high organic matter. It is possible to get high yield in poor soil condition with a good irrigation and fertilizer management. It is well adapted to humid soil but its waterlogging tolerance is poor but it can tolerate short-term waterlogging (Açıkgöz, 1994; Manga at all, 2002). It grows in both acidic and basic soils (Polok, 2007). It is highly adaptable in slightly saline soils (Geçit at all, 2009).

Cultivation and Management

A firm and well-prepared seedbed is essential for successful establishment because the seed size of perennial ryegrass is small. Perennial ryegrass should be planted in early-spring and fall. In temperate regions fall-seeding results with well-establishment. If it is utilized winter pasture, the best planting time is early-fall. Irrigation is required to escape drought stress in spring with low precipitation otherwise it does not persist because of weak root system that is affected high temperature condition in summer season. The seeding rate differ using purpose. It is 2-3 kg per da in pure stand, 1 kg per da in mixtures with legumes. If perennial ryegrass seeds will be planted as broadcast, the seed rate is doubled. Lastly, the seeding rate is 24-40 kg per da when the seed is used in lawn.

The seeding deep is also important for well-establishment. That seeding deep should be 1-2 cm and row space 15-30 cm. Both seeder and broadcast seeding techniques are successful to cultivate perennial ryegrass in well-distributed precipitation regime. Fertilizer should be applied based on soil analysis results. Fertilizer N application in perennial ryegrass is resulted with high yield because it belongs to gramineae family. In establihment year fertilizer N and P_2O_5 should be applied together. The fertilizer rate of P_2O_5 and N should be 5-6 and 4-5 (half of the fertilizer N required) kg per da, respectively. The rest of fertilizer N should be applied at the beginning of active growth period.

The effectiveness of the applied nitrogen fertilizer differs according to the period of seasons. 8-10 kg nitrogen fertilizer should be enough in the region with well-distributed precipitation regime with an annual average of 400-600 mm. Baytekin et al. (2009) reported that perennial ryegrass produced high dry matter yield with fertilizer N application of 18 kg per da in irrigated condition. When perennial ryegrass is grown in mixtures with legumes, the need for fertilizer N is low thanks to rhizobium activities in legume roots. Applying fertilizer after cutting/grazing and/or before irrigation increases nitrogen utilization efficiency. However, the most effective application method should be determined by considering the condition of the soil, plant and animal needs and sustainability.

Uses for Hay

Perennial ryegrass is a forage plant utilized in hay production because of its high digestibility, palatability that maintains the later stages of development. To obtain high-quality forage for hay, harvest perennial ryegrass at the seed head emergency and early anthesis stage. At this cutting time, perennial ryegrass contains crude protein 10-15 %, ADF 35-40 % and NDF 50- 63 % (Kılıçalp et al, 2019). Late harvesting time does not affect too much forage quality of perennial ryegrass negatively. However, if the harvest is delayed further, crude protein ratio and the digestibility of leaves and stems decreases (Açıkgöz, 2021, Baytekin et al, 2009; Manga et al, 2002). In a study conducted in Samsun ecological condition, the crude protein ratio varied between 4.68-8.50% at different harvest times (Sancak and Manga, 1991). Perennial ryegrass is also grown in mixtures with white clover and red clover for hay production.

In the many region of Turkey, two-three harvests are possible. The cutting height is around four to five cm. The yield of the perennial ryegrass differ according to palnting time and irrigation water availability. In a study in which some agricultural characteristics of 37 perennial grass (*Lolium perenne* L.) germplasm collected from the natural flora of Turkey, avearge plant height varied between 45.00 – 102.60 cm and dry matter yield between 12.4 - 177.6 g/plant (İnal, 2019). In the study carried out in the Ol-joro-Orok region of Kenya, the dry matter yield varied between 14.6 and 18.0 t/ha in perennial ryegrass parcels (Mwendıa vd., 2019). A study conducted in Ireland, dry matter yield was determined in three maturity (early, medium and late) periods and two ploidy (diploid and tetraploid) levels of perennial ryegrass. In early, medium and late stages, dry matter yield were determined with 14.08, 10.58 and 14.46 t/ha, respectivelly. In the diploid and tetraploid levels, dry matter yield were determined with 14.03 and 14.71 t/ha, respectivelly (Burns, 2013).

In a study conducted with perennial ryegrass in China, the effect of 6 different cutting treatments on dry matter yield was investigated for two years (treatments; 8 cutting, 4 cutting, 2 cutting, 1 cutting in Jun, 1 cutting in August and no cutting in a year). It has been shown that as the number of cuttings increases, the total yield in two years increases, but this increase caused the yield of the pasture to decrease in the second year. For optimum yield, the best cutting frequency was determined as four times a year (Wen and Jiang, 2005).

Figure 5. Pollination and post-fertilization view in perennial ryegrass (Samsun)

Sağlamtimur et al. (1986) reported that perennial ryegrass had fresh yield with 2620-4700 kg/da in following two years in ecological condition of Çukurova, Adana. In a study conducted with perennial ryegrass, the average dry matter yield was determined with 2019 kg/da at the average plant height of 43.97 cm in two years in the Harran plain, Adana (Şılbır et al, 1994).

Figure 6. Spike period in perennial ryegrass (Samsun)

In a study conducted in Samsun conditions, perennial ryegrass is grown with forage chicory in the mixture. The mixture was harvest at the budding period of chicory. In a study conducted in Samsun conditions, perennial ryegrass mixtures were designed with forage chicory, lucerne, and red clover in the mixture. Dry matter yields of pure stand perennial ryegrass were obtained with 356 and 284 kg/da in the following two years. Dry matter yields of the mixture with chicory and red clover were determined with 2424 kg/da in the first year and 1669 kg/da in the second year. The mixture was harvested at the budding stage of chicory. Dry matter yields of the mixture with lucern were determined with 1345 kg/da in the first year and 1452 kg/da in the following year (Can and Ayan, 2019).

Uses for Grazing

Perennial ryegrass is a cool-season perennial bunch-type grass with high palatability and digestibility. Its tolerance to grazing, wear, and persistence make this species highly valued for cattle and sheep grazing systems. Thanks to its fast-growing ability, grazing may be started after three to four months of planting.

Mixtures with perennial ryegrass can be grazed as both summer and winter pasture in temperate climates. Grazing should start when perennial grass pastures reach the length of 20-25 cm at 5 cm of stubble. Post grazing, the pasture should graze for 2-3 weeks to recover. Sheep gain high live weight in mixtures including perennial ryegrass. It can be grown in pure stand or mixture with forage legumes and other grass in sown pasture systems. It is a good pasture species in mixture with various legumes, especially white clover, strawberry clover and subterranean clover. In recent years, sown pastures with perennial ryegrass, white clover (*Trifolium repens*), narrow-leaved plantain (*Plantago lanceolata*) and chicory (*Cichorium intybus* L.) have been designed in order to provide rapid live weight gain in lambs (Somasiri et al, 2015). Hutton et al. (2011) reported that milk production and live weight gain in sheep grazing on perennial ryegrass dominated pastures are higher in a study conducted in New Zealand. In France's ecological condition, Niderkorn et al. (2016) determined that perennial ryegrass and white clover mixtures increased the feed intake of sheep and positively affected their grazing motivation.

In the ecological conditions of Samsun, 3 cuttings were made in the first year during the grazing maturity period in the sown pasture mix with red clover, perennial ryegrass, and forage chicory. Dry matter of 2270 kg/da was obtained. In the second year, 4 cuttings were made and a dry matter yield of 3488 kg/da was obtained. In the same experiment, a dry yield of 1527 kg/da in the first year and 2677 kg/da in the second year was obtained in the mixtures with white clover, perennial ryegrass, and forage chicory (Can and Ayan, 2020).

One of the important problems seen in animals grazing in pastures is mycotoxin poisoning. Animals that graze plants contaminated with mycotoxins may cause some problems, particularly in the immune system. The most common mycotoxin poisoning in pastures is ryegrass stagger and fescue-poisoning. Ryegrass stagger can be a problem, caused by some alkaloids produced by the fungus of Neotyphodium lolii. Due to the secondary metabolites (ergopeptin, ergovaline) produced by the plants in which these endophytes are found, some toxic effects can be seen in animals consuming these plants. Nervous disturbances such as head shaking, spasms, and kicking in the feet are seen in animals that graze contaminated plants with these fungi. For this reason, the live weight gain in livestocks decreases. This problem is resolved by changing the feed source (Allen and Segerra, 2001; Menna et al., 2012). As a result of intensive research and applications, the seeds of infected grass plants were obtained with isolates of endophytes that produce the least or no toxins.

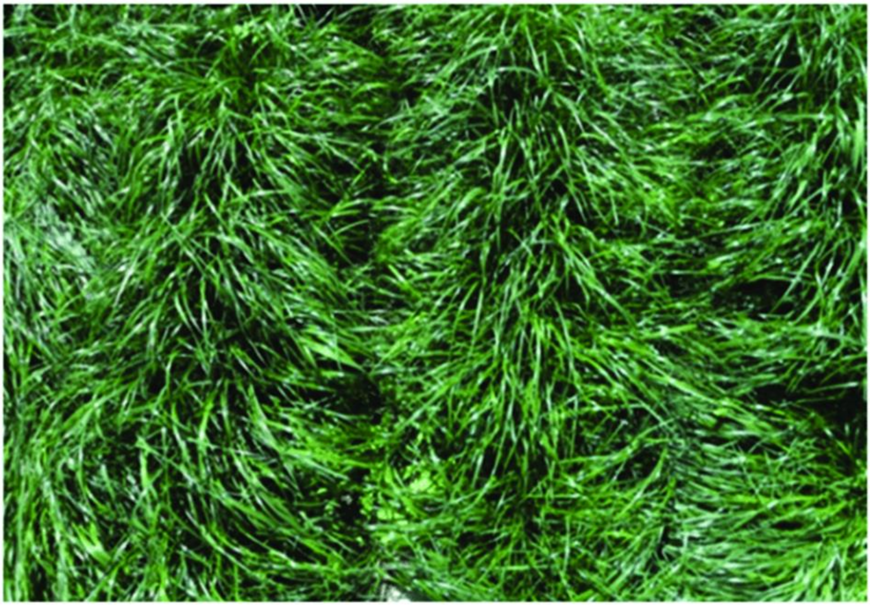

Figure 7. Perennial ryegrass grazing maturity period. (Petrova et al. 2022)

Uses for Turf

In order to better benefit from the contribution of green to nature and human beings, the feature of grass to be used in the area greened and its capability to the ecological conditions of the region should be considered. Perennial grass is used extensively in parks and gardens, sports fields, highways, and for many other different purposes (Açıkgöz, 1994; Avcıoğlu, 2014). It is one of the important turf plants thanks to its dense texture of leaf structure, bright green color, and quick establishment feature. It is mainly used in almost all turf mixtures, especially in sports fields. Many turf types of grass cultivars have been bred with short height and tolerance to diseases and frequent mowing in different countries (Açıkgöz 2021). Perennial ryegrass is also used for inter seeding of current turf. Warm-season grass plants become dormant in the fall and the color of the plants turns yellow. Perennial ryegrass seeds sprinkled on these areas form a green cover during the winter and spring months until warm season plants begin to develop the following year. Thus, a green image is provided in gardens and parks all year round.

The perennial grass can be grown pure stand or a mixture in green areas. In these mixtures, other turf grass plants can be used, as well as legumes such as narrow-leaved white clover (Trifolium repens L.). For the purpose of green field establishment, the seed bed should be prepared with a good soil cultivation. Weed control is important whether planting is in spring or autumn. Perennial ryegrass can compete with weeds because it covers the soil quickly. Turf type grasses should be mowed from a height of 4-5 cm. The cutting frequency should be adjusted according to the developmental stages of the plants. Cuttings should be interrupted in hot and dry weather. The mown grass should be collected with a rake and removed from the plot.

In a study conducted in Bursa conditions, it was reported that the covering speed was at the highest level in mixtures with a high percentage of perennial ryegrass, and a high value of 8.0 in terms of color value was obtained in mixtures with a high percentage of perennial ryegrass (Oral and Açıkgöz, 1999). A study was conducted on the suitability of some perennial ryegrass (*Lolium perenne* L.) cultivars for green areas in the Aegean Region coastal zone conditions. According to the results of two years of research, it was determined that Ballet and Greenway varieties were very successful in terms of covering degree, number of tilling, color, texture, general appearance and infrequency degree characteristics and were well adapted to the conditions of this region (Demiroğlu et al, 2010).

Türk and Sözören (2016) determined that the effects of nitrogen fertilizer applications on turf performance are important in a study they conducted using different grass varieties and different nitrogen doses in Isparta conditions. They stated that with increasing nitrogen doses, winter endurance, ground cover rate, leaf color, regeneration power, tiller number, general appearance and dry matter yield values also increased. In Samsun ecological conditions, in a study carried out to determine the weed suppression rate of mixtures in green areas, it was determined that the covering speed values of the mixtures made with *Lolium perenne* varied between 43-53 days, and the covering speed of the mixtures made with *Festuca arundinacea* ranged between 53-64 days. In addition, it has been determined that the weed rate is very low at 50 and 60 g/m^2 sowing rates (Saygın, 2019).

Figure 8. Use of perennial ryegrass in green areas (Anonymus 4).

Seed Production

Perennial ryegrass seed production is concentrated in certain parts of the world. Northern European countries, especially Denmark and the Netherlands, US state of Oregon and New Zealand are the main centers of seed production.

Sowing is done between 15-20 cm row space in areas that receive regular precipitation or can be irrigated. In sowing, 1-2 kg/da of seeds are used. *Lolium perenne* grows very quickly in appropriate conditions. The biggest problem in perennial ryegrass seed production is lodging. After the heading stage, the plants lodge easily, especially in areas with abundant precipitation. Pollination and fertilization of lodged plants is greatly disrupted and yield loss occurs in seed production. Lodging problem; sowing rate, fertilization and growth regulators are tried to be prevented.

Fertilization in seed production requires more attention than fertilization in hay production and should be given in limited amounts. Extra nitrogen encourages vegetative growth and causes plants to lodging. It is sufficient to give 8-12 kg/da of nitrogen in areas that can be irrigated or receive regular precipitation. A study was conducted using perennial ryegrass varieties named Lasso, Tetramax, Tove and Spira in order to investigate the effect of nitrogen fertilization on hay and seed yield in Samsun-Çarşamba ecological conditions. Nitrogenous fertilization was considered as a factor and applied as 0, 4, 8, 12 kg N per decare. At the end of the research, it was determined that the highest hay and seed yield was obtained from the Tove variety, the highest hay yield was obtained from 8 kg nitrogen application per decare, and the highest seed yield was obtained from the plots without nitrogen application (Aşçı et al. 2003). In a study conducted in Tekirdağ ecological conditions, it was stated that nitrogen fertilization had a positive effect on the seed yield, number of fertile tillers, plant height and biological yield of perennial grass (*Lolium perenne* L.) and negatively affected the harvest index. With this research, it was determined that the suitable dose of nitrogen fertilizer for seed production of perennial ryegrass plant was 12 kg N/da (Nizam, 2009).

In areas where there is no water shortage, grazing or cutting of perennial ryegrass fields in the fall does not have a negative effect on seed yield. Autumn grazing increases the number of fertile tillers, reduces the risk of lodging and is known to reduce winter damage.

Harvesting of perennial ryegrass seed is done at a time when the moisture content of the seed drops by 30%. After harvesting with a combine harvester in Northern European countries, the seeds are dried with air circulation in the warehouses. In some cases, all the plants are mown and brought to the barn. The dried plants are then threshed. In drier areas, plants can be harvested with a combine in the yellow ripening phase. Not delaying the harvest period is important in terms of seed loss.

Figure 9. Milk-dough stage of perennial ryegrass (Samsun)

In Northern European countries, the seed yield of perennial ryegrass varies between 30-100 kg/da. In irrigated areas, it can exceed 100 kg/da. In temperate regions, the seed yield can reach 250 kg/da. Forage grass seed yields are often low and variable with only 10-20% of florets producing saleable seed. Seed yield can be influenced directly or indirectly by agronomic components such as plant height, leaf area, dry-matter yield, and lodging resistance. In perennial ryegrass the difference between potential seed yield and actual seed yield is large and variable (Elgersma 1990, Rolston et al. 2007). Elgersma (1990) found that seed yield in perennial ryegrass was more correlated with the number of seeds per unit area than with seed weight. We conclude that the total availability of N has an effect on the fresh weight of the plants, the number of seeds and the N accumulation in the seeds, and that the effect of an additional N application is dependent on the current plant N status.

Diseases and Pests

Perennial ryegrass is susceptible to some types of fungi, and in moist areas, rust-colored molds appear in the middle of the tufts. Stalk, stem rust and bacterial wilts occur due to weather changes and species susceptibility. At the end of summer and at the beginning of autumn, rust disease may occur in the stalk and tuft, especially with precipitation. This situation does not create a toxic situation for livestocks, it only leads to a decrease in the quality of the grass and a decrease in taste. In addition, perennial ryegrass is susceptible to rye spur and bunt disease in moist areas. Care should be taken that animals do not graze on contaminated areas.

Neotyphodium lolii or *Acremonium lolii* endophyte fungi can be seen in some areas, causing nervous diseases and partial paralysis. Fungicide application is recommended against this fungus that spreads by seeds. Pests such as *Listronotus bonariensis*, *Heteronychus arator*, *Balanococcus poae*, *Aploneura lentisci* can be seen in perennial ryegrass that damage the stem and roots.

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CHAPTER 17

Tall Fescue (*Festuca arundinacea* Schreb.)

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INTRODUCTION

Tall fescue is a perennial, cool season, C3 species with high growth rate. Three major morphotypes (continental, Mediterranean and rhizomatous) are described for this species. Tall fescue is the most suitable cool-season turfgrass for the Mediterranean region. Tall fescue is drought resistant and maintains itself under limited fertility conditions. It is also ideal for waterways, pond banks, and farm lots. It is the best grass for areas of heavy livestock and machinery traffic. Endophyte-free and friendly-endohyte varieties are now available. Here in this review, crop properties of tall fescue is given with different approaches.

Tall fescue (Species: *Festuca arundinacea*; Genus: *Festuca*; Family: *Poaceae*) is a perennial, cool season, C3 species native to Europe. Its high growth rate, drought resilience and herbivory protection accelerated its spread from Europe. It turned into an invasive species in native grasslands and other habitats and a native biodiversity reducer. Its association with fungal endophytes result with bioactive alkaloid production which help plant for plant protection against insects, larger grazers and nematodes. This increase success of the plant. Following the introduction of *F. arundinacea* as a forage grass, poor animal performance reports emerged particularly in North America. Ergot alkaloids produced within the grass was linked to tall fescue toxicosis in animals. This toxicosis can result with aborted foetuses in livestock and some species of wild animals. Endophyte-free grasses are less aggressive compared to infected counterparts, and do not have same threat (CABI, 2021).

Tall fescue is a perennial grass producing loose, large, sometimes dense tussocks, without short rhizomes and stolons. Culms are unbranched, erect, smooth and 40-200 cm long. Lower sheaths are un-fused, smooth and rounded on the back. Leaves are dark-green, usually flat, stiff, 1-12 mm wide, 10-105 cm long, rough or smooth below only and scabrous on margin. Panicles are 6-50 cm long, green or purplish, wide, erect or pendant, includes rough branches in pairs. Pedicels are up to 8 mm long. Spikelets are elliptic to oblong, 8-18 mm long and with 3-10 florets (Gibson and Newman, 2001).

Genetic improvement of allohexaploid *Festuca arundinacea* Schreb. (syn. *Lolium arundinaceum* [Schreb.] Darbysh.) could benefit from the use of non-domesticated germplasm to diversify breeding populations through the incorporation of novel and superior allele content. Three major morphotypes (Mediterranean, continental and rhizomatous) with varied degrees of hybrid interfertility are described for tall fescue (Hand et al., 2012).

Water and climate change issue is present in many countries. Drought stress is among main stresses effecting turfgrass growth, yield and quality. Tall fescue is the most suitable cool-season turfgrass for the Mediterranean region. Its heat tolerance is higher than Kentucky bluegrass and perennial ryegrass (Caturegli et al., 2015).

AGRONOMY

Tall fescue is desired to plant in transition-zones (Sarmast et al., 2015). It is an important turf and forage grass widely prefered for home lawns and golf areas in transition zone states of the United States (Zhou et al., 2016). Summer dormancy is an important stress escape mechanism of cool season perennial grasses under extreme summers (Talukder et al., 2020). Tall fescue is a temperate grassland species but in different regions in the world heat, drought, and poor grazing management applications reduce crop's persistence during summers. Poor ground cover and low tiller population density in winter result with reduced sunlight capture and limited growth. Knowledge on fertilization, defoliation management and establishment methods on tall fescue may improve sward management with better persistence and winter growth (Scheneiter and Amendola, 2012).

Brink et al., (2010) compared the productivity, nutritive value, and persistence of tall fescue and orchardgrass (*Dactylis glomerata* L.) when harvested by regimes representing lax and severe hay production and rotational grazing. Crops were harvested infrequently (40-65 days harvest interval) or frequently (when plants reached 25 cm sward height) to a 5-cm or 10-cm residual sward height. Tall fescue and orchardgrass annual yield was greater than all meadow fescues when harvested infrequently. Instead, differences among grasses were relatively small when harvested frequently, particularly at 10-cm residual sward height.

In many parts of Australia, climatic conditions are challenging for pasture producers. Combined effects of moisture deficit stress and heat during summer or early autumn, and cold-temperature stress with transient waterlogging during winter and early spring is a normal condition. Pasture species must show adaptation to survive. Few species fit to both waterlogging and drought stress. Tall fescue has adaptive traits which are not possessed by other pasture grasses. Summer-active tall fescue is generally more heat tolerant and deeper rooted than perennial ryegrass. It has comparable nutritive value during most of the year and benefit from improved summer productivity (Raeside et al., 2012).

Tall fescue is well adapted to acid, wet soils and produces more forage than other cool-season grasses on soils with a pH <5.5. Tall fescue is drought resistant and can maintain itself under limited fertility conditions. It is also ideal for waterways, pond banks, and farm lots. It is the best grass for heavy livestock and heavy machinery traffic. In the past, animals readily grazed tall fescue between April-early June, and again in the autumn, but they showed reluctance to graze it during July and August. Some of the reduced summer palatability results with poor animal performance and is associated with the presence of an endophytic fungus in the plant. The fungus grows between the plant cells and overwinters in the base of the plant. The fungus produces alkaloids which are toxic to animals. These alkaloids are thought to result with poor conception rates, low birth weights, and low daily gains of animals grazing fungus-infected tall fescue. By plant breeding, Endophyte-free and friendly-endohyte varieties are now available. Tall fescue is the best adapted cool-season grass to stockpile for use in autumn and winter. Also tall fescue is generally have higher quality in fall because of greater leaf retention compared to other cool-season grasses. Thus, tall fescue can supply most of the spring, autumn and winter feed for a beef cow herd. Endophyte-free and friendly-endohyte varieties are higher in quality than endophyte fungus infected varieties. Endophyte-infected varieties are suited for planting on reclaimed strip mines and for other conservation uses where soil conditions are adverse for plants. Spring seedings should be made as early as possible to avoid hot dry weather when the seedlings are small. Late-summer seedings usually have less weed competition and more favorable moisture conditions than spring seedings. For seeding tall fescue alone, 10-12 kg of seed per ha is adequate. For best results, band seed tall fescue 0,5 cm deep. Press wheels used in conjunction with band seeding add additional stand insurance. If the seedbed is dry and not firm, cultipack before seeding to make a firm seedbed. Don't graze closer than 7-10 cm, and allow at least 30 days for tall fescue to recover. Although tall fescue can achieve adequate yields on low pH soils, maximum productivity is at pH 6-7. If tall fescue is seeded alone, plow down 0-50-150 kg/ha (NPK) and apply 22-22-22 kg/ha acre at planting (banded if possible) at seeding. While small amounts of nitrogen and potash are beneficial at seeding, too high a concentration of these elements can interfere with germination. If pure tall fescue stands are used, high yields can be expected if fertilizer is applied during the winter or very early spring. This is especially true for the nitrogen fertilizer. Tall fescue to be used for hay should receive 45 to 70 kg N during the winter period. The same amount should be applied if tall fescue is to be used for early grazing. If much fall pasture is desired, re-apply fertilizer in July (Hall, 2016).

Genetics

Tall fescue is widely used in temperate regions throughout the world as a dominant forage grass as well as a turfgrass, in pastoral and turf industry. However, utilization of tall fescue is limited due to leaf roughness, poor regeneration ability and poor stress resistance. Understanding agronomic traits and describing germplasms will help to overcome these constraints. Morphological evaluation of tall fescue germplasm is a key component to select rational parents for hybridization. Describing morphological traits of tall fescue germplasm is costly and time-consuming but biotechnologic approaches can supplement conventional breeding efforts to improve tall fescue. Association mapping is a powerful approach to identify association between agronomic traits and molecular markers and widely used for enhancing utilization, conservation and management of the tall fescue germplasms (Lou et al., 2015).

In tall fescue breeding, a great effort is devoted to soft-leaved variety development due to common acceptance that leaf softness is positively correlated with digestibility and animal preference. In advanced breeding programs, it becomes difficult to discriminate the leaf softness between genotypes. Also, there is evidence that the digestibility of the softest varieties is not higher compared to coarse leaved varieties (Cougnon et al., 2016).

The potential of resistance to *Microdochium nivale* is still not recognized for numerous plant species. The forage grasses of Lolium-Festuca complex are important for grass-biomass production in the temperate regions. *Lolium multiflorum* is a grass with a high forage quality and productivity but relatively low resistant to *M. nivale*. But *F. arundinacea* has a higher resistance but lower forage quality. These two species cross with each other and the intergeneric hybrids possess complementary characters of both genera (Plazek et al., 2018).

The Continental morphotype of tall fescue is a main forage and turf grass species. Instead, it suffers from summer drought, especially in dry and hot climates. On the other hand, the Mediterranean morphotype of tall fescue display summer dormancy. Hybridization of the two morphotypes seems to be an efficient way to introgress summer dormancy from Mediterranean morphotypes into elite cultivars of the Continental morphotype (Kopecky et al., 2019).

Abıotıc and Biotic Stress

Plants frequently subject to periods of soil and air water deficits during their growth cycle. Drought is among the major factors limiting plant growth (Kosmala et al., 2012). As a result of global water scarcity, management strategies for planting and maintenance of vegetation, especially turfgrass, are changing in many countries. Tall fescue is among the most important and common used cool-season turfgrass species which is considered as drought tolerant (Mahdavi et al., 2020). Climate change impacts rainfall patterns and lead to drought stress in rainfed conditions. Drought tolerant crops are required on marginal lands (low precipitation recieving or soils with low water retention) for biomass production. It is essential to identify genotypes with improved drought tolerance and water use efficiency (Martensson et al., 2017). There is a growing interest in the use of deficit irrigation and perennial pasture species other than perennial ryegrass (*Lolium perenne* L.) in temperate agriculture, as a response to decreasing availability of irrigation water (Turner et al., 2012).

Festuca arundinacea is a model plant species for a group of forage grasses, comprising the Lolium-Festuca complex to recognize the crucial mechanisms of tolerance to water deficit and recovery after stress cessation. The *L. multiflorum/F. arundinacea* introgression forms are excellent plant materials for dissecting these important traits into several components (Masajada et al., 2018). Frost tolerance is the main component of winter-hardiness. With this trait, plants sense low temperature and respond by activation of cold acclimation process. The molecular mechanisms of this acclimation is not fully understood in the agronomically important group of forage grasses, including Lolium-Festuca species. The capacity to acclimate the photosynthetic machinery to cold could be one of the most crucial components of forage grass metabolism to improve frost tolerance (Augustyniak et al., 2018). Tall fescue, as a major cool-season forage and turf grass species is severely influenced by heat stress (Li et al., 2017).

Frequency and intensity of floods and the extent of salt-affected lands are expected to increase in pastures and grassland ecosystems as a result of global climate change. In general, F. arundinacea proved more tolerant to waterlogging than to salinity or combined treatments, and showed promising variability among cultivars with respect to root relative growth rate under the evaluated stresses, which can be used in future breeding programs (Menon-Martinez et al., 2021).

The most serious and frequently occurring disease of tall fescue is brown patch, caused by a basidiomycete fungus, *Rhizoctonia solani* (Zhou et al., 2016). Tall fescue plants are frequently exposed to Phyllophaga white grubs (*Coleoptera*: *Scarabaeidae*). Regarding the rate of damage caused by the white grubs to tall fescue and difficulty of its ecological and economical control, production of resistant cultivars is a priority (Hosseini et al., 2019).

Animal Feeding

Tall fescue is the primary pasture forage offered to goats in the southeastern United States (Browning et al., 2006). Cows grazing stockpiled tall fescue had increased nutrient intake during late gestation, resulting in greater fetal growth compared to cows consuming summer-baled tall fescue hay (Niederecker et al., 2018).

Tall fescue toxicosis adversely affects calving rate and weight gains reducing returns to cow-calf producers in the south–central United States. A grazing study conducted by xxx to estimate animal and economic performance implications of endophyte-infected fescue and calving season. Establishing novel endophyte-infected tall fescue on 25% of pasture acres resulted in improved calving rates (87% vs. 70%), weaning weights (532 lbs vs. 513 lbs), and partial returns per acre ($257 vs. $217). Additionally, fall-calving cows had higher calving rates (91% vs. 67%), weaning weights (550 lbs vs. 496 lbs), and partial returns per acre ($269 vs. $199) than spring calving cows (Smith et al., 2012).

In a two year study, Curtis et al., (2008) evaluated the effect of different forage allocations on the performance of lactating beef cows and their calves grazing stockpiled tall fescue. Allocations of stockpiled tall fescue at 2,25, 3,00, 3,75, and 4,50% of cow-calf pair body weight/d were set as experimental treatments. Conventional hay-feeding was also evaluated as a comparison to grazing stockpiled tall fescue. Allocating cow-calf pairs stockpiled tall fescue at 2,25% of body weight/d likely optimized its use. Because cow body condition was easily regained in the subsequent spring and summer months, less forage was used during winter, and calf gain per hectare was maximized (Curtis et al., 2008).

Conclusions

Tall fescue is a perennial, cool season, C3 species with high growth rate. Three major morphotypes (continental, Mediterranean and rhizomatous) are described for this species. Tall fescue is the most suitable cool-season turfgrass for the Mediterranean region. Tall fescue is drought resistant and maintains itself under limited fertility conditions. It is also ideal for waterways, pond banks, and farm lots. It is the best grass for areas of heavy livestock and machinery traffic. Endophyte-free and friendly-endohyte varieties are now available. Crop is suitable for forage, turfgrass and heavy metal extraction from contaminated soils.

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CHAPTER 18

Timothy (*Phleum pratense* L.)

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INTRODUCTION

Timothy is a cool-season perennial grass reaching up to 150 cm in height with its erect stems. It is grown mainly in Nordic European countries, in some parts of Canada, Western U.S. states, Japan, Serbia as a highly palatable pasture, hay and silage grass. Timothy is well adapted for cultivation in northern latitudes. Timothy grass is the most frequent cause of grass allergy in Europe. 8,5 t/ha dry matter yield was obtained in Poland in a trial. Photoperiod is the most important regulator of flowering in timothy. In addition, vernalization response was reported in many accessions.

Timothy (Family: *Poaceae*, Genus: *Phleum*, Species: *Phleum pratense* L.) is a cool-season hexaploid perennial grass (Tanhuanpaa et al., 2016). Timothy is a tufted or single-stemmed, tall, robust, hairless, short-lived grass that grows in stools or clumps, reaching up to 150 cm in height. Its stems are erect, often forming a small bulb at the base. The blade is rolled when young, 3-10 mm wide, flat, slightly rough on the margin, reaching 45 cm long, pale green to greyish green. The spike-like panicle is cylindrical, 6-30 cm long. Spikelets are one flowered and breaking up at maturity above the glumes. Seeds are small, 2 mm long, with a 1000-seed weight of 0,3-0,7 g. Plant produces 4000-10,000 tillers/m^2. Maximum number of leaves per tiller is up to 6-8. It is grown worldwide as a highly palatable pasture grass, particularly suitable for hay making. However, it is invasive and a noxious weed in parts of its introduced range, dominating other plants, altering native plant communities and often forming monocultures (Hubbard, 1968).

Timothy is a long-day grass species well adapted for cultivation in northern latitudes (Seppanen et al., 2010). It is an important grass forage used for pasture, hay, and silage in regions with cool and humid growth seasons (Ould-Ahmed et al., 2014). Timothy is an important grass in Nordic European countries, North America (Varvas et al., 2013), in some parts of Canada (Ashikaga et al., 2010), in Hokkaido (Japan) (Ashikaga et al., 2009), in Serbia (Tanhuanpaa et al., 2016). Timothy is an important forage crop in many Western U.S. states and marketing of timothy hay is primarily based on esthetics. Green color is an important attribute (Reisig et al., 2009). Norwegian agriculture relies heavily on a safe supply of seed of winter-hardy timothy cultivars (Havstad & Aamlid, 2013). It produces elongating tillers in spring growth and later in summer. As the quantity and quality of harvested biomass is dictated by canopy architecture and the proportion of stem-forming flowering tillers, the regulation of flowering is of great interest in forage grass production (Seppanen et al., 2010). Timothy canopy consists of three tiller types, of which the stem forming vegetative elongating tiller and generative tillers contribute the most to dry matter yield. Flowering signals alter the tiller composition, so they have important effects on yield formation of timothy (Jokela et al., 2014).

Total 88 timothy accessions from Nordic countries and eight accessions around Europe were analysed with SSR markers by Tanhuanpaa & Manninen, (2012). The differentiation between accessions was low. Most of the variation (94%) in the studied timothy material was due to variation within accessions and only 5% was between accessions and

1% between countries. Lack of geographical differentiation may reflect the outcrossing and hexaploid nature of timothy. Nordic timothy material were diverse enough for breeding purposes and no decline in the level of diversity was observed in varieties compared to wild timothy populations.

Timothy-grass is among the most valuable pasture grasses in Poland. The cultivar “Skald” is recommended for inclusion in future breeding programmes due to high stability and good values for many agronomic traits (Bocianowski et al., 2021).

Allergy

The *Poaceae* family is composed of 12.000 plant species. Some of them produce highly allergenic anemophilous pollen grains (Visez et al., 2021). Timothy grass is the most frequent cause of grass allergy in Europe (Ciprandi et al., 2017). Grass pollen grains are an important source of aeroallergens eliciting respiratory allergic diseases worldwide. In the field of allergology, Phleum pratense pollen is considered as a model for other grass taxa for studies on grass allergy (Farah et al., 2020).

Agronomy

Radkowski et al., (2020) conducted field trials between 2017–2019 at the Małopolska Plant Breeding in the Plant Breeding Stations in Poland in three locations to determine yield and chemical composition of some timothy genotypes under different habitat conditions. Trials were set up in in mid-May. Seeding rate was 10 kg/ha. In the autumn, phosphate fertilizers were applied at a rate of 26–35 kg P /ha in enriched superphosphate form with potassium fertilizers at a rate of 66–83 kg K /ha in potassium salt form. Nitrogen fertilization was applied before sowing at a rate of 80 kg N /ha in ammonium nitrate form. In the following spring, 80 kg N·/ha; after the second cut, 60 kg N /ha; after the third cut, 40 kg N /ha applied in ammonium nitrate form. Phosphorus was applied once in spring at a rate of 26–52 P /ha in the form of enriched superphosphate. Potassium were applied in spring at 42–58 kg K /ha and after the first cut at 42–58 kg K /ha in the form of potassium salt. The dry matter yields ranged from 0,9-8,5 t/ha according to the applied treatment. Higher yields were obtained at the first harvest date. Dry matter yields were highest for the Skald cultivar. Crude protein content varied between 104,5-230,1 g /kg DM., depending on the crop and year of harvest. Crude fiber values ranged between 173,9-274,8 g /kg DM, depending on the crop and harvest year.

In the study of Wang et al., (2014a), a late variety of timothy, “Hokusyu”, was used to grow grass material for silage analysis. Seeding date was July 26, 2006, in Hokkaido, Japan. Seeding density was 20 kg/ha. The N fertilizer rate was 160 and 240 kg/ha per year, being designated as standard and high level applications, respectively. The fertilizer rate distribution was 2/3 on May 7, 2007, and 1/3 on June 25, 2007. Urea was used for N fertilization. The total annual phosphoric acid and potassium fertilizer rate were 60 and 150 kg/ha, respectively in all treatments. For the phosphoric acid and potassium fertilizations, superphosphate of lime and potassium sulfate were used, respectively.

The distribution and timing of fertilization were the same as for the N fertilization. Grass was harvested on June 22, 2007. For grass, DM ratio at high dose was 174 g/kg. With standart dose DM ratio was 136 g/kg. ADF content was 323 g/kg DM in high dose and 360 g/kg DM in standart dose.

Wang et al., (2014b) determined K fertilizer requirement of a late variety of timothy (Hokushu). Planting was performed in a field in Hokkaido, Japan. Seeding density was 20 kg/ha. K fertilizer rate was 125 and 375 kg/ha per year in the standard and high level of K fertilizer level treatments, respectively. Two-thirds of the fertilizer amount was applied on May 7, 2008 and the remaining third was applied on June 20, 2008. The total annual N and phosphate (P) fertilizer rates were 160 and 26 kg/ha, respectively. The distribution and periods of treatment were similar to K fertilizer. Potassium sulphate (K2SO4), urea, and superphosphate (Ca(H2PO4)2) were used as K, N, and P fertilizers, respectively. Pasture grass was harvested on June 18, 2008. K content of grass in the high treatment was increased by 14,5% compared with standart treatment. The water soluble carbohydrates content of grass in the high treatment was reduced by 13,2% compared to standart treatment.

Ostrem et al., (2020) compared growth and development of timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) during winter. A high above ground biomass and tiller production in ryegrass compared to timothy during the autumn levelled out towards the spring due to rapid loss of ryegrass tillers in winter. The reduction also caused a considerable reduction in carbohydrates per unit area in ryegrass. Timothy kept most of its above ground biomass, slightly increased carbohydrate content, and achieved a higher level of frost tolerance.

Timothy is one of the most important forage grass grown at high latitudes. Its sward canopy structure determines the quantity and quality of the silage yield. Photoperiod is the most important regulator of flowering in timothy. In addition, vernalization response was reported in most of the tested accessions. Flowering is also associated with decreased digestibility of grass stems. Variations determined among accessions in their responses to vernalization and photoperiod. This information can be utilized in breeding for high-yielding new cultivars for different growing conditions at high latitudes and for different harvesting strategies (Jokela, 2015).

Crop composition at harvest affects the ensiling process and the resulting silage quality. In the study of Tremblay et al., (2005) higher rates of N-fertilizer application to timothy decreased the concentration of water-soluble carbohydrates, increased the buffering capacity (BC) and nitrate concentration primarily in the early stages of development. Ammonia-N concentration in the silages increased by 0,85, 0,56 and 0,67 when rates of N-fertilizer application were 60, 120 and 180 kg/ha, respectively, compared to zero N fertilizer application. The ensiling properties of timothy were less favourable at high N fertilizer rates. Silage pH generally increased with increasing rates of N-fertilizer application. Silage quality was reduced by increased N-fertilizer application, primarily at the early developmental stages. Water-soluble carbohydrate concentration, BC, and their ratio were poor predictors of silage quality.

Six experiments were carried out in climatically different two regions in Norway to compare different procedures for autumn management and use of regrowth in seed crops of timothy (cv. Grindstad). The experiments were laid out after seed harvest in mid-August in crops with a stubble height of 5 cm (two experiments) or 12–15 cm (four experiments). Cutting to 5 cm on 15 September or 15 October, with or without an application of 50 kg N /ha immediately after seed harvest, and with or without an additional application of 30 kg N /ha after cutting, were compared with an uncut and unfertilized control treatment. As a main effect, autumn cutting increased seed yield in the subsequent year in only one experiment; this was laid out in a 13 cm stubble on a fertile soil near the coast. In the remaining five experiments seed yields were unaffected by autumn management regardless of climate or stubble height. Autumn cutting and N application increased the number of seed heads in two experiments, but this was offset by a drop in other seed yield components. On average, for two cutting dates and for plots receiving an application of 50 kg N /ha, after seed harvest, the dry matter (DM) was 1.430 kg/ha on an inland site with 12–15 cm stubble, 1.400 kg/ha on a coastal site with 5 cm stubble and 2.460 kg/ha for two coastal sites with 12–15 cm stubble. Whereas forage yield and quality were fairly stable from the first to the second cut at the inland site, the yield of DM increased, but the crude protein and energy concentrations decreased from 15 September to 15 October at the coastal sites. It is concluded that the stubble and regrowth in seed crops of timothy cv. Grindstad can be harvested for forage without any effect on seed yield in the next year (Havstad & Aamlid, 2002).

Animal Feeding

Timothy is an extraordinary roughage for dairy cows and racing horses (Cui et al., 2020). The effects of harvest date of timothy on the chemical composition of herbage and silage, and on the voluntary intake, liveweight gain and feed conversion efficiency by finishing lambs, were evaluated by Bernes et al., (2008). The herbage was harvested and ensiled on threedifferent dates: 16 June (before heading), 20 June and 26 June. There were clear effects of later dates of harvest increasing the concentration of NDF, and reducing the degradability of OM and NDF, and the rate of GP, of silages made from this herbage. Later harvest dates decreased the voluntary intake of silage, liveweight gain and feed conversion efficiency. Lambs fed the early-cut silage had a liveweight gain of 152 g/d and those fed the silage harvested 10 d later had a liveweight gain of 76 g/d. Changes in the chemical composition of herbage and silage and in in vitro degradation characteristics of silages with later harvests were associated, to a large extent, with the reduction in voluntary intake and liveweight gain of lambs.

Conclusions

Timothy is a cool-season perennial grass reaching up to 150 cm in height with its erect stems. It is grown as a highly palatable pasture, hay and silage grass. Timothy is well adapted for cultivation in northern latitudes. Timothy grass is the most frequent cause of grass allergy in Europe. 8,5 t/ha dry matter yield was obtained in Poland in a trial. Photoperiod is the most important regulator of flowering in timothy. In addition, vernalization response was reported in many accessions. Up to 35 kg P /ha, 83 kg K /ha, 240 kg N/ha per year fertilizer usage were determined in different studies in different countries when literatures analysed.

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CHAPTER 19

Tall Wheatgrass (*Thinopyrum ponticum* (Podp.) Barkworth & D.R Dewey

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INTRODUCTION

There is no definitive historical record of when the agriculture of forage crops began on Earth. Because the cultivation of forage crops has been carried out since the unwritten periods of history. It probably started when people learned to feed animals in prehistoric times. People who used to benefit from naturally grown plants, later, especially after they settled are thought to be interested in this culture (Ahlgren, 1956). Forage crops cultivation, which has a very important place in agricultural production is the insurance of plant and animal production and also it is the most basic way of producing sustainable and safe roughage. Forage crops are defined as plants that contain the nutrients that livestock have to take into their bodies so that they can live and produce the products expected from them, and do not adversely affect animal health and animal products when fed to animals in a certain amount, both cultured and grown in nature. Forage crops, the cornerstone of agriculture, whose main principle is animal feeding have a great importance in terms of containing the necessary nutrients for the stomach microflora of animals, being rich in minerals and vitamins, increasing the reproductive performance of animals, providing high quality animal products, improving the physical and chemical structures of agricultural soils, preventing erosion and creating turf establisment. The sources of forage crops used in the supply of quality roughage are grasses, legumes and forage crops of other family. In addition to legume forage crops in cultivation of forage crops, there are many alternative grases forage crops that considered green grass, dry grass and silage, usable in green space facility and in soil protection, be able to take place in crop rotation systems, can be grown lean or mixed, has the potential to be roughage. The Poaceae family, which is the subclass of monocotyledoneaus, contains 650-785 genera and 10.000 species (Watson and Dallwitz, 1992). Grasses are the most used plant family of people in the world for nutrition and different purposes. All cereals and 75% of the cultivated forage crops are grasses. Grasses are the most important plants of rangeland in the cool season zone of the world. Grasses's cultivation on farmland as a forage crop is quite old. Nowadays, nearly 100 species of wheatgrass feed plants, which are used in agricultural area, meadow pastures, parks and gardens are cultivated. Grasses are of great importance in terms of animal nutrition, both as forage crops species grown in agricultural lands and as natural species grown in meadows and pastures. As a rangeland plant grasses are more resistant to grazing than legumes. Grasses are highly adaptable. They form the dominant plants of natural vegetation in unfavorable climate (cold, hot and arid) and soil (inefficient and deteriorated) conditions. They are resistant to low yielding, acidic and saline soil conditions, waterlogging and poor drainage. In places where the Mediterranean climate is dominant, the dominant plants of the winter period are the cool season grasses and the hot season grasses of the summer period.

About 150 of the grasses, which make up 75% of the cultivated forage crops, are wheatgrass species. About 11 of the 150 species mentioned have gained importance in terms of agriculture (Serin and Tan, 2009).

Wheatgrass, which is one of the grasses, have many species used as forage crops in the warm and cool climates of the world. The importance of these species is increasing day by day. Wheatgrass species are very resistant to cold and drought. There are species that can grow on alkaline, saline, wet and deconstructed soils where other plants cannot grow. Wheatgrasses, which form rhizomes and have a strong root system, by forming a good lawn cover, hold the soil tightly and prevent erosion. They are used for the renewal of destroyed meadow rangeland. Seed production of wheatgrass species is high. Sowing them with drill is easy. They produce delicious and high nutritional feed. Since all the vegetative parts of the rhizome and ball-forming wheatgrass species are not preferred by the animals, they have the opportunity to shoot again from the remaining green parts. Therefore, they are resistant to grazing. High hay yields and nutritive value of wheatgrass, resistance to grazing and wearing, germination of seeds even at low temperature and with their rapid development in early spring It has been reported that they are important plant species for rangeland under continental climate zone (Elçi and Açıkgöz, 1993; Elçi, 2005; Altın et al., 2009). Apart from animal nutrition, wheatgrass species are also widely used in the greening of parks, gardens and sports areas.

Table 1. Some important wheatgrass species (Hanson and Karnahan 1956; Açıkgöz, 2021)

Latin name	**Turkish name**
A. cristatum (L.) Gaertn.	Otlak ayrığı
A. dasytachyum (Hook) Scribn	Kum ayrığı
A. desertorum (Fish, Link) Schult.	Kır ayrığı
A. elongatum (Houst) Beauv.(Thinopyrum ponticum (Podp.) Barkworth& D.R Dewey) *A. fragile (Roth) Nevski.*	Yüksek otlak ayrığı
A. inerme (Scribn Smith) Rydb.	Kılçıksız ayrık
A. intermedium (Haust) Beauv. (Thinopyrum intermedium (Host) Dewey)	Mavi ayrık
A. repens (L.) Beauv. (Elytrigia repens L. Newski=Elymus repens)	Tarla ayrığı
A. riparium Scribn ve Smith	Dere ayrığı
A. sibiricum (Wild) Beauv.	Sibirya ayrığı
A. smithii Rydb.	Batı ayrığı
A. spicatum (Pursh) Sribn ve Smith.	Yeşil ayrık
A. trachycaulum (Link) Malte.	Silindir ayrık
A. trichophorum (Link) Richt.	Tüylü ayrık
Elymus trachycualus	Narin ayrık

In taxonomic studies on this genus, the naming of wheatgrass species has been renewed and some species previously named *Agropyron* have been included in different genera. This new classification is important for the recognition of plants.

Tall Wheatgrass

One of them, the tall wheatgrass, was classified as *Agropyron elongatum* (Host) Beauv. in previous years and was included as *Thinopyrum ponticum* (Podp.) Barkworth& D.R Dewey in the new taxonomy. The chromosome number of the tall wheatgrass, which has a similar genome with the intermediate wheatgrass, is 2n=70 (Açıkgöz, 2021).

Table 2. Scientific classification

Kingdom	Plantae (Bitkiler)
Section	*Magnoliphyta* (Kapalı tohumlular)
Clade	*Liliopsida* (Bir çenekliler)
Family	*Poaceae* (Buğdaygiller)
Subfamily	*Pooideae*
Order	*Poales*
Genus	*Thinopyrum*
Species	*Thinopyrum ponticum*

Scientific classification of tall wheatgrass is given in Table 2. The tall wheatgrass is in the family of wheatgrass (Poaceae(=Gramineae) and is from the Pooideae subfamily. The origin of the tall wheatgrass is an important part of Turkey, the Mediterranean Basin and Russia. It was taken from Turkey to the USA in 1909 and is now found in all western countries, in many regions of the UNITED States and Canada (Weintraub, 1953; USDA, 2008; Barkworth et al., 2007). A long-lived, perennial plant, the tall wheatgrass is a tall (90-180 cm), erectly developed, coarsely structured, hard and soft-forming plant (Duke, 1983).

Figure 1: Tall wheatgrass (Anonymous, 2015)

In the early stages of development, this hardness and erection are even more pronounced. Its blue-green colored, hairiness or hairless leaves are curled inward. The auricles are long, narrow, pliers-shaped and embrace each other or narrow to the bottom, taking the form of triangles. The veins of its long leaves, which become coarse in a short time, are pronounced. According to most wheatgrass species, it takes longer to ripen, spike and flower. The flower community is sparsely populated. Since in the peduncle spike between the internod are flat, spiklets appear to be sorted one way. There are many flowers in the spikelets. Spikes are 10-30 cm long,spklets are 1.5-3 cm long. The lower outer glume is 7-9 mm long with 7 veins, the upper outer glume is 8-10 mm and 9-veins, the ends are blunt, the inner glumes are 10-12 mm, 5-veins and without awns. The palea is 8-10 mm long (Bakır, 1970). The hulled fruits are large. The seed is 0.5-1.0 cm long and weighs 1000 grains 5-7 g.

Figure 2. Tall wheatgrass seeds (Anonymous, 2015)

Salty and alkaline meadows, marshes and seasides are natural habitats of these plants. Tall wheatgrass, which has an annual rainfall of 350-400 mm or adapts well to irrigated lands, is highly resistant to heat and cold. Thanks to its deep roots, it is able to withstand temporary droughts and is used for rangeland breeding in arid and semi-arid regions (Garcia et al., 2002). Gençkan (1983) reported that, it can be grown even in the arid regions of Australia where the rainfall is 200 mm. The annual precipitation in the places where it grows is 300-2100 mm, the average annual temperature is 5-19˚C and the pH ranges from between 5.3-9.0 (Duke, 1983). Tall wheatgrass is suitable to be used as a base rangeland, since it grows better in high grazing separation, ground water close to the surface, poor drainage, wet alkaline and salty soils compared to other plants. It adapts to irrigated or saline soils with high groundwater. It even prefers soils with high groundwater (Jensen et al., 2006). It withstands waterlogging very well. Hay yield is high in moist wet areas. It can survive waterlogging caused by heavy rains in the spring for five weeks. The ability of the wheatgrass to grow and maintain itself in moist, medium alkaline soils provides a wide use in restoring these areas. They can adapt to high values up to 10.1 soil pH. Apart from where there is a high amount of salt, they can be used to produce roughage in problem areas (Oram, 1990). The most important feature of tall wheatgrass is that it is resistant to salinity. tall wheatgrass from wheatgrass species yields with a loss of 50% yield at high salinity, where other plant species cannot grow (Özgül, 1974). With these features, these plants are in the class of forage crops that are resistant to salinity (Tekeli and Ateş, 2009). It can grow even in areas with soil salinity of 26mS cm^{-1} (Ogle et al., 2008). With this feature, tall wheatgrass is a very important forage crops that can be used for breeding salty soils (Altın et al., 2009). Its tolerance to salinity is quite high, especially in wet areas (Crowle, 1966; Forsberg, 1953; Rauser and Crowle, 1963). Tall wheatgrass, suitable for balancing the groundwater level in moderately saline areas, can reduce soil salinity (Bleby et al., 1997). Due to this known feature, it is cultivated in California to help use salty underground drainage water (Zheng et al., 2005). In the study named effects of halomorphic soils conditions on plant numbers emerging in square meter of some perennial forage species it was determined that wheatgrass species showed higher germination and seedling emergence in excessively saline soil conditions compared to type of control (Temel et al., 2015). In a study in which the effect on botanical and yield component in some Agropyron species of different salt concentrations in some wheatgrass species were determined, it was observed that high grassland was less affected by saline conditions than both species. Furtermore in terms of morphological influence, it has been shown that high grassland is more compatible with saline conditions (Koç, 2017). Among the forage species that can grow in saline and alkaline soils, such alfalfa, birdsfoot, white clover, tall wheatgrass, crested wheatgrass, perennial ryegrass, smooth bromegrass, tall fescue, the most durable species has been determined as tall wheatgrass. Considering the height of the plant, the measurements were 14.5 cm and 11.0 cm in thetall wheatgrass grown in normal soil and salt-alkaline soil, respectively (Tan et al., 2002). Its seeds usually germinate very slowly and its seedling growth is slow.

Young seedlings cannot compete strongly with weeds throughout the planting year. For this reason, it should be plant in clean soil in its cultivation. Plants should be allowed to mature and scatter the seeds before harvesting or grazing in the year of planting (Oram, 1990).

If it can be established in both spring and autumn, it is best for autumn. 2.5-3.0 kg da^{-1} for hay production and 2.0-2.5 kg da^{-1} for seed production should be used. Sowing depth should not exceed 2-3 cm. The spacing between rows varies depending on the purpose of cultivation. In arid conditions, it gives good results in row spacing of 50-60 cm for hay and 100 cm for seeds. Due to its late maturation, it is recommended to plant the tall wheatgrass pure sowing rather than intercropping (Asay, 1995). It is planted in pure sowing as a soil and moisture protective plant due to its high special adaptability and its continued development until the end of summer. However, it can be planted mixed with alfalfa and sainfoin in arid conditions, and with alfalfa and red clover in wet conditions. Maintains its greenery until summer. For hay, it should be mown before heading. Its yield is quite high. 300-500 kg of dry herbage can be taken per decare. Yield can reach 1 ton/da in humid regions. 2 tons da^{-1} of dry herbage was taken from some varieties in the irrigated conditions of the GAP Region (Tükel et al., 1993). Tall wheatgrass is a moderately self-fertile plant. Seed production is good in regions with a long growing season.

For the seed, threshing from the bundles by mowing in the yellow dough period reduces the loss of seed. Since there is no uniform maturation in the spike, first mowing and threshing after drying reduces seed loss. It can also be harvested directly with a combine harvester during the period when the scattered is low. Seed yield of tall wheatgrass varies between 20-50 kg da^{-1}.

Tall wheatgrass is used as hay, silage and grazing, as well as used in the breeding of salty soils. Since it starts to develop early in the spring and stays green for a long time in the summer, it can be used as a rangeland plant. It provides quite high yields in semi-watery conditions or imgated alkaline soils. Its ripening is about a month after the crested wheatgrass. The value of feed is not as high and tasty as others (Duke, 1983). Animals that graze the tall wheatgrass in early spring do not like to eat plants that quickly coarsen afterwards. In these circuits, animals graze tall wheatgrass only if there are no other plants in the environment (Hafenrichter et al.,1968; Kernick, 1978). By siloing the coarse grass of the tall wheatgrass, a softer and tastier feed is obtained.

Good quality dry grass is obtained when the tall wheatgrass is harvested before it is spiked and when it is green. In the early period, the content of digestible proteins and total digestible nutrients is higher than other wheatgrass types. The crude protein value of thetall wheatgrass decreases from 20% in early spring to less than 10% in June and less than 5% in July (Sedivec and Barker, 1998). If harvested in the early period, it is easily consumed by sheep and cattle. Unlike many natural grass, it shows good development and growth after harvesting (Smith et al., 1994). After the first three mowing years, its yield decreases significantly. When planted in a intercropping with legumes, higher quality dry hay and higher grass yields are obtained (Duke, 1983). An average of 707.4 kg da $^{-1}$ year dry hay was obtained from the binary mixtures with alfalfa for six years (Altın, 1988). Nitrogen fertilizer application at the end of the autumn season before or after the rains may cause more dry matter formation in the next spring season (Lauriault et al., 2002). In a six-year period, 848.5 kg da $^{-1}$ year of hay was taken from the high grass weed planted in 30 cm row spacing and applied 21 (15+6) kg N da^{-1} in Erzurum. The dry herbage yields of this species at 10.5 (7.5+3.0) kg N da^{-1} applications of clover and meadow clover binary mixtures were 815.8 kg da $^{-1}$ year and 795.5 kg da $^{-1}$ year, respectively. In the researches, 800-900 kg da^{-1} dry herbage yield containing 8-10% crude protein was obtained from tall wheatgrass in irrigated conditions (Altın, 1987; Aydın et al., 1994). Kusvuran et al. (2005), conducted a two-year study to determine the adaptation capabilities of alfalfa (*Medicago sativa*) tall wheatgrass (*Agropyron elongatum*) in the ecological conditions of K.K.T.C in 2000 and 2001. As a result of the study, a total of 10828.72 kg da^{-1} of green herbage and 2642.39 kg da^{-1} of dry hay were obtained from alfalfa, and these amounts were 1571.03 kg da^{-1} and 613.73 kg da^{-1} in tall wheatgrass. Researchers have reported that tall wheatgrass has satisfactory yield. In a study investigating the effect of *Agropyron elongatum* (Host) P. Beauv.] on yield, yield components and protein ratio, when different doses of ammonium sulphate fertilizer were applied, 120 kg pure N ha^{-1} and 160 kg pure N ha^{-1} doses were observed in dry herbage yield increased by 30% and 58%, respectively. As a result of the research, the highest protein ratio ranged from 6.47% and 160 kg pure N ha^{-1} ammonium sulfate dose (Acar et al., 2020). Martyniak and Zurek

(2014) reported that tall wheatgrass contains 426 and 586 spiked stems per $m^{2,}$ respectively, when 25-50 cm row spacing is used in a normal sowing rate. In the same study, they reported that the yield of tall wheatgrass varied between 500-900 kg ha^{-1}. Scheinost et al. (2008) reported that the seed yield of tall wheatgrass land in dry conditions was 336 kg ha^{-1}, and in irrigated conditions it had a seed yield of 672 kg ha^{-1}. Vogel and Moore reported that different tall wheatgrass populations comprise between 6.60% and 0.50% crude protein ration and protein yields ranged from 24 g to 48 g per plant. Due to its late maturation, it provides green fodder during a long grazing period. Tall wheatgrass can remain green during this period, in spite of the fact that most plants dry out in the second half of summer. End-of-season grazing can be continued until there are stubbles at a height of 20 cm in order to prevent heavy grazing the following year. In the following year, grazing should not be started before the plant is 25 cm tall (Asay, 1995). It gets rough quickly with the progress of maturation. Animals avoid rough stems as they graze their leaves. It can be used as a rangeland plant because it starts to develop early in the spring and stays green for a long time in the summer. Autumn development is also favorable. Moreover, tall wheatgrass is an important plant grown for the purpose of establishing rangeland in wet and alkaline soils with poor drainage near ground water and also on sandy lands. It not only ensures the improvement of unsuitable lands of this nature, but also allows them to be evaluated as rangeland. It is also of great value in terms of erosion control. Fields that are not heavily grazed or mown from the bottom take on a bushy appearance in a few years. These areas are used as an ideal protection and reproduction area especially for wild animals. Due to its height and forming a tight ball, it is a nesting area for birds, a food source for birds with its seeds remaining on the plant during periods of heavy snow cover, and a protection area for some farm animals during calving or lambing (Asay and Jensen, 1996). In addition to these, it is a source of resistance to salinity, drought and diseases in soil improvement programs (Asay, 1995). It also provides benefits in controlling wind erosion and managing excessive snowfal.

Result

Tall whatgrass is one of the rare fodder plants that are successfully grown in wet, alkaline, salty soils. It is also of great value in terms of erosion control. For this reason, problematic soils out of agriculture is important in terms of both the improvement of salt affected soils and the quality-roughage production. It is a great deficiency that there is not enough research done in our country on tall wheatgrass. As a matter of fact, there is no registered cultivar in our country. However, considering the advantages of the plant, the studies on this subject should be increased and new cultivars should be developed suitable for the conditions of our country.

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CHAPTER 20

The Wheatgrass

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INTRODUCTION

The wheatgrass, a cool-season perennial grasses, is a member of the Triticeae tribe, including cultivated cereal crops such as wheat, barley, rye, etc. (Wang and Jensen, 2009). It is found that about 150 and 200 species of wheatgrass show distribution at the temperate climate in the world. The wheatgrass has been traditionally included in the *Agropyron*. But in recent years, some species belonging to *the Agropyron* genus were involved in *Pseudoroegneria, Thinopyrum, Elytrigia, Elymus,* and *Pascopyrum* genus as the result of taxonomic studies that comprised genomic, biological relationships, plant morphology (Altın et al., 2009).

The wheatgrass differs in fertilization biology from complete self-fertility to self-sterility (Jensen et al., 1990; Altın et al., 2009). But, two-third of the wheatgrass is the self-fertile species within these groups. The majority of species in *Elymus* and a few species in *Thinopyrum* are self-pollinating (Wang and Jensen, 2009). *Agropyron, Pseudoroegneria, Pascopyrum* are predominately cross-pollinating (Jensen et al., 1990).

Owing to the competitive ability against annual invasive species, it uses weed control in semi-arid environments. There is a direct correlation between rhizomes and this ability. Some parts of wheatgrass species occur bunch. The others arise rhizomes (Altın et al., 2009). *Agropyron* species have more rhizomatous plants than in the following genera: *Pseudoroegneria*, *Thinopyrum, Pascopyrum*, and *Elymus*. Rhizome protects herbivory, trampling, and storage tissue for vegetative propagation and dispersal to the environment (Wang and Jensen, 2009).

The wheatgrass's reproductive systems and growth habits cause differences in botanical properties and have been distributed worldwide. However, more than two-thirds of species are native to Eurasia and Asia, while only one species is native to North America (Table 1). For this reason, crested wheatgrass was first introduced into the USA from Russia, Siberia, and Turkey in 1898 to be cold and drought tolerant (Anonymous, 2021).

Table 1. Origin and Distribution of the wheatgrass species (Wang and Jensen, 2009).

Genus	Number of Species	Center(s) of Origin	Number of Species in Turkey[1]
Agropyron	2 to 15	Eurasia	2
Elymus	About 150	Eurasia and Australia	19
Pascopyrum	Only 1	North America	-
Pseudoroegneria	15 to 20	Eurasia or Asia	-
Thinopyrum	About 10	Mediterranean to western Asia	-

[1]Source: TUBIVES, 2021

According to TUBIVES data, about 10 percent of wheatgrass is found in Turkey, and 38 subspecies grow in Turkey considering sub-species. (Table 2). Turkey’s geography has a wealth of biodiversity and endemism, and ten wheatgrass species/sub-species grown in our country are labeled as endemic species.

Table 2. The wheatgrass distribution of the taxon over Turkey based on province

Genus	Taxon	Endemism	Province in Turkey
Agropyron GAERTNER	*A. cistatum* subsp. *incanum*		Hakkâri, Bitlis, Erzurum, Trabzon, Van
	A. cristatum subsp. *pectinatum* var. *imbricatum*		Bitlis, Ağrı, Tunceli, Van
	A. cristatum subsp. *pectinatum* var. *pectinatum*		Kars, Ağrı, Ankara, Edirne, Erzurum, Eskişehir, Malatya, Kahramanmaraş, Niğde, Van, Bayburt, Kırıkkale
	A. deweyii	+	Van
Elymus L.	*E. caninus*		İstanbul, Ankara, Erzincan, Rize, Trabzon
	E. clivorum	+	Muş
	E. elongatus subsp. *elongatus*		İstanbul, Çanakkale, İçel, Tekirdağ
	E. elongatus subsp. *ponticus*		Ankara, Edirne, Kütahya, Aksaray
	E. elongatus subsp. *turcicus*		İstanbul, Çanakkale, Denizli, Erzincan, Erzurum, İzmir, Samsun, Sivas
	E. elongatus subsp. *salsus*	+	Kayseri
	E. erosiglumis	+	Adıyaman, Malatya, Sivas
	E. farctus subsp. *farctus* var. *farctus*		İstanbul, Çanakkale
	E. farctus subsp. *bessarabicus* var. *bessarabicus*		İstanbul, Balıkesir, İçel, Ordu, Samsun
	E. farctus subsp. *bessarabicus* var. *striatulus*		Edirne
	E. farctus subsp. *rechingeri*		Çanakkale
	E. flaccidifolius		İstanbul, Denizli, İzmir
	E. gentryi		Hakkâri
	E. hispidus subsp. *podpyerae*		Iğdır, Kars, Hakkâri, Siirt, Ağrı, Antalya, Artvin, Gümüşhane, Kahramanmaraş
	E. hispidus subsp. *hispidus*		İstanbul, Bitlis, Ankara, Çanakkale, Erzincan, İçel, İzmir, Kütahya, Kahramanmaraş
	E. hispidus subsp. *barbulatus*		Bolu, Iğdır, Kars, Hakkâri, Mardin, Bitlis, Ankara, Antalya, Erzincan, Erzurum, Eskişehir, Gümüşhane, İçel, Muş, Nevşehir, Sivas
	E. hispidus subsp. *pulcherrimus*		Ardahan, Van
	E. koshaninii		Siirt, Kahramanmaraş
	E. lazicus subsp. *divaricatus*	+	Antalya, Elâzığ, Erzurum, Kayseri, Konya, Kütahya, Malatya, Kahramanmaraş, Sivas
	E. lazicus subsp. *lazicus*		Artvin, Gümüşhane, Rize
	E. lazicus subsp. *lomatolepis*	+	Erzincan
	E. libanoticus		Adana, Hakkâri, İçel, Niğde, Van
	E. longearistatus subsp. *sintenisii*	+	Gümüşhane, Trabzon

	E. nodosus subsp. *sinuatus*		Ardahan, Artvin
	E. nodosus subsp. *caespitosus*		Kars, Kastamonu, Artvin, Erzurum, Gümüşhane
	E. nodosus subsp. *gypsicolus*	+	Sivas
	E. nodosus subsp. *platyphyllus*	+	Kars
	E. panormitanus		Bingöl, İçel, İzmir, Konya, Manisa
	E. pycnanthus		Düzce, İstanbul, Gümüşhane
	E. repens subsp. *repens*		Bolu, İstanbul, Ardahan, Kastamonu, Ağrı, Antalya, Artvin, Erzurum, Rize, Trabzon, Van
	E. repens subsp. *elongatiformis*		Iğdır, Kars, Hakkâri, Bitlis, Ağrı, Ankara, Erzurum, Konya, Sivas
	E. sosnowskyi	+	Kars, Erzurum
	E. tauri subsp. *tauri*		Kastamonu, Antalya, İçel, Muğla
	E. transhyrcanus		Hakkâri, Erzurum

Source: TUBIVES, 2021

Uses Areas

The wheatgrass shows a wide range from sub-humid to arid climate conditions in steppe or desert regions due to reproductive systems and growth habits. It uses multi propose in the world with having their properties. Uses areas are given in subtitles[3].

1.1. Soil and biodiversity conservation in rangeland

Pasture yield is seriously affected by climate conditions and overgrazing, which damage soil and vegetation in rangeland, mainly arid and semi-arid regions. Plant species decrease gradually to result in the plants did not grow due to overgrazing. The weed, which has no feed value and is sensitive to fire, increases in this situation, and wildfire risk may arise in this area. In addition, the soil without

[3]Lately, "wheatgrass" has been used for vegetative organs of wheat (*Triticum aestivum)*, and the juice that uses a medicinal is obtained from these organs. However, it should not be forgotten that wheat is included in the *Triticum* genus and is not included in the genus mentioned above.

vegetation can be susceptible to wind and water erosion in time. Seed mixtures of the wheatgrass are used in rangeland restoration and revegetation projects due to their rapid establishment characteristics, persistence, salinity, and drought tolerance in the burned and damaged areas (Asay et al., 2001; Renault et al., 2004; Jones and Larson 2005; Aschenbach, 2006; Wang and Jensen, 2009).

Species from the crested wheatgrass have been widely used for revegetation and grazing on North American rangelands for over 100 years (Robins and Jensen, 2020). Waldron et al. (2005) investigated the invasiveness of mixtures includes seven North America native perennial grass, Russian wild rye, crested and Siberian wheatgrass in Fort Carson (Colorado). Introduced species (i.e., Siberian and crested wheatgrass) were competitive because of fast germination and rapid root growth in the spring of between 1999 and 2001.

In 1960, the wind erosion severely occurred in 16 000 ha of Karapınar (Turkey), where precipitation is below 200 mm. Fast-growing grasses such as crested wheatgrass and tall wheatgrass in drought rangeland were used to combatting erosion in this area between 1962 and 1973 (Anonymous, 1986; Koç et al., 2019).

Black and Siddoway (1971) suggested that soil and water conservation were used as a barrier of tall wheatgrass, which was easy and in a short time to establish, had a stiff stem that remained erect all winter, and was adapted an expansive range of soil and climate conditions.

1.2. Forage crops

The wheatgrass has produced quality feed to livestock in drought pasture due to properties such as fast-growing in spring, resistance to grazing and trampling, high yield, and feed value (Altın et al., 2009). The use of stockpiled wheatgrass as a source of fall and winter forage is gaining popularity on western rangelands (Waldron et al., 2005; Wang and Jensen 2009).

Crested wheatgrass (*Agropyron cristatum* (L) Gaertner) (x=7, 2n= 2x, 4x, 6x). Crested wheatgrass and its close relative, desert wheatgrass, make excellent hay and pasture on many types of soils in arid and semi-arid regions (Figure 2). ‘Ephraim’ crested wheatgrass was introduced from Ankara, Turkey, to Utah, the USA, in 1946 (Anonymous, 2012). Crested wheatgrass crosses with desert wheatgrass (*A. desertorum*) to produce fertile hybrids varieties such as HyCrest, HyCrest II (Sedivec et al., 2007). However, some taxonomists do not consider crested and desert wheatgrass distinct species (Zlatnik, 1999; Sedivec et al., 2007).

Crested wheatgrass, naturally grown in steppe rangeland, is a forage crop with 15-20 years of productivity that complies with the grazing rules (Sedivec et al., 2007).

Crested wheatgrass is presented to a quality feed source, especially in spring for the livestock. In the earing stage, it is delicious and nutritious feeds, and their feed values decrease due to increasing cellulose ratio as they mature (Altın et al., 2009). Crested wheatgrass varieties (i.e., Ephraim, HyCrest, and Nordan) were at or above the 10% crude protein

(CP) until the seed-set stage, dropping below 7% CP in July when plants were mature and dried. All three varieties had a CP of 5% or less by mid to late August when fully ripe. Total digestible nutrients (TDN) varied among types and the growing season. However, all three varieties than above 60 % TDN. ADF ranged from 26% to 29% in the 2.5-leaf stage to 46 percent to 49 percent by early October (Sedivec et al., 2007).

Tall wheatgrass (*Elymus elongatus* (Host) Runemark) (x=7, 2n=2x, 10x). (Syn.: *Agropyron elongatum*, *Thinopyrum ponticum*)

Tall wheatgrass makes fair to good hay and straw to poor pasture in arid and semi-arid regions where annual precipitation is between 250 mm and 400 mm (Sedivec et al., 2007; Acar et al., 2020). In addition, it is used for revegetating saline-alkali soils and hay, silage, and grazing by livestock (Altın et al., 2009).

Tall wheatgrass is less palatable than most other wheatgrasses but is helpful for hay and pasture on soils unsuitable for other wheatgrasses (Okkaoğlu et al., 2011). Palatability for hay is fair to good, depending on the stage of maturity when harvested.

Figure 1. Tall wheatgrass grown in Karapınar conditions in spring (L) and in summer (R) (Acar et al., 2020)

In early spring 2018 and 2019, ammonium sulfate fertilizer was applied to tall wheatgrass cv. Szarvasi-I at different dosages (Control, 40, 80, 120, and 160 kg N ha^{-1}) in Konya, Karapınar, where annual precipitation was above 250 mm, and wind erosion was vulnerable (Figure 1). The two-year mean hay yield was 1183 kg ha^{-1} of control parcels and 1873 kg ha^{-1} of 160 kg N ha^{-1} ammonium sulfate dose. The CP content of 6.47% on the blooming stage in July was obtained from 160 kg N ha^{-1} dose because of poor soil of the Karapınar region (Acar et al., 2020).

Tall wheatgrass cv. Alkar was high in CP content during the vegetative growth stages in May and early June. However, CP dropped below 10 % by the flag leaf stage, and it fell below 7 % by late July during the seed set. TDN was above 55 % until late July, when fully mature. ADF did not change at 44% from flag leaf (mid-June) through late July, topping at 46% in early October (Sedivec et al., 2007).

Intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth et D.R. Dewey). (x=7, 2n=6x) (Syn.: *Agropyron intermedium*, *Elytrigia intermedia*)

Intermediate wheatgrass is a vigorous, fast-growing, moderately long-lived, sod-forming grass used extensively for hay, pastureland, and soil conservation (Figure 2). Intermediate wheatgrass is a widely adapted grass that makes good hay and is fair to good pasture in arid and semi-arid areas on many soils types (Sedivec et al., 2007).

Figure 2. Crested wheatgrass (L) and Intermediate wheatgrass (R) grown in Konya conditions (Org.)

Intermediate wheatgrass is palatable to livestock and a preferred feed for cattle, sheep, and horses in spring, early summer, and fall. It is considered a desirable feed for these animals in summer and winter (Ogle et al., 2003, Demiroğlu et al., 2010).

All four varieties (i.e., Manska, MDN-759, Reliant, and Oahe) were at or above the 10% CP through the boot stage, falling under 5% CP by the third week in July in maturing plants. These varieties had a CP of 4 % or less from late August through early October. ADF increased dramatically from the 2.5-leaf stage (i.e., 26-28 %) to seed set (i.e., 39-43%). The varieties were at or above 55% TDN until mid-September, remaining about 50% in early October. Thus, all types met the minimum requirements of a lactating cow until mid-September and a dry cow until early October (Sedivec et al., 2007).

1.3. Turfgrass

Grasses are often used both in the recreation area and in sports games. Recently, precipitation has been decreased by climate change in Turkey and the whole world. Therefore, lawns that use water economically come into prominence in the park. Wheatgrass uses as low-maintenance turfgrass in areas where irrigation water is limited and maintenance is reduced (Hanks et al., 2005; Robins et al., 2006, Wang and Jensen, 2009).

Asay et al. (1999) began a breeding program to improve crested wheatgrass for low-maintenance turfgrass production, resulting in the release of 'RoadCrest CW', the first turf-type crested wheatgrass. Some native North American wheatgrasses, particularly thickspike wheatgrass [*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould] and western wheatgrass [*Pascopyrum smithii* (Rydb.) Á. Löve] is also used in revegetation and possesses low-maintenance turfgrass potential (Robins and Bushman, 2020).

Bayat et al. (2016) investigated the turf quality of 24 crested wheatgrass genotypes under drought stress at different levels (control, 4, 8, 12, 16, and 20 days). The means of plants under drought stress at control, 4 and 8 days had similar turf quality with a scale of 5.66 (1-9 visual scale 9 indicating the best turf quality). However, turf quality fell after 8 days of drought stress, and the quality gradually decreased under 12, 16, and 20 days drought stress with scales 4.65, 2, and 1.55, respectively. Nevertheless, the results showed that some genotypes had tolerance to drought stress at 20 days.

Robins and Bushman (2020) suggested that the potential of wheatgrass mixtures meet low-maintenance performance expectations, which provide a mixture system with improved turf quality traits.

1.4. Using in Industry

Using a food crop as an alternative energy source for fuel could drive up food prices and create a food crisis in poor regions (Ileleji et al., 2010). For this reason, the bioenergy crops are typically densely populated, high-yielding plant species. They should grow under a low-cost and low maintenance environment and possess high energy values (Rahman et al., 2014). Tall wheatgrass is promising bioenergy species (Csete et al., 2011). Dry matter production of *Elymus* crop was dependent on soil types, water supply, and fertilization. It ranged from 13 up to 25 t DM ha^{-1}. The lifespan of *Elymus* cultivation for energy purposes can be 10-15 years long (Martyniak et al., 2017).

Kopecký et al. (2017) studied to biofuel value of corn (*Zea mays* L., hybrid Sima) and tall wheatgrass (*Elymus elongatus* subsp. *ponticus* cv. Szarvasi-1) in the area sensitive to erosion. The research was determined to 14.5 t ha^{-1} of corn yield of DM and 8.6 t ha^{-1} of tall wheatgrass of the yield of DM. The result stated that total soil loss was 94.21 t from a cornfield, but just 2.03 t from a tall wheatgrass field. Thus, tall wheatgrass saves soil about 98%. Therefore, in erosion vulnerable areas and less intensive farming systems, tall wheatgrass may be an alternative to the currently dominant corn.

Tall wheatgrass is also a hopeful biomass source for paper pulp production. Thus, pulp from tall wheatgrass can be regarded as an alternative source of fibers that can be used to produce definite kinds of paper and cardboard products (Danielewicz et al., 2015; Martyniak et al., 2017).

1.5. Using in plant breeding for germplasm resources

Improves Tolerance of Biotic Stress

Wheatgrass has been used extensively as a valuable source for cereal breeding. The wheatgrasses are generally resistant to many of the common plant diseases. Disease resistance genes *Lr19, Lr24, Lr29,* and *Lr38* for leaf rust (*Puccinia recondite* Rob. Ex Desm.), as well as *Sr24, Sr25, Sr26,* and *Sr43* for stem rust (*P. graminis* Pers.) have been successfully transferred from *Thinopyrum* species into wheat (McIntosh et al., 1998). Intermediate and tall wheatgrasses are resistant to tan spot (*Pyrenophora tritici-repentis* (Died.) Drechsler), and tall wheatgrass is also resistant to *Fusarium* head blight (*Fusarium graminearum* Schwabe). Furthermore, intermediate and tall wheatgrasses are resistant to barley yellow dwarf virus and wheat streak mosaic virus and have been transferring resistance to these viruses into wheat by serious efforts (Wang and Zhang, 1996; Zhang et al., 1996; Crasta et al., 2000; Cox et al., 2002; Fedak and Han, 2005; Wang and Jensen, 2009).

Some species within the Triticeae tribe were evaluated for the Columbia root-knot nematode (*Meloidogne chitwoodi)*. Species from the genus *Thinopyrum (Th. bessarabium)* expressed more resistance to *M. chitwoodi* than species-genus *Agropyron (A. cristatum), Pseudoroegneria (P. spicata)*. The variation among genera and within species indicates that it would be possible to select Triticeae grasses for resistance to *M. chitwoodi* into cultivated cereals (Jensen and Griffin 1994, 1997).

Triticeae grasses can be grouped into three categories for resistance to the Russian wheat aphid (*Diuraphis noxia*): (1) moderately resistant genus *Elytrigia*, (2) tolerant to moderately susceptible genus *Agropyron*, *Pseudoroegnria*, *Elymus* and *Pascopyrum*, and (3) susceptible genus *Thinopyrum* (Kindler et al., 1993, 1999; Wang and Jensen, 2009).

Improves Tolerance of Abiotic Stress

Some wheatgrass species are tolerant to low temperatures and poor soil conditions. For example, *A. desertorum* is colder and drought tolerant than *E. elongatus,* whereas the opposed is true for salt tolerance (Tabaei- Aghdaei et al., 2000, Demiroğlu Topçu et al., 2015). Tall wheatgrass is found to have higher morphological properties and elemental content than crested wheatgrass and desert wheatgrass under different salt concentrations (Figure 3) (Koç and Acar, 2017; 2018; Koç Koyun et al., 2021). Multiple genes on several chromosomes control salt tolerance in these perennial grasses. Therefore, improving salt tolerance in the wheatgrass forage species and transferring salt tolerance by introducing alien genes into wheat is complex and more complicated than the transfer of pest resistance, which is usually controlled by a single gene (Wang end Jensen, 2009).

Figure 3. Belonging photos of crested wheatgrass at 5 EC dS m^{-1} NaCl (a), tall wheatgrass at 5 EC dS m^{-1} NaCl (b), at 15 EC dS m^{-1} NaCl (c) (Koç, 2017)

Sodium exclusion, which *Kna1* controls on chromosome 4D and *Nax1* on chromosome 2A of wheat, is the primary mechanism found in these perennial *Triticeae* species. The enhanced Na^+ exclusion in wheat was obtained from 5J. The ability to exclude Na+ was strongest 3E of *E. elongatus* than 5J of *Th. bessarabicum* (Colmer et al., 2006). Qiao et al. (2007) stated that the growth and development of *E. elongatus* having Na^+/H^+ antiporter gene transported to salt in the vacuoles weren't affected by salinity at different levels. However, *W4909, W4910,* and *PhI* had increasing sodium ion concentrations in leaf tissue but maintained a relatively stable K^+/ Na^+ ratio (Mott and Wang, 2007).

An introgression of salt tolerance from *E. elongatus* into wheat was made using UV-induced asymmetric somatic hybridization between two species (Chen et al., 2004). Wang et al. (2003) successfully transferred the salt tolerance from *Th. junceum* chromosome into wheat chromosomes using *Ph1* gene to induce homoeologous recombination in the hybrid of a wheat-*Thinopyrum* addition line and *Ph1* line.

Copete-Parada et al. (2021) used the *Ph1b* mutant to induce structural aberrations and translocations between wheat and the 4P, 5P, and 6P genome chromosomes which contain many desirable genes. By using the two approaches, a total of 19 wheat-*A. cristatum* translocations have been identified, in which 13 were induced by the Chinese Spring (CS) wheat variety *Ph1b* mutant (CS *ph1b*). In addition, the wheat-4P, -5P, and -6P *A. cristatum* translocations were characterized by in situ hybridization. All the wheat-*A. cristatum* translocation lines obtained were valuable for identifying *A. cristatum* chromosome 4P, 5P, and 6P related genes and provided genetic resources and new germplasm accessions for the genetic improvement of wheat.

Wheatgrass is a valuable forage crop both precious gene source in breeding for us with naturally growing in our country about 10 percent of the wheatgrass in the world and have wide range uses areas if we summarized. In conclusion, it should not be forgotten that wheatgrass contributes to solving agricultural problems with these properties.

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