SUSTAINABLE FORAGE PRODUCTION AND ECOLOGICAL SAFETY

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Assoc. Prof. Dr. Seyithan SEYDOSOGLU

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PREFACE

All impacts to the environment are tied directly or indirectly to world population. Grasslands and pastures are among the biggest ecosystems in the world. Forage production unites all branches of agriculture (soils, plants, animals, machines, chemicals, economics, management etc) into a single system and adopts itself to ecology to provide benefits to human socities. But grasslands, pastures and other feed crop production activities also maintains soil fertility, conserves soil & water resources, designs a habitat for wildlife and recreational areas during producing feeds for livestocks. Managers of livestock enterprises should consider forage yield, quality, availability, animal potential and supplemental feeds. But a forage scientist needs to well trained in an interdisiplinery way related to knowldge branches like plant protection, water management, ecology, seed production, alternative uses, genetic resources, crop improvements, storage & preservation, marketing, dissemination of knowledge, utilization etc. As an enviroment modifier, a forage scientist must be a lifelong learner to find and adopt to gaps threatening global ecosystem, too. Here in this book, reader may find selected articles related to this highly diversified knowledge branch.

Assoc. Prof. Dr. Gulcan DEMIROGLU TOPCU

Assoc. Prof. Dr. Seyithan SEYDOSOGLU

Haziran, 2021

CHAPTER I

AN ALTERNATIVE FORAGE CROP FOR TUKEY RIBWORT PLANTAIN (*Plantago lanceolata* L.)

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INTRODUCTION

It is known that there is a significant deficit of quality roughage This deficit of quality roughage negatively affects livestock production in our country (Acar et al., 2020). More than 70% of the agricultural operating costs are feeding costs. To maintain sustainability and produce a high yield of quality forage cheaper, they must produce the feed themselves. High-quality roughages are the cheapest feeding stuff, as well as reduce or eliminate the need for concentrate feed. Therefore, it reduces the agricultural enterprise's dependence on external resources. Quality roughage needs of livestock are met from forage crops grown in field agriculture and natural, and sown pasture areas. In recent years, the production of forage crops, excluding corn, has been stagnant in Turkey. Considering the climate, soil, and plant characteristics, a fractional increase in forage production can be achieved by improving existing pastures. It is significant to establish sown pastures to provide roughage in areas where natural pastures cannot meet the needs or where productivity is low. Therefore, it would be a rational way to embrace livestock production based on sown pasture to find a permanent solution to the existing problems in Turkey. In sown pasture mix, including legumes, grasses, and fobs increases the diversity of the mixture in terms of botanical and phytochemical. In sown pasture mix, including legumes and grasses as well as fobs (*Sanguisorba minor* L., *Cichorium intybus* L., *Plantago lanceolata* L., etc.) increase the diversity of the mixture in terms of botanical and phytochemical. Increasing the phytochemical diversity of the mixtures creates a positive synergistic effect among the plants, thus increasing the dry matter intake and nutrient utilization efficiency. In addition, as a more balanced feed is proposed compared to simple mixtures, stress effects on the animal decreases, and the animal welfare increases. (Provenza et al., 2003; Distel et al., 2020; Beck and Gregorini, 2020).

Naturally found in the natural pastures of our country, Plantain is one of the important alternative forage crops to increase the phytochemical diversity of the mixtures (Pain et al., 2015). It grows under any soil conditions as well as its high tolerance to drought, diseases, and pests. It contributes to the earlier start of the grazing thanks to its rapid development and easy establishment (Wilson et al., 2020). Plantain is a palatable forage crop and provides high mineral content feed. It is especially high in calcium, magnesium, and sodium. The annual total dry matter yield of plantain is 8-9 tons ha^{-1} when grown in pure stand, and 13-17 tons ha^{-1} in the mixture (Powell et al., 2007). Thanks to the anthelmintic effect of plantain, it reduces the internal parasite burden in livestock (Minnee et al., 2017; Wilson et al., 2020). The natural hormone effect of the proper proportion of secondary compounds improves animal health, improves digestion and the nutrient efficiency use by affecting the rumen protozoan and bacterial population, thereby reducing greenhouse gas emission (Mueller-Harvey et al., 2019).

Including plantain in the mixture meet the mineral substance need, improve the components of the milk, prevent bloating and significantly contribute to animal health as well providing a good liveweight gain in livestock.

Distribution, taxonomy and plant characteristics

Plantain (*Plantago lanceolata* L.) is a cool-season perennial forb that belongs to the *Plantaginaceae* family. There are about 1700 different species subdivided into 241 genera group. It originated in Europe, Russia, central and western Asia, and north Africa. It was introduced to temperate and dry zone (Figure 1).

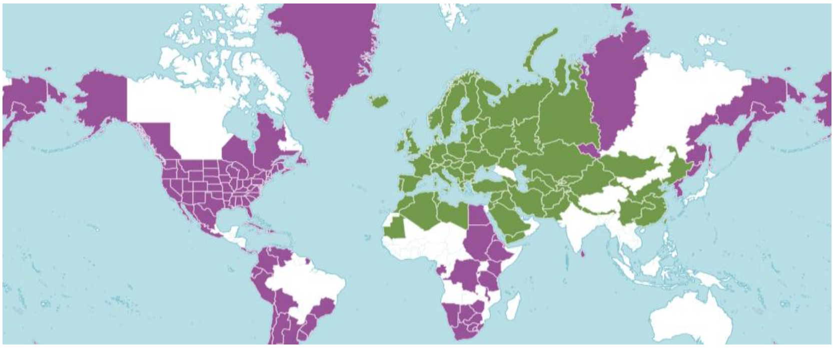

Figure 1. Distribution area of plantain (Green: Native; Purple: Introduced) (Anonymous 1)

In archaeological excavations, pollen ruins of plantain were found about 4000 years ago, and it is estimated that it was used for different purpose in Northern European countries (Jonsson, 1983). People living in Europe carried the plantain plants with them on their travels and spread it all over the world. The presence of plantain wherever Europeans are lived caused the natives in America to call the plant "White man's footprint". Planta, which means foot sole in Latin, was later adapted as Plantago (Samuelsen, 2000). Plantain is an ancient medicinal herb that has been known for centuries. In the first century, Greek physicians used plantain leaves in the treatment of dog bites (Roca-Garcia, 1972). In Denmark, it is reported that the leaves are mixed with honey and applied to the injured area, and when it is boiled with butter and eaten, it heals any organ in the human body (Molgaard, 1986).

Plantago genus includes 24 species throughout Turkey (Table 1). According to the Red Data Book, which lists endangered plants, 2 species are endemic, 5 species are rare, and 2 species are endangered in Turkey (Tukel et al., 2005).

Table 1. List of Plantago species in Turkey

Plantago major spp. *major*	*Plantago lanceolata*
Plantago major spp. *intermedia*	*Plantago argentea*
Plantago coronopus spp. *coronopus*	*Plantago lagopus*
Plantago coronopus spp. *commutata*	*Plantago albicans**
Plantago weldenii	*Plantago loeflingii**
*Plantago crassifolia**	*Plantago cretica*
Plantago maritina	*Plantago bellardii*
Plantago holosteum	*Plantago squarrosa**
Plantago media	*Plantago scabra*
Plantago atrata	*Plantago afra*
Plantago gentianoides spp. *gentianoides*	*Plantago sempervirens**
*Plantago anatolica***	*Plantago euphratica***

** Endemic and endangered species; * Rare species (Tubives, 2021)

Plantago major L. and *Plantago lanceolata* L. are the most plantain species in Turkey (Figure 2.). Plantain has been used for human treatment for many years in our country. *P. major* is used in the treatment of asthma and toothache by drying all plant parts, and its leaves are in salads in the Eastern Anatolia region. *P. lanceolata* is used as tea, syrup or pill for cough and asthma patients, and ointments obtained from the leaves of the plant are used as an emollient for eye irritation and anti-itch relief (Tukel et al., 2005).

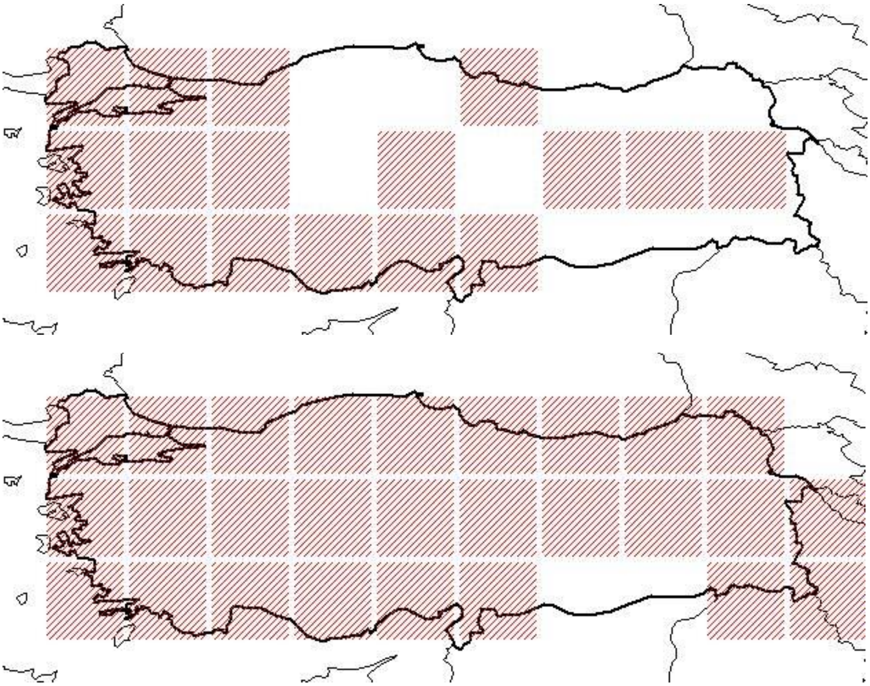

Figure 2. Distribution of common *Plantago* species in Turkey (A: *Plantago majör:* B: *Plantago lanceolata*) (Tubives, 2021)

Although it has been used in various ways as a vegetable and medicine for thousands of years, it has a recent history as a forage crop. Although Plantain has a long history of use as a forage crop in Europe's natural pastures, it has not been included in modern farming systems (Foster, 1988). The fact that chicory, which is one of the alternative forage crops with high yield and good animal performance has increased the importance of plantain. Considering their preference by animals and their presence in temperate zone pastures have made plantain an open candidate for future studies (Stewart, 1996). For the first time, in the Manawatu region of New Zealand, studies were carried out to collect plants with high seed yield potential as well as grass yield in 1987. 'Grasslands Lancelot' registered after various breeding stages in New Zealand in 1993 and in Australia in 1996 (Rumball et al., 1997). **Grasslands Lancelot** is a variety for developed sheep pastures with easy establishment, disease-resistant, and high shoots biomass. The **Ceres tonic** variety, which was developed later, is originated to the Portuguese temperate region. It grows upright, leaf size is larger than Grassland Lancelot, and its winter and summer activity is higher than Grasland Lancelot. The variety **Hercules** is a bi-annual plantain that has a higher dry matter yield than 'Ceres Tonic' and blooms 28 days later. It is originated to Europe. It has good growth all year round with high summer and autumn growth and it suitable for all soil conditions. The **Endurance** variety is a broadleaf organic plantain that is BioGro certified. Also, it is available as conventional seed source. The large taproot of it enables this crop to be very tolerant to droughts. Endurance variety has a water utilization. It blooms twenty-five days later than Tonic. The **Boston** variety is a fast-growing, deep-rooted, drought, heat and cold tolerant, mineral-rich, soft-leaved perennial pasture plant. It blooms twenty-eight days later than Ceres Tonic. Boston has small seeds compared to other varieties (Anonymous 2). The **Tuatara** variety is a new variety of plantain developed in New Zealand. Its performance is well in arid conditions thanks to its deep root system. Unlike other varieties, it is suitable for summer and autumn grazing (Anonymous 3). The **Oracle** variety is a broad-leaved pasture plant. It is grazing-resistant and has strong growth throughout the year, especially in late spring, summer, and autumn (Figure 3).

Figure 3. Some varieties of plantain and summer growth

Plant characteristics

Root: It has a thick rhizome and fibrous root system. **Stem:** Plantago lanceolata L. is a stemless herbaceous perennial forage crop. Its height can reach 20 to 80 cm. **Leaves:** Leaves are arranged in a dense rosette form. Petioles are as long as leaves (10-20 cm long). Leaves are lanceolate, 1 to 3 cm broad, and glabrous or sparsely pubescent. **Flower:** It is bisexual and its inflorescence is a short spike, densely flowered with white flowers set. **Fruit:** Fruit is a capsule, 3-4 mm long, and it has 1 to 3 seeds. **Seeds:** Seeds are black or yellow brown to dark brown. rectangle with 2-3 mm long and mucilaginous when wet. The mass of 1000 seeds is 1-1.5 g (Anonymous 4) (Figure 4)


Figure 4. Plant parts and development periods of plantain

Yield and nutritive value

Plantain, which has a wide distribution throughout the world, is a very new forage plant for many countries. It provides high-quality feed, which is consumed willingly by animals. It has a high digestion rate and non-structural carbohydrate content, rich in mineral matter. It also has effects preventing swelling and parasite formation in the rumen, especially in early spring. In addition, it has an important forage potential due to its rapid establishment, its ability to develop in various soil structures, and its tolerance to many common diseases and pests as well as drought. (Stewart, 1996; Rumball et al., 1997).

Yield and nutritive value

Plantain, which has a wide distribution throughout the world, is a very new forage plant for many countries. It provides high-quality feed, which is consumed willingly by animals. It has a high digestion rate and non-structural carbohydrate content, rich in mineral matter. It also has effects preventing bloat and parasite formation in the rumen, especially in early spring. In addition, it has an important forage potential due to its rapid establishment, its ability to develop in various soil structures, and its tolerance to many common diseases and pests as well as drought (Stewart, 1996; Rumball et al. 1997).

Recently, forbs (plantain, chicory) have been using with red and white clover in mixtures for livestock feeding. The reason for this is that the nutritive value and dry matter production of perennial grass + white clover mixtures are generally low in the summer and autumn periods. Forbs have high positive effects on animal performance of both sheep and cattle in summer season. It is do not recommended to grazed in late autumn and winter. After grazing, 8 cm residue must be left. If plantain is grazed with a rotation of 3 or 4 weeks, it supplies regular pasture production for up to 5 years for sheep and cattle (Cranston et al., 2015). In a study conducted in New Zealand, yield and plant loss of plantain, chicory, and meadow clover were compared in 8, 12, and 19 weeks after planting. They determined hay yield of 849, 2606, 5216 kg ha^{-1}, respectively and total dry matter yield of 17 t ha^{-1} in plantain based on harvest time without fertilizer and watering. After the first grazing, the plant loss of plantain has the lowest of 3.0%. It has indicated that to reduce the plant loss of plantain, it should wait for at least six and seven true leaves formation after grazing (Powell et al., 2007) Plantain shows opportunistic growth in the summer and the main growth periods are spring and autumn, also grows moderate in the winter period (Moore et al., 2006). Plantain may produce from 14.9 to 19.1 t ha^{-1} dry matter yield in dryland conditions, but it depends on season, plant number, early grazing, and fertilization (Stewart, 1996; Powell et al., 2007; Minnee et al., 2013; Glassey et al., 2013) indicated that when grazing started early, the number of plants per m^2 decreased from 155 to 86 plants in the first year. Lee et al. (2015), determined the effect of plantain and chicory on yield (seasonal and total) and plant number at different grazing height (150, 250, 350 and 450 mm) in New Zealand. As the result of this study, the highest plant loss in plantain is on the 150 mm (62%) of the leaf length. Table 2 shows that the highest dry matter yield is in the summer season due to abundant plant stems. The highest total dry matter yield is 13.67 t ha^{-1} at the plots of leaf length of 450 mm. However, the stem ratio of the plants harvested in the late period increased in all seasons and generally the ratio of crude protein, ash and digestibility decreased. In terms of yield and nutritive value, it has been suggested that the most appropriate grazing height is leaf length of 250 mm.

Table 2. Plantain seasonal and annual dry matter yields (t ha^{-1})

Season/ leaf height (mm)	150	250	350	450
Winter	0.60	1.54	2.29	2.82
Spring	3.27	3.52	4.54	4.52
Summer	4.54	4.34	4.52	4.95
Autumn	1.40	1.29	1.21	1.38
Total	9.79	10.69	12.54	13.67

(Lee et al., 2015)

The leaves of plantain are very palatable for animals (Fraser and Rowarth, 1996) Although plantain contains lower cell wall, cellulose, and fiber in terms of nutritive value compared to perennial ryegrass, it has less crude protein and more lignin content than perennial ryegrass (Stewart, 1996). As maturity advances, the cellulose and hemicellulose content increase significantly both in the leaf and stem of plantain. As expected, the increase in both components has a negative effect on the digestibility of the plant. 60 % of plantain consists of stem especially in late summer and early autumn (Derrick et al., 1993; Stewart, 1996). The crude protein ratio of plantain has changed in different development stages (Vegetative stage: 104.8 g kg $^{-1}$, Flowering stage: 110.8 g kg $^{-1}$ and Early seed stage: 66.4 g kg $^{-1}$). NDF and ADF values increased rapidly as the plant's maturity advanced (Table 3).

Table 3. Nutrient matter composition of plantain

Items (g kg^{-1}) /Phenological stage	Vegetative	Flowering	Early seed
Crude protein	104.8	110.8	66.4
ADF	313.1	328.1	377.9
NDF	382.2	463.3	552.1

(Kara et al., 2018)

The grazing preferences of lambs on red clover, perennial ryegrass, chicory, and plantain were investigated in New Zealand. Forage quality in terms of crude protein (9.1-17.7%), ADF (27.0-23.6%), NDF (41.5-34.0%), water-soluble carbohydrate (13.5-10.2%), and in vitro digestibility ratio (68.3-74.8%) were observed in spring and summer period respectively. In spring plantain has low crude protein ratio, low in vitro digestibility ratio, high ADF and NDF because it contains 66% stem. Lambs prefer red clover and chicory higher than plantain and perennial ryegrass due to their lower fiber content (Pain et al., 2015). Genç et al. (2017), determined that the most common plant in the soil area of Samsun's Kızılırmak delta was plantain (18.27%) in Turkey. Nutritive values of plantain; Crude protein ratio was 13.72%, ADF was 32.43% and NDF was 33.93%. The nutritive value of leaf, hull, and husk was determined during the seed formation period of plantain samples collected from 6 different districts of Nevşehir. It has been determined that the crude protein ratio of leaves, husks, and seeds is 12.82-3.39-1.30%, ADF is 25.20-52.86-39.39%, NDF is 32.74-73.19-55.92% respectively and it has been stated that plantain has the potential to be an alternative roughage for ruminants in terms of nutritive value (Kara et al., 2015).

Plantain contains more macro and micronutrients than many commonly used legumes and grasses (Pirhofer-Walz et al., 2011). Nutritive quality parameters needed by animals are low in potassium, molybdenum, and selenium, while other elements are in a medium or high level (Table 4).

Plantain contains high levels of calcium, magnesium, sodium, phosphorus, zinc, copper, and cobalt, like a perennial ryegrass-white clover mixture, and Its macro and micronutrient content are higher (Stewart, 1996; Pirhofer-Walz et al., 2011). In a study comparing a mixture of plantain and chicory with a grass-dominated mixture; as macro elements: Ca (11.7-6.0 kg^{-1}), Na (5.3-1.8 kg^{-1}), P (3.4-2.6 kg^{-1}), K (33.6-28.0 kg^{-1}), and Mg (1.6-1.8 kg^{-1}), as microelements: Cu (18.6-

14.1 kg^{-1}), (Fe: 162.1-153.3 kg^{-1}), Mn (93.7-108.4 kg^{-1}), and Zn (30.0-23.6 kg^{-1}) were determined.

Table 4. Macro and micronutrient content of plantain leaves

Elements	Medium Range	Level Found	Content
	Macronutrient (g kg^{-1})		
Phosphorus	3.8-4.5	4.8	high
Potassium	25-30	19.7	low
Sulphur	3-4	5.3	high
Calcium	6-10	17.7	high
Magnesium	2-3	2.5	medium
Sodium	1.5-3	6.2	high
	Micronutrients (mg kg^{-1})		
Iron	100-250	182	medium
Manganese	60-150	109	medium
Zinc	30-50	37.7	medium
Copper	10-12	15.1	high
Molybdenum	0.50-1.2	0.27	low
Cobalt	0.10-0.20	0.36	high
Selenium	0.08-0.15	0.053	low

(Harrington et al., 2006)

In terms of nutrients, they reported that other elements, except for Mg and Mn, were higher in the mixture of plantain + chicory, and that it can meet the macro and microelements required for animals by including plantain and chicory in the mixture (Rodríguez et al., 2020). According to the growth stages of the plantain (vegetative, flowering, and early seed), while Ca, Na, P, Mg, K, Fe and Cu decreased, Zn and Mn content increased with the development periods (Kara et al., 2018).

The effect of plantain on animal health and the environment

Microelements such as copper and selenium, which are low in animals, are extremely important in performing vital functions. Copper, the most abundant microelement in the animal body; plays an important role in events such as bone and tissue formation, embryo development during pregnancy, especially cellular respiration (Sarıbay and Özsoy, 2019). Selenium is stated to be an important component of the defense system in addition to its functions in the skeletal and cardiac muscles, red blood cells, and kidneys (Humann-Ziehank, 2016; Mehdi and Dufrasne, 2016). Moorehead et al. (2002), determined the amount of copper and selenium in the liver of lambs grazing on perennial ryegrass and plantain pastures for 85 days, found higher levels of copper (2250-716 nmol kg^{-1}) and selenium (671-380 nmol kg^{-1}) in the livers of animals grazing with plantain. They also determined that deep-rooted plants such as plantain have higher copper and selenium uptake in the same soil than crop rooted plants such as perennial grass. For animal husbandry to be sustainable, one of the ways to keep the internal parasites under control, to increase the reproduction rate in sheep, to reduce the risk of bloating in cattle and to reduce the greenhouse gas emission is to give importance to plants containing seconder compounds (Ramirez-Restrepo and Barry, 2005). Secondary compounds (tannins, glycosides, and flavonoids) are the plant's self-protection mechanism. The positive or negative effects of these compounds on animals vary on the amount and chemical structure of the compounds. In addition to tannins, plantain contains some secondary compounds such as iridoid glycosides (catalpol and aucubin) and flavonoids (asteoside, apigenin, and luteolin) (Hoskin et al., 2002). The low content of tannins in the plant (10-30 g kg^{-1}) reduces methane release and provides protein bypass. However, its high content of tannins (> 50 g kg^{-1}) affects digestion negatively, absorption of protein and other nutrients or enzyme activities in the digestive system (Hoskin et al., 2002, Min et al., 2006; Kara et al., 2018).

Stewart, 1996 stated that the tannin level of chicory was between 0.4% and 1%. Kara et al. (2018), determined that it was 10.4 g kg^{-1} during vegetative period, 6.0 g kg^{-1} during flowering period and 4.6 g kg^{-1} during seed setting period in chicory collected from natural vegetation. Hoskin et al. (2002), reported that chicory is in the group of plants containing low levels of tannins (12-16 g kg^{-1}) and does not adversely affect animal health. Iridoid glycosides (catalpol and aucubin) and phenylpropanoid glycoside (asteoside), which are important seconder compounds of plantain, vary according to the age of the plant and the frequency of grazing (Jansma, 2016). In general, the content of plantain catapol ranges from 0.11 - 8 mg g^{-1}, aucubin content 3.58 - 22 mg g^{-1}, and acteoside content between 9.64 - 15.6 mg g^{-1} (Ramirez-Restrepo and Barry, 2005; Jansma, 2016). Dry matter in the plantain consists of 0.96% in the Tonic variety and 9% acteoside in the Lancelot variety reported by Fajer et al. (1992). These secondary compounds are known to improve kidney functioning and N-utilization of animals and reduce nematode larvae and worm loads (Rumball et al., 1997; Alomar et al., 2018). They examined the parasite burden of lambs grazing in mixtures of permanent pasture (ryegrass, bromegrass, tall fescue, cocksfoot, yorkshire fog grass and white clover) and Pl-C (plantain and chicory). Researchers have identified fewer larvae in the faeces of lambs grazing with Pl-C (77.10 average number per kg DM) than lambs grazing on a permanent pasture (279.82 average number per kg DM) (Alomar et al., 2018).

While creating artificial pasture mixtures, it is necessary to protect animal health as well as its effects on the environment.

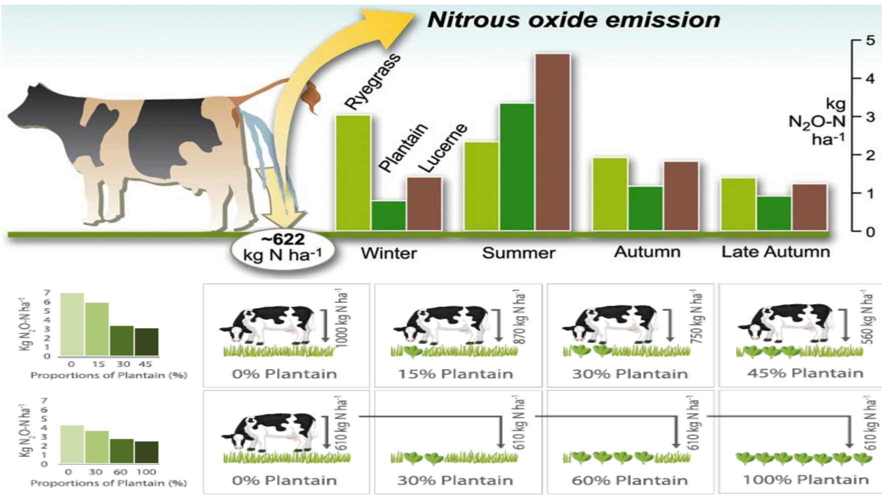

Figure 5. Nitrous oxide emission effect of plantain (Luo et al., 2018; Simon et al., 2018)

Especially the urine and feces of cattle contain high levels of nitrogen (N) compared to the plant species grazing. It is converted into nitrate (NO_3-N) by N nitrification by microorganisms in the soil. Some of the high nitrate is used by plants, while the other part, depending on the water movement, reaches the water resources by infiltration or runoff and causes pollution. Some researchers found that since plantain contains a secondary compound, the urine of cattle include a lower N concentration compared to legumes and grasses, they also reported that Nitrous oxide emission (N_2O-N) decreased by increasing the rate of plantain in the mixtures (Figure 5). In the laboratory study, it was found that the loss of ammonia (NH_3) in the rumen is reduced thanks to the seconder compounds contained in the plantain, which indicates that it has the potential to reduce the amount of urea in the urine excreted from cows (Navarrete et al., 2016). In another study conducted on animals grazing on pastures formed by plantain, perennial grass and plantain + white clover, it was determined that the animals grazing with plantain did not have any loss in milk production and their urine contained less urea. Researchers also reported that setting up plantain-based pastures could offer a low-cost feeding as well as reducing the carbon footprint on dairy farms (Navarrete et al., 2018; Judson et al., 2018).

Cultivation

Plantain prefers neutral and medium soils rich in organic matter. Plantain can tolerate a wide pH range (4.2–7.8), but 6.5 to 7.3 is considered optimum (Stewart, 1996). Plantain can grow in a wider range of soils, unlike chicory, but it does not thrive in sandy, extremely salty, or high-water levels (Mook et al., 1989; Troelstra and Brouwer 1992). 500 mm of annual rainfall is needed for good development. Plantain is a winter active plant, unlike chicory, but has a lower spring growth than some grasses like perennial ryegrass. Overall, plantain can develop in poor soils in terms of mineral media, but in a study in New Zealand, good P, K, and S fertilization have increased the longevity of the plant. (Anonymous 5). Plantain is highly tolerant of drought; It is equivalent to cocksfoot and higher than perennial ryegrass. In case of drought, its rate in pasture mixtures increases over time (Stewart, 1996). Additionally, its distribution in pastures in sub-tropical regions indicates that plantain is tolerant of summer heat. Although some roots of the plantain are shallow, other tap roots reach deep into the soil that provides good drought tolerance (Nie et al., 2008).

Plantain can be planted in spring or autumn. It is recommended that the seeding rate should not be less than 8-10 kg ha^{-1} in pure stand plantings, 1-3 kg ha^{-1} in mixtures, and the planting depth should not be less than 10 mm. Seedling development of plantain is faster than many forage plants like perennial ryegrass, but it is relatively bad at competition with other plants in mixtures after seedling development (Fraser and Rowarth, 1996). A well-prepared, weed-free, clean seedbed is needed for a good seedling emergency. Especially in the mixture, it is necessary to choose the species with weak competitive ability. As in many species, plantain has a high response to nitrogen fertilization. Well-prepared nitrogen fertilization increases leaf quantity, shoot growth, and overall yield, but has a limited effect on root growth (Woodward et al., 2013). The competitive ability of plantain is largely dependent on the nitrogen level in the soil. In soils with low nitrogen, plantain uses the nutrients in the deeper layers of the soil and takes advantage against grasses. However, in soils with enough nitrogen, it increases the ratio of grasses and decreases the rate of plantain in the mixture (Stewart, 1996; Powell et al., 2007). The need for phosphorus and potassium of plantain is the same as perennial ryegrass. 25-40 kg ha^{-1} P and K application are sufficient on the planting. However, plantain needs nitrogen even in summer. Especially in spring/summer, 70-80 kg ha^{-1} N urea application is recommended for each post grazing (Anonymous 6).

CONCLUSION

In Turkey, forage crop cultivation is carried out only with legume and grass species. However, in countries where forage crop farming is developed, alternative feed crops are widely used as well as legumes and grasses. Alternative forage crops are extremely important with rapid establishment and drought tolerance in terms of extending the vegetation period. Plantain is one of the best examples of alternative forage plants with its low soil selectivity, drought-tolerant, loved by animals, rich in mineral matter, preventing bloat and parasite formation in animals. With the spread of alternative forage plants such as plantain in our country, i) the vegetation period of sown pastures is prolonged ii) by increasing the botanical and phytochemical diversity of the mixtures, a more balanced diet of the animals is provided iii) the natural hormone effect of the seconder compounds and the effects of reducing internal parasites increases the fattening performance of the animals consuming these plants iv) provides a low-cost sustainable production v) a significant contribution is made to reducing the carbon footprint in dairy farms. Considering these advantages of plantain, studies for the development of new varieties of this plant should be started as soon as possible in our country.

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CHAPTER II

BIOACTIVE FORAGE LEGUMES

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INTRODUCTION

Legumes are an excellent source of significant amounts of protein, peptides, lipids, dietary fibre, carotenoids, phenolic, glycosides, tannins, saponins, alkaloids, protease inhibitors, lectins, condensed tannins, polyphenol oxidase, p-anisic acid and other phytochemicals.

Alfalfa, soybeans, black soybeans, azuki beans, sainfoin, red clover are good sources of bioactive compounds. Preserve protein from degradation during silage process, increase in protein protection during in vitro rumen fermentation, associative effects on volatile fatty acids in silage, improvements in silage quality, improvements in digestive processes in ruminants, are a few detected benefits of these natural chemicals.

This article is a brief presentation of the accumulated knowledge on bioactive compounds of forage and pasture legumes and related subjects.

Bioactive phenolic compounds are powerful antioxidants in traditionally used medicinal and industrial crop plants. Comparative analysis of total phenolics, flavonoid contents, phenolic acid composition, and antioxidant activity in 26 species of families Asteraceae, Rosaceae and Lamiaceae was done. Leaf extracts was highest for total phenolic, total flavonoid contents and antioxidant activity for *Stachys byzantine* L. (Lamiaceae), *Calendula officinalis* L. (Asteraceae) and for *Potentilla recta* L. (Rosaceae). The highest syringic acid content was in the leaf extracts of plant family Asteraceae with range 0.782 to 5.078 mg g^{-1} DW. Family Rosaceae was containing higher "p-anisic acid" in the range 0.334–3.442 mg g^{-1} DW. Significant differences of phenolic acids content was obderved in the leaf extracts of different families (Sytar et al., 2018).

Plant bioactive compounds (PBC) are widespread in the plant kingdom, including in forage species (Niderkorn and Jayanegara, 2021).

Legume seeds are rich protein sources for animal nutrition for their protein, lipids, dietary fibre. Legume seeds contain diversified compounds known as bioactive compounds. These compounds vary in their biochemistry and can be proteins, glycosides, tannins, saponins, alkaloids and many others. Their physiological effects and distribution in all legumes are diverse. Some of these compounds are important in plant defence mechanisms against predators or environmental conditions. Some others are reserve compounds, accumulated in seeds as energy stores in readiness for germination. Others are heat-labile antinutritional factors, such as protease inhibitors and lectins. On the other hand tannins, saponins and phytic acid are heat stable but can be reduced by dehulling, soaking, germination and/or fermentation (Muzquiz et al., 2012).

Some forage legumes species contain naturally bioactive secondary compounds, which could improve silage quality and digestive processes in ruminants. Silages containing bioactive legumes are better conserved than the pure grass silages. Bioactive legumes may able to preserve protein from degradation during the silage process. Inclusion of bioactive legumes can improve silage quality. Also polyphenol oxidase may be more efficient than condensed tannins to improve the nitrogen value of silage (Copani et al., 2014).

Alfalfa and red clover are the most common and important perennial legumes used as high quality feed for livestock production. Alfalfa, red clover, and some other Fabaceae are rich in phytoestrogens, a nonsteroidal compounds having estrogenic activity for prevention and treatment of many diseases. Due to many good features, they can find applications in pharmaceutical, nutraceutical and cosmetics, too (Tucak et al., 2018).

Nineteen domestic legume varieties, including 6 soybeans, 7 black soybeans, 4 azuki beans, and 2 mung beans, were evaluated for contents of dietary fiber, total phenolics, and flavonoids. Nine varieties of legumes (black soybean TN6, TN3, BM, and WY; soybean KS1, KS2, and KS8; azuki bean AKS5 and AKS6) were good sources of bioactive compounds. The dark-coat seeds, such as azuki beans and black soybeans, contained high amounts of phenolic compounds and contributed to high antioxidative ability (Lin and Lai, 2006).

In the study of Niderkorn et al. (2019), the bioactive legumes sainfoin (*Onobrychis viciifolia*) and red clover (*Trifolium pratense*) was found to rich in condensed tannins and polyphenol oxidase.

Adding bioactive legumes which contain condensed tannins or polyphenol oxidase such as red clover in grass species silages produce associative effects on volatile fatty acids in silage. Also bioactive legumes increase protein protection during in vitro rumen fermentation (Copani et al., 2015).

Main bioactives in legumes include polyphenols, peptides, saponins, and carotenoids. Legume bioactives act through interaction with membrane receptors and key enzymes in animal body (Moreno-Valdespino et al., 2020).

Control of parasitic infections with gastrointestinal nematodes associated livestock species essentially relies on the use of commercial anthelmintic drugs. However, resistance to anthelmintics is nowadays widespread in worm populations. According to Hoste et al. (2012), the use of tannin-containing fodders as nutraceuticals may be a solution against these worms.

Tannin-containing legumes have attracted much interest due to their animal health and nutritional benefits. Several tannins are anti-nutritional but a few can produce valuable benefits for controlling parasitic nematodes resistant to anthelmintic drugs. A 5% dietary maximum limit of tannins is suggested. Plants vary in tannin contents and composition depending on species, variety and growing conditions. A recent research in Europe named ‘LegumePlus' is focused on new tools for analyzing soluble and insoluble tannins in plants, silages and digesta by isolating different types of tannins from a wide spectrum of plants to assess their purity and composition (Mueller-Harvey et al., 2015).

Forage legumes secondary compounds are less susceptible to proteolysis than other legumes. Including Red clover (*Trifolium pratense*) in silages is a promising strategy for improved animal performance (Copani et al., 2016).

Ensiling bioactive legumes (*Onobrychis viciifolia* and *Trifolium pratense*) in mixtures with grass improved fermentation and proteins protection from degradation within the silos in the study of Niderkorn et al. (2016).

Chung et al. (2008) was grown soybeans in a single location to evaluate and compare their antioxidant properties and isoflavone profiles. Total phenolic content of extracts of genotypes was significantly different from each other. “V01-4937” soybean was the variety with highest total phenolic and isoflavone content.

Marie Curie Research Training Network named ‘HealthyHay’ reported big intra-species variation in agronomic characteristics and bioactive constituents by a detailed screening of a sainfoin (*Onobrychis viciifolia*) germplasm collection. Tannins were shown wide quantitative and qualitative differences. Tannin contents varied five-fold, average polymer size varied seven-fold, prodelphinidins were between range of 53-95% and trans-flavanols were between 12-34% of the tannins. Wide variations were also observed for monomeric polyphenols and enzymes involved in their biosynthesis. Total flavonol and flavan-3-ol contents were important variables for distinguishing between sainfoin accessions. Also “dihydroflavonol 4-reductase” and “flavonol synthase” were useful for screening. The project used and established new techniques for screening legume bioactive compounds and their anti-parasitic effects and nutritional and environmental benefits like “in vitro anthelmintic assays”, an “anti-coccidial assay”, an “automated pressure evaluation system” for volatile fatty acid and methane production, a “pepsin-cellulase digestibility assay” and ensiling studies (Mueller-Harvey, 2014).

CONCLUSION

Legumes are an excellent source of significant amounts of protein, peptides, lipids, dietary fibre, carotenoids, phenolic, glycosides, tannins, saponins, alkaloids, lectins, and many other phytochemicals. Alfalfa, soybeans, black soybeans, azuki beans, sainfoin, red clover are good sources of bioactive compounds. Red clover increase protein protection during in vitro rumen fermentation. Red clover in grass species silages produce associative effects on volatile fatty acids in silage. Some legumes species improve silage quality and digestive processes in ruminants. Silages of bioactive legumes are better conserved than the pure grass silages. Bioactive legumes may able to preserve protein from degradation during the silage process. Forage legumes secondary compounds are less susceptible to proteolysis than other legumes.

Basic comparative analysis may be a fast method to start screening to see where to concentrate in the first stage on the way to categorise species and varieties of Turkey. May get help from new techniques for forward detailed screening legume bioactive compounds and their anti-parasitic effects and nutritional and environmental benefits. ‘LegumePlus' and ‘HealthyHay’ projects may be analysed in detail before starting a detailed screening programme covering Anatolian legume species.

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CHAPTER III

EFFECTS OF HARVEST TIME ON YIELD, QUALITY AND CHLOROPHYLL CONTENT IN DIFFERENT MAIZE GENOTYPES

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INTRODUCTION

One of the biggest problems in livestock production in Turkey is the inability to close the quality roughage deficit. (İleri et al., 2018). Considering ecological and economic conditions, it is seen that there is an increase in corn production especially for silage to close this gap. Each cultivation area of maize, which has the highest production after alfalfa, has increased to 526261 ha in 2020, and the production amount has reached 27186949 tonnes. (TURKSTAT, 2021). In recent years, there has been an increase in the cultivation area due to the high yield of maize per unit area and high nutritional value and quality. In addition, the most cultivated type for silage in the world is maize. However, genotype x environmental compatibility is very important for high yield and quality. For this reason, it is of great importance to determine the most suitable genotype or genotypes with adaptation studies to be carried out in certain ecological conditions. Accordingly, all kinds exhibit different agronomic characters in different ecological conditions. (Argillier et al., 2000). Maize is one of the most used plants in the cultivation stage due to its adaptability.

Dry matter level increases depending on the development of maize. However, in the same milk line in the grain, the dry matter level of the plant may differ between different silage maize hybrids, as well as in the same silage maize year by year (Johnson et al., 2002; Bagg, 2007). These differences affect the silage quality and are at a level that will affect the nutritional content (Cammel et al. 2000; Ferraretto and Shaver 2012).

Determining the harvest time can affect the nutritional value of maize grown for silage. The energy concentration is low due to the weak starch accumulation in the seed, except that the maize, which is harvested especially in the very early period, experiences excessive nutrient loss with the silage flow. In contrast, mature maize silage harvested late is low in nutritional value due to poor starch and fiber digestion. (Wiersma et al., 1993). In response to the negative effects of late harvests, low lignin content at timely harvest will increase NDF degradability and silage corn will have a positive effect on the performance of dairy cows (Keleş and Çıbık, 2014).

The study carried out in line with these purposes was carried out in order to determine the differences in terms of feed yield and quality among the varieties already planted in the region's ecology. In addition, considering the effects of the harvest time on maize silage formation and dry matter accumulation, 2 different harvest times were preferred. These preferred harvest times were selected especially from the harvested times of maize for silage or harvest, and agronomic differences between them were studied. The fact that the study is 2 years old reveals the relations between the variety and harvest time, and it is a resource for the producer of the region.

MATERIAL and METHODS

This experiment was conducted in Aydın ecological conditions in 2019-2020 with 5 different maize genotypes and 2 different harvest times with 3 replications. (Table 1). The soil on which the experiment is carried out is a soil with low organic matter and sandy loam (Table 2).

Table 1. FAO Groups of maize genotypes

Genotypes	FAO Groups
DKC 4240	750
PL712	650
Macha	600
Torro	680
Diptic	550

Table 2. Soil features of the experiment field

		Values	Explanation
Texture	Sand	56.06	SL Sandy Loam
	Silt	32.30	
	Clay	11.64	
pH		8.16	Alkaline
%Total Salt		0.0093	Saltless
%Lime		2.07	Low
%Organic Matter		1.20	Low
Phosphorus (P)		19	Medium
Exch. Potassium (K)		903	Very High
Exch. Calcium (Ca)		2740	Medium
Exch. Magnesium (Mg)		1164	Very High
Exch. Sodium (Na)		46	Low
Useful Iron (Fe)		8.32	Enough
Useful Manganese (Mn)		4.66	Enough
Useful Zinc (Zn)		0.64	Critical
Useful Copper (Cu)		1.73	Enough
Available Boron (B)		1.55	High

The planting was done in the 3rd week of April, with a 70 cm row spacing and 13.3 cm above the rows. Fertilizing operations were carried out in the experimental area with 15-15-15 compound base fertilizer as 50 kg da^{-1} and 20 kg da^{-1}. According to the annual climate data in the experimental area, due to the insufficient amount of rainfall in the months of the growing season, the irrigation process was carried out by siphon irrigation method for 4 times. In addition to the difference between 2019 and 2020 according to the amount of rainfall in April and May, there is no similarity compared to the average of long years. Considering the average temperatures, it was determined that 2020 was warmer than the maize growing period (Figure 1).

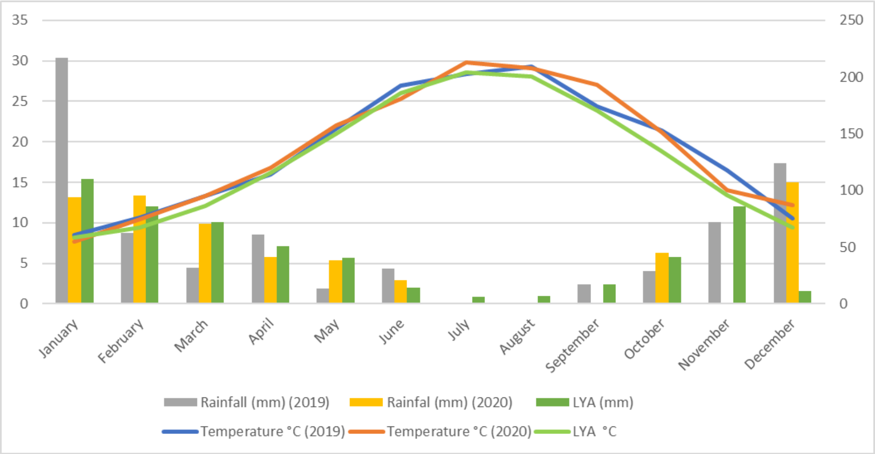

Figure 1. The average monthly climate values for the years of 2019-20 and long years of Aydın province (MGM, 2021). Climate data between the years 2019-20 was obtained from the Meteorology Station of the Faculty of Agriculture of Aydın Adnan Menderes University (LYA: Long Years Average)

The harvesting processes in the experiment were carried out at the beginning of milking stage and dough maturation stages of all kinds according to the observations made on the plants. Harvest operations were carried out by cutting all the remaining plants after removing the edge effects in the plots. Herbage yield was obtained as a result of the harvesting process. Plant height and stem diameter parameters were measured with 10 samples taken from each plots. The samples taken from the plots were then crushed in the shredding machine and the sample weights were weighed. The withered samples were then dried in an oven (MST-Microtest) at 70 ^{o}C for 48 hours (Cook and Stubbendieck, 1986). The dried samples were ground in a 2 mm screen grinding mill and made ready for chemical analysis. Analyzes were carried out with the aid of Dumas dry burning nitrogen analyzer (with 0.05 gr sample) to calculate the crude protein ratio. (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were assayed according to (Van Soest et al. 1991) using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY, USA). After crude protein yield calculation, relative feed value (RFV) was calculated according to Horrocks and Valentine (1999). SPAD measurements were carried out with the average of all leaves of 10 plants under full sunlight before the formation times of each genotype. (SPAD-502, Konica-Minolta, Japan).

The agronomic datas were analyzed by one-way analysis of variance (ANOVA) with three replicates of a split plot-randomized complete block design with merge of years and their interaction using proc GLM (SAS 1999). Where ANOVA was significant, means were separated by Duncan's multiple test ($P < 0.05$ and $P < 0.01$ were defined as a significant threshold and trend).

RESULTS and DISCUSSION

While the agronomic measurements revealed that there is a statistical difference between the varieties in terms of plant height depending on the years, it has been observed that the year is not significant. Particularly prominent varieties DKC7240 and Macha varieties have values well above the average values. While the average of years varies between 236.63-237.75 cm, the two-year average of the DKC7240, which has the highest value, is 254.25 cm. While there was only a statistical difference between years in terms of stem diameter, a thicker stem diameter was detected in the average of the measurements made in the second year. However, no difference was found between the varieties and the harvest time In the researches carried out, average plant height in Bulut (2016), 174-210.5 cm, Akdeniz et al. (2004), 143.7-242.6 cm and Özata et al. (2012), 300.2 cm. Kara and Sürmen (2018) found the plant height 209 cm averagess using the Diptic variety. İleri et al. (2018), determined the plant height between 212-280 cm by using different varieties in Central Anatolia conditions. The results are generally similar to the experiment. Herbage yield and hay yield are important criteria for variety selection. In this respect, when the herbage yield is examined, it is seen that there is a statistical difference between the year, variety and harvest time. However, in terms of interactions, only a difference was found between the year x variates interactions. The average herbage yield obtained in the second year is higher than the first year. The importance of useful rainfalls in plant development is known. This may be due to the oil differences experienced in the second year. When the differences between the varieties were examined, the highest yield was obtained with the DKC7240 variety with 10500.6 kg da^{-1}. Diptic variety, which has the lowest yield, is generally preferred for grain production and is an early variety. In this respect, it is generally preferred as the second product and its yield is lower than other types. While Seydoşoğlu and Saruhan (2017) obtained similar herbage yields; Kara and Sürmen (2018) found lower yields in Diptic variety in the same ecology, Diptic variety did not yield satisfactory results in this trial as well. The reason for a lower result may be due to the difference in harvest time, climatic factors and the difference in planting time. İleri et al. (2018) obtained similar and relatively lower results in their trials may be due to the cooler central Anatolian conditions in which the experiment was conducted. With the dry matter accumulation according to the harvest time, there is a higher yield in the dough stage period. The hay yield is similar to the herbage yield. However, among the varieties, the Macha variety stands out in terms of dry matter accumulation. Dry matter accumulation is important in terms of nutrition as well as positive effects on silage formation. It is seen that the harvest time is higher in dough maturity depending on the dry matter, while the values vary between 2391.07-2768.30 kg da^{-1} (Table 3.) (Figure 2). While 1656-2556 kg da^{-1} values obtained by Alagöz and Türk (2020), Seydoşoğlu and Saruhan (2017) in Diyarbakır conditions and Seydoşoğlu and Cengiz (2020) in Siirt conditions were lower results, both the different genotypes and the different ecological conditions may have affected this stop. Erdal et al. (2009) showed similarity to the 1877-2922 kg da^{-1} trial obtained in Antalya conditions.

Table 3. Agronomic characteristics of maize genotypes with different cutting stages and 2 years

	Plant Height (cm)	Stem diameter (mm)	Herbage yield (kg da^{-1})	Hay yield (kg da^{-1})
Year				
2019	237.75	20.75 a	7692.3 b	2351.91 b
2020	236.63	26.77 b	9102.0 a	2807.47 a
Genotypes				
DKC7240	254.25 a	25.48	10500.6 a	3243.9 a
PL712	229.75 b	23.44	7086.4 d	2140.0 c
Macha	254.58 a	24.28	9554.2 c	3223.9 a
Torro	234.37 b	23.42	8714.7	2469.5 b
Diptic	213.00 c	22.19	6130.0 e	1821.2 d
Cutting Stages				
Milking Stage	238.71	23.78	8019.6 b	2391.07 b
Dough Stage	235.66	23.74	8774.8 a	2768.30 a
Mean	237.19	23.76	8397.1	2579.6
		ANOVA		
Year	ns	**	**	**
Genotypes	**	ns	**	**
Cutting stages	ns	ns	**	**
Y*G	**	ns	**	**
Y*C	ns	ns	ns	ns
G*C	ns	ns	ns	ns
Y*G*C	ns	ns	ns	ns

Ns: Non significant **: $p<0.01$, *: $p<0.05$

In addition to agronomic characters, fiber and quality values affect both the formation and value of silage. In this respect, statistical differences between year, variety and form time in ADF averages were determined from fiber analysis. DKC7240, which has the lowest ADF among the varieties, also has a high value in terms of yield. In addition, ADF rate increased due to ligninization during the dough stage in terms of harvest time. There is a similar situation in our evaluation in terms of NDF. However, there was no difference between the years. While there was no difference between years for the crude protein ratio, which is one of the most important parameters of forage quality, as expected, there was a statistical difference in interactions between varieties and harvest time. Neylon and Kung (2003) found the rate of NDF lower with an average of 41% in their trials in Delaware / USA, while İleri et al. (2018) and Alagöz and Türk (2020) obtained similar values. Güney et al. (2010) (45.0-56.9%) and Çarpıcı (2016) (50.6-55.9%) also have similar values. The average ADF rates obtained in the study are determined by Öner and Güneş (2019) (25.61-30.80%) and İleri et al. (2018) (22-26%), while Bayram (2010) (28.67-40.92%), Özata et al. (2012) (24.1-40.9%) and Martin et al. (2012) (22.7-44.0%) and Alagöz and Türk (2020) (38.20-41.77%). Among the varieties, the variety with the highest crude protein ratio was Macha with 9.50%, followed by DKC7240 with 9.33%. Due to ripening, there was a decrease in the crude protein ratio during the dough stage and the dry matter increase increased accordingly. Kara and Sürmen (2018) are in the same ecology and Alagöz and Türk (2020) achieve similar value, while İleri et al. (2018) achieved lower results. According to the crude protein yield, there are differences between the time of year, variety and harvest time. Due to the high hay yield in the second year, the crude protein yield is higher in the second year (252.07 kg da^{-1}). Among the varieties, Macha has the highest value with 305.54 kg da^{-1} (Table 4) (Figure 2).

Table 4. Fiber and crude protein values of mazie genotypes with different cutting stages and 2 years

	ADF(%)	NDF(%)	CPR (%)	CPY(kg da^{-1})
Year				
2019	38.10 b	53.16	9.00	213.17 b
2020	40.91 a	52.63	8.92	252.07 a
Genotypes				
DKC7240	37.03 d	50.54 d	9.33 b	299.80 a
PL712	38.44 c	52.54 c	8.54 d	182.57 c
Macha	39.72 b	51.65 cd	9.50 a	305.54 a
Torro	40.22 b	53.73 b	8.99 c	221.70 b
Diptic	42.10 a	56.02 a	8.45 d	153.48 d
Cutting Stages				
Milking Stage	37.50 b	48.30 b	9.29 a	224.57 b
Dough Stage	41.51 a	57.49 a	8.63 b	240.66 a
Mean	39.50	52.90	8.96	232.62
		ANOVA		
Year	**	ns	ns	**
Genotypes	**	**	**	**
Cutting stages	**	**	**	**
Y*G	**	*	**	**
Y*C	**	**	ns	ns
G*C	ns	**	**	ns
Y*G*C	ns	**	**	ns

Ns: Non significant **: p<0.01, *: p<0.05

Relative feed value calculations are made based on total digestible nutrient and dry matter intake parameters. For this reason, the values have similar groups. While there was no difference between years according to the averages of relative feed value, there was a statistical difference between varieties and harvest time. Among the varieties, the variety with the highest value was the DKC7240. PL712 and Macha followed. In terms of harvest time, a decrease in value was observed during the dough stage. SPAD değerleri genetik farklılıkları belirlemede ve hasat zamanı yeşil kalma özelliğini görme açısından da değerlendirilmektedir (Szulc et al., 2021). The images came from maize leaves with known levels of nitrogen, measured with a SPAD meter. In order to establish a correlation between the N concentration and the SPAD measurement, an average value in SPAD units and a representative color value were assigned to every leaf (Reyes et al., 2017). While the SPAD value expresses the chlorophyll each of them has, its height also gives us an idea in terms of phytosanitary. In this respect, when looking at the averages, there is no difference between the cultivars for SPAD values, but differences between the year and harvest time were detected. This situation can be interpreted with the decrease in chlorophyll and the increase in dry matter accumulation due to the harvest time. (Table 5) (Figure 2). Erdoğan and Koca (2020) made SPAD measurements in 4 different periods in their experiment in the same ecology. In the experiment, they obtained higher values with the SPAD measurements they made in the same period. These values varied between 51.0-63.6. The reason for this may be due to the different varieties, cultivation conditions and different applications used.

Table 5. Total digestible nutrient, Dry matter intake, Relative feed value and SPAD-502 values of different maize genotypes with cutting stages and 2 years

	TDN	DMI	RFV	SPAD
Year				
2019	59.21 a	2.27 b	104.57	48.00 a
2020	57.02 b	2.31 a	102.67	46.30 b
Genotypes				
DKC7240	60.05 a	2.40 a	112.34 a	50.57
PL712	58.95 b	2.30 bc	105.36 b	46.97
Macha	57.95 c	2.34 b	105.37 b	45.83
Torro	57.56 c	2.26 c	101.34 c	46.70
Diptic	56.09 d	2.15 d	93.69 d	45.68
Cutting Stages				
Milking Stage	59.68 a	2.49 a	115.55 a	48.74 a
Dough Stage	56.56 b	2.09 b	91.69 b	45.56 b
Mean	58.12	2.29	103.62	47.15
		ANOVA		
Year	**	*	ns	*
Genotypes	**	**	**	**
Cutting stages	**	**	**	**
Y*G	**	*	**	ns
Y*C	**	**	**	ns
G*C	ns	**	**	ns
Y*G*C	ns	**	*	ns

Ns: Non significant **: p<0.01, *: p<0.05

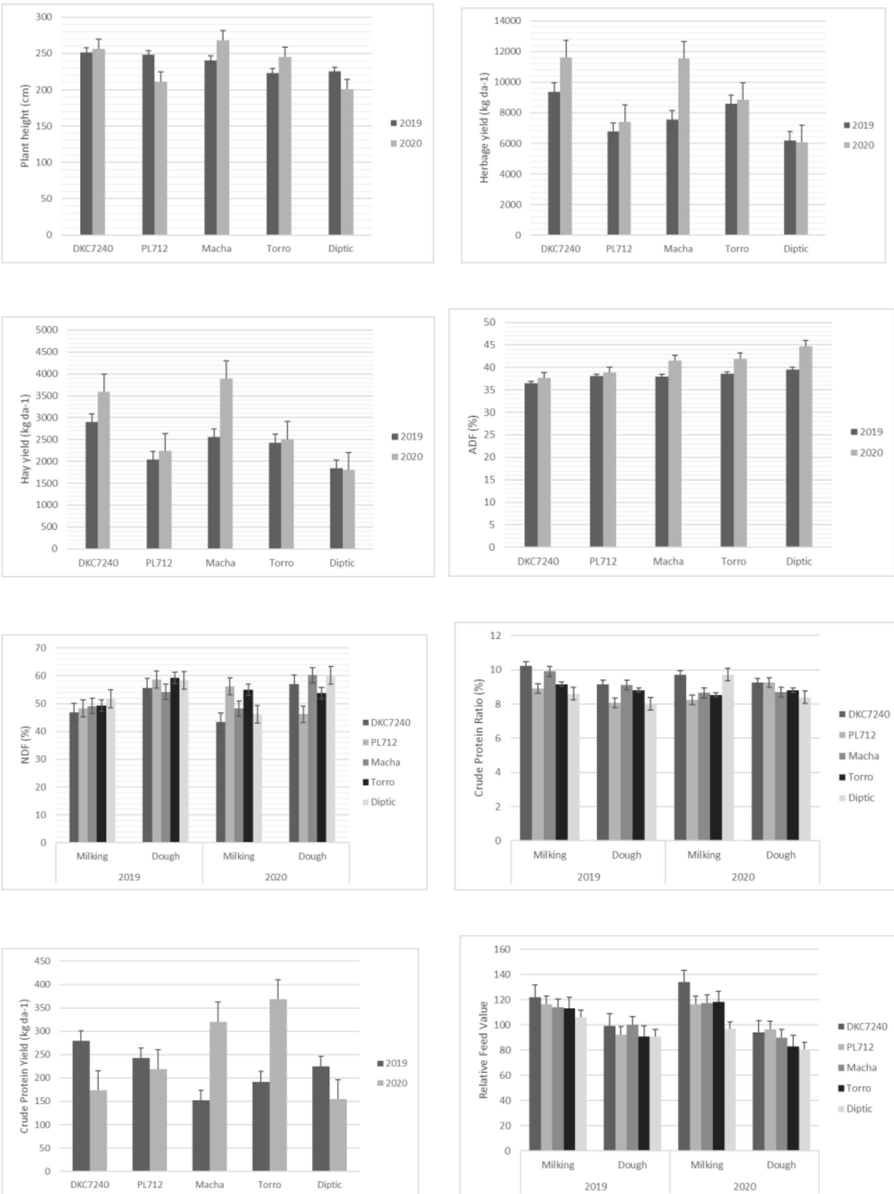

Figure 2. Significant two and three-way interactions of the experiment

CONCLUSION

Maize is a plant that is considered as a product of a wide variety of industries besides human and animal nutrition. However, it is the most prominent source of forage in livestock production among the purposes of use. However, its dependence on ecological conditions reveals that the selection of different genotypes according to each ecological condition is important in order to optimize yield and quality. In this respect, commercial companies and organizations develop new varieties every year and try to create more efficient and quality varieties. At the same time, harvest time is a very important criterion in order to minimize the losses in silage formation and dry matter accumulation. While early harvest time causes losses in silage, late harvest leads to decreases in quality. In this respect, in this study, the forms of 5 different maize genotypes grown in the region were harvest in 2 different times and their agronomic and quality characteristics were examined. As a result of the study, DKC7240 and Macha varieties are the most prominent varieties in terms of yield and quality. In addition to this, it is seen that harvest time is important in yield increase and quality decrease, while some features are seen to be at the forefront in both periods. It seems that both forms of time can be preferred when economic and ecological conditions are observed.

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CHAPTER IV

SHRUB FORAGE *Trichanthera gigantea*

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INTRODUCTION

Using shrubs to feed animals can be a part of extensive livestock production systems with their capacity to support environment by multiple nature-friendly outputs of this old method. Crops in the tropics are generally different in chemical content and productivity as a result of stabil hot and humid climate in tropics with negative affects for their utilization as ruminant feeds. But their adaptation to sub-tropics may be different than tropics and tests with many species might be an appropirate method to find new profitible feed sources to fix to the mild coastal zones of Mediterranean environments like Turkey. Also continuation of a probable deficiency or excessivity problems may be overcome with using supplements or mixing with other types of species like conducted in tropics.

Trichanthera gigantea is a shrubby forage crop of great importance in the diet of farm animals in the tropical regions of Latin America and Asia. Here in this mini review, we presented some of the main parameters related to *Trichanthera gigantea* species in focus with its feed value, forage value and critical yield improving applications.

Silvopastoralism uses shrubs and trees to feed ruminants. It can find a place in extensive livestock production but intensification of grass-based systems removed woody species from agricultural feed systems in many parts of the world. Woody species are now promoted again to support environment-friendly production systems to provide carbon sequestration, soil erosion control, air pollution limitations and biodiversity conservation. Positive effects on rumen digestion and parasite control was also documented for different plant species. Under optimal conditions, feeding ruminants from woody fodder sustains animal production (Vandermeulen et al., 2018).

Trichanthera gigantea is a shrubby forage crop of high importance for farm animal feeding in the tropical parts of Latin America and Asia (Suchiapa et al., 2011). Trichanthera gigantea, from Colombia and neighbouring countries in Central and South America successfully introduced to Vietnam, Cambodia and the Philippines in a wide range of tropical ecosystems (Rosales, 1997).

Most of the animal feed plants are developed on marginal land and integrated with food crops and plantations. Trichantera gigantea is an animal feed plant which is a tree legume with good nutrition and shade tolerance (Herdiawan and Harmini, 2020).

It can easily be established from cuttings for their leaves and green stems to be harvested 8-9 months after plantings, at intervals of two to four months with an annual fresh biomass yield of about 60 tonnes/ha (containing about 10 tonnes of dry matter and 2 tonnes of protein). Its chemical composition and fermentability is a good feed for livestock (Rosales, 1997).

In a study with T. Gigantea, propagules of plants with three nodes produced higher shoots per stake (6), with a higher length (4.27 cm) under a greenhouse. In the field, after 11 months, plants taller than 160 cm with many branches were obtained. The leaves reached 24 cm long and 12 cm wide, independently from the planting frame used. Frame with 0.75 m^2 yielded 533 kg DM/ha leaves and of 373 kg DM/ha fresh stems, which was higher than frame with 1.0 m^2 (213 and 135 kg DM/ha for the leaves and fresh stems, respectively). As a conclusion, using stakes of T. gigantea plants with different number of nodes may be prefered. For best result (higher amount of shoots), three nodes are needed. Use of a 0,75 m^2 plantation frame also resulted with higher yields of dry foliage when compared to 1,0 m^2 frame. As an overall result; using propagules with three nodes and a planting frame of 0,75 m^2 for the propagation of T. gigantea is the best option to be used (Espinosa et al., 2013).

Meals of sun dried leaves of Trichantera gigantea meals and fresh leaves fed to ducks with diiferent inclusion rates in poultry diets with three levels (0, 2 and 6% air dry basis of Trichantera leaf meal). Mean egg production and egg quality of laying hens and quails were similar for the control and experimental diets. The cost of production tended to be lower for diets with Trichantera leaf meal (Nhan et al., 1997).

Trichanthera gigantea tested as a substitute for the conventional protein sources in the diets of growing rabbits. Rabbits fed with four dietary treatments. Diet 1 was a control where diets 2, 3 and 4 contained 9%, 18% and 27%, respectively of Trichanthera gigantea in place of control diet for 7 days. Animals observed for 8 weeks. The crude protein and crude fibre contents of Trichanthera gigantea were 23.9 and 23.8% in dry matter (DM), respectively. Crude protein and ether extract digestibility decreased significantly from 83.6 to 74.5% and 91.0 to 76.4%, respectively. Crude fibre increased from 13.9 to 25.0% with increased levels of Trichanthera gigantea. Inclusion of Trichanthera gigantea in the diets significantly increased daily average DM intake from 51.4 to 73.6 g, protein intake from 11.2 to 16.7 g, growth rate from 12.8 to 18.2 g/d and hot carcass weight from 1203 to 1301 g, relative to the control. As a result, levels up to 27% of Trichanthera gigantea may be added in the diet of growing rabbits to promote feed intake and growth performance without influencing the feed conversion efficiency (Sarwatt et al., 2003)

Studies were carried out on different methods of establishing the Trichanthera tree (using brown or green stem cuttings, or the growing points) and to see the response of plants to N fertilization. Vegetative propagation capacity by planting the growing points was much greater (70 surviving plants produced in 180 days from one "mother" plant) than from brown (3.4 plants) or green stalks (28 plants). A linear response in biomass production was observed when N fertilizer (from urea) was increased to 240 kg N/ha/year. The optimum level of fertilizer appeared to be 160 kg/ha/year (40 kg N/ha/cut). Biomass production in the dry season was reasonably high, supplying fresh forage also in the transitional periods (November and March) (Ha and Phan, 1995).

A study was conducted to determine the effect of cutting intervals on leaf yield and quality of the green fodder Trichanthera gigantea to feed poultry and rabbits. Five different cutting intervals were compared: NT1: 40 days, NT2: 50 days, NT3: 60 days, NT4: 70 days and NT5: 80 days of cutting intervals. From NT1 to NT5, the leaf dry matter yields were 7.34, 12.13, 12.41, 11.94 and 11.80 tons/ha/year, respectively. From NT1 to NT5, CP yields were 1.88, 3.13, 3.06, 2.78 and 2.69 tons/ha/year. Increased cutting intervals from 40 to 80 days increased the proportion of dry matter in the fresh leaves from 12.91% to 21.04% and increased crude fiber proportion on dry matter from 9.92% to 12.50%, but reduced the crude protein proportion on dry matter from

25.56% to 22.77%.For dry matter yield and leaf chemical composition of green fodder of T. gigantea, the most suitable cutting intervals for Trichanthera gigantea were 50 - 60 days (Tu et al., 2020).

Effect of different nitrogen (N) fertilizer application levels on leaf yield and quality of the green fodder Trichanthera gigantea was tested. Leaf meals were targeted to be used in poultry feed to improve meat and egg quality. Five formulas of five different nitrogen applications were NT1: 0 kgN, NT2: 20 kgN, NT3: 40 kgN, NT4: 60 kgN and NT5: 80 kgN/ha/cutting. From NT1 (0 kgN) towards the NT5 (80 kgN/ha/cutting), the leaf dry matter yield was 10.33, 11.22, 11.85, 12.13 and 12.15 tons/ha/year, respectively; the crude protein yield was 2.41, 2.70, 2.95, 3.15 and 3.24 tons/ha/year, respectively. The increase of N application from 0 kgN to 80 kgN/ha/cutting was decreased the dry matter in the fresh leaf by 10.8%; increased crude protein on leaf dry matter by 14.1% and decreased crude fiber on leaf dry matter by 11.6%. For optimum leaf dry matter, crude protein yield and chemical composition of leaves, applied N fertilizer for field production of Trichanthera gigantea might be 40-60 kg N/ha/cutting (Tu et al., 2019).

Buctot (2018) aimed to determine the growth performance and carcass characteristics of broilers fed with varying levels of Trichanthera gigantea leaf meal with a study. Broilers given with T1 diet (commercial feeds) exhibit highest feed consumption, but diet with 15% *T. gigantea* leaf meal produced the highest weight gain resulting to excellent feed conversion efficiency (0.95) and high return above feed and chick cost (Php 55.75). The acceptability rating for skin and flesh color is comparable for all treatment diets. The inclusion of *T. gigantea* promotes faster growth rate even at lower feed consumption.

CONCLUSION

Trichantera gigantea is an animal feed plant which is a tree legume with good nutrition and shade tolerance in tropics. It can easily be established from cuttings for their leaves and green stems to be harvested 8-9 months after plantings, at intervals of two to four months with an annual fresh biomass yield of about 60 tonnes/ha (containing about 10 tonnes of dry matter and 2 tonnes of protein). Its chemical composition and fermentability is a good feed for livestock.

This species' adaptation to sub-tropics like South coastal zones of Turkey may be different than tropics. Field tests with *Trichantera gigantea* might be an appropirate method to see its adaptation possbility and fix to the mild coastal zones of Mediterranean agroclimates of Turkey to diversify forage crops. Probable deficiency or excessivity problems may be overcomed with using supplements or mixing with other types of species like conducted in tropics. Benefiting from other properties of this multi-purpose plant in local might be another advantage hidden in this approach.

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CHAPTER V

FROM AGROECOLOGY TOWARDS CIRCULAR AGRICULTURE

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INTRODUCTION

Ecology simply means natural science. Ecology is a science that examines the relationships of living things with each other and their environment. What is important for ecology is the study of the environment in which living things live and their mutual relations with other living things. From a different point of view, ecology is a science that affects all living things and deals with the common basic issues of living things.

So what is agroecology? It simply means "Sustainable Agricultural Science". In a broader sense, it is the Science Department that Examines Sustainable Agriculture and Food Systems. In other words, it can be defined as the area where agricultural techniques and systems that do not harm the environment are studied.

Agroecology is defined in different ways by many people on the subject. For some researchers, agroecology is seen as a science that seeks to understand how agricultural ecosystems work and often involves the human factor (Carroll et al., 1990, Altieri, 1995, Gliessman, 2007). Altieri (1995-2002) stated that for some agricultural organizations, producers and non-governmental organizations (NGOs) who adopt agroecology, agroecology refers to farming methods based on the application of some principles derived from biology and is based on some principles as stated below.

- Increasing biomass recycling and maintaining balance in the nutrient cycle,
- Obtaining suitable soil conditions, applying mulch or cover crops, increasing the organic matter of the soil,

- Creating a closed system in order to minimize nutrient losses from the system,
- Promoting the functional biodiversity of the system to include intra and interspecies biodiversity,
- Promoting biological interactions such as by restoring soil fertility and by not following any other way than ecological methods in pest control.

One of the important goals of agroecological systems is to promote food security, which is defined as people's access to food that is sufficient in quantity and quality, nutritious and suitable for their own culture, in order to lead a healthy life.

With the rapid population growth and technological developments, humanity, trying to obtain more products per unit area in order to meet the increasing nutritional need in agriculture, has rapidly increased the use of chemical fertilizers and pesticides. With these inputs used in an uncontrolled manner, agriculture could not be a complete solution to the nutritional problem in the world, but it caused soil to deteriorate, pollute and even disappear. Many studies have shown that wrong practices in agriculture cause environmental pollution, pollution of groundwater resources and threaten human and animal health through chemical residues that occur in grown products. Despite all these negative developments, the peasant or small farm sector, which offers numerous ecologically based agricultural solutions, offers promising models for maintaining yields and maintaining ecological integrity without agrochemicals, by promoting biodiversity.

With these models, production is made in many countries with not less than 50% of domestic consumption (ETC Group, 2009).

Peasant agriculture contributes to food security despite climate change and economic and energy crises. These contributions have led to the introduction of food sovereignty and agroecological based production systems as a concept, which has attracted great attention in the world in the last two decades. Two international reports on work in this field (IAASTD, 2009; de Schutter, 2010) reveal the need to increase and improve food production in the frame of the most efficient agricultural systems by adopting agroecology to feed the human population for nine billion by 2050.

Considering the future scenarios regarding climate, energy and economy, it is understood that agroecology is one of the safest ways for sustainable development. Agroecology is seen as a new "agricultural revolution" on scientific, methodological and technological foundations in the world. Agroecology-based production systems provide biological diversity by forming the basis of food safety, as well as using energy efficiently and being socially fair.

The roots of the agroecological proposal

Most of the developing countries have a significant peasant population consisting of hundreds of ethnic groups with roots dating back 10,000 years from traditional agriculture. In many countries around the world, small farmers provide a large part of agricultural production. For example, in Latin America, it is known that small producers with a population of no less than 16 million contribute about

41% of agricultural production. These farmers are also responsible for 51% of corn production, 77% of bean production and 61% of potato production in these countries. There are approximately 33 million small farms in Africa, corresponding to 80% of the farms in the region. Most farmers in Africa produce on less than 2 hectares of land, and these farmers account for two-thirds of all farmers. It is known that almost half of the small farms in the world (193 million hectares) are found only in China. 75 million rice producers in China probably produce rice using methods similar to those used more than 1,000 years ago.

There are many studies revealing that agricultural production by small farmers contributes significantly to food security, livelihoods of the rural people, and local and national economies. 70% of the food produced in the world is grown on land with an average size of 2 hectares. In fact, most of the food consumed in the world today is grown from local seeds and without industrial agrochemicals. Local producers, who grow more than five thousand native plant species, have donated more than 1.9 million plant seeds to the World gene banks.

Traditional farmers in many parts of the world have managed harsh environments sustainably. These farmers did not need mechanization, chemical fertilizers, pesticides or other modern agricultural technologies in their production, by developing or inheriting complex farming systems adapted to local conditions. One of the most prominent features of peasant farming systems in agricultural production is the production with polyculture farming models and the presence of a large number of plant diversity. The strategy of farming with a large number of species helps to obtain satisfactory yields in the long term, and even low technology and limited resource use can maximize returns. While this genetic diversity helps farmers to be aware of production-related assets such as soil quality, slope, water availability and protect their crops from diseases, pests, drought and other stresses, at the same time makes it easier for them to benefit from all agricultural ecosystems. For these reasons, most agroecologists agree that traditional agroecosystem systems can help to solve the problems originated from climate change, energy and financial crisis. Genetic diversity also enables farmers to benefit from different microclimates. Rural women traditionally carry out most biodiversity conservation activities. Women are therefore an important source of information on seed storage and locally based gastronomy in their own farms. For these reasons, the majority of agroecologists agree that when people face challenges such as climate change, energy and economic crisis, agricultural ecosystems can solve many of these challenges.

The productivity, efficiency, and flexibility of peasant agriculture

Many advocates of the green revolution and other modern farming programs agree that the integration of traditional farming systems into modern farming systems is a positive step for people to get a share of increased income and achieve prosperity. Many people agree that small agricultural farms are inefficient and often provide food security, although they have no meaningful marketable production potential. Many scientists believe that there is no overproduction with traditional systems, as it produces by hand and does not benefit from mechanization. Productivity may be low, but the reasons seem more social than technical. Once the small farmer is successful in providing his food, he does not feel pressure to increase yield or innovate (Rosset, 1999; Altieri, 2002).

From the point of view of productivity, it is accepted that higher efficiency is obtained in polyculture agriculture in the same management style than monoculture agriculture. These yield advantages in polyculture farming can range from 20% to 60%. Because polycultures reduce the damages caused by weeds, insects and diseases, as well as provide more efficient use of existing water, light and food resources. For example, it has been demonstrated that in Mexico, 1.73 ha of monoculture corn must be grown in order to obtain the food produced by 1 ha of corn-squash-bean polyculture agriculture. In addition, compared to the dry matter yield of 2 t / ha of monoculture maize, the corn-squash-bean polyculture cultivation produces 4 t / ha dry matter (Gliessman, 1998). Corn and beans form the basis of food security in many Latin American rural areas. A study by Isakson (2009) in Guatemala showed that although most villagers earn their main income from different activities, 99% of respondents in a survey on these issues stated that agroecological activities are important for themselves and their families' food security.

There are ample evidence to suggest that most peasant systems are productive despite using very low chemicals. Recent research shows that many small farmers are preparing for and even coping with climate change by using drought-resistant local varieties, following soil conservation practices, as well as using many other traditional methods. After extreme climatic events in the last two decades, agricultural performance observations have revealed that flexibility to climate disasters is closely related to the typical biodiversity levels of small farms. Teixeira et al. (2021) reported that agroecosystems use reduced external inputs and require some practices that encourage ecological processes to improve soil quality and fertility. The researcher stated that this way, agroecological practices can be efficient without the need for extensive use of external inputs. Understanding the agroecological characteristics of traditional agroecosystems is necessary in order to understand the basis of climate change resilient farming systems.

Growth and influence of agroecology

Studies which include many farmers and NGOs show that agroecological systems do not produce very low-scale production. A production increase of 50-100% is obtained in many alternative production styles. In some of these systems, efficiency is increased several times based on more labor, technical knowledge and skills than expensive purchased inputs. Although these systems were initially adopted by many NGOs and community leaders as localized efforts in isolated rural areas, they are now seen as work adopted by hundreds of peasant communities in many countries. The success in dissemination of these systems does not only come from the diversity resulting from better use of local resources. It also depends on the state's contribution to local and regional markets such as credit, seed support and agroecological technologies, as well as the trainings received on these subjects.

Even the most traditional farming systems are not static systems and they undergo many changes over time. There are some main forces shaping the agricultural systems implemented. We can list these forces as advances in science and technology, changes in climate, population growth, agricultural subsidies, market power, consumer demand, food sovereignty and land reform. Agroecologists have had the potential to exist in a changing and developing world by using some of the principles and practices on which agroecology is based to redesign and optimize small farming systems.

However, the sustainability of this heritage is constantly threatened by modernization. In addition to the experiences gained in the management of agricultural diversity and natural resources, it is very important to protect and preserve these systems ecologically and culturally (Koohafkan and Altieri, 2010).

Although agroecological movements have achieved many positive gains over time, there are many factors that limit the full application of agroecological methods. It is important that agroecological alternatives are adopted by a large number of people, that they are accessible to all, and that they are fair and sustainable. For this, the policies to be implemented by the institutions related to these works and the reforms to be made in the research and development agendas are of great importance.

Circular agriculture

All over the world, modern farming methods affect nature, people's health and food production. Many countries face great difficulties in accessing clean water, especially in addition to nitrogen and phosphate pollution. How do we feed ourselves when we imagine that our ecosystems have deteriorated to the point where vital products can no longer grow? In this case, it turns out that what we need to do is to ensure sustainable food production on this planet where soils are depleted, biodiversity is rapidly declining, there is little clean drinking water and more than 820 million people do not have enough food. Based on this idea, in recent years, a new concept called "Circular Agriculture" has been introduced as a way of getting rid of the known disadvantages of modern agriculture by countries that have advanced in agriculture.

Circular agriculture starts with the recovery of soil fertility. Soil is one of the most important resources of circular agriculture. Nutrients in the soil have an important role in circular agriculture. For this reason, it is extremely important that the soil is healthy. The fertility of the soil and the amount of organic matter in the soil are important for high yields. In addition, it helps the nutrients, trace elements and water in the soil to hold better.

Circular agriculture aims to minimize the harmful substances and waste outputs that occur in a production. In this system, waste products from a production chain are raw materials for others. The slogan in circular agriculture is taht production is done locally if possible, regionally and / or internationally if necessary. This means less food travels and fewer products shipped around the world.

Circular farming is more than a method, it is a task, and in this system every farmer must find the most appropriate answers for his production. There are a number of measures in this agricultural system, from creating ideal conditions for attracting beneficial insects to avoid using pesticides, to generating its own energy in the biogas plant with waste from its own production. The focus of circular agriculture is not to drag the farmer into the maximum production despair at the lowest cost, but to minimize the use of raw materials. Some goals have been set to achieve the circular agriculture perspective:

1. This farming system will work if farmers are paid a fair price for their produce. Otherwise, producers in financial difficulties will face problems in adopting the working methods of circular agriculture.
2. In this agricultural system, more value should be given to food. The higher the value of the food, the less waste there will be. Valuing food also means encouraging consumers to buy sustainable products.

Circular farming has focused on some ecological principles to create an optimum combination of many components. İn these principles, there are farmers, subject-matter people, firms related to circular farming, researchers and and modern technology. Circular agriculture not only uses resources and energy used in production efficiently to obtain a good yield, but also tries to put very little pressure on the environment, climate and natüre. Circular farming does not mean a return to rural nostalgia of the early 1900s. Circular agriculture means using the biomass obtained in agricultural production as well as the increased output from the production of the food sector as renewable resources. It means making production with scarce resources, saving much more and consuming less biomass. Circular farming has some principles. One of the important of these principles is that circular agriculture does not use more land or resources than is absolutely necessary. Fields are primarily used in the production of food products, planting successive products for the best use of the field, ensuring production in the field almost throughout the year, adding mixed products to the rotation whenever possible.

Although it excites people to think that world agriculture will be more sustainable with the concepts of ecology and circular agriculture, it is still a question of how circular agriculture can be designed to provide the most benefit for future food production and offer the best expectations for farmers. While farmers can play a key role in this change, it cannot be inferred that they can do this alone. All parties must strive to overcome technical, economic, legal and social obstacles to such a change. For this, the development of a wide variety of new revenue and business models and chain systems is essential.

CONCLUSION

There are many traditional farming systems in the developing world. These systems include many agricultural diversity and reflect an important agricultural heritage on a global scale. This very important agricultural heritage is unfortunately under constant threat from many modernization advocates. Agricultural biodiversity is a very important issue for the future of humanity. In addition, the management and sustainability of soils and water resources is extremely important. Saving and preserving the ecological foundations of these agricultural systems is the guarantee of our future (Koohafkan and Altieri, 2010). Food sovereignty is defined as the right of everyone to have access to food in sufficient quantity, quality, rich in nutrients and suitable for their own culture. The essence of agroecological systems is to promote food sovereignty for people to live a healthy and dignified life.

Agroecological movements have started to spread in many countries of the world. However, there are many obstacles to this proliferation and these obstacles restrict the spread and full implementation of agroecological movements. Large-scale reforms are required for the spread of agroecological movements. Major changes are needed in some policies, research and development activities to ensure food safety of people. Only in this way can it be ensured that large masses adopt agroecological activities (Altieri, 2009).

The spreading potential of local agroecological innovations depends on the skills and ownership of the various stakeholders and relevant institutions involved in these issues. These skills include building the necessary alliances for farmers to gain increased income, such as agroecological knowledge and access to land, seeds, government services, solidarity markets. The active participation of farmers and scientists in the process of technological innovation and dissemination through Campesino a Campesino models will be key role (Altieri and Toledo, 2011).

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CHAPTER VI

ANNUAL RYEGRASS (*Lolium multiflorum* Lam.)

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INTRODUCTION

Annual ryegrass (*Lolium multiflorum* Lam. or *Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot), which is called Italian grass, is a cool season plant originating from southern Europe and belonging to the Poaceae family. Annual ryegrass is closely related to perennial ryegrass (*Lolium perenne* L.) and they are widely distributed throughout the world including Europe, North and South America, New Zealand, and Australia (Lopes et al., 2009). *Lolium multiflorum* is often subdivided into two types as Italian ryegrass and Westerwolds ryegrass. Italian types require winter cold in order to flower, but Westerwolds types flower in increasing day length and/or warm temperatures (Aamlid et al., 1997). Annual ryegrass is an important short- duration grass. It has high palatability and digestibility and so it is highly valued forage for livestock (Rhind, 1974; Hannaway et al., 1999, Demiroğlu Topçu et al., 2021).

Identification

Annual ryegrass may be identified by vegetative parts such as leaf, stem, collar, and root or floral parts such as inflorescence, spikelet, and seed like other grasses. See Figures 1–8.

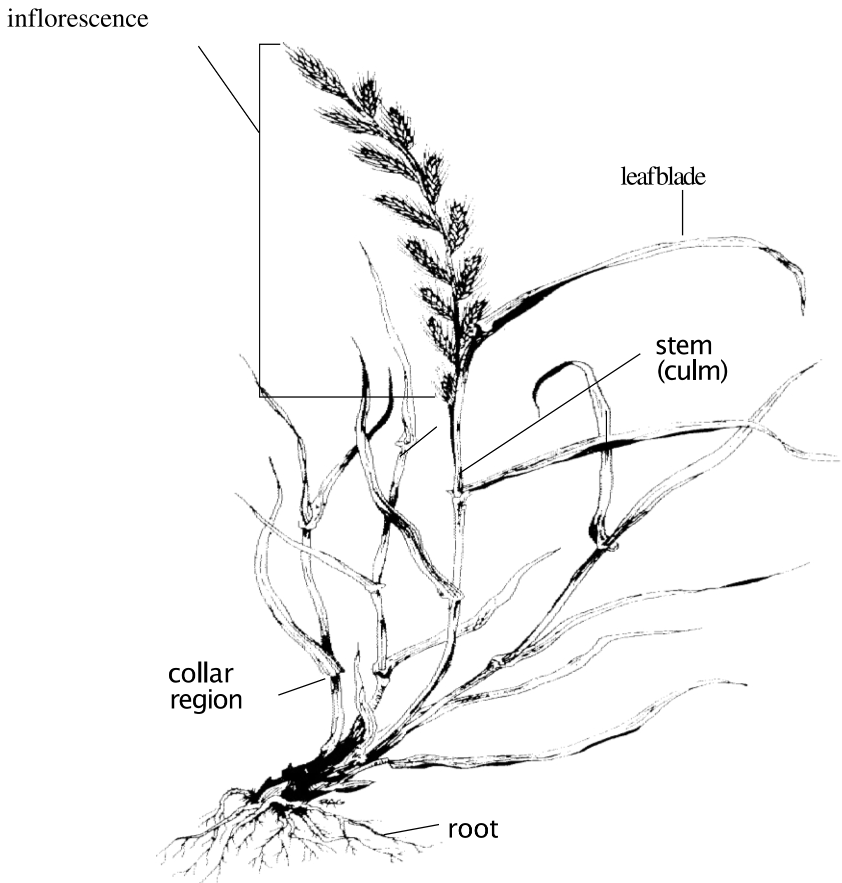

Figure 1. Annual ryegrass plant (Hannaway et al., 1999)

Vegetative parts

Leaf

Leaf blades of Italian ryegrass are rolled in the bud, but in perennial ryegrass they are folded. Leaf blades change from 4 to 10 mm wide and from 6 to 20 cm long. They are sharply taper-pointed and keeled (Figure 2). Blades are bright green. They have prominently ridges on the upper surface. Lower surfaces are hairless, glossy and smooth and, they have a prominent midrib. Leaf margins are slightly rough. The blade is joined to sheath at the collar, a zone of meristematic tissue (Figure 3). The leaf sheath is split and overlapping. It has no hairs (Hannaway et al., 1999).

- Blade (lamina): It is above the collar and part of the leaf
- Keel: Keel: It is central ridge on back or outer surface of folded leaf or seed
- Leaf: It is main lateral part of a stem. It serves as the main photosynthesis organ

Meristem: It is a group of actively dividing cells. Roots, shoots, leaves, and flowers are derived from it (Figure 3).

Sheath: It is lower part of the leaf. It encloses the stem internode

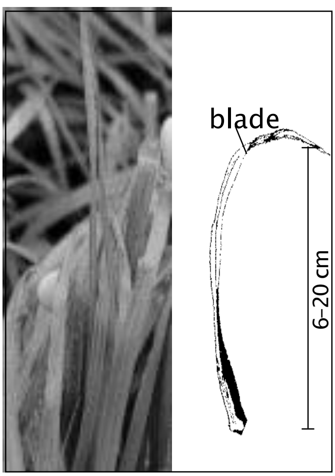

Figure 2. Leaves (Hannaway et al., 1999)

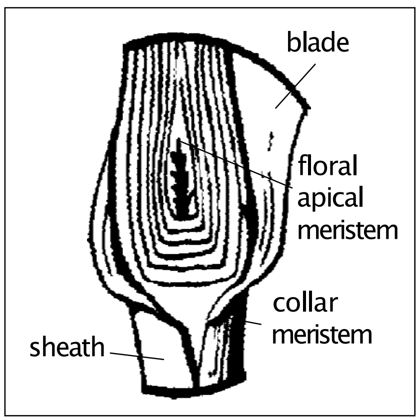

Figure 3. Meristems (Hannaway et al., 1999)

Stem

Stems (culms) are comprised of nodes and internodes. Each node bears a leaf. The uppermost culm segment is called the peduncle, the structure that supports the inflorescence. Annual ryegrass stems vary from 30 to 100 cm tall depending on cultivar, moisture, and environmental conditions. Annual ryegrass has pale green or yellowish stem base (Hannaway et al., 1999).

- Internode: It ia a stem region between nodes
- Node: It is where the leaf attaches to the stem

Collar

The collar region is a narrow band of meristematic tissue accounting for increasing ligule blade length. When the leaf achieved its maximum length, cells of collar stops dividing. This region in annual ryegrass is narrow, hairless, and yellowish to whitish-green. Ligule is 1-4 mm (Figure 4). Auricles are narrow and hairless (Hannaway et al., 1999; Whitson et al., 2000).

- Auricle: Small claw or ear like outgrowths at the junction of the sheath and blade of some grasses
- Collar: Zone of meristematic tissue at the junction of the sheath and the blade
- Ligule: Outgrowth at the inner junction of the leaf sheath and blade, often membranous, sometimes a fringe of hairs

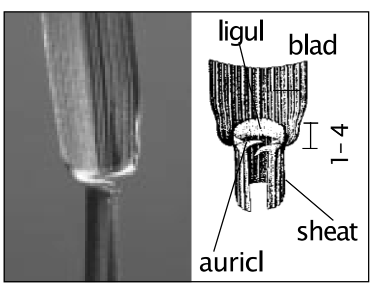

Figure 4. Collar region (Hannaway et al., 1999)

Root

Annual ryegrass has a highly branched and dense root system with many fibrous, adventitious roots (Figure 5). It has no stolons or rhizomes (Hannaway et al., 1999).

- Adventitious: Second root system that develops from the lower nodes of tillers
- Seed (seminal) roots: Short lived first roots

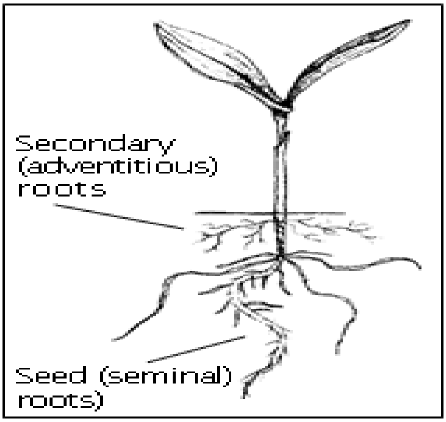

Figure 5. Roots (Hannaway et al., 1999)

Floral parts

Inflorescence (seed head)

Inflorescence in Italian ryegrass begins when the third head emerges from its sheath. This physiological development shows the transition from the vegetative stage to the generative stage and the formation of caryopsis (Beddows, 1973). The inflorescence terminates the stem (culm). In annual ryegrass it is a solitary spike, 10 to 40 cm, but typically about 30 cm. It has 5 to 38 alternately arranged spikelets attached edgewise directly to the central axis (rachis) (Hannaway et al., 1999). See Figure 6.

- Culm: Stem of grasses comprised of nodes and internodes, each node bearing a leaf
- Inflorescence: Seed head terminating the stem
- Peduncle: Uppermost culm segment supporting the inflorescence
- Rachis: Central axis of the seed head
- Spike: Inflorescence in which spikelets are attached directly to the rachis
- Spikelet: Unit of the grass inflorescence, generally composed of two glumes and one or more flowers (florets), each borne between a lemma and palea.

Figure 6. Inflorescence (Hannaway et al., 1999)

Spikelet

Annual ryegrass spikelets are 8 to 30 mm long, excluding awns, and contain 10 to 20 florets. Florets are 6 to 10 mm attached to the rachilla (Figure 7). The terminal spikelet has two glumes. The inner glume is absent in the other spikelets (Hannaway et al., 1999).

- Awn: Slender, bristle-like projection of the lemma
- Floret: Lemma and palea with the enclosed flower
- Glumes: Bracts at the base of the spikelet cradling the enclosed florets
- Rachilla: Central axis of the spikelet, each segment supporting a floret

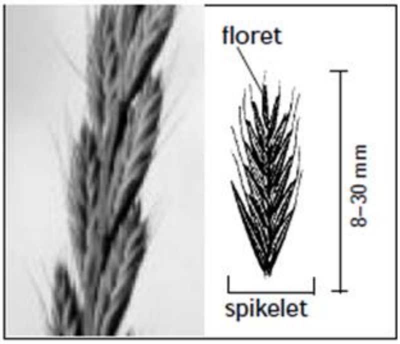

Figure 7. Spikelets and florets (Hannaway et al., 1999)

Seed

A seed is a mature ovule enclosed by a lemma and a palea. The lemma, the lower bract, is 4 to 8 mm long, with a straight, slender awn up to 15 mm. The rachilla segment is somewhat wedge-shaped (Figure 8). Seeds per kg average 502,000; with a range of 440,000 to 550,000 per kg (Hannaway et al., 1999).

- Bract: Modified leaf, differing from foliage leaves in size, shape, color, and texture
- Lemma: The lower of two bracts enclosing the flower
- Palea: The upper of two bracts enclosing the flower

- Rachilla segment: Portion of the rachilla that breaks off and remains at the base of each seed

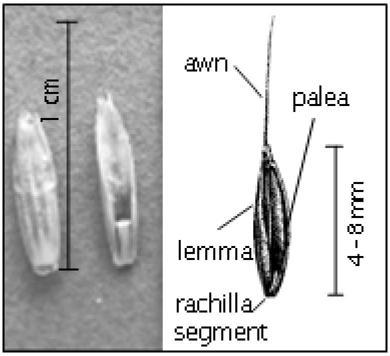

Figure 8. Seed (Hannaway et al., 1999).

Adaptation

Annual ryegrass likes cool and moist climates. It grows best between 20-25 °C. Early spring and fall are best times for annual ryegrass to grow. It is more heat tolerant than perennial ryegrass, but even if there is enough water, temperature stress causes summer production to suffer (Hannaway et al., 1999). In cool regions annual ryegrass shows a biennial tendency. In cold climate it regrows quickly and produces seed in late spring. Although few plants survive more than a year, this reseeding characteristic can create a weed problem in some regions. It may be a weed problem in oat and wheat crops. It shows herbicide resistance and increases possible weed problems (Gill, 1995).

Ryegrass generally prefers fertile, well-drained soils. It likes loam or sandy-loam soils. It grows even on many soil types, including poor or rocky soils. In many climates it tolerates clay or poorly-drained soils (Evers et al., 1997, Baytekin et al., 2009). The annual lawn is tolerant of 15-20 days flooding at temperatures below 27 °C. It can survive in various soil types. It can grow in soils that heavy and high water content. It prefers 5.5-7.0 soil pH (Valenzuela and Smith, 2002). It grows in soils from 5.0 to 7.8 pH. If the pH is below 5.0, aluminum toxicity can be a problem. High pH can cause chlorosis due to iron and manganese deficiency (Hannaway et al., 1999).

Annual ryegrass doesn't like drought or low temperatures. Italian ryegrass can withstand -22 ° C (Carey, 1995; USDA, 2002). Since it has a strong seedling and plant growth, it has the ability to suppress small seeded and slower growing species (Davies, 1928).

Benefits

Planting annual ryegrass provides erosion control, increases percolation, reduces compaction and acts as a nurse crop for fall legumes. About 1.2 million hectares of Italian ryegrass are grown in the United States, and 90 % of this production is used for winter pastures (Hall, 1992). Italian ryegrass is extremely tasty and nutritious for all types of livestock. It has many varieties grown for pasture, hay and silage (Carey, 1995; Hall, 1992; USDA, 2002). The high yield and forage quality of Italian ryegrass makes it a popular feed source as an excellent food source when there is a shortage of hay (Hall, 1992; Hannaway et al., 1999). Italian ryegrass is used to prevent soil erosion in the north-west and north-east regions of the USA, while on the other hand it is used to absorb excess nitrogen in the soil where corn and other row crops are located (Hall, 1992). Beside this, Italian ryegrass is used for soil stabilization. Since Italian ryegrass has a very dense, fibrous and not goes too deep root system, it develops rapidly and prevents erosion. On the other hand, it allows the growth of other species that grow slower and have a longer life span (Hafenrichter et al., 1968; Hall, 1992; Hannaway et al., 1999).

Pasture

Italian ryegrass pastures are some of the best quality pastures in the southeastern United States. Annual ryegrass is used as pasture for cattle, heifers, and dairy cows. Its strong vigor, high yield and quality make Italian ryegrass very valued for temporary pastures in the coastal Northwest. Italian ryegrass is a fast growing and highly productive plant. It has a short life span and aggressive development. In this regard, Italian ryegrass is not very desirable in long-term pastures (Hannaway et al., 1999). When grazing, it should be divided into sections to prevent heavy grazing. After each grazing, it is necessary to topdress and irrigate once.

Silage and hay

Italian ryegrass is usually grown for silage. The high production capacity of this plant reveals once again the importance of the plant, especially when it is thought that there may be feed shortages (Budak et al.,2017) Like the all other forage crops, the quality of Italian ryegrass silage is greatly affected by the maturity stage. In order to obtain optimum yield and quality, the best harvesting time is the period from boot to early-heading stage. Harvesting annual Italian ryegrass for hay is not recommended in areas such as the coastal Pacific Northwest having high rainfall. Because in this region weather is rainy and humidity and good hay-curing lasts too long (Hannaway et al., 1999).

Although the fact that Italian ryegrass has many leaves can make it difficult to dry it compared to other gramineous, it is very easy to make hay from warmer months' harvests (Joel, 2014).

Erosion fighter

Ryegrass has an extensive and dense root system. So, it is a good soil holder plant. The cover crop comprised from Italian ryegrass establishes quickly even in poor, rocky or wet soils. Because of these specifications, plant tolerates some flooding once established. It is suited for field strips, grass waterways or exposed areas (Clark, 2008).

Soil builder

Ryegrass has dense but shallow root system. These roots help improve water infiltration. On the other hand they enhance soil tilth. Italian ryegrass' rapid aboveground growth helps increase organic matter of soil. Although it is possible to obtain 10089 kg dry matter ha^{-1} yield in a full season with high humidity and fertilization, approximately 4484 to 8968 kg dry matter ha^{-1} of dry matter can be easily taken (Clark, 2008). Italian ryegrass can also be used as a cover plant alone or with some other species, and when used in this way, it helps to survive other species that grow slowly, have a long life or are resistant to winter in soil (Hannaway et al., 1999).

Weed suppressor

When planted with some other legumes or Poaceae, Italian ryegrass also serves as a weed control due to its early development. It also helps as a live cover of mulch in continuously harvested production systems when sufficient moisture and fertilizer is available. In places where there is no snow cover and long-term cold prevails, it can be damaged by the winter cold and die. Even in such cases, it creates a mulch layer against weeds that may appear in early spring (Clark, 2008).

Nutrient catch crop

Italian ryegrass is a plant that uses high nitrogen. In addition to the nitrogen it uses, it also reduces N leakage with precipitation. A study conducted at the University of California has shown that Italian turf can capture up to 48 kg N ha^{-1} of nitrogen with its dense fibrous root system (Williams et al., 1990).

Nurse/companion crop

Italian ryegrass helps the slow growing legumes plants to settle well and overwinter, even if it is damaged by the winter cold in cold regions (Clark, 2008).

Emergency forage

Italian ryegrass gives very palatable forage. Grazing period of pasture consisted of Italian ryegrass alone or mixed with other plants can be extended in late fall and early spring (Budak et al., 2017). In addition, when alfalfa is affected by winter cold and dies, Italian ryegrass can be used as an emergency feed because of its quickly growing and producing a lot of feed in a short time.

Varieties

There are a large number of cultivars commonly known in Italian ryegrass. If considered as animal feed, improved varieties should be used. There are diploid (2n = 14 chromosomes) and tetraploid (4n = 28 chromosomes) varieties in Italian ryegrass. Tetraploid varieties produce larger plants with wider leaves and mature later (Clark, 2008; Sarrantonio, 2012).

Diploid

Each chromosome is present twice in the cell. Ryegrass then has narrow leaves, thin stems and a generally small seed. Diploids have good emergence, persistence and predominant tillering (Hall, 2016).

Tetraploid

The number of homologous sets of chromosomes is doubled compared to diploids. Each cell contains the same chromosome four times, resulting in long and broad leaves, larger stems and larger seed but tetraploids are not necessarily higher yielding. They have the characteristic of containing more sugar and thus being more palatable (Hall, 2016).

Winterhardiness of the Italian ryegrass varies between varieties. Italian ryegrass can live for 2-4 years in coastal areas without seed ripening and under good management. Westerwold types, on the other hand, show a shorter life (Alderson and Sharp, 1995). Italian ryegrass varieties are divided into three categories called early, mid-early and late. While this grouping is useful to some extent, there is fundamental overlap between these varieties (Hannaway et al., 1999).

Establishment and fieldwork

Italian ryegrass germinates and establishes well even in cold soil. While 23-33 kg ha^{-1} seed are planted in spreading sowing, 11-22 kg ha^{-}

^{1} of seed at a depth of 0.6-1.3 cm is sufficient to create a good cover in row planting. There is no need to incorporate with other seeds while broadcasting. Irrigation after planting helps to create a good germination and growth.

Using uncertified seeds will lead to weed growth. A pure stand should not be expected if common annual ryegrass is seeded, as annual ryegrass is hybridized with perennial ryegrass and turf-type annual ryegrass species.

Winter annual use

Italian ryegrass is planted in the autumn in regions with mild climate. In cool areas, it can be planted from mid-summer to early autumn. However, sowing should be done at least 40 days before the first frost (Hofstetter, 1992, Demiroğlu Topçu et al., 2016). Late planting may cause the plant to be damaged by the winter cold. If aerially seeding prefer, the seed amount should be increased by 30% compared to broadcast sowing (Ball and Burdett, 1977).

Italian ryegrass can be planted into corn at last cultivation or later (with 2-5 kg ha^{-1} red or white clover) or after silage corn is harvested. Or it can be planted into soybeans when the leaves of the beans turn yellow or later (Hofstetter, 1988; Hofstetter, 1992). When overseeding into solanaceous crops such as peppers, tomatoes and eggplant, it must be waited until early to full bloom of the plants.

Spring seeding

Italian ryegrass can be planted after small grains or an early-spring vegetable crop, for a four to eight-week summer period before a fall vegetable crop (Sarrantonio, 1994).

Mixed seeding

Italian ryegrass can be planted at 9 to 17 kg ha^{-1} with a legume or small grain in fall or early in spring. Ryegrass will dominate the mixture unless seeded at low rates or mowed regularly. The legume will compete better in low-N conditions. The legume must be planted at about two-thirds of its normal rate. P and K fertilizers are important when growing annual ryegrass with a legume.

Some Californian farmers have found that a 50:50 mixture of ryegrass and crimson clover can be successfully grown for autumn plantings in vineyards (Ingels, 1995).

Although it is not always a common practice, it can be thought that the planting Italian ryegrass with oats at a rate of 22 kg ha^{-1} or planting at a rate of 12 kg ha^{-1} into small grains that overwintered can provide a good autumn grazing. Seeding with red clover or other large-seeded cool season legumes may also work well, although in some cases ryegrass is damaged by winterkill (Clark, 2008).

For temporary pastures, annual ryegrass can be planted in mixture with red clover, white clover, oats, or a Brassica species, such as kale. For cover crop and erosion control, it can be mixed with tall fescue, orchardgrass, or creeping red fescue in areas where precipitation is greater than 720 mm. For areas with 480 to 720 mm, tall fescue and subterranean clover can be used (Hannaway et al., 1999).

Maintenance

Ryegrass must not be overgrazed or cut closer than 8 to 10 cm. A ryegrass stand can survive many years in orchards, vineyards, and other areas if allowed to reseed naturally and not subject to heat, cold or drought (Clark, 2008).

Annual ryegrass gives good respond to high soil nutrient levels. It can grow in a soil pH range of 5.0 to 7.8. If pH is below 5.0, aluminum toxicity may create a problem. Higher pH can cause chlorosis due to iron and manganese deficiencies. By meeting but not exceeding soil, plant, and animal needs it is possible to have a continual ryegrass management. Fertilization requirements and harvest/grazing management must be balanced for high yielded and quality forage, optimum N2 fixation by forage legumes, maximum recycling of animal manures and municipal biosolids. Fertilization should be based on a soil test (Hannaway et al., 1999). Annual ryegrass gives maximum yield responses to N fertilization given at the time of growth. This period is usually early spring in warmer climate and late spring in colder regions. Annual ryegrass yields generally increase with N application rates following each harvest.

Killing and controlling

Annual ryegrass can be killed mechanically by disking or plowing, preferably during early bloom before it sets seed (Williams et al., 1990; Sarrantonio, 1994). Annual ryegrass can’t be killed completely by mowing (Dabney, 2007). Annual ryegrass can be killed with non -persistent contact herbicides, although some users report incomplete kill and/or resistance to glyphosate (Gill, 1995; Nelson, 2007). Achieving good control of annual ryegrass with glyphosate herbicides before planting a summer plant such as corn or soybeans depends on timing, application rate and weather conditions. Glyphosate with ammonium sulfate and surfactant in late March to early April must be applied. Label directions must be examined carefully with respect to pH and mixing order. Adding ammonium sulfate, other glyphosate additives or citric acid is for ensuring that the calcium, magnesium, iron and other dissolved minerals in the water do not interfere with the glyphosate activity. Weather conditions can affect how well glyphosate controls annual ryegrass.

Cutting and grazing management

Cutting or grazing greatly affect forage quality, productivity, and persistence. Demiroglu Topcu et al., (2021) found that the all characteristics studied in annual ryegrass were affected from cultivar and harvest stage. Quality is affected from maturity stage. Annual ryegrass must be harvested at the boot stage to obtain high quality forage. For silage, plants must be wilted prior to ensiling. Lower moisture will reduce losses from silage. With a five cuttings system, 40 % of yield is obtained in the first harvest, 15 to 20 % in the second harvest and 10 to 15 % in subsequent harvests. Late maturing varieties can reach to maturing 10 to 14 days later. But this delaying may cause damage in rainy regions. In case of rain damage, to obtain high-quality forage; grazing, green chopping, or ensiling early spring growth is a solution. To provide plant recovery, annual ryegrass must be fertilized with N immediately following the initial harvest (Hannaway et al., 1999).

Pest management

Weed potential

Although Italian ryegrass has many beneficial uses, it is said that Italian ryegrass is a weed in some countries. For example it is known a weed in wheat and small grain crop in some USA states (Liebl and Worsham, 1987; Webster and MacDonald, 2001). In general, it is said that Italian ryegrass is one of the most common and troublesome weeds in wheat and small grains in some southern states of the U.S.A. (Elmore, 1988). It is reported that Italian ryegrass x wheat interaction caused reduction of some characteristics of wheat such as height, leaf number, tillering, leaf area, percent total nonstructural carbohydrate (Stone et al., 1998). Appleby and Brewster (1992) stated that 20 Italian ryegrass per m^2 reduced winter wheat yields severely. Yield losses in wheat up to 60 % due to the competition of Italian ryegrass was reported (Appleby et al., 1976). On the other hand, In Australia it was reported that annual ryegrass (*Lolium rigidum* Gaudin), a relative species of Italian ryegrass decreased dry matter production and grain yield of wheat by reducing the number of fertile tillers and spikelets (Reeves, 1976). Italian ryegrass is not recommend to sow together with perennial grass or legumes, because it may be aggressive and may harm the other components of the mixture (Miller, 1984). It is the most common

Lolium species in Arkansas and most often has been misidentified as poison ryegrass (*Lolium temulentum* L.) or perennial ryegrass (Bond et al., 2005).

Insect and other pests

Ryegrass attracts few insects and generally can reduce insect levels in legume stands and many vegetable crops, such as root crops and brassicas. Rodents become occasionally a problem when ryegrass is used as living mulch.

Forage quality and nutritive value of Italian ryegrass are affected from leaf diseases. Leaf spot, barley yellow dwarf virus, and blast cause minor problems. Although rust is not toxic to animals, palatability can be affected from rust. The spores of rusts and smuts can cause significant respiratory problems for horses (Hannaway et al., 1999). Annual ryegrass also can host pin nematodes (*Paratylenchus projectus*) and bromegrass mosaic virus.

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CHAPTER VII

BENEFITS OF COVER CROPS

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INTRODUCTION

Cover crop cultivation is an old practice (Kaye and Quemada, 2017). Cover crops are generally single or perennial herbaceous plants that grow rapidly and cover the soil with the dense habitus they form on the surface (Kitiş, 2010). In other words, cover crops can be defined as plants used to cover the soil surface (Sharma et al., 2018). Cover crops are also known as green fertilizers, catch crops or live mulch. Green manure plants are generally nitrogen fixing legumes and are grown to supply nitrogen to the main crop that follows itself. Catchers are plants grown in production systems during fallow periods to get nutrients, especially nitrogen, that would be lost if there is no main crop in the field. Live mulches cover products grown during and after the main crop's growing season (Acir and Günal, 2019). These plants are widely cultivated to protect the soil from erosion and prevent nutrient loss in deeper layers through seepage and runoff (Sharma et al., 2018). In recent years, the use of cover crops has become widespread in both field and garden agriculture in order to increase soil fertility and weed control (Aykas et al., 2010).

The germination and development of ideal cover crops should be fast, be able to bind atmospheric nitrogen, tolerant to adverse climatic conditions, send their roots deep to the root zone of nutrients that the main products cannot receive, produce large amounts of biomass in a short time, be easy to process and grow, should not compete with the main crop, be tolerant to insects and pests, have the ability to suppress weeds, and planting must have an appropriate cost for it (Reddy, 2016). Cover crops can be divided into different groups as summer-winter and legume-non legume plants (Kitiş, 2010; Sharma et al, 2018). Summer cover crops include cowpea (*Vigna sinensis* L.), buckwheat (*Fagopyrum esculentum* Moench.), yellow lupine (*Lupinus luteus* L.) and kidney vetch (*Anthyllis vulneraria* L.). Cover crops that can be used for winter are common vetch (*Vicia s*ativa L.), hairy vetch (*Vicia villosa* Roth.), hungarian vetch (*Vicia pannonica* Crantz.), narbon vetch (*Vicia narbonensis* L.), pea (*Pisum sativum* L.) and phacelia (*Phacelia tanacetifolia* Bentham) (Kitiş, 2010). Legume cover crops allow the use of atmospheric nitrogen for plants to be grown later, while non-legume cover crops are used to prevent soil erosion and minimize nitrate leakage (Smith et al., 1987; Meisinger et al., 1991, Demiroğlu Topçu et al., 2020a). Nitrogen fixation with legumes helps to reduce the use of nitrogen fertilizers for the next crop (Ladha et al., 2004). Non-legume cover crops are plants grown to help improve many properties of the soil (Sharma et al., 2018). Cover crops can act as an alternative host for some insects and pathogens, although they cause additional equipment and labor costs in the enterprises (Lu et al., 2000). Also, some non-legume cover crops may grow back into competition with the main crop if they are not destroyed properly. Although they have some negative aspects, they have positive benefits in many aspects such as improving the soil health, preventing the development of especially weeds, preventing soil erosion, providing a natural environment for predators and parasitoid insects, controlling insect and pest populations that cause problems in production, preserving soil moisture and improving soil quality. Long-term use of cover crops is beneficial in terms of soil fertility and storage of soil water (Qi and Helmers, 2010).

BENEFITS of COVER CROPS

Prevention of soil erosion

Cover crops are grown mainly to prevent soil erosion (Parker, 1915). In our country, there is a serious erosion problem in forest, rangeland and agricultural areas in parallel with climate, topography, soil characteristics and socio-economic conditions. 59% of the agricultural lands which constitute the majority of the land use, 64% of the rangelands and 54% of the forest lands are exposed to various degrees of erosion. 14.26% precipitation, 3.36% soil, 47.55% topography and 34.82% vegetation are effective in soil losses occurring in our country. When we evaluate in terms of land use; of the displaced lands in our country occurs 38.71% in agriculture, 4.17% in forest and 53.66% in rangeland areas (CDNSAP, 2019). For this reason, cover crop cultivation is extremely important in terms of preventing erosion in agricultural areas. Laloy and Bielders (2010) reported that cover crops reduced erosion by more than 94% during the planting period compared to bare soil. Cover crop cultivation is also very effective in preventing finger erosion, which is the first stage of water erosion, as it prevents the corrosive effect of the raindrop (Kaspar and Singer, 2011). The use of cover crops with reduced and non-tillage significantly reduces erosion (Myers, 2017). In the reduced soil tillage system, chisel or disc tools are generally used in primary soil tillage, disc tools or cultivators are used in secondary tillage and seed bed preparation. In the non- tillage method, no soil cultivation is done before planting after the harvest of the main crop (Aykas et al., 2010). Cover crops with fine-branched root structures such as perennial ryegrass (*Lolium perenne*

L.), oats (*Avena sativa* L.) and rye (*Secale cereale* L.) have high potential to control soil erosion (De Baets et al., 2011). Soil erosion control is achieved by growing cover crops during autumn, winter and early spring, depending on when the crop is grown. Especially rye, which is used as a cover crop, develops rapidly in autumn and provides excellent protection against erosion as this development continues throughout the winter (Özeker and Ulutürk, 2006). It has been determined that the use of cover crops (lentils, triticale and peas) together with non-tillage agriculture in semi-arid conditions will reduce erosion and improve soil aggregation (Blanco-Canqui et al., 2013).

Preservation of soil moisture

Cover crops allow water to seep into the lower layers of the soil by covering the soil with biomass and improving the soil structure with their roots. Different cover crop species may have different effects on infiltration due to the amount and composition of biomass. Therefore, the infiltration rate varies depending on how much the cover crop grows (Acir and Günal, 2019). Folorunso et al. (1992) found that cover crops such as smooth brome (*Bromus inermis*), settled vegetation and strawberry clover (*Trifolium fragiferum*) increased the infiltration rate of the soil by 37-41% and the total water intake of the surface soil by 20-101%. Sare (2021) reported that non-legume cover crops such as smooth brome and rye increased infiltration by 8-462%. Also, legume cover crops such as crimson clover (*Trifolium incarnatum*), hairy vetch and strawberry clover increased the infiltration rate by 39-528%. In the field trials, infiltration increased approximately 180% with the presence of plant residues on the soil surface. The soil moisture required for early germination and development is provided depending on the time the cover crop is mowed or mixed into the soil. However, water in the soil can be actively consumed by the cover crop. In this case, this problem can be reduced relatively by mixing the cover crops with the soil approximately 7-14 days before the planting of the main crop (Wagger, 1989).

Ensuring weed control

Cover crops prevent the germination and development of some of the early spring weeds due to the competition and shading they create during their development. Cover crop wastes remaining on the soil surface can physically change germination conditions with the help of the environmental conditions (light, soil temperature and humidity) in which the seed is located and allelopathy (Creamer et al., 1996). With the use of cover crops such as smooth vetch (*Vicia dasyca*rpa L.) and oat in corn cultivation, the seed amount of weeds such as *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., *Amaranthus retroflexus* L. and *Datura stramonium* L. at a depth of 0-5 cm has decreased by 30-70% (Dube et al., 2012). McLenaghen et al. (1996) reported that white mustard (*Sinapis alba* L.) used as a cover crop reduced the amount of weeding up to 4%. The allelopathic effects of some cover crops on various weeds are shown in Table 1 (Özeker and Ulutürk, 2006).

Table 1. Weeds on which some cover crops show allelopathic effect

Cover crops	Weed
Hairy vetch	Goose foot, Yellow feather millet, Yellow buckthorn, Field ivy
Red clover	Field ivy, Wild mustard, Italian ryegrass
Rye	Goose foot, Red rooted foxtail
Wheat	Field ivy
Velvet beans	Yellow buckthorn, Sand grass

Swanton et al. (1999) reported that weed damage is dependent on the biological characteristics of the plants grown, environmental conditions and the density of soil covering. Masilionyte et al. (2017) found that the most effective cover crops in preventing weed growth in both low and medium humus soils are white mustard and a mixture of white mustard-buckwheat. Hançerli (2017) stated that the cover crops that reduce weed growth the most in corn cultivation under Çukurova conditions are fenugreek (*Trigonella foenum-graecum* L.), common burnet (*Poterium sang*uisorba L.), Berseem clover (*Trifolium alexandrinum* L.), dwarf chickling (*Lathyrus cicera* L.) and bitter vetch (*Vicia ervillia* (L.) Willd.), respectively.

Improving soil health

Cover crops can reduce the negative effects of soil compaction (Hubbard et al. 2013; Welch et al. 2016). It has been determined that Brassica type cover crops reduce the effect of soil compaction because they can break the compacted soil layers (Chabi-Olaye et al. 2005). In addition, since the root canals of cover crops in the soil improve aeration in compacted soils, they cause a decrease in the volume weight of the soils (Chen et al. 2014). Fourie et al. (2007) found that the organic matter content of the soil in sandy soils increased depending on the cover crop species and cover crop management practices. In an experiment conducted under greenhouse conditions, the effects of seven different cover crops (broad bean, pea, vetch, rye, oat, wheat, mustard) on the phosphorus cycle in the soil were investigated. In the study, it was determined that cereals and mixtures used as cover crops have a greater effect on soil phosphorus than legumes (Maltais-Landry, 2015). Nunes et al. (2018) reported that the use of the no-till system with cover crops would be more beneficial for soil health and crop yield.

Storage of carbon in the soil

Cover crops are an important agricultural practice in sequestering carbon in the soil. Roots and shoots of cover crops feed bacteria, fungi, earthworms and other soil organisms, causing the carbon level in the soil to rise over time (Acir and Günal, 2019). In a study conducted in the United States, it is estimated that approximately 30-105 million tons of carbon can be stored annually with minimum tillage and harvest waste management, 14-29 million tons with the use of rotation and winter cover crops, 11 to 30 million tons with proper fertilization and irrigation (Follett, 2001). Tillage system and use of cover crops are effective in the carbon accumulation in the soil. For example; Higashi et al. (2014) found that with the use of no-till system and rye as a cover crop, the carbon accumulation in the soil increased. Poeplau et al. (2015) concluded that rye used as cover crop increased the organic carbon accumulation in the soil. Wolff et al. (2018) reported that carbon accumulation is higher in the cover crop farming system with minimum tillage.

Prevention of nitrate leakage

The excess nitrate (NO_3) formed as a result of the application of nitrogen fertilizer when the plant does not need it or when it does not need it, washes away from the plant root area by washing or leaking with rainfall and irrigation water, causing pollution by passing into surface and underground waters (Gürbüz, 2019). Cover crops are considered a good tool to reduce NO_3 leakage from agricultural ecosystems (Thapa et al., 2018). It has been determined that non-legume cover crops can reduce the amount of NO_3 leaking into freshwater systems by 56% on average. It has been determined that rye grown as a cover crop in the USA for five years reduces the NO_3 concentration in the drainage water by an average of 48% (Demiroğlu Topçu et al., 2020b). After the summer crop, the soil nitrogen remaining from the planting of a non-legume winter cover crop is retained and the N loss that occurs with washing or surface water flow is reduced (Özeker and Ulutürk, 2006). With winter fallow application and a recommended fertilization, the NO_3-N concentration in the leachate was 15.1-23.2 mg L^{-1}, whereas in the case of a cover crop planted in the fall, this concentration was 7.4-15.8 mg L^{-1} (Feaga et al., 2010). Nitrate leakage is 40% lower than in conventional fertilization systems in legume cover crop application and 70% lower than conventional and bare fallow systems in non-legume cover crop application (Tonitto et al., 2006).

Increased worm population in soil

Long-term use of cover crops contributes to improvement of soil structure and increases the soil worm population (Sharma et al.2018). In particular, the increase in the worm population in the soil is an indicator that the soil is healthy and has good physical properties (Bahar et al., 2010). A study conducted in Ireland for 3 years examined worm populations in twelve cover crops and weed management combinations. In this study, the highest worm population was detected in the pea cover crop (Roarty et al., 2017). Korucu et al. (2018) reported that the worm population in parcels with cover crops is 1.2-1.4 times higher than those without cover crops. Researchers found that the worm population in plots where cover crops were grown was 3.2-3.5 times higher than in plots that did not grow cover crops the following spring.

Ensuring the fight against pests

Organic matter formed in the soil with cover crops causes an increase in biological activity. These organisms reduce the damage of root-pathogens that inhibit the growth of the plant (Bahar et al., 2010). Also, cover crops help reduce the use of pesticides to struggle pests (Sharma et al.2018).

Providing a habitat for predatory and parasitoid insects

Cover crops help the natural cycle by providing food to beneficial insects at different stages of their development by creating a natural environment. At the same time, they provide predator insects with aphids, mites, caterpillars and similar creatures (Bahar et al., 2010). Some cover crops protect the natural habitats of some creatures that feed on green worm larvae and eggs that cause damage to cotton. In addition, some cover crops also provide nectar to honey bees and pollinators (Sharma et al., 2018).

CONCLUSION

The use of cover crops, which have many short and long term benefits, provides an advantage in agricultural production. Producers who want to benefit from these positive effects should determine their needs in line with field conditions and choose the most suitable species or species as cover crops. It should not be forgotten that cover crops are an important application that should be emphasized in terms of adaptation to climate change.

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CHAPTER VIII

COMPARISON OF HUNGARIAN VETCH (*Vicia pannonica* Crantz.), HAIRY VETCH (*Vicia villosa* Roth.) AND COMMON VETCH (*Vicia sativa* L.) SEEDS IN TERMS OF SOME PHYSICAL AND PHYSIOLOGICAL PROPERTIES

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INTRODUCTION

In recent years, serious problems with the supply of the basic needs of the particular animal feed production are emerging. Fluctuations in feed prices and various problems occur in reaching these products at the desired time and amount. For this reason, researches on available feeds and especially on feeds that animals can enjoy are increasing day by day. After having the biggest share alfalfa forage crops group Fabaceae (legumes), which is a member of the family comes from vetches in Turkey (Çaçan and Kökten, 2017). Fabaceae family is the second largest family with 1145 taxa in 69 genera in our country, and vetches are the third largest genus with 89 taxa in this family (Kozan, 2013). It is a forage plant that is produced as green-dry forage or grain of vetches, used for green manure material and grazing for animals (Karaca and Çimrin, 2001; Avcı et al., 2003). As a result of the studies carried out, it can also be evaluated as concentrate feed due to the protein content of the grains above 20% (Açıkgöz, 2001; Seydoşoğlu, 2014).

Table 1. Vetch cultivation area and production amounts in Turkey

Years	Planted Area (da)	Vetch Production (Green forage) (t)
2015	4 365 182	4 281 259
2016	4 428 378	4 542 042
2017	4 456 256	4 597 600
2018	3 869 465	4 273 945
2019	3 914 980	4 303 868

Vetch production made sown area (green forage) continues to decrease in the last two years, but interest continues in Turkey (Table 1) (TURKSAT, 2020). Vetch can be planted together with Poaceae. Particularly, Poaceae grown in an upright form prevent the vetches from lying (Kavut and Geren, 2018). In addition, the quality of the feed cut in this way increases and contributes especially to the nitrogen need of pastures (Gökkuş and Koç, 1993). Feed cost constitutes approximately 70% of the cost of an agricultural enterprise for animal production. Therefore, the availability of high quality and sufficient feed will also support the financial burden of the enterprise (Yaylak and Alçiçek, 2003; Mut et al., 2020).

Hungarian vetch (*Vicia pannonica* Crantz)

Hungarian vetch is a fodder plant grown in a wide geography from Spain to the Caucasus after being cultivated in Central Europe especially in Hungary the Danube countries, the Eastern Mediterranean Region from the beginning of the 20th century (Gençkan, 1983).

Hungarian vetch stands out with its ability to grow in high altitude regions, resistant to drought and winter conditions (Budak, 2017; Turan, 2019). While it can remain under the snow cover, it has a sensitive structure to snow-free-frost conditions. In terms of drought, the amount of precipitation can withstand the low summer season (Gençkan, 1983). Although it is highly selective in terms of soil properties, it can grow in medium-heavy, heavy or lime-rich soils.

In this study, the Doğu Beyazı variety of Hungarian vetch was selected and some physical and physiological characteristics of this seed were determined.

Hairy vetch *(Vicia villosa Roth.)*

Hairy vetch, belonging to this part of the pre-grown in Western Asia with the Mediterranean because it is a plant native wild forms are found mostly in Turkey. Since it has a common root structure and can keep the moisture in the soil well (Gençkan, 1983), resistant to cold weather conditions (Özpınar and Sabancı, 2014). In addition, it is preferred by the producers in evaluating the lands that are seen as arid and barren. Hairy vetch, which can be grown in almost any type of soil, can also be cultivated mixed with cereals (Geçit et al., 2018).

In this study, Ceylan variety of hairy vetch was selected and some physical and physiological characteristics of this seed were determined.

Common vetch *(Vicia sativa L.)*

It is reported by researchers that common vetch has been seen in Central and Northern Europe in much earlier periods, as well as being the homeland of the Mediterranean and West Asia Regions. On the other hand, it can be grown almost anywhere in the world today (Gençkan, 1983). Common vetch is the most cultivated species in Turkey (Kaplan, 2013). Its grains are used as wet-dry grass or concentrate fodder. It is also used by producers as cover crops and green fertilizers to enrich the soil from erosion (water-wind) severity and organic material in open lands (Geçit et al., 2018, Demiroğlu Topçu et al., 2020).

In this study, the Cumhuriyet variety of common vetch was selected and some physical and physiological characteristics of this seed were determined.

This study was conducted to determine some physical and physiological characteristics of Hungarian vetch, hairy vetch and common vetch seeds and to compare these vetch species in terms of these characteristics.

MATERIAL and METHODS

This study was carried out in the laboratories of Bingöl University Faculty of Agriculture, Biosystem Engineering and Field Crops departments in 2021. In this study, the Doğu Beyazı of the Hungarian vetch (*Vicia pannonica* Crantz), the Ceylan of the hairy vetch (*Vicia villosa* Roth.) And the Cumhuriyet varieties of the common vetch (*Vicia sativa* L.) were selected and the seeds of these varieties were examined. The properties of the seeds were statistically compared at $p < 0.05$ significance level.

Some Physical Characteristics of Vetch Seeds

Depending on the climatic characteristics of each plant, soil (pH, salinity, drought, etc.) and genotype differences, the characteristics of its seeds also vary (Dumanoğlu et al., 2021). According to the researches, the geometric (long-medium-short) and shape (round-oval-long) characteristics of the seeds are classified by considering some characteristics of the seeds (Yağcıoğlu, 2015) (Table 2). With the help of these determined data, the average arithmetic and geometric diameter (mm), sphericity values of the seeds can be determined by using the following equations (Mohsenin, 1970; Alayunt, 2000; Kara, 2012). Characteristics of seeds are applied and used in the agricultural production chain from sowing to harvest and even in the product processing stage afterwards. Therefore, the current characteristics of the seeds need to be determined.

Table 2. Classification of seeds according to their geometric and shape features

Seeds according to their geometric features	Grain width / Grain length (b/a) (mm)	Seeds according to shape characteristics	Length (a), Width (b), Thickness (c) (mm)
Long	0.6	Round	a ≈ b ≈ c
Middle	0.6 – 0.7	Oval	a/3 < b ≈ c
Short	> 0.7	Long	c < b < a/3

$$D: (L + W)/2 \qquad (1)$$

D: Average arithmetic diameter of the seed (mm)
L: Seed length value (mm)
W: Seed width value (mm)

$$Do: (L * D^\wedge 2)^1/3 \qquad (2)$$

D_0: Average geometric diameter of the seed (mm)
L: Seed length value (mm)
D: Average arithmetic diameter of the seed (mm)

$$\Phi: Do/L \qquad (3)$$

Φ : Sphericity Value of the Seed
Do : Average geometric diameter of the (mm)
L : Seed length value (mm)

In this study; 100 seeds were sampled randomly within the seeds of the examined vetch species and the length, width and surface area properties of the seeds were determined with the help of the Nikon SMZ 745T stereo microscope, which has its own software. (Dumanoğlu and

Geren, 2020). In addition, the counting and weighing processes of the seeds were completed in a way that the thousand-grain weights were randomly separately and in four repetitions (Dumanoğlu et al., 2019).

Some physiological characteristics of vetch seeds

In this study, germination time (day) and rate (%) of seeds belonging to three different vetch species (Doğu Beyazı, Cumhuriyet and Ceylan) were determined. The seeds taken from the varieties randomly were firstly pre-cooled for 1 week (in a refrigerator at + 4 °C) in accordance with ISTA (2007) rules. After this process, under controlled conditions (20-25 ° C, 60% humidity, dark environment, 10 days) using MEMMERT brand incubator, they were germinated in petri dishes in four repetitions.

Statistical analysis

In this study, some physical (shape-size, surface area, average arithmetic-geometric diameter, sphericity, thousand grain weight) and physiological properties of seeds belonging to vetch varieties were determined. It was determined that the obtained data had differences at the significance level of $p<0.05$ and statistically DUNCAN grouping was made using the SPSS V.21 program.

RESULTS and DISCUSSION

Some physical characteristics of vetch seeds

It was determined that three different vetch species examined in the study had an average length of 4.264 mm, a width of 4.091 mm, a surface area of 13.879 mm^2, an arithmetic diameter of 4.119 mm, a geometric diameter of 23.081 mm, a sphericity of 5.702 and a grain weight of 40.748 g. After the statistical analysis, it was determined that there were differences between vetch species at $p<0.05$ significance level. Apart from the width (mm) feature, the common vetch and hairy vetch are the same, and the Hungarian vetch is grouped separately (Table 3).

Table 3. Some physical characteristics of seeds of vetch varieties

Seed Features		Common vetch	Hungarian vetch	Hairy vetch	Avg.
Length (mm)	Avg.	4.478[a]	3.889[b]	4.426[a]	4.264
	Stdv.	0.382	0.261	0.347	0.330
Width (mm)	Avg.	4.406[b]	3.706[c]	4.162[a]	4.091
	Stdv.	0.346	0.275	0.321	0.314
Surface area (mm^2)	Avg.	15.103[a]	11.660[b]	14.873[a]	13.879
	Stdv.	2.193	1.573	2.150	1.972
Avg.Arithmetic diameter of the seed (mm)	Avg.	4.262[a]	3.802[b]	4.294[a]	4.119
	Stdv.	0.322	0.254	0.317	0.298
Avg.Geometric diameter of the seed (mm)	Avg.	27.578[a]	19.029[b]	22.636[a]	23.081
	Stdv.	6.266	3.869	6.118	5.418
Sphericity of the seed	Avg.	6.089[a]	4.840[b]	6.178[a]	5.702
	Stdv.	0.908	0.655	0.908	0.824
Thousand grain weight (g)	Avg.	47.350	33.375	41.350	40.748
	Stdv.	0.117	0.115	0.083	0.105

Considering the seed characteristics of the three different vetch species examined in this study, it was found to have a short and oval structure.

Some physiological characteristics of vetch seeds

In the study, according to the data obtained as a result of germination processes performed under controlled conditions of genotypes belonging to three different vetch species; It was determined that 91% of Hungarian vetch germinated within 1.587 days, 98% of hairy vetch in 1.189 days and common vetch 99% within 1.063 days. It was determined that all three vetch species have a very high germination rate and also the ability to germinate in about 1.5 days.

Table 4. Germination rate and time of seeds belonging to vetch varieties

Vecth Seed	Germination rate (%)	Germination time (day)
Hungarian vetch	91	1.587
Hairy vetch	98	1.189
Common vetch	99	1.063

RESULTS

It was observed that common vetch and hairy vetch gave higher values than Hungarian vetch in terms of length, surface area, average arithmetic diameter, average geometric diameter and sphericity among the physical properties examined in the study. In terms of width, the highest value was obtained from hairy vetch. Hairy vetch was followed by common vetch. The lowest value was obtained from the Hungarian vetch. Although the hairy vetch gave high values in terms of all physical properties, it gave the lowest value in terms of thousand grain weight. Common vetch and Hungarian vetch yielded similar results in terms of thousand grain weight.

In terms of physiological features, it has been observed that common vetch and hairy vetch give better results than Hungarian vetch as well as physical properties. It was determined that common vetch and hairy vetch germinated in a short time compared to Hungarian vetch and their germination rate was higher.

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CHAPTER IX

CURRENT STATUS AND POTENTIAL OF LEGUME FORAGE CROPS IN TURKEY

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INTRODUCTION

The average daily protein amount that an adult should consume in order to have a sufficient and balanced diet is 70 g. Half of it must be of animal and half of it must be of vegetable origin. The importance and quality of animal proteins are due to primarily from their digestion rate and the amino acid combination of they contain. Increasing the production of animal products, which are so important in terms of human nutrition, is possible by providing the quality roughages that needs of animals.

Roughages are qualified and cheap, they minimize the use of expensive concentrate feeds and contribute significantly to the livestock enterprises. Feed expenses constitute approximately 70% of the total expenses in a livestock enterprise. 78% of feed expenditures are spent on roughages and 22% on concentrate feeds (Harmanşah, 2018). Therefore, regulations to be made for the widespread use of forage crop production are of great importance in terms of feeding animals. Grasslands (14.6 mil. ha) is the primary source of roughage in Turkey. However, their production potential has decreased due to excessive and heavy grazing. In order to eliminate the existing roughage deficit, the cultivation areas of forage crops should be increased. Studies on this subject are promising. As a result of supports to forage crops as alfalfa (*Medicago sativa* L.), maize (*Zea mays* L.), vetch (*Vicia* sp.), sainfoin (*Onobrychis viciifolia* Scop.) and fodder pea (*Pisum arvense* L.) has provided significant increases in cultivation area. Our livestock presence is increasing with every year and our feed deficit continues. Although there is not enough roughage provided in grasslands and there is a significant increase in forage crops cultivation areas, the current production gap is significant (Demiroğlu Topçu and Özkan, 2017).

Legumes are the richest family in terms of species, includes approximately 430 genera and 13000 species (Akman and Güney, 2011), by adding nitrogen to the soil with *Rhizobium* sp. bacteria, reduces the use of fertilizers in crop production and also maintains soil fertility and vitality. In addition, environmental pollution is minimized together with underground and aboveground resources. For example, in studies conducted, the amount of nitrogen fixation in a alfalfa field is 14.8-29.0 kg da^{-1}, 26.8 kg da^{-1} in white clover, 15.4 kg da^{-1} in a red clover and 18.4 kg da^{-1} in a hairy vetch (Tan and Serin, 2009). It is stated that the nitrogen fixation efficiency of legumes increases in areas where legumes are grown mixed with cereals (Lüscher et al., 2016), it has been determined that the amount of fixation N_2 changes between 10-38 kg da^{-1} in one year and 1-7 kg da^{-1} of it transferred to cereals (Nyfeler et al., 2011). Legumes fluff up and aerate the soil at effective root depths. These deep-rooted legumes also take the nutrients and bring them to the upper layers of the soil. Thus, the loss of nutrients from the soil is reduced, and the pollution of groundwater resources and ecosystem is prevented. It is known that alfalfa and sainfoin roots can go down to 7-10 m depth in loamy, sandy-loamy soil conditions (Acar and Ayan, 2012). Perennial legumes significantly increase the amount of carbon in the soil (Iwaasa and Lemke, 2014). Carbon capture means that CO_2 in the atmosphere passes to the soil in the form of stable humus with plant residues (Lal, 2006). With the increase of C in the soil, atmospheric CO_2 decreases. In addition, soil fertility and organic matter increases, erosion decreases, thus groundwater quality improves (Undi et al., 2016).

Legumes are used extensively for animal feeding purposes. Legumes are high in nutrients and rich in protein, vitamins and minerals. Broad bean (*Vicia faba* L.), bitter vetch (*Vicia ervilia* (L.) Wild) and alfalfa have been used for animal feeding since ancient times. It is known that legumes have been grown since the Hittite and used for animal feeding on the Anatolian geography (Tan and Serin, 2009). Large-grained legumes such as fodder pea, common vetch (*Vicia sativa* L.), Narbon vetch (*Vicia narbonensis* L.), bitter vetch and grasspea (*Lathyrus sativus* L.) are used for grain in animal feeding.

Turkey is located at the intersection of two different gene centers. With this feature, it is the gene center of many plant species. 3900 of a total of 12700 plant species are endemic. Flora of Turkey has provided the raw material for plant breeding especially. The rich plant genetic resources of the region have been negatively affected by intense agriculture and over grazing of natural grasslands. Turkey is the center of many temperate legumes species (Maxted et al., 1991). For example, The genus *Vicia* L. comprises approximately 190 species in the world and 64 species in Turkey (Erik and Tarıkahya, 2004; ILDIS, 1999; Gur and Tuna, 2016). A total of 35 taxa, including 23 species and 10 subspecies and 10 varieties belonging to the vetch genus, are located in the Thrace Region of Turkey (Orak et al., 2017). The rich legume forage crops genetic resources in Turkey are frequently used for breeding varieties by breeders.

Roughage production and rate of meeting the needs of animals in Turkey

Roughage production in Turkey is generally obtained from grasslands and forage crops. Hay provided from grasslands was calculated as 14.617.000 tons according to the data of 2020. Hay production of plants grown as forage crops was 19.292.863 tons. Silage production calculated as hay has an important place with 8.971.474 tons. The remaining 10.321.389 tons after the silage production removed is considered as hay. As a result, Turkey's total roughage production in 2020 was 33.909.863 tons of hay (Anonymous, 2021a).

An animal's (1 Animal Unit-AU) daily need for fresh forage is 1/10 of live weight. When calculated as hay, it is 2.5% of its live weight. Turkey's total animal existence for the year 2020 was 19.802.466 AU.

The current animal existence annual roughage need (19.802.466 x 12.5 kg/AU x 365 days) is 90.348.751 tons. Turkey's roughage deficit is: 90.348.751 - 33.909.863 = 56.438.888 tons. The ratio of the produced roughage to meet the needs of the animals is 37.53%.

In Turkey, alfalfa, vetch species, sainfoin, fodder pea, clovers (*Trifolium* sp.), grasspea, fodder beet (*Beta vulgaris* L.), forage turnip (*Brassica rapa* L.), cereals, sorghum (*Sorghum* sp.) and Italian ryegrass (*Lolium multiflorum* Lam.) are widely grown as forage crops. As a result of the support given to forage crops in order to increase the production of high quality roughage in Turkey, a significant increase has been achieved in the cultivation area and production of alfalfa, maize, vetch species, sainfoin and fodder pea. Especially developments in maize production for silage are promising. Cereals, especially oat

(*Avena sativa* L.), has gained importance as a forage crop for fresh forage. Cereals are preferred due to their high yields, as well as producers having suitable equipment for planting and maintenance. In forage crops, grasses has 43.57 %, legumes 56.15 % and other families have a production area of 0.28 % (Anonymous, 2021a). The production of legume forage crops has an important place in forage crop cultivation due to their supplements and the need for forage to meet the protein needs of animals.

Production area of legume forage crops

Legume forage crops grown in Turkey have been evaluated for the last ten years (2011-2020). Legume forage crops production areas are presented in the Table 1 (Anonymous, 2021a).

Table 1. Forage legumes production area of Turkey (ha)*

Year	Alfalfa	Sainfoin	Vetch	Bitter vetch	Clover	Fodder pea	Grass Pea	Total
2011	558.552	153.644	475.475	6.902	434	-	-	1.195.009
2012	674.183	196.334	569.425	8.274	509	-	27.861	1.476.588
2013	628.641	191.439	499.043	7.141	415	-	23.549	1.350.229
2014	692.305	194.908	426.934	4.772	415	3.739	23.180	1.346.256
2015	662.045	191.403	436.518	3.924	405	4.327	19.572	1.318.198
2016	650.110	193.694	442.837	3.257	405	5.579	15.584	1.311.468
2017	659.431	196.180	445.625	2.927	400	6.959	14.264	1.325.790
2018	635.105	181.733	386.946	2.787	2,5	10.437	12.790	1.229.804
2019	641.212	175.276	391.498	2.561	4,5	14.609	9.884	1.235.046
2020	662.888	174.494	375.943	2.293	5,5	24.319	8.769	1.248.714

* Anonymous, 2021a

The cultivation area forage legumes in Turkey was 1.248.714 ha according to 2020 data (Table 1). Generally, alfalfa, sainfoin, clover, vetch species, bitter vetch, fodder pea and grasspea are grown as forage legumes. Alfalfa and sainfoin cultivation are at the forefront in long-term forage cultivation. Alfalfa is grown in irrigated areas and sainfoin in arid areas where irrigation is not possible. Vetch species, bitter vetch, fodder pea and grasspea are the most preferred plants in annual forage legume cultivation. Annual forage legumes are especially important in terms of crop rotation. The organic matter amounts of the field agriculture areas in Turkey are very low and this problem can be solved with the positive contribution of legumes in increasing the soil organic matter.

In the production of forage legumes in Turkey, alfalfa has the largest production area and twice as much as the second row of vetches. Alfalfa cultivation in Turkey increased from 558.552 ha in 2011 to 692.305 ha in 2014. Despite a slight decrease in the following years, alfalfa cultivation was carried out on 662.888 ha in 2020 (Table 1).

Sainfoin is grown in much less area than alfalfa. Sainfoin cultivation increased from 153.644 ha in 2011 to 196.334 ha in the following year (2012). Within a year, there has been an increase in the cultivation area of approximately 40.000 ha. Until 2018, there was not much change in sainfoin cultivation area. After 2018, the sainfoin cultivation area has started to decrease. According to the data of 2020, sainfoin cultivation was carried out in 174.494 ha (Table 1).

Clover cultivation area was 434 ha in 2011. Clover cultivation area continued at the same amount until 2017. However, it decreased dramatically in 2018 to 2.5 ha. Clover cultivation was carried out in 5.5 ha of land in 2020 (Table 1).

Among the annual forage legumes, vetch is the most cultivated species. Generally, common vetch, Hungarian vetch (*Vicia pannonica*

Crantz.), hairy vetch (*Vicia villosa* Roth.) and Narbon vetch are cultivated. Especially common vetch and Hungarian vetch cultivation is quite common. The total amount of cultivated area of four species are given together in the table. Vetch cultivation increased from 475.475 ha in 2011 to 569.425 ha in 2012. This increase is quite high with 90.000 ha. In 2013, it decreased again to 499.043 ha and to 375.943 ha in 2020. The vetch cultivation area has decreased by approximately 100.000 ha in a period of ten years. Vetch cultivation has been adversely affected by the introduction of annual forage legumes such as grasspea and fodder pea since 2012 (Table 1).

Bitter vetch cultivation areas are similar to other vetch cultivation areas. Bitter vetch cultivation increased from 6.902 ha in 2011 to 8.274 ha in 2012. After 2012, it decreased to 2.293 ha in 2020 (Table 1).

Grasspea has been included in TurkStat data after 2012. Grasspea was recorded as 27.861 ha in 2012. Grasspea cultivation area has decreased continuously each year and in 2012 it decreased to 8.769 ha (Table 1).

The only species that has increased in the last ten years among annual forage legumes is the fodder pea. Fodder pea was included in TurkStat data in 2012 and 3.739 ha cultivation area was reported. By increasing regularly every year, 24.319 ha of cultivation area was reached in 2020. As producers become acquainted with fodder pea, it appears that its production will increase even more (Table 1).

Forage legume supports made by the Ministry of Agriculture and Forestry has positive effect on cultivation by producers. In 2020, supports were given to vetch species, bitter vetch, grasspea, fodder pea, forage broad bean, berseem clover (*Trifolium alexandrinum* L.) in annual legumes, and alfalfa, sainfoin, white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), yellow flower gazelle (*Lotus corniculatus* L.) plants in perennial legumes (Anonymous, 2021b). In order for the producers to benefit from the support, they have to grow in at least 1 da area.

Table 2. Forage legumes production area supported by Ministry of Agriculture and Forestry (ha)*

Year	Alfalfa	Sainfoin	Vetch	Total
2011	56.176	30.233	28.801	115.210
2012	53.944	28.649	265.136	347.729
2013	58.440	27.233	269.407	355.080
2014	50.247	29.578	264.273	344.098
2015	38.680	22.794	223.647	285.121
2016	43.089	24.419	209.719	277.227
2017	89.732	46.143	240.364	376.239
2018	152.632	64.681	186.955	404.268
2019	192.429	59.933	171.876	424.238
2020	223.216	62.259	140.290	425.765

*Anonymous, 2021b

In 2020, support amounts were 60 TL da^{-1} for annual legume forage crops and 90 TL da^{-1} for perennial legume forage crops. In addition, support for using bumblebee (*Bombus*) was applied as 60 TL. The fact that the amount of support for perennial legume forage plants is 50 % higher has encouraged the producers. The amount of support given to alfalfa was 130 TL da^{-1} in 2011 and before, and it was effective for the development of alfalfa farming. Since 2012, the supports have been reduced to 90 TL da^{-1}. This may have led to a decrease in alfalfa cultivation area after 2014. On the other hand, sainfoin 90 TL support provided in 2011 remained the same in 2020. Vetch production support has increased from 30 TL to 60 TL. The continuous increase in support given to forage crops, especially between 2011 and 2012, led to the highest levels of forage cultivation area after 2011 (Table 2) (Anonymous, 2021b).

In 2011, the legume forage plant support payments were made in 115.210 ha area, in 2020 it reached 425.765 ha (Table 2). Only 34.10% of the total forage legumes cultivation was able to benefit from the supports.

Forage legumes production

Fresh forage productions of forage legumes grown in Turkey are presented in Table 3.

Alfalfa ranks first in the fresh forage production of forage legumes in Turkey. Vetch is the most produced forage legume after alfalfa and the third is sainfoin. Although fodder pea is produced less than these three species, a rapid increase is observed in its production. Grasspea, bitter vetch and clover are produced in limited quantities.

Alfalfa production is increasing, although there are minor fluctuations. Fresh forage production, which was 12.076.159 tons in 2011, reached 19.290.519 tons in 2020 (Table 3).

Sainfoin production follows a more stable course. Fresh forage production, which was 1.571.606 tons in 2011, was 1.934.697 tons in 2020 (Table 3).

The production of clover was reported as 3.160 tons of fresh forage in 2011. Clover production decreased gradually until 2017 (2.280 tons). However, as of 2018, it has been recorded as very low, as if it has almost no production. It was reported as 46 tons in 2018, 67 tons in 2019 and 96 tons in 2020 (Table 3).

Table 3. Fresh forage production of legumes of Turkey (Tons)*

Year	Alfalfa	Sainfoin	Vetch	Bitter vetch	Clover	Fodder pea	Grass Pea	Total
2011	12.076.159	1.571.606	4.442.017	51.091	3.160	-	-	18.144.033
2012	11.536.328	1.459.570	4.245.417	42.894	3.018	-	169.419	17.456.646
2013	12.616.178	1.630.572	4.492.466	54.566	2.528	-	158.671	18.954.981
2014	13.432.968	1.646.256	4.168.085	30.455	2.478	70.422	146.812	19.497.476
2015	13.949.958	1.655.985	4.281.259	24.849	2.378	84.821	138.554	20.137.804
2016	15.714.381	1.982.047	4.542.042	20.363	2.378	121.124	116.703	22.499.038
2017	17.561.190	2.001.379	4.597.600	17.327	2.280	139.366	103.029	24.422.171
2018	17.544.946	1.934.847	4.273.945	16.507	46	210.706	98.238	24.079.235
2019	17.949 264	1.781 789	4.303.868	14.855	67	283.928	78 912	24.412.683
2020	19.290 519	1.934 697	4.542.965	14.562	96	452.776	82 026	26.317.641

* Anonymous, 2021a

There is a similar situation to sainfoin in the production of fresh forage by vetches. Fresh forage production, which was 4.442.017 tons in 2011, was determined as 4.542.965 tons in 2020 (Table 3). Although there is a decrease in vetch cultivation areas, it is seen that there is no decrease in production. It is normal to have some fluctuations in climatic reasons over the years. Vetch is one of the species that breeding studies were carried out intensively among the forage crops in Turkey. New varieties have been registered for many years. Obtaining these varieties from Turkey's own gene resources and breeding them in different ecologies resulted in increases in yield. Despite the decrease in the cultivation area, the production amount has been preserved with the newly improved varieties.

While the production of bitter vetch fresh forage was 51.091 tons in 2011, it has decreased regularly to 14.562 tons in 2020 (Table 3).

Grasspea production has been included in TurkStat records since 2012 and 169.419 tons of fresh forage has been produced. There is a steady decline in the production of grasspea as in the production of bitter vetch. Grasspea fresh forage production decreased to 82.026 tons in 2020 (Table 3).

Fodder pea is the most produced forage legume after vetch among annuals, which started to be registered by TurkStat in 2014, were produced as 70.422 tons of fresh forage in the same year. Fodder pea is on the rise, unlike other annual forage legumes crops. As a matter of fact, the fresh forage production of fodder pea, which was 70.422 tons in 7 years, has increased to 452.776 tons (2020) (Table 3).

Seed production of forage legumes of Turkey

One of the main problems in the production of forage legumes in Turkey is that the need for certified seed cannot be met sufficiently. In addition to this, another problem is that the seed production in quality and standards is not sufficient.

Turkey is an important seed production center when evaluated in terms of many climatic characteristics such as temperature, light duration, light intensity, precipitation and relative humidity and its insect population. Self-pollinated forage crops and seed production are generally carried out by public institutions. It is noteworthy that private sector initiatives have started recently. Seed production amounts of legume forage plants produced in Turkey between 2011-2020 are given below 2011 – 2020 periods are given as below (Table 4).

There is an increase every year in the production of legume forage seeds. In the last 10 years, significant increases have been achieved in all species up to 3-14 times in the amount of seeds produced for forage crops (Table 4). Alfalfa increased three times and fodder pea increased fourteen times. However, except for alfalfa, 7 % and 4 % of the seed amount needed in sainfoin and vetch can only be met respectively.

While the amount of seed distributed in alfalfa in Turkey was 416 tons in 2002, it was 5.456 tons in 2019. In vetch, this amount increased from 803 tons to 1.231 tons in the same years. It is seen that the distribution of sainfoin seeds has partially recovered with the distribution of 773 tons in 2019, when there was a sharp decrease since 2002 (885 tons) (Anonymous, 2021a).

Table 4. Legume fodder crops seed production of Turkey (Tons)*

Year	Alfalfa	Sainfoin	Vetch	Fodder pea
2011	473	200	876	374
2012	670	2	876	381
2013	610	12	385	484
2014	560	46	686	440
2015	634	31	974	811
2016	794	188	1114	1585
2017	887	385	1139	2321
2018	3000	307	1572	2121
2019	3501	773	1526	3656
2020	3456	556	2487	5398

*Anonymous, 2021c

When forage crops seed amounts are examined, it is seen that the amount of seed produced in many forage crops is not sufficient for the domestic market. In 2020, a total of 6.895 tons of forage seed seeds were imported. The amount of seed exported was 1.400 tons. Despite the fluctuations in our country, the demand for certified seeds is in an increasing trend. The use of certified seed varies depending on the training and foresight of the producer, as well as the size of the enterprise and its capital status. However, it is far below the desired level. In order to meet the need for certified seeds in forage crops and to ensure the production of seeds of registered varieties, incentive measures should be taken in addition to the modern equipment of public institutions. In addition, support should be provided for the production of forage seeds and seeds of private organizations.

In line with these purposes, certified seed use support is paid by the State in order to increase the use of certified seeds. This support was given as 20 TL / da for vetch, fodder peas and sainfoin and 30 TL / da for alfalfa in 2020. Supports for certified seed production are presented on the Table 5. These supports given cause increases in both certified seed production for legume forage crops and certified seed use. This is clearly seen in the increase in seed production of legume forage crops between 2011 and 2020.

Table 5. Certified seed production support in Turkey 2020*

	Certified	Original
Vetch, sainfoin, fodder pea	1.50 TL/kg	1.60 TL/kg
Alfalfa	4.00 TL/kg	5.00 TL/kg

*Anonymous, 2021c

In addition to research and variety development studies for both efficiency and quality, planning should be made taking into account market demands. For a rapid development in the seed sector, the genetic diversity of our country, the dynamic and developing private sector, the knowledge in the public and universities should be evaluated together. The steps taken by the institutions or organizations that have registered varieties and the interest of the farmers will positively affect the production of forage crops.

Registered forage legumes varieties that have been improved in Turkey

In Turkey, there are 135 forage legumes varieties registered between 1963-2020, as well as the varieties registered as introductory material from abroad and included in the National Variety List. Registered forage legumes includes 55 vetch species and 53 alfalfa. The breeding of these species has been developed by Agricultural Research Institutes, Faculty of Agriculture and private seed companies. Among the Registered Vetch species, there are 31 varieties with common vetch and 14 Hungarian vetch (Anonymous, 2021d). Most of these varieties have been developed by selection made from materials collected from the natural flora of Turkey.

There are 14 fodder peas, 10 clover, 5 grasspea, 7 sainfoin and 1 forage cowpea (*Vigna unguiculata* L. Walp) varieties registered in Turkey (Anonymous, 2021d). There are also 3 white clover varieties developed for green areas in the national variety list.

When the registered varieties are examined on the basis of species, it is understood that the studies are mostly focused on the production of forage crops in field. It is necessary to attach importance to the seed production of the varieties known in country and preferred by the producer. Subsequent field days and agricultural fairs will increase the interest of sector representatives and farmers.

CONCLUSION

Turkey is a country with high animal production potential with 19.8 mil. AU. The feed requirement of the animals is met from the grasslands of 14.6 mil. ha. Another forage production source is forage crops with a production area of 2.224.029 ha. In forage crops, grasses has 43.57 %, legumes 56.15 % and other families have a production area of 0.28 %. Forage legumes have a cultivation area of 1.248.716 ha. 26.317.641 tons of fresh forage is produced from this area. The most cultivated forage legume is alfalfa and followed by vetch species, sainfoin and fodder pea, respectively. Support is provided by the Ministry of Agriculture and Forestry to increase the production of forage legumes. For this purpose, a total of 425.765 ha forage legumes production area was supported. The plant that benefits most from the supports is alfalfa.

Forage legumes seed production is increasing from year to year. In this increase, seed production of alfalfa, vetch and fodder pea stands out. However, seed production is insufficient in terms of meeting requirement. This deficit is covered by imports.

There are 135 registered forage legumes varieties. Most of the varieties are alfalfa and vetch. Also, there are fodder pea, clover, grasspea, sainfoin and forage cowpea varieties.

The cultivation and production of forage legumes in Turkey is insufficient. However, it has the potential to increase production. Producers should be encouraged to produce forage legumes with support and demonstration studies. Farmers should be informed by training courses and seminars. Mechanization should be increased in the cultivation of forage crops and its spread throughout the country. For wet and dry conditions, it is necessary to increase the product range of forage legumes. New alternative plants should be offered to producers. Dependence on imports should be reduced by supporting the developing seed and breeding sectors.

Due to the decrease in grasslands in the last 50 years, roughage production has decreased significantly. A significant increase has been achieved in roughage production (19.3 mil. tons) with the cultivation area of forage crops reaching 9 %, but it is not sufficient. The production amount is expected to reach 29 mil. tons with the gradual increase of the cultivation areas of forage crops to 15 %. With this projection, 51 mil. tons of quality forage production will be achieved. The total need for roughage of our animals is 90.3 mil. tons (Anonymous, 2021a). In this case, it is possible to meet 39 mil. tons of roughage deficit with new solutions.

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CHAPTER X

GROWTH-PROMOTING ABILITY OF *BACILLUS* AND *PSEUDOMONAS* AND THEIR EFFECT ON INDUCED TOLERANCE İN GUAR (*Cyamopsis tetragonoloba* [L.] TAUB.) AGAINST DROUGHT STRESS

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INTRODUCTION

The ability of plants to acclimatize to varying changing climactics has been affected by extraordinary changes in the world's environmental conditions. Drought, which is regarded as the main reason for yield loss, has a negative effect on most plant physiological processes. The cells of plants react to a loss of water via increased abscisic acid (ABA) production in their roots, which increases water uptake, resulting in stomatal closure of the leaves and a reduction in leaf expansion, thus reducing dehydration (Schillaci et al., 2019).

A plant exhibits complex responses to drought that affect various components, which affect not only cell water potential, but also induce stomatal closure and bring about decreased photosynthesis, assimilation of nitrates, and numerous anabolic enzyme reactions. Moreover, induced active oxygen species generation, including hydrogen peroxide, superoxide radical, and hydroxyl radical (which result in lipid peroxidation and, by consequence, membrane injury), degradation of proteins, inactivation of enzymes, bleaching of pigments, and DNA strand disruption also occur. There has been the suggestion of a number of mechanisms for tolerance based on physiological and biochemical changes as a result of drought. Despite plant tolerance mechanisms, which include increased antioxidative activity, significant yield reductions exist due to metabolic processes being disturbed both during and after water stress (Chakraborty et al., 2013).

There has been the suggestion of a number of strategies to control the adverse effects that drought stress has on plants, of which the most investigated approaches include the breeding of tolerant plant varieties as well as genetic engineering. However, the mechanisms of abiotic stress tolerance are highly complex, which makes the introduction of new tolerant varieties quite difficult, because, in some regions, plants that have undergone genetic modification are not well-accepted. The induction of stress tolerance via various biological and chemical agents, known as priming, is an alternative strategy that was proposed by Kasim et al. (2013).

Plant growth promoting bacteria (PGPB) could potentially be used in place of synthetic chemicals to improve the growth of plants because it may aid in supporting soil productivity and environmental health. PGPR are microbes, and they facilitate beneficial effects on the development of plants via direct or indirect mechanisms. PGPR's are directly responsible for the acquisition of nutrients, phytohormone synthesis, siderophore production and antioxidant system improvement. Indirectly, PGPR can trigger the immune system of the plant against phytopathogens, thus stimulating plant growth. Additionally, PGPR has a significant effect on the physiology of a plant, including abiotic stress response amelioration (De Lima et al., 2019).

It has been shown that endophytic bacteria have many effects that are beneficial to the host plant, where the involved mechanisms are likely similar to those that were reported for rhizosphere bacteria by Szidercis et al. (2007). Endophytic bacteria also assist in the growth of plants by enhancing the uptake of minerals and contributing essential vitamins, in addition to adapting and modifying root metabolism and morphology. In addition to the growth-promoting characteristics of plants mentioned above, endophytic bacteria are also responsible for synthesizing plant hormones in very small quantities, including IAA, abscisic acid (ABA), cytokine and gibberellins, which have a role in regulating plant development and growth (Ullah et al., 2019). The last two decades have witnessed some reports on the utilization of such microbes for induction of tolerance against abiotic stresses (Chakraborty et al., 2015). An element of agricultural systems for enhancing tolerance to drought in plants, known as integrating microbes, must be supported in order to enhance sustainable crop production. Kaushal (2019) reported that microbes have the ability to enhance plant drought tolerance through mechanisms of microbial-induced systemic tolerance (MIST) that involve different modifications on the molecular, physiological, and biochemical level in host plants.

In plant tissues, the most commonly observed endophytic bacteria include species of *Pseudomonas*, *Bacillus*, *Klebsiella*, *Enterobacter*, *Streptomyces*, and *Serratia*. Once they have passed through the endodermis, many species of bacteria can then spread from the roots and colonize other stem organs (Schillaci et al., 2019). Among the *Bacillus* genus, the gram-positive and gram-negative *Pseudomonas* is the most extensively researched rhizobacteria that aids plant health. *B. amyloliquefaciens, B. licheniformis, B. megaterium, B. pumilus*, and *B. subtilis*, are some important members of the genus *Bacillus,* and are reported for plant growth and stress management. An increased agricultural production in response to *Pseudomonas* inoculation has been reported through different mechanisms (Vimal et al., 2018). It is a fact that when compared to *Pseudomonas*-based fertilizers, *Bacillus*-based biofertilizers are more active. This is because *Bacillus* spp. more effectively produces metabolites and has superior spore-forming characters, which enhances cell viability in products that are commercially formulated (Radhakrishnan et al., 2017).

Guar (*Cyamopsis tetragonoloba* (L.) Taub.) (Syn. *Cyamopsis psoraliodes*) is a leguminous crop that is drought-resistant. It is an annual herb that grows on sandy, arid, and semiarid soil, and it is a hardy, tall, and bushy plant that has a deep root system (Kumar et al., 2018). However, during active crop growth, water stress causes growth cessation due to its influence on photosynthesis, in addition to other physiological processes, and/or death due to dehydration (Kumar et al., 2015). It was reported by Mac et al. (2016) that drought stress in arid and semiarid areas that occurs at different stages of crop development could possibly limit the growth and productivity of plants more than other forms of abiotic stress. Vyas et al. (2001) and Kusvuran and Kusvuran (2019) reported that during pod formation and the vegetative stage, water stress had a negative effect on various enzyme activities, and growth, photosynthesis and seed yield in guar.

Extensive time and effort is required to enhance a crop's resistance to drought stress via traditional breeding. Hence, selecting and applying appropriate beneficial PGPR is significant for reducing drought stress. To our knowledge, no previous studies exist that have investigated the role that bacteria play in reducing water stress in guar plants. In the present study, whether the response of PGPR, like *Pseudomonas fluorescens* PF1, *Bacillus subtilis* QST 713, *Bacillus megaterium* mediates guar (*Cyamopsis tetragonoloba* (L.) Taub.), to drought stress was investigated. The objectives herein were: 1) to investigate if *Pseudomonas fluorescens* PF1, *Bacillus subtilis* QST 713 and *Bacillus megaterium* inoculation could enhance the growth under drought stress, (2) to determine the effect that these bacteria have on the physiological (phonesthetic pigments, phenols, flavonoids, leaf water potential, leaf water content, and K, Ca, Mg, Fe, Cu, Mn, Zn ions contents), biochemical (antioxidant mechanisms) responses of guar to drought stress.

MATERIAL and METHODS

The experiment was carried out at Cankiri Karatekin University, Cankiri, Turkey under greenhouse conditions. First, the seeds were surface sterilized using 70% ethanol for 5 to 10 min, and then thoroughly washed with double-distilled water. Next, the seed inoculation was performed via seed dressing with *Pseudomonas fluorescens* PF1 (PF), *Bacillus subtilis* QST 713 (BS), *Bacillus megaterium* (BM) cultures of approximately 10^9 CFU mL^{-1}. After that, the bacteria solutions (10 mL 1 L^{-1}) were sprayed on the plant foliage and allowed to run off every other week (a total of three times). The guar plants were grown in 12-L plastic pots that contained peat: perlite at a ratio of 2:1 under greenhouse conditions comprising day/night temperatures of 26 ± 2 °C and 18 ± 2 °C ±2, and relative humidity of 65% ± 5. The seedlings were irrigated with a nutrition solution for the first 40 days after sowing (DAS) following the method of Kusvuran and Kusvuran (2019). During the experiment, the weight of the pot was considered when the amount of irrigation water was determined. Hence, the pots were weighed every day. All of the pots attained field capacity prior to implementation of the experimental traits.

At 40 DAS, application of the watering treatments was applied for a period of 17 days. The experiment comprised 5 treatments: 1) the control (S0: Field capacity of 100%), 2) S1 (75% depletion of the available water holding capacity (AWHC)), 3) S2 (50% depletion of the AWHC), 4) S3 (25% depletion of the AWHC), and 5) S4 (no irrigation water applied), and four treatments of bacteria: un-inoculated, BS, PF, and BM. Upon conclusion of the experiments (57 DAS), evaluation of the plants was performed via some morphological (shoot fresh and dry weight, length, and diameter; root fresh and dry weight; and leaf number and area), physiological (leaf water potential (LWP) and relative water content (RWC), photosynthetic pigments (Chl-a, Chl-b, and total carotenoid contents), ion contents (K, Ca, Mg, Fe, Cu, Mn, Zn) and biochemical parameters, including the total phenolic content (PC), total flavonoid (TF) contents, lipid peroxide content (MDA), and APX, SOD, GR, and CAT antioxidative enzyme activities.

Relative water contents (RWC) and leaf water potential (LWP)

Estimation of the RWC was performed using the methods of Sanchez et al. (2004) and Turkan et al. (2005). Calculation of the RWC was performed as follows: RWC (%) = [(FW–DW) / (TW – DW)] × 100. Here, TW is the turgid weight after floating for 5 h on deionized water. The 3rd fully-expanded leaf was measured across the middle of the photoperiod to attain the LWP (Ψw) via a pressure chamber (Muries et al., 2013).

Photosynthetic pigments

The method suggested by Arnon (1949) was used to determine the total carotenoid and Chl-a and Chl-b contents. Extraction of the leaf pigment was done using 80% (v/v) acetone and a spectrophotometer was used to measure the absorbance of the extraction (Shimadzu UVmini-1240; Shimadzu Corporation, Kyoto, Japan) at 663, 645, and 470 nm.

MDA content

Lipid peroxidation was measured using the level of MDA determined via the reaction of thiobarbituric acid (TBA) (Heath and Packer, 1968). A mortar that was pre-chilled was used to homogenize the frozen samples, to which 2 volumes of ice-cold 0.1% (w/v) trichloroacetic acid (TCA) was added, and centrifugation was performed for 15 min at 15,000 × *g*. As an assay, a mixture comprised of a 1-mL aliquot of the supernatant was added to 2 mL of TBA (0.5%, w/v) in 20% TCA (w/v), and heated to 95 °C for 30 min, after which, it was cooled rapidly in an ice bath. Following centrifugation of the supernatant at 10.000 × *g* for 10 min at 4 °C, the absorbance was read at 532 nm and values were subtracted if they corresponded to non-specific absorption at 600 nm.

Tissue elemental analysis

For the determination of ion contents, guar leaves were dried for 48 h at 65 °C. Following that, a mill was used to grind the samples to pass through a 20-mesh sieve. The resulting powder was then turned to ash over a period of approximately 6 h at 550 °C, which was then dissolved in 3.3% HCI. Determination of the leaf K, Ca, Mg, Fe, Mn, Zn, and Cu concentrations was performed via atomic absorption spectrometry (Jones, 2001).

Total phenolic and total flavonoid contents

Determination of the TP contents in the leaves was performed using a Folin-Ciocalteu reagent, which was expressed in milligrams. The standard used was gallic acid (Singleton et al., 1999). A colorimetric assay was used to determine the flavonoid contents (Medina-Juárez et al., 2012). Expression of the total flavonoids (TF) was done on the basis of FW, as the milligrams of quercetin equivalent/gram.

Antioxidative enzyme activities

A mortar and pestle were used to extract the enzymes from 0.5 g of leaf tissue, in addition to 5 mL of extraction buffer that contained 50 mM of potassium-phosphate buffer, at pH 7.6, and 0.1 mM of disodium ethylenediaminetetraacetate. Centrifugation of the homogenate took place for 15 min at 15,000 × *g*, and the resulting supernatant fraction was used to perform the enzyme assay. All of the enzyme extraction operation preparations were performed at 4 °C. The SOD assay was performed according to the method of Karanlik (2001), via monitoring the reduction of the superoxide radical (O_2^-)-induced nitro blue tetrazolium at 560 nm. Monitoring the disappearance of HO was used for the determination of the CAT activity. Determination of the APX activity was performed via measurement of the ascorbate consumption from its absorbance at 290 nm. The amount of enzyme that was determined necessary to consume 1 μmol of ascorbate min^{-1} was one unit of APX activity (Cakmak and Marschner, 1992). From the absorbance of nicotinamide adenine dinucleotide phosphate (NADPH) at 340 nm, the measurement of its enzyme-dependent oxidation was then used for determination of the GR activity. One unit of GR activity was defined as the volume of enzyme necessary to oxidize 1 μmol of NADPH min^{-1}.

A completely randomized plot design was used for the experiment, comprising three replicates. The mean values were compared using the Tukey multiple range test. $P<0.05$ was accepted as statistically significant using JMP software for Windows (version 7.0 SAS Institute Inc., USA). Data were presented as the mean ± standard deviation (SD) and error bars represent the standard errors of the means in all of the figures.

RESULTS

The response of plant growth parameters, including the shoot and root fresh and dry weights, shoot length and diameter, number of stems and leaves, and leaf area per plant have been presented in Table 1. The effect of "bacteria and treatment" interaction on all parameters was significant ($P<0.01$). When compared to the control, these traits had decreased at various levels under drought stress. The greatest decrease was observed in the S4 treatment comprising un-inoculated plants. A decrease was observed in the fresh (46.59 and 13.97 g $plant^{-1}$) and dry weights (9.85 and 9.26 g $plant^{-1}$), by 9 and 15%, in the S1 and S2 treated plants, respectively. However, the decrease was more severe, by 39 and

63%, in the S3 and S4 treated plants. Drought stress resulted in negative effects on the seedling biomass, in addition to other morphological parameters, which included the shoot and root fresh and dry weights, shoot length and diameter, number of stems and leaves, and leaf area per plant, and in the S3 and S4 treated plants, significant reductions were observed in these characteristics. In the S1 and S2 treated plants, the decrease was 1%-29%, while in the S3 and S4 treated plants, the decrease was 15-71%. Inoculation of bacteria significantly increased these parameters under both control and drought treated conditions. Morphological parameters in inoculated plants with BS, PF, and BM increased to 4-57% when compared to the un-inoculated plants under control condition. Additionally, however, bacterial application under S3 and S4 conditions reduced the negative effects of stress by 6-49%. Under drought stresses, BM was determined to be more effective bacteria treatment and reduction was determined to only 1-22%.

According to "bacteria and treatment" interaction on RWC and leaf water potential were significant at $P<0.01$. Guar plants treated with drought stress at different levels (S1, S2, S3, and S4) exhibited a decrease in RWC at 13, 19, 27, and 37% when compared to the control plants (Figure 1). However, significant improvement was observed in the RWC of the plants treated with bacteria, by 10.6, 8.8, 9.9, and 13.9% when compared with control plants (un-inoculated) under drought stresses. At S4, maximum improvement was observed in the RWC with BM, where the increase in RWC compared with its un-inoculated was 17%. Leaf water potential, (Ψ) ranged from -0.17 to -0.65 MPa (un-inoculated stressed plants) and was significantly affected by the drought levels. These results showed that BS, PF and BM inoculation promotes positive influence on Ψ under drought stresses (5-200% increase). According to the results, under S4 condition, the highest Ψ was established with BM treatments (-0.38 MPa).

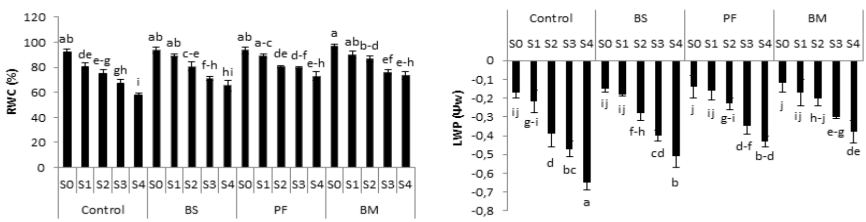

Figure 1. Effects of bacteria applications on RWC and LWP of guar plants under drought conditions (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied. Each value represents the average of three replicates. For each parameter, different letters represent a significant difference at $P<0.05$ using the Tukey test.)

Chlorophyll, a primary pigment that is involved in the process of photosynthesis in plants, comprises contents that reflect the photosynthesis levels of plants (Figure 2). The photosynthetic pigments such as Chl-a, Chl-b, and total carotenoid in guar leaves decreased under drought stress in plants without the bacterial treatments. Drought stress reduced Chl-a, Chl-b, and total carotenoid contents by 3-6, 11-27, 15-40, and 26-47% at S1, S2, S3, and S4, respectively, when compared to control. An increase in the photosynthetic pigments was observed following microbial inoculation in guar plants in the control and drought-stressed plants (average by 11-23%). However, this recovery in inoculation of drought stressed guar plants with BM showed 17-44, 13-28, and 12-52%.

To confirm the drought-induced oxidative stress, an evaluation of the intercellular levels of stress biomarker MDA was performed (Figure 2). The MDA values, which are important indicators of oxidative damage, differed significantly in the inoculated and un-inoculated plants. The MDA content was observed as the lowest in the control plants (1.31-3.32 µmol g^{-1} FW), and it was significantly increased under drought stress. With regards to the MDA levels, the highest was observed in the S4 treated plants (28.34 µmol g^{-1} FW) when compared to the control plants. However, inoculation of plants with bacteria (BS, PF, and BM) diminished the effects of drought stress on this parameter and significantly decreasing the MDA contents when compared to the un-inoculated drought-stressed controls. Inoculation of the plants with BS, PF and BM decreased MDA by 25, 38, and 43 %, respectively, compared to S4 un-inoculated plants.

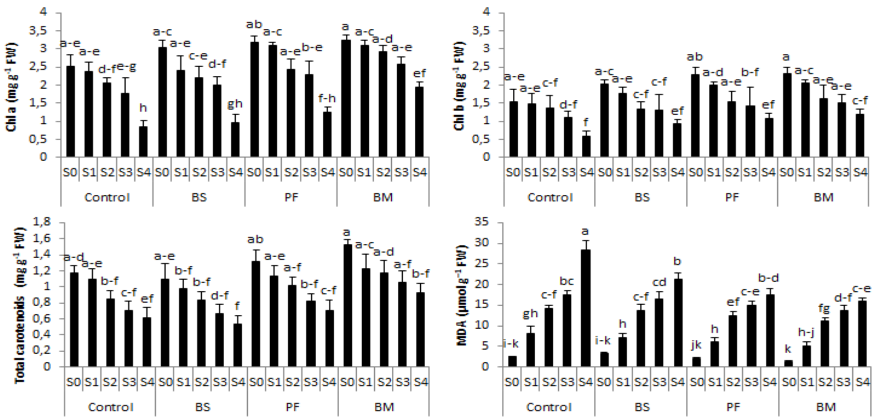

Figure 2. Effects of bacteria applications on RWC and LWP of guar plants under drought conditions (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied. Each value represents the average of three replicates. For each parameter, different letters represent a significant difference at P<0.05 using the Tukey test.)

The three bacteria were evaluated for their ability to improve K, Ca, Mg, Cu, Fe, Mn, and Zn accumulation in pots under different drought level conditions and the 'Bacteria × Drought Treatment' interaction was observed as significant (P<0.05). Plants under drought stress exhibited a significant decrease in the macro and micro nutrition accumulation (Figure 3). Under drought conditions (S1, S2, S3, and S4), these reductions determined among 10-80% compared to control plants.

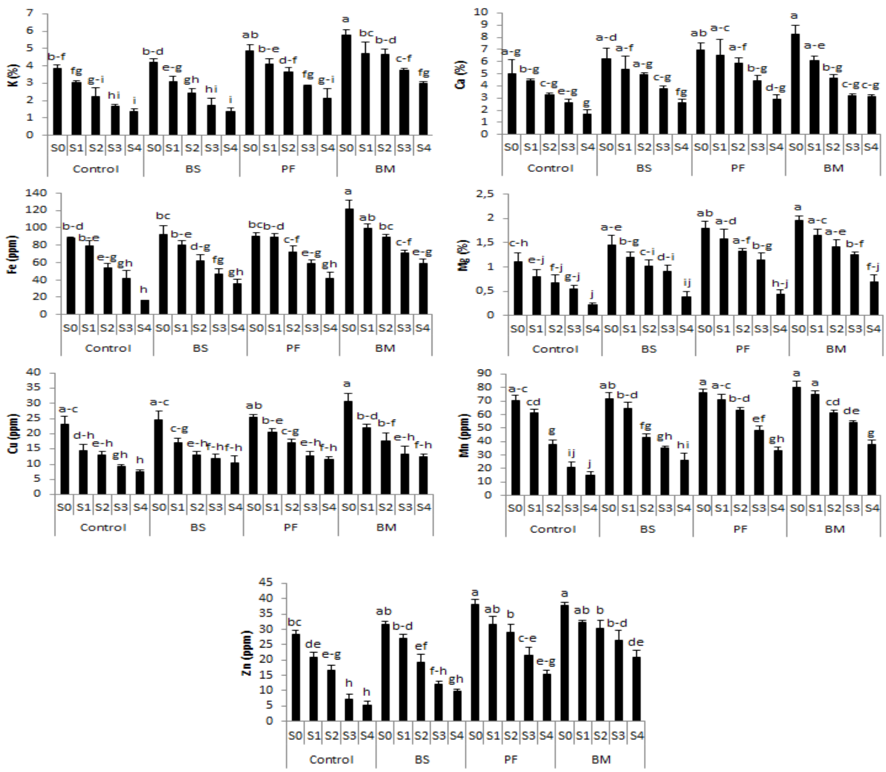

Figure 3. Effects of bacteria applications on RWC and LWP of guar plants under drought conditions (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied. Each value represents the average of three replicates. For each parameter, different letters represent a significant difference at P<0.05 using the Tukey test.)

The nutrition content responded positively to inoculation treatments and inoculation of BS, PF and BM significantly increases in K, Ca, Mg, Cu, Fe, Mn, and Zn contents by 28-82% rations were determined in the inoculated plants under drought stress when compared to the un-inoculated ones. These reactions at S4 condition, the guar plants inoculated with BM were more effective in the shoots when compared to the plants that were un-inoculated (about 119%, 83%, 213%, 65%, 270%, 147%, 284% increase, respectively). The effects that drought stress had on the guar in the presence of BS, PF, and BM were studied by evaluating the total flavonoid and phenolic contents (Figure 4). The interaction between bacteria and treatment led to significant differences in the total flavonoid and phenolic contents ($P<0.05$). When exposed to water stress, total flavonoid and phenolic contents reduced among to 20-70% compared to control. The maximum mean values obtained were in the inoculated with BM at control condition (27.54 µgGAE mL^{-1} of total phenolic; 15.16 mgQE 100 g^{-1}). Bacteria treatments resulted in total phenolic and flavonoid content mean values that were significantly increased when both individually compared with the drought stressed (increase of 2%–97%) plants and control.

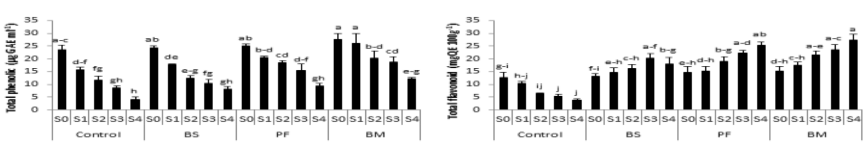

Figure 4. Effects of bacteria applications on RWC and LWP of guar plants under drought conditions (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied. Each value represents the average of three replicates. For each parameter, different letters represent a significant difference at $P<0.05$ using the Tukey test.)

Antioxidative enzyme activity (SOD, CAT, GR and APX) levels were evaluated in control, un-inoculated stressed and inoculated-stressed plants under different drought levels (Figure 5). While guar inoculated with BS, PF or BM exhibited antioxidant activity that was similar to that of the un-inoculated plants without drought stress. With drought stress, antioxidative enzyme activities increased by 17-507% compared to control plants. These activities (SOD, CAT, GR and APX) were significantly increased in the inoculated drought-stressed plants when compared to the un-inoculated drought-stressed plants. The water stress influenced guar inoculated with BS, PF or BM exhibited an increase in antioxidant activity of 1%–124% when compared to the un-inoculated drought-stressed plants.

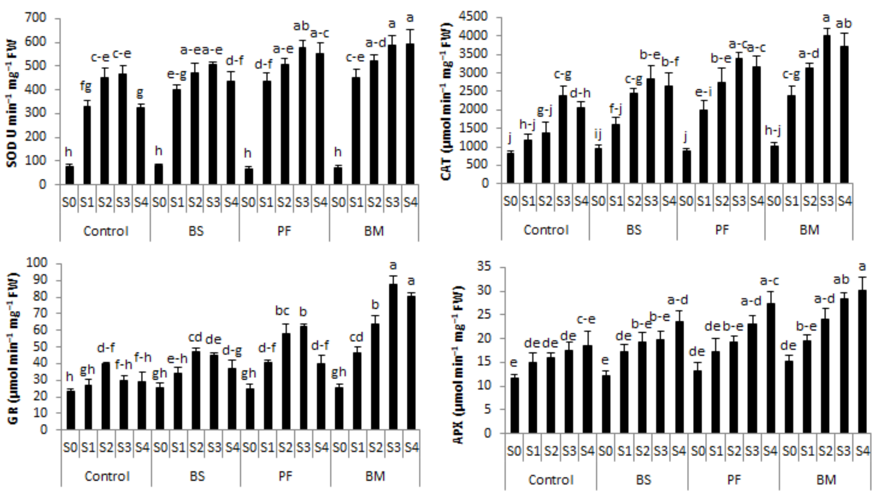

Figure 5. Effects of bacteria applications on RWC and LWP of guar plants under drought conditions (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied. Each value represents the average of three replicates. For each parameter, different letters represent a significant difference at $P<0.05$ using the Tukey test.)

Table 1. Effects of the application of bacteria on the guar plant growth parameters under drought stress (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied)

		Shoot fresh weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Root fresh weight (g plant^{-1})	Root dry weight (g plant^{-1})	Shoot length (cm plant^{-1})
Control (non-inoculated)	S0	52.02±3.63^{c}	10.93±1.15^{de}	4.36±0.33^{d-h}	1.23±0.17^{c-f}	62.40±2.00^{gh}
	S1	46.59±2.26^{cd}	9.85±0.97^{ef}	3.51±0.21^{h-j}	1.03±0.05^{f-h}	59.70±1.20^{h-j}
	S2	43.97±2.09^{d}	9.26±1.02^{fg}	3.37±0.10^{ij}	0.90±0.08^{h-j}	56.40±1.15^{ij}
	S3	30.62±1.76^{f}	6.95±0.83^{ij}	2.35±0.17^{kl}	0.64±0.04^{kl}	51.33±0.83^{k}
	S4	18.11±1.45^{i}	4.19±0.53^{k}	1.25±0.16^{l}	0.42±0.02^{l}	45.41±1.42^{l}
Bacillus subtilis (BS)	S0	65.78±2.85^{ab}	13.29±1.12^{c}	6.47±0.32^{a}	1.69±0.15^{a}	78.67±1.69^{ab}
	S1	63.63±3.56^{b}	13.26±1.05^{c}	5.65±0.63^{a-c}	1.39±0.09^{b-d}	75.33±1.49^{b-d}
	S2	47.55±2.46^{cd}	9.98±0.81^{ef}	5.61±0.29^{a-c}	0.97±0.08^{g-i}	73.67±2.09^{c-e}
	S3	30.62±2.76^{f}	6.01±0.66^{j}	3.41±0.34^{h-j}	0.81±0.03^{i-k}	66.66±1.59^{fg}
	S4	20.22±1.29^{hi}	4.33±0.73^{k}	2.96±0.18^{jk}	0.72±0.02^{jk}	59.73±1.25^{h-j}
Pseudomonas fluorescens (PF)	S0	65.30±2.11^{ab}	15.31±1.22^{b}	5.19±0.29^{b-d}	1.28±0.03^{b-e}	81.66±3.47^{a}
	S1	66.74±3.86^{ab}	13.65±1.38^{c}	5.01±0.18^{c-e}	1.25±0.13^{c-f}	79.23±2.92^{ab}
	S2	45.69±1.98^{d}	11.53±0.79^{d}	4.89±0.31^{c-f}	1.10±0.07^{e-h}	69.33±2.20^{ef}
	S3	29.22±1.58^{fg}	7.42±0.69^{hi}	4.33±0.26^{d-h}	1.09±0.05^{e-h}	58.67±1.80^{h-j}
	S4	23.31±1.24^{gh}	5.94±0.46^{j}	4.19±0.23^{e-i}	1.06±0.04^{e-h}	55.33±1.93^{jk}
Bacillus megaterium (BM)	S0	70.10±3.56^{a}	17.24±1.10^{a}	6.06±0.22^{ab}	1.48±0.05^{ab}	77.67±1.88^{bc}
	S1	51.37±2.78^{c}	10.54±1.08^{de}	5.49±0.35^{bc}	1.43±0.03^{bc}	71.66±1.46^{de}
	S2	46.51±1.26^{cd}	10.38±0.98^{d-f}	5.07±0.27^{c-e}	1.25±0.11^{c-f}	71.41±2.79^{d-f}
	S3	37.70±1.12^{e}	8.31±0.59^{gh}	4.89±0.31^{c-f}	1.17±0.04^{d-g}	66.67±1.50^{fg}
	S4	28.92±1.70^{fg}	6.71±0.67^{ij}	4.02±0.32^{f-i}	1.13±0.07^{e-g}	57.73±1.62^{ij}

Table 1. Effects of the application of bacteria on the guar plant growth parameters under drought stress (S0: Field capacity of 100%, S1: 75% depletion of the AWHC; S2: 50% depletion of the AWHC, S3: 25% depletion of the AWHC, S4: no irrigation water applied) (Continous)

		Shoot diameter (mm plant^{-1})	Steam Number (num. plant^{-1})	Leaf Number (num. plant^{-1})	Leaf Area (cm^{2} plant^{-1})
Control (non-inoculated)	S0	6.26±0.62^{c}	8.10±0.80^{b-f}	55.33±1.86^{cd}	588.5±23.93^{a-c}
	S1	6.19±0.81^{c}	7.66±0.59^{c-f}	53.66±1.37^{cd}	489.9±26.14^{c-g}
	S2	5.72±0.51^{c-e}	6.00±0.45^{e-g}	52.33±2.73^{d}	376.9±28.71^{g-i}
	S3	5.69±0.93^{c-e}	4.33±0.65^{gh}	46.66±2.88^{d-g}	357.95±37.90^{h-i}
	S4	4.72±0.68^{f}	2.66±0.56^{h}	22.33±1.37^{i}	241.94±14.76^{j}
Bacillus subtilis (BS)	S0	7.48±0.78^{b}	10.00±0.73^{a-c}	79.00±3.90^{a}	750.90±36.50^{a}
	S1	5.81±0.86^{cd}	9.33±1.07^{a-c}	73.66±2.52^{ab}	568.26±49.43^{b-d}
	S2	5.66±0.72^{c-e}	8.66±0.83^{a-d}	47.00±1.79^{d-f}	515.02±12.37^{c-f}
	S3	5.28±0.92^{d-f}	8.56±0.71^{a-d}	40.33±1.83^{e-h}	461.02±24.13^{d-h}
	S4	5.09±0.49^{ef}	5.33±0.51^{fg}	36.33±1.58^{h}	332.76±20.66^{ij}
Pseudomonas fluorescens (PF)	S0	5.46±0.95^{d-f}	10.66±1.09^{a}	54.00±2.65^{cd}	659.22±50.72^{ab}
	S1	5.41±0.90^{d-f}	10.33±1.03^{ab}	54.33±3.39^{cd}	539.68±63.63^{c-e}
	S2	5.05±0.66^{ef}	8.33±0.52^{a-e}	49.00±1.55^{de}	445.49±14.28^{e-i}
	S3	4.87±0.61^{f}	6.66±0.58^{d-g}	37.33±1.25^{gh}	426.91±27.88^{e-i}
	S4	4.12±0.81^{g}	5.66±0.39^{fg}	38.00±1.10^{f-h}	407.96±26.50^{f-i}
Bacillus megaterium (BM)	S0	8.49±1.02^{a}	10.67±1.96^{a}	70.00±2.73^{ab}	714.55±32.97^{a}
	S1	5.39±0.57^{d-f}	10.00±1.23^{a-c}	62.00±3.90^{cd}	517.89±28.66^{c-f}
	S2	5.29±0.48^{d-f}	9.33±1.10^{a-c}	54.33±3.39^{cd}	462.58±56.44^{d-h}
	S3	4.86±0.22^{f}	8.00±0.73^{b-f}	51.00±1.37^{d}	415.07±36.52^{f-i}
	S4	4.84±0.68^{f}	7.66±0.59^{c-f}	47.33±2.14^{d-f}	388.40±15.71^{g-i}

*Each value represents the mean of three replicates. Different letters for each parameter represent statistically significant differences at $P < 0.05$ using

DISCUSSION

Increases in the incidences of drought, which occur as the result of climate change, interfere with agricultural productivity because water deficiency during a drought disrupts plant cellular metabolic machinery. Water deficiency results in a decrease in the division and enlargement of cells due to enzyme activity damage, which then leads to plant organs that are smaller overall (Schillaci et al., 2019). A water deficit causes a significant decrease in the diameter of the stem. A decrease in the availability of water might affect the metabolic and physiological activities of plants, which are responsible for modifying morphologic characteristics, especially those related to growth (Galvao et al., 2019). A decrease in growth occurs as a result of a decrease in cell turgor, which is directly related to the expansion of cells (Padilha et al., 2016).

This strategy is performed by plants to decrease the area of transpiration and, consequently, reduce water loss in the environment. When severe stress occurs, plants exposed to dehydration for a prolonged period of time are unable to maintain or regain their leaf area (Sahoo et al,. 2013; Galvao et al., 2019). In addition, leaves exhibit weakened photosynthesis, which then decreases the accumulation of dry matter and grain yield. Our results showed that in un-inoculated guar plants, the growth decreased with drought stress when compared to the control plants and this reduction was seen more clearly due to increasing drought level (Table 1). Inoculating the guar plants with bacteria had a significant effect on all of the morphological traits studied herein. Bacterial endophytes existed in the above-and belowground tissues of the examined terrestrial plants, which have the ability to affect the physiology and growth of plants under normal conditions and under stress. Endophytic bacteria are able to directly stimulate the growth of plants via phytohormone and volatile production, which enhances the acquisition of nutrients, and suppresses ethylene synthesis that has been induced under stress (Dudeja, 2016).

Kaushal (2019) indicated positive effects of hormonal contents such as cytokinins and gibberellins which play a significant role in the growth and survival of plants, were also determined in drought-stressed PGPR-treated plants. It was reported by Naveed et al. (2014) that, under drought stress, two different maize cultivars exhibited a reduction in damage following inoculation with two different PGPR, which was most likely the result of hormones that the bacteria produced and the stress-reducing enzymes that were synthesized by the bacteria and the plants together. Auxin IAA production, in combination with cytokine, has been observed in a number of strains of endophytic bacterial, which both have a pivotal role with regards to the development of plants (Dudeja, 2016). Hence, enhanced root growth, which also results in better soil water and mineral uptake, positively affects plant growth.

The bacteria, which were used in this study, might have contributed to growth and development by allowing an increase in IAA and cytokine under drought stress. Egamberdieva et al. (2017) reported that many endophytic bacteria exhibited the potential to improve the growth of plants, in addition to the inoculation and stress tolerance of endophytic bacterial isolates, which in turn results in significantly increased plant height, number of leaves per plant, and fresh and dry weights, (Shi et al., 2009; Dudeja, 2016; Egamberdieva et al., 2017). In chickpea, common bean, and wheat, the inoculation of bacteria was observed to improve the growth of drought-stressed wheat, in addition to improving their survival, and fresh and dry weights (Kasım et al., 2013; Kumar et al., 2016; Galvao et al., 2019). The results also indicate that different bacteria differed with regards to their drought stress tolerance. Under drought stress, the BM strain exhibited the highest ability. Agriculturally, this could be very significant, as determining strains that have the highest ability under various stress conditions would be highly beneficial because these bacteria could be used as bioinoculants under various stress conditions.

Plant leaf RWC has been considered as a possible indicator of the water status of a plant, as a result of it playing a role in tissue metabolic activity. A decrease in RWC is reflective of a loss of turgor, which then results in restricted cell expansion and consequently, reduced plant growth (Castillo et al., 2013). Decreased irrigation resulted in plants exhibiting mild dehydration, which was observed as a decrease in water capacity caused by increasing difficulty with water uptake or a lower level of substrate water. Plants under water stress had significantly lower leaf and stem water potential values (Acosta-Motos et al., 2017). The shoot DM decrease observed in the current study can be attributed to a reduction in RWC. It was reported by Nxele et al. (2017) that the RWC is one of the easiest agricultural variables that can be used to screen plants for drought tolerance.

The application of treatments of bacteria to guar seedlings under stress increased root DM, which enhanced the RWC of the shoots.

Although the RWC values exhibited a decrease under drought stress, at an average of 24%, with the inoculation of bacteria, the RWC was observed to have increased by 10% under the same conditions (Figure 1). Under stress conditions, there was a greater increase in RWC in seedlings inoculated with BM in this study. Under drought stress, an increase in leaf RWC via bacterial inoculation suggested that the bacteria may have increased leaf water relations in guar and supported the continuation of cell turgor pressure. High RWCs in maize (Casanovas et al., 2002) and wheat (Creus et al., 2004) that had been inoculated with *Azospirillum* sp. may have resulted from bacterial ABA, which induced stomatal closure and diminished drought stress. It was suggested by Dodd et al. (2010) that it could be of interest to investigate if the effects of bacterial inoculation on plant water content in relation to the production of bacterial ABA or an alteration in physiological process sensitivity, like stomatal closure.

According to our results, bacteria treatment increased leaf water potential and BM application was more effective than other bacteria relative to the control. Arzanesh et al. (2012) reported that different strains had an effect on the leaf water potential, which was the parameter that most effectively influenced crop yield, indicating the various abilities they had under stress via the production of differing levels of plant hormones. It could be interesting to discuss the various mechanisms that produce these types of differences. Creus et al. (2004), in their study growing *Azospirillum brasilense* Sp245-primed wheat under drought stress, reported that significantly increased water content, RWC, water potential, and apoplastic water function were observed in the shoots and roots when compared to unprimed plants. Furthermore, it was reported by Pereyra et al. (2012) that the inoculation of wheat seedlings with *Azospirillum* provided better water status under osmotic stress as a result of morphological modifications in the architecture of the coleoptile xylem.

It was reported by Gill et al. (2010) that water deficit causes stomatal closure, and a reduction in turgor pressure, photosynthesis, and chlorophyll (Chl) content. Reduced chlorophyll contents under osmotic and drought stress has been attributed to damaged pigments, pigment-protein complex instability, and significant chloroplast membrane damage and loss (Bhardwaj et al., 2018). It has been reported that bacteria increases plant photosynthetic capacity via direct influence on stomatal conductance and cellular tolerance toward dehydration (De Lima et al. 2019). In our study, inoculated plants had higher levels of photosynthetic pigments such as Chl-a, Chl-b, and total carotenoids (11-23% higher) (Figure 2). Moreover, the results of the current study showed that *Bacillus megaterium* and *Pseudomonas fluorescens* had significantly higher effects on photosynthetic pigment maintenance under drought stress when compared to *Bacillus subtilis*. These results agree with the finding of Radhakrishnan et al. (2017) and El-Esawi (2018) who indicated oxidative stress such as drought, salinity prevents the synthesis of pigments and reduces photosynthesis, whereas microbes stimulate photosynthetic pigment synthesis in plants under stress, which then increases photosynthesis and reduces stress-induced negative effects via strengthening of the chlorophyll biosynthetic pathways.

Membrane phospholipids comprise polyunsaturated fatty acids that are the main targets of ROS during water deficiency that initiates lipid peroxidation and fatty acid degradation, which generate different cytotoxic products, including MDA. The MDA content is a biomarker that is used to quantify or measure oxidative stress-induced lipid peroxidation (Kaushal, 2019). Atmospheric CO_2 is reduced under induced oxidative stress due to stomatal closure, and NADPH consumption via the Calvin cycle is then decreased. The over-reduced ferrodoxine that is produced during the transfer of photosynthetic electrons results in electrons possibly being transferred from PS-I to oxygen, which form superoxide radicals (O_2^-) via the Mehler reaction (Islam et al. 2016). It was reported by Wang et al. (2012) that the leaves of BBS (*Bacillus cereus* AR156, *Bacillus subtilis* SM21 and *Serratia* spp. XY21)-primed cucumber plants exhibited decreased relative electrical conductivity and MDA levels when compared to the control plants.

Herein, it was observed that oxidative stress was induced by drought stress in guar plants due to an increase in lipid peroxidation. On the other hand, it should be noted that the inoculated drought-stressed plants exhibited decreased MDA contents when compared to the drought-stressed plants, which indicated lower ROS accumulation and damage to membranes in the inoculated plants (Figure 2). The inoculation of *Bacillus megaterium* resulted in a significant reduction in the MDA contents in the guar plants, which indicated that *Bacillus megaterium* caused a reduction in oxidative stress and, in turn, significantly reduced MDA. This improved effect on the accumulation of MDA could be connected to an increased accumulation of secondary metabolites, which aid in stabilizing subcellular structures, such as membranes and proteins, scavenging free radicals, and buffering the potential of cellular redox under stress (Islam et al., 2016). MDA content reduction in stressed and inoculated plants may be an effective mechanism for attenuating the activation of the defenses of plants. Furthermore, this process ensures membrane integrity and reduces the leakage of important ions (Latef et al., 2020).

One of the causes of the adverse effects of abiotic stresses on plant growth and development is the imbalance of nutrient uptake and metabolism. It was reported in several cases that addition of macronutrients exogenously leads to a certain degree of stress alleviation (Chakraborty et al., 2015). The mobility and diffusion of nutrients in the soil is affected by drought as a result of poor soil structure caused by water deficiency. Increased K^+ levels reduce the stomatal conductance that is necessary to sustain turgor pressure under drought stress. In addition to this, K^+ scavenging activity aids in preventing the formation of ROS during NADPH oxidase metabolism and photosynthesis (Radhakrishnan et al., 2017). In plants, calcium is a necessary cell growth and tissue regulator. It aids in a plant's adaptation to different stress factors and acts as an osmoticum in vacuoles, cell wall reinforcing agents, membrane-stabilizing elements, and is a messenger that is secondary to many signals (Gafur and Putra, 2019).

The application of drought stress decreased the K^+ and Ca^{2+} content in leaves and roots of guar plant (Figure 3). Barnawal *et al.* (2013) reported that potassium (K^+), P, and N uptake decreased the number of drought-damaged plants, while microbe treatments, like *Bacillus* spp., resulted in increased macro nutrients in plants under stress. When compared to the control plants under drought conditions, the average contents of K+ and Ca^{2+} in guar shoots and roots increased significantly with all three bacterial strains (average 43 and 46% increase). Microbes play a role in the decomposition of organic matter as well as solubilization of nutrients, which become available to the roots. Magnesium promotes enzyme-substrate interactions by forming chelate bonds, which speeds up enzymatic reactions. It also participates in the synthesis, transport and storage of carbohydrates, proteins and fats. The most essential function of magnesium is chlorophyll formation, which plays a significant role in the light energy absorption that is necessary for photosynthesis (Kostrzewska et al., 2019; Hlisnikovský et al., 2019).

The magnesium content of un-inoculated guar shoots was decreased by drought stress whereas bacteria inoculation resulted in an increase content of Mg (82%) in comparison to the un-inoculated control plants. Drought affects plant growth by hindering photosynthesis and metabolic activities. Fe^{2+} homeostasis is essential for photosynthesis efficiency (Briat et al., 2015) and it usually decreases under abiotic stress conditions (Hu et. al. 2007; Sánchez-Rodríguez et al. 2010). It was reported by Radhakrishnan et al. (2017) that some species of *Bacillus* spp. improved the growth of drought-stressed plants via an increased level of Fe. In the current study of guar plants, increased Fe contents in the leaves were determined in the plants that had been inoculated with BS, PM or BM by an average 32% levels.

Furthermore, micronutrients such as Zn^{2+}, Mn^{2+}, and Cu^{2+} increased in bacteria-inoculated guar plants. It is a well-known fact that drought stress may have an effect on micronutrient availability, specifically on those that diffuse slowly, in addition to their competitive uptake and transport. Armada et al. (2014) reported that these changes were thought to be adaptive responses to water deficiency.

It was reported by Marulanda et al. (2009) that, in drought-stressed soil, plants exhibited increased dependence on microbial activity, which aided in increasing water uptake and nutrients. The establishment of drought-stressed plants significantly depends on the perseverance and survival of the bacterial community in the soil rhizosphere (Rodríguez et al. 2008). Plant nutrient concentrations, such as Ca^{2+}, Mg^{2+}, Zn^{2+}, Mn^{2+}, and Cu^{2+} have been reported to increase with the application of *Bacillus thuringiensis*, *Bacillus megaterium*, and *Bacillus* spp. to drought-stressed salvia (*Salvia divinorum* L.) and lavandula (*Lavandula angustifolia* L.) plants (Armada et al., 2014).

In plants, phenolic and flavonoid compounds also perform many other roles, such as in cell wall structural components, taking part in the developmental process and growth regulation, in addition to defense mechanisms against abiotic and biotic stressors (Taibi et al., 2016). The results of the current study indicated that the inoculation of bacteria aided in maintaining a significant increase in the total phenolic and flavonoid contents when compared to the un-inoculated drought-stressed plants (5-94% increase). The results are a clear indication that bacteria have a stimulatory affect on phenolic and flavonoid compounds accumulation in guar (Figure 4). The elevation in the total phenol and flavonoid levels was thought to be caused by significant rates of photosynthesis, which were dependent on the existence of a large photosynthetic area and high levels of photosynthetic pigment in addition to a yeast treatment used as a biofertilizer (Dineshkumar et al., 2018).

Herein, analyses were performed to determine if inoculation with bacteria resulted in guar plants possessing improved resistance to drought stress. Skewness that was induced due to the overproduction and detoxification of ROS in guar plants, as the result of an increase in photosynthetic machinery disruption and photorespiration, was a significant change under water deficiency or drought stress conditions. In plants, oxidative stress is caused by ROS like hydrogen peroxide, hydroxyl radicals, superoxide anion radical, and singlet oxygen, which lead to catastrophic lipid, protein, and nucleic acid damage. Although an increase in levels of ROS induces oxidative damage, low levels of ROS are significantly important for plants, because they play a role in signaling events that activate a number of defensive pathways. Therefore, it is necessary that ROS are regulated by coordinating control of their generation and quenching systems, and managing oxidative stress damage and signaling functions. Plants are equipped with a fundamental antioxidant defensive network that can suppress an excess amount of ROS.

Antioxidant mechanisms comprise the enzymatic group, which includes SOD, peroxidase, APX, GR, CAT, APX, and guaiacol peroxidase, and components that are nonenzymatic, such as flavonoids, glutathione, ascorbate, tocopherols, and carotenoids, (Kaushal, 2019).

In the current study, significantly increased antioxidant enzyme activity, i.e. SOD, CAT, APX, and GR, was observed in the drought-stressed guar plants when compared to the control plants (Figure 5). It was clearly seen that this increased enzyme activity was related to increased levels of stress and suggested that BM treatment could alter plant drought stress. CAT was reported by Guo et al. (2006) as the main enzyme that scavenges H_2O_2, whereas SOD is the active oxygen radical (O_2^-) into H_2O_2 (Kakar et al., 2016). Our elucidation of mechanisms that were elicited by bacteria, BS, PF, and BM, exhibited significantly increased levels of SOD and CAT, which indicated that, through the increased ability of SOD, abiotic tolerance could contribute to the scavenging of excess O_2^- and CAT, which would in turn prevent an increase in H_2O_2.

It was also suggested that APX is necessary to protect chloroplasts from increased levels of ROS in plants under drought stress. APX is an antioxidant enzyme that plays a significant role in the ascorbate-glutathione redox cycle, and it is a crucial scavenger of ROS. During stress, on the other hand, GR plays an essential role in preserving the reduced glutathione pool under stress conditions. Kasim et al. (2013) reported that varying effects were observed in the ascorbate-glutathione redox cycle enzyme activity as a result of bacterial priming in the drought-stressed leaves of guar plants. It was reported by De Lima et al. (2019) that the negative effects caused by water stress can also be mitigated by PGPR via the reduction of oxidative damage as a result of ROS through enzymatic or ROS-scavenging antioxidant activity, which are both regulated plant responses to water stress. Chakraborty et al. (2013), in their study of wheat, reported that in GY and MW, which are both susceptible varieties, SOD and CAT were both decreased from the beginning of drought stress, and inoculation with either *Ochrobactrum pseudogregnonense* or *Bacillus safensis* aided in maintaining high levels of the enzymes, thus alleviating drought.

In addition, a number of studies in the literature have reported altered antioxidant enzyme levels in plants as a result of inoculation with PGPR, which is a significant MIST mechanism against drought stress (Armada et al., 2012; Gururani et al., 2013; Cohen et al., 2015; Kaushal, 2019). Moreover, increased ROS-detoxifying enzymatic activity was observed in the inoculated plants when compared to those that were un-inoculated. Sufficient evidence exists to conclude that enhanced antioxidant enzyme activity plays a significant role in the modulation of ROS levels in plants during severe stress (Zhou et al., 2017). This indicated that the effective ability that enzymatic activity had in controlling potential oxidative damage following inoculation with bacteria (Islam et al., 2016). Thus, the results presented herein have exhibited the role that *Pseudomonas fluorescens* PF1 (PF), *Bacillus subtilis* QST 713 (BS), and *Bacillus megaterium* (BM) play in mitigating tolerance to drought stress via activation of the antioxidant system in guar plants.

Figure 6. Effects of different bacteria applications under drought stress

CONCLUSION

Plant stress-protecting agents, which reduce drought, salinity, heavy metals, waterlogging, and pathogenicity, will be significantly important in future as a result of global climate changes. With this in mind, the use of microbes may be a beneficial stress-protecting agent for plants that leads to favorable solutions toward sustainable and environmentally friendly agriculture. Results of the current study confirmed that the inoculation of guar plants with *Pseudomonas fluorescens* PF1, *Bacillus subtilis* QST 713, and *Bacillus megaterium* resulted in an improved capacity for drought stress tolerance, via preservation of the RWC, improved SOD, CAT, APX, and GR enzyme activity, and an increase in the accumulation of secondary metabolites, which suggested improved growth in the guar plants, as a result of physiological and biochemical changes under drought stress. Specially, *Bacillus megaterium* was more efficiently improved the growth of the drought-stressed guar plants. Our results suggest that *Pseudomonas fluorescens* PF1, *Bacillus subtilis* QST 713, and *Bacillus megaterium* can effectively be used as potential promoters of plant growth for guar during water stress conditions.

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CHAPTER XI

BIOLOGICAL NITRIFICATON INHIBITION CAPACITY OF FORAGE AND PASTURE CROPS

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INTRODUCTION

Agricultural activity has large influence on the global nitrogen cycle by introducing huge amounts of nitrogen into ecosystems with fertilizers. About 50% of the nitrogen fertilizers applied to soils is not absorbed by plants and lost as ammonia, nitrate and nitrous oxide. This nitrogen leak into the environment have a negative effects on ecosystem and global warming. Also, reducing nitrification of soil nitrogen may improve long-term productivity of grasslands and forage-based production systems. Some plants have ability to reduce soil nitrification by releasing inhibitors from roots, a phenomenon termed biological nitrification inhibition. Release of these inhibitors from roots is a tightly regulated physiological process, with extensive genetic variability field crops and pasture grasses. Effective nitrification inhibitor in the root-exudates of the tropical forage grass Brachiaria humidicola was discovered and named as “brachialactone”. “Sorgoleone” is a “biological nitrification inhibitor” released by sorghum plants to reduce soil nitrification. This article is designed to review biological nitrification inhibition at forage and pasture crops

Agricultural activity has large influence on the global nitrogen (N) cycle by introducing huge amounts of reactive nitrogen (fertilizers) into ecosystems. A big part of this nitrogen leaks into the environment with iportant negative effects on ecosystem and global warming. Natural ecosystems use multiple pathways in reaction to this flow. Agricultural systems cycle it primarily through the nitrification process which allows reactive N leak into the environment (Subbarao et al., 2012).

The N use efficiency of agricultural plants is poor. About 50% of the N fertilizer applied to soils is not absorbed by plants and lost as ammonia (NH_3), nitrate (NO_3^-), and nitrous oxide (N_2O). These losses are driven by volatilization of NH_3 and by nitrification and denitrification reactions catalysed by soil microorganisms (bacteria and archaea) (Coskun et al., 2017).

Regulating nitrification could be a key strategy in improving agronomic N recovery and N use efficiency (Subbarao et al., 2007).

Certain plants can suppress soil-nitrification by releasing inhibitors from roots, a phenomenon termed biological nitrification inhibition (BNI) (Subbarao et al., 2009).

Effective nitrification inhibitor in the root-exudates of the tropical forage grass Brachiaria humidicola was discovered and named as “brachialactone”. This inhibitor is a cyclic diterpene with a unique ring system and a γ-lactone ring. It contributed 60–90% of the inhibitory activity released from the roots of this tropical grass. Brachialactone block both ammonia monooxygenase and hydroxylamine oxidoreductase enzymatic pathways in Nitrosomonas. Plant regulates the release of this inhibitor which is triggered and sustained by the availability of ammonium (NH_4^+) in the root environment. Brachialactone release is restricted to the roots that are directly exposed to NH_4^+ (Subbarao et al., 2009).

A highly sensitive bioassay using recombinant luminescent *Nitrosomonas europaea* was developed to detect and quantify the amount of nitrification inhibitors produced by plants (Subbarao et al., 2007).

Release of BNIs from roots is a tightly regulated physiological process, with extensive genetic variability field crops and pasture grasses. A shift to low-nitrifying agricultural systems may be obtained by using species and varieties with high BNI capacities (Subbarao et al., 2013).

"Sorgoleone" is a "biological nitrification inhibitor" released by sorghum plants to reduce soil nitrification. Sorghum genotypes release varying quantity of sorgoleone. Genetic differences exist for "Sorgoleone" release and its functional link with biological nitrification inhibition capacity. Sorgoleone inhibits Nitrosomonas activity and lowers soil nitrification (Tesfamariam et al., 2014).

Nuñez et al., (2018) was conducted a study with hybrid population of *Brachiaria humidicola*, a forage grass with high "biological nitrification inhibition" potential but with low nutritional quality. They identified hybrids with high levels of BNI activity. They also discovered that, the microcosm incubation and in vitro bioassay may be used as complementary methods for effectively assessing BNI activity. The full expression of BNI potential of *Brachiaria humidicola* genotypes grown in the soil (i.e. low nitrification rates) requires up to one year to develop, after planting.

"Biological nitrification inhibition" capacity of 119 germplasm accessions of Guineagrass (*Megathyrsus maximus*) was tested in a greenhouse experiment. Measured parameters were 1) rates of soil nitrification; 2) abundance of ammonia-oxidizing bacteria (AOB) and archaea (AOA); 3) the capacity of root tissue extracts to inhibit nitrification in vitro. Reductions of nitrification activity ranged between

30-70% across the germplasm collection. The “Biological nitrification inhibition” capacity was not correlated to nitrogen uptake of plants, possibly due to intraspecific variation for exploitation different nitrogen sources in these grass species. A cluster of accessions, which contain desirable agronomic and environmental traits, was further analysed. Results showed the ability of *M. maximus* to reduce soil nitrification and N2O emissions and their relationship with productivity and forage quality (Villegas et al., 2020).

Among grass pastures, “Biological nitrification inhibition” capacity is strongest in “low-nitrogen environment” grasses such as *Brachiaria humidicola* whereas is weakest in “high-nitrogen environment” grasses such as Italian ryegrass (*Lolium multiflorum*) and *B. brizantha*. Synthesis and release of BNIs is a “highly regulated and localized” process, triggered by the NH4+ in the soil. This condition facilitates release of “Biological nitrification inhibitiors” to soil-nitrifier sites. Genotypic variation is found for “Biological nitrification inhibition” capacity in *B. Humidicola* (Subbarao et al., 2013).

Several tropical grasses, particularly *Urochloa humidicola* is associated with low soil nitrate content and reduced nitrogen losses from pasture systems. Combination of different mechanisms, particularly stimulation of N immobilization may be responsible for the “Biological nitrification inhibition” capacity observed as low NO3− soil content and reduced N losses (Vázquez et al., 2020).

Synthesis and release of “Biological nitrification inhibitiors” from plants is a highly regulated process triggered by the presence of NH4+ in the rhizosphere. Among the tropical pasture grasses, the BNI function is strongest in *Brachiaria* sp. and sorghum in their root systems (Subbarao et al., 2013).

Temperate grassland type 126 varieties from 26 species screened for the soil nitrification rate potential (SNP) in pots. Categories of grasses, legumes and fodder crops were similar, but varieties were very different from each other for potential nitrification rates. Soil nitrification rate potential range for all forages was 0.15 - 0·24 µg / g dry soil/h, which indicates 71% difference between highest and lowest rates. Italian ryegrasses had SNP values mostly greater than the mean value for all grasses whereas, the lowest rate among the grasses was in the perennial ryegrass AberMagic. In the legumes, the subterranean clover cultivars had low SNP values, white clovers rates was lowest with Sulla. The variation in SNP within the fodder crops tested was small (11% difference between the highest and lowest rates). The variation in Trifolium subterraneum was almost half of the variation found in *T. repens* probably due to *T. subterraneum*'s autogamy (self-pollinating) where genetic variation is expected to be small (Bowatte et al., 2016).

CONCLUSION

Selecting for potential for release of biological nitrification inhibition or genetic improvement for low-nitrifying targets may be started to be put in selection programmes.

Phenotyping forage germplasm collections under greenhouse conditions in soilless culture may help to find genotypes with high biological nitrification inhibition activity.

Suppressing nitrification can thus facilitate retention of soil N to sustain long-term productivity of grasslands and forage-based production systems. Certain plants can suppress soil nitrification by releasing inhibitors from roots.

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CHAPTER XII

THE IMPORTANCE OF MEADOW-RANGELANDS, ANIMAL EXISTENCE AND FORAGE CROPS CULTIVATION IN THE AGRICULTURAL POTENTIAL OF TOKAT PROVINCE

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INTRODUCTION

Today, one of the biggest problems of our World is the inability to create adequate and balanced nutritional conditions for humans by making the best use of natural resource (Erol, 1996). Roughage needed in animal production is mainly supplied from three resources. These resources are natural meadow-rangelands, forage crops and plant production residues. However, when we consider the roughage production balance, we see that our livestock farming is significantly dependent on meadow and met by large amount of plant production residues (grain straw and stubble) and concentrated feeds which increase the cost of feeding. Today, unfortunately the efficiency of the animal products of our animal existence is quiet low.

Due to the high prices of the animal products and their low yield, our people cannot be nourished with sufficient levels of animal proteins (Avcıoğlu et al., 2000; Alçiçek, 2001). One of the causes of this situation is the insufficiency of quality roughage which is one of the most important input of livestock breeding (Ayan et al., 2006). Forage crops grown in field agriculture and natural meadow-rangelands are the important feeding resources providing quality, cheap and abundant roughage to animals. Besides being a cheap resource, quality roughage is also important in terms of being rich in minerals and vitamins, increasing the reproductive power of animals, preventing many metabolic diseases related to nourishment and providing high quality animal products (Serin and Tan, 2001a).

There are 14.6 million hectares (ha) of meadow, rangeland area in Turkey and this ratio covers approximately 18.7 % of the country's area (TURKSTAT, 2020). The regions which are rich of meadow area are Eastern Anatolia and Central Anatolia Regions. Black Sea Region follows these. According to the report of Anonymous (2021), dry grass yield of meadows and rangelands in Turkey is between 60-70 kg da^{-1}. Highest yield on the basis of the region is obtained from Black Sea (100 kg da^{-1}) and Eastern Anatolia Regions (90 kg da^{-1}). Some researchers, with an optimistic point of view state that hay yield of meadows is 80 kg da^{-1} (Ak, 2013). Turkey's arid climate, irregularities in the rainfall regime of the regions, problems in meadow management are the reasons for medium and low quality meadows in the country. In addition to this, one of the most important problems encountered is overgrazing of the meadows. This situation renders meadows and rangelands into poor quality and causes animals not being fed in a balanced and yield oriented manner. Whereas meadow and rangeland plants grow quality green grass with raw protein in 12-20% and 60-70% digestion ratio (Alcaide et al., 1997; Arslan, 2008; Parlak et al., 2011). Overgrazing which causes animals to be fed with additional feed even during the grazing season (Gonzalo and Bachiller, 2004) limits livestock farming to be done with the desired productivity and profitability.

Today, not being able to reach the desired level of yield required to be obtained from the meadow and rangelands due to several negative reasons, increases the pressure on the cultivation and production of forage crops. Cultivation of forage crops which is the most important way of reaching continuous and safe quality roughage is the insurance of plant and animal production (Akman et al., 2007). When the cultivation of forage crops becomes qualified and effective, the extreme pressure on meadow and rangelands will decrease. Meadows and rangelands which are deteriorated or are very close to deterioration will have the opportunity to renew themselves (Yolcu and Tan, 2008).

Many studies have been conducted in Turkey and in some regions so far to reveal the presence of animals and the condition of meadow-rangeland and forage crops (Açıkgöz et al., 2005; Cevheri and Polat 2009; Sayar et al., 2010; Temel and Şahin, 2011; Turan et al., 2015; Sayar 2017; Demiroğlu Topçu and Özkan, 2017; Özkan, 2020; Okçu, 2020; Özkurt et al., 2020). In this study which was prepared by evaluating the data provided by Turkish Statistical Institute (TURKSTAT). It was aimed to examine the problems and offer solution suggestions by analyzing the meadow-rangeland and forage crop cultivation areas, the production amounts and presence of available animal stock in Turkey and in Tokat province.

Existence of Land In Turkey And In Tokat Province

Our country has a surface area of 783.562 km^2. According to the data provided by Turkish Statistical Institute (TURKSTAT) in 2020, it is seen that there is a total are of 231 million in Turkey, 156 million da (67.49 %) of which consists of Grains and Other Vegetable Products, 7.9 million da (3.36%) Vegetable Gardens area, 35 million da (15.40%) Fruit Gardens, Beverage and Spice Plants, 54 thousand da (0.02%) Ornamental Plants and 31.7 million da (13.71%) Fallow area (Table 1).

Total arable land presence in Black Sea Region is 26.810.842 da. The presence of this land constitutes 11.59% of Turkey's total arable land presence. Province of Tokat has a surface area of 9 959 km^2 and it is seen that there is a total are of 3 million in Tokat, 2.4 million da (78.38 %) of which consists of Grains and Other Vegetable Products, 176.3 thousand da (5.71%) Vegetable Gardens area, 162.4 thousand da (5.26%) Fruit Gardens, Beverage and Spice Plants, 332 da (0.01%) Ornamental Plants and 328 thousand da (10.63%) Fallow area (Table 1).

Table1. Turkey's and Tokat's land existences, distribution (da) (TURKSTAT, 2020)

Regions	Total land	Area of cereals and other crop products	Fallow land	Area of vegetable gardens	Area of fruits, beverage and spices	Ornamental plants area
Marmara	30.092.405	21. 773. 035	2.386. 484	1.274.454	4.634.629	23.803
Aegean	27.746.160	16.141. 110	1. 815. 883	1.294.249	8.476.905	18.013
Mediterranean	22. 285.397	13.569. 466	1. 538. 896	1.634.888	5.532.931	9.216
Centreal Anatolia	69.357.052	50.451. 706	15. 125.201	1.751.761	2.027.182	1.202
Black Sea	26. 810. 842	14. 910. 956	3. 888. 919	855. 467	7.154.407	1.093
East Anatolia	25. 361. 690	18.216. 591	5.181. 067	336. 197	1.627.625	210
South East Anatolia	28. 969. 775	20. 408. 964	1.789. 966	616. 749	6.154.071	25
Turkey	231. 363. 961	156. 149. 720	31. 732.521	7.792.463	35.635.187	54.070
Tokat	3. 087. 708	2. 420.172	328. 425	176.329	162.450	332

Existence of animals in Turkey and in Tokat Province

According to the data provided by Turkish Statistical Institute (TURKSTAT) in 2019, our country has approximately 17.9 million (%26.83) bovine livestock, 48,5 million (72.77%) small livestock, 260 thousand (0.40%) single hoofed and 66.6 million animal existence in total. While the highest animal existence with 15.4 million pieces found in Eastern Anatolia Region, it is followed by Central Anatolia region with approximately 12 million and Southeastern Anatolia Region with 11 million pieces. Black Sea has the lowest animal existence with 4.6 million pieces. Eastern Anatolia Region which has 23.15% of the total animal existence of Turkey has been the center of livestock farming and has always took the first place in terms of animal species.

According to the data provided by Turkish Statistical Institute (TURKSTAT), bovine livestock, small livestock and single hoofed animal potential in our country and Animal Unit (AU) numbers calculated by taking international (AU) converting coefficient into account are given in (Table 2).

It is seen that in our country have bovine livestock corresponding 14.9 million AU (74.19%), small livestock corresponding 5.1 million (25.31%) and single hoofed corresponding approximately 99 thousand AU (0.50%) and 20.1 million AU animal potential in total. Highest animal potential is found in Central Anatolia Region with 2.9 million AU whereas lowest animal potential is found in Mediterranean Region with 1.28 AU. Eastern Anatolia Region constitutes 17.93% of the animal potential as AU in our country. Eastern Anatolia Region takes the first place in terms of animal count with 3.7 million animals constituting 20.98% of total number of animals while Central Anatolia follows this region with 3.4 million animals. (Table 2).

Table 2. In some regions of Turkey general number of animals and HB 2019 value (TURKSTAT, 2019)

Regions	Bovine Livestock		Small Livestock		Single Hoofed Animal		Total	
	Number of Animals	Animal Unit (AU)	Number of Animals	Animal Unit (AU)	Number of Animals	Animal Unit (AU)	Number of Animals	Animal Unit (AU)
Marmara	2.278.855	2.050.693	5.303.678	530.368	28.063	9.532	7.610.596	2.590.593
Aegean	2.802.015	2.602.234	5.259.694	500.580	40.208	15.955	8.101.917	3.118.769
Mediterranean	1.397.666	1.281.541	6.318.397	567.700	17.391	6.903	7.733.454	1.856.144
Centreal Anatolia	3.437.083	2.978.931	8.466.094	1.238.014	30.498	10.466	11.933.675	4.227.411
Black Sea	2.462.811	2.013.230	2.103.045	210.304	33.058	10.383	4.598.914	2.233.917
East Anatolia	3.750.166	2.677.300	11.604.413	1.158.749	63.555	26.076	15.418.134	3.862.125
South East Anatolia	1.745.633	1.321.781	9.408.118	887.632	47.709	19.418	11.201.460	2.228.831
Turkey	17.874.229	14.925.710	48.463.439	5.093.347	260.482	98.733	66.598.150	20.117.790
%	26.83	74.19	72.77	25.31	0.40	0.50	100	100

According to the data provided by Tokat Provincial Directorate of Agriculture and Forestry, existence of bovine and small livestock mentioned in Table 3 while the distribution of animal group is mentioned in Table 4.

Table 3. Existence of animals in Tokat Province (Anonymous, 2020)

Animal Breed	Number of Animals	%
Bovine Livestock	314.917	40.7
Small Livestock	453.991	58.6
Other	5.134	0.7
Total	774.042	100

It is seen that in Tokat Province have bovine livestock corresponding 314.9 thousand (40.7%), small livestock corresponding 453.9 thousand (58.6%) and other animals corresponding approximately 5 thousand (0.7%) and 774 thousand animal potential in total (Table 3).

When the Table 3 is analyzed, it is seen that total bovine livestock existence is 774.042 and there are 314.917 cattle, 101.171 of which is culture breed cattle, 167.166 crossbreed cattle, 34.253 domestic cattle, and 12.325 buffalo. Small livestock existence is 453.991, 373.956 of which is sheep and 80.035 is goat (Tablo 4).

In the calculation of grazing right and grazing capacity in the Pasture law, the amount of the livestock is taken into account and Animal Unit (AU) is used in calculations. Animal Unit (AU) refers to the way in which number of animal are converted into 500 kg live weight which is a unit for cattle.

In order to eliminate the problems faced in determining the number of animals belonging to different races and breed which evaluates meadows, the use of internationally used Animal Unit (AU) conversion coefficient will provide convenience in calculations (Gökkuş et al. 1995). Animal Unit (AU) numbers calculated by considering the bovine and small cattle livestock existence provided by Tokat Provincial Directorate of Agriculture is shown in Table 4.

Table 4. Existence of bovine and small livestock in Tokat Province (Anonymous, 2020)

Animal Group			Number of Animals	%	Animal Unit coefficient	Animal Unit (AU=BBHB)
Bovine Livestock	Cattle	Culture	101.171	33.4	1.00	101.171
		Crossbreed	167.166	55.3	0.75	125.374
		Domestic	34.253	11.3	0.50	17.126
		Total Cattle	302.592	96		243.671
	Buffalo		12.325	4	0.90	11.092
Total Bovine Livestock			314.917	100		254.763
Small Livestock	Sheep		373.956	82.4	0.10	37.395
	Goat		80.035	17.6	0.08	6.403
Total Small Livestock			453.991	100		43.798

The present condition of meadow-rangeland in Turkey and in Tokat Province

When the meadow and rangeland existence is evaluated in our country, 1.449.313 ha constitutes meadow while 13.167.375 ha constitutes rangeland of the total 14.616.688 ha meadow and rangeland area according to the data provided by agricultural census in 2001. Eastern Anatolia Region has the largest land in terms of meadow and rangeland existence with 56.80% share. More than half of total meadow land and more than 1/3 of rangeland area are found in this region. When this data is evaluated, Eastern Anatolia Region takes the first place with 37.53% share while Central Anatolia Region takes the second place with 31.27% and Black Sea Region takes the third with 10.38% (Okcu, 2020).

Tokat province has a surface area of 1.004.200 ha. while its meadow-rangeland area has a 12.54% share with 126.020 ha. Pasture law with no 4342 and the regulations enacted within the scope of the law allowing meadows to be rented for the purpose of improvement entered in force by becoming a law in 1998 in our country. In accordance with this law, determination, restriction, allocation and improvement of these lands are carried out in Tokat province as well as in other cities under the chairmanship of meadow commissions. In 2020, 57.997 ha area was detected, 56.844 ha was restricted and 28.538 ha was allocated in Tokat Province.

Figure 1. A view from Tokat Province rangelands-October 2020

The present condition of forage plants lands in Turkey and in Tokat Province

According to the data provided by Turkish Statistical Institute (TURKSTAT) in 2020 cultivation area of forage plants is 17.4 million da. Feed is manufactured from 60.7 million tons of green grass. Forage plants cultivation is widespread especially in developed countries in the field agriculture. Although forage plant production has increased with the support of the Ministry of Food, Agriculture and Livestock in recent years, this increase is not in the required level when compared with the developed countries. In the forage plant producing countries this ratio is 23% in USA, 25% in France and England, 30% in Italy, 31% in Holland and 37% in Germany. Forage plant cultivation area has 11.2% share in total arable land in our country.

When the regions engaged in forage plant cultivation are examined, Eastern Anatolian Region where animal production is high, has the biggest potential with 6.4 million da (31.19%). Cultivation of forage plants in Black Sea Region is 2.3 million (11.37%) and 4.8 million-ton (9.12%) respectively in terms of cultivation area and production (Okcu, 2020).

Table 5. Forage crops area sown (da) and production (tons) in Turkey (Turksat, 2020)

Forage crops	Area sown (da)	Production (tons)
Sainfoin	1.744.949	1.934.697
Wild vetches	22.936	14.562
Maize	5.262.613	126.142 (Herbage) 27.186.949 (Silage)
Beets for fodder	16.701	83.763
Turnip (for fodder)	46.568	237.491
Wheat (Green)	178.655	348.838
Barley (Green)	313.189	537.066
Rye (Green)	68.512	98.195
Pea (Green)	243.191	452.776
Cow vetches	3.759.436	4.542.965
Clover	55	96
Alfalfa	6.628.887	19.290.519
Meadow grass	446.371	293.848
Oats (Green)	3.240.182	3.850.475
Sorghum (Green)	23.323	87.920
Triticale (Green)	350.085	558.643
Grass pea (Green)	87.694	82.026
Italian ryegrass	253.297	971.691
Total	17.424.031	60.698.662

Forage crops area sown (da) and production (tons) in Turkey are shown in Table 5. Considering our country in general in terms of cultivation areas, alfalfa with approximately 6 million da has the first place in forage plant production and it is followed by silage corn with 5.26 million da and vetch plants with 3.7 million da. When production amounts are taken into consideration silage corn with 27 million ton places in first row and followed by 19.2 million tons of alfalfa and 4.5 million ton cow vetches plants in second and third (Table 5).

Table 6. Forage crops area sown (da) and production (tons) of the districts of Tokat Province

Districts	Area sown (da)	Production (tons)
Zile	20.198	76.717
Yeşilyurt	25.400	25.453
Turhal	34.320	70.995
Sulusaray	18.045	20.651
Reşadiye	7.720	4.232
Almus	47.722	47.432
Artova	26.835	26.578
Başçiftlik	3.765	1.996
Erbaa	21.450	76.625
Niksar	40.710	134.533
Pazar	10.450	55.280
Merkez	87.355	346.722
Total	**343.970**	**887.214**

Forage plants cultivation area in Tokat Province agricultural lands is 343.970 da. While forage plants cultivation area is on average 25-30% of the total agricultural land in countries where livestock farming is developed (Semerci and Kurt 2006), it is around 12.49% in the Province of Tokat (Table 6).

Due to its high adaptability and longevity, high vitamin and nutritional quality, suitability for grazing, trefoil plant is a forage plant which is mostly produced among vegetative production in the Province of Tokat. Maize is also grown as a silage plant in a considerable amount in Tokat due to its easy silage, high digestion rate (Table 7).

Table 7. Forage crops area sown (da) and production (tons) of Tokat Province

Forage crops	**Area sown (da)**	**Production (tons)**
Common vetch (Green)	36.497	18.406
Hungarian vetch (Green)	9.105	8.166
Alfalfa (Green)	171.202	466.186
Sainfoin (Green)	17.323	12.411
Oats (Green)	42.705	25.822
Triticale (Green)	1.295	777
Maize (Silage)	62.770	350.444
Beets for fodder	546	2.735
Turnip (for fodder)	352	1.149
Grass pea (Green)	2.175	1.118
Total	**343.970**	**887.214**

Level of roughage production and the rate of meeting the need in Tokat Province

Roughage sources produced in the Province of Tokat and their level of meeting the needs of animals are given in Table 8. Likewise, in our country, meadow-rangeland (1.260.200 da) and forage plants lands (343.970 da) constitute high quality roughage resources in Tokat province.

Table 8. Balance of roughage resources and animal existence in Tokat Province in 2020

Source	**Area sown (da)**	**Production (tons)**
Meadow-Rangeland	1.260.200	82.422
Forage Crops	343.970	887.214
Total	1.604.170	969.636
Animal Existence	Animal Unit (AU=BBHB)	
Bovine Livestock	254.763	
Small Livestock	43.798	
Total	298.561	
	Rough Feed Required (ton)	
Total	1.362.184	
Quality Roughage Deficit	392.548	

It is suggested that farm animals are fed with green grass equivalent to 10% or with dry grass equivalent to 2.5 % of their live weight every day. Therefore, an animal with 500 kg live weight should approximately consume 12.5 kg. day^{-1} quality dry grass in order to meet survival nutrient need (Gökkuş et al., 1995). Accordingly, there is a need for 1.362.184 ton quality roughage equivalent to 298.561 AU=BBHB in order to meet the survival share of the animal existence in Tokat province. However, it is seen that quality feed produced in Tokat province remained at 969.636 ton level. In this case, it is understood that the amount of the roughage shortage is 392.548 ton (Table 10).

Thereby, shortage of roughage is tried to be compensated with low feed value hay, hull and husk and intensive and mixed feed sources. Since intensive feed sources are expensive and will increase the cost of animal products such as meat and milk as well as will lead to metabolic diseases (NRC 1989; Alçiçek 2002; Alçiçek 2010), the solution of the problem should be sought in roughage sources.

CONCLUSION

In the light of the information given, it is possible to say that our current animal presence in Turkey and Tokat province cannot be fed sufficiently and appropriately. Beyond that, we have a roughage production level that is far from meeting the living share of our animals and their roughage requirements.

In our country there is no sectoral co-operation between the enterprises engaged in plant production and animal production, as result marketing problems emerge. At the point when marketing problems arise, a desired level of development cannot be achieved in subject matters essential for roughage production such as seeds, technical know-how, mechanization and irrigation. The productivity of our meadows are low since there are irregularities in the management of our meadows and their grazing organization (Figure 2).

Figure 2. An image of the effects of not complying with the grazing time in Tokat Province rangelands

In our country forage crops cultivation is generally carried out as a second product after the main product and has no chance to compete with the main product. Roughage production cost is high due to inputs such as seed, diesel fuel and irrigation and the continuation of the support given by The Ministry of Agriculture and Rural Affairs and reduction of the cost are important in terms of competition.

Livestock farming should be made profitable by stabilizing the animal products. Yet, in order for the forage plant cultivation to develop, first of all it is necessary to sell the animal products with reasonable prices and increase the purchasing power of those who are engaged in livestock farming. It should be rigorously provided that forage plants take part in plant rotation for the sustainable productivity. Incentives in the use of certified seed should be meticulously continued in the production of forage plants. The idea of establishing a roughage office which has been discussed for a long time should be put into practice and in order to compete with the world market in roughage sector, roughage exchange should be established and the expansion of roughage trade should be considered.

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CHAPTER XIII

EFFECTS OF DIFFERENT ROW SPACINGS AND DIFFERENT FERTILIZATION DOSES ON THE SEED YIELD AND SOME YIELD PROPERTIES OF THE PERENNIAL RYEGRASS

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INTRODUCTION

One of the most important plant assets around the areas we live in is the green area plants. These plants are used in a wide range of areas in our country as well as in developed countries, and besides their physical and mental relaxation effects, they also create resting environments that human needs. The areas of use of green areas, which are a part of our lives with their aesthetic, functional and recreational effects, are increasing day by day. It is especially used in football, tennis, golf, hockey, skiing, athletics tracks and various sports areas, green areas are established for many different purposes such as park-garden, summer gardens, hotels, airport and roadside (Beard, 1973; Cockerham et. al., 1989; Açıkgöz, 1994; Demiroğlu et. al., 2010; Avcioglu, 2014).

There are many different plant species and varieties that make up the green area texture around us. Trees, shrubs and ground cover plants are undoubtedly the most valuable elements that beautify living spaces in areas where they are used. Among the ground cover and erosion preventive plants used in landscape works, turfgrass have the highest share (Beard, 1973; Evans, 1988; Acikgoz, 1994, Avcioglu, 2014).

One of the most used plants in green areas in the world and in our country is *Lolium perenne* L. This plant grows naturally in different climatic and soil conditions of our country (Kır et al., 2010). It is the first plant to be cultivated among forage crops from the *Poaceae* family. It develops well in rainy regions and moist soils. It has poor drought resistance. It develops well in slightly salty soils. Sowing depth should be 1,5-2 cm. If spreading is to be done 2,5-3 kg of seeds should be thrown per decare. For high efficiency, planting should be 20-40 cm between rows (Hope, 1983; Genckan, 1983; Acikgoz, 2001; Avcioglu, 2014). It has a distinct importance among the plants that can be used in creating green areas; it is one of the most suitable plants to be used in mixtures with its coarse structure, ball life form, dense tillering, dark green color, very dense roots, strong and deep (Beard, 1973; Evans, 1988; Acikgoz, 1994; 2001; Salman et al., 2011; Avcioglu, 2014). In addition, it is a pasture plant that is highly resistant to heavy grazing and can therefore be preferred in sheep and cattle grazing systems (Genckan, 1992; Jung et. al., 1996).

Turfgrasses when compared to other cultivated plants; botanical, biological, ecological and economic aspects have their own unique characteristics, this situation creates serious privileges in green field area as opposed to other cultivated crop cultivation. The most important of these privileges is the seed production issue. Because seed production in green area plants requires much more sensitivity and effort than seed production of many cultivated plants. For this reason, the regions with the most suitable climate and soil conditions should be selected for the production of a good green area plant seed. Seed production regions; It should be determined by considering many climatic factors such as light, temperature, precipitation, humidity and wind. What should be done in order to obtain the best seed in these determined regions; Care should be taken in fertilizing, irrigation, weed control, adjusting row spacing, fighting diseases and pests, and harvesting and threshing (Beard, 1973; Evans, 1988; Acikgoz, 1994, Avcioglu, 2014).

The seed supply of the perennial grass, which has many areas of use in our country, is largely provided by imports. In addition to reducing the import of the varieties to be developed, it is possible to increase the seed yield of the varieties we produce with some cultural measures. The application of nitrogen, which is one of the main macro nutrients required in the cultivation of *Poaceae*, as a fertilizer is therefore important (Nizam, 2009). Nitrogen fertilization is very important in cereal family plants to promote growth at critical times (Kelly, 1988). When the water and nutrients are unlimited, they respond positively to nitrogen applications. This reaction of the wheatgrass increases in the response curve against nitrogen from the beginning to the maximum yield and decreases after reaching the maximum efficiency. This point where the reaction is reduced is usually determined as the optimum nitrogen ratio (Holmes, 1989). This reaction of the wheatgrass against nitrogen differs from region to region depending on the climate. In perennial grass plant; Tan et. al., (1991) 4-6; Rowarth et. al., (1998) 10; Young III et. al., (1999) 15; Nizam (2004) 16; Nizam (2009) 24; Rolston et. al., (2005) and Salman et. al., (2017) reported that they obtained the highest yields at 30 kg/da N doses.

Giving information about *Lolium perenne* plant, Gençkan (1983), and Acikgoz (2001) reported in their books that perennial grass has a seed yield of 30-120 kg/da. Some of the researchers working on the subject; Heblethwaite and Ahmet (1978) 60-80; Fisakov (1984) 129; Riewe and Mondart (1985) 30-83,5; Acikgoz and Karagoz (1987) 1. year 50-60, 2. year 30; Tan et. al., (1991) 41,5-52,4; Incesu and Avcioglu (1991) 130; Polat and Avcioglu (1995) 141,3-176; Balasko et. al., (1995) 130; Acikgoz et. al., (1996) 6,2-30,9; Rowarth et. al., (1998) 30-218 at a nitrogen dose of 10 kg/da; Young III et. al., (1999) an average of 73,4-183,2 at a nitrogen dose of 15 kg/da; Yilmaz and Avcioglu, (2002) in the 20 cm row spacing, first year 114,5-122,1, second year 97,3-48,3, and in the continuation of in the research Yilmaz and Avcioglu, (2009) third year 15,2-18,3 and the fourth year is 10,8-9,8; Nizam (2004) at a nitrogen dose of 16 kg/da in the first year 10,1-24,3, in the second year 10,2-48,6, and in the continuation of in the research Nizam (2009) at 24 kg/da nitrogen dose in the first year 89,3 and second year 55,2; Rolston et. al., (2005) 93-98 in one line, 171-208 in the other at 30 kg/da nitrogen dose; Salman et. al., (2017) reported the highest seed yields at 30 kg/da nitrogen dose as 99,3 kg/da.

In addition, some researchers, together with and in addition to the researchers reporting results on seed yield (Canode, 1967; Kun, 1983; Topal, 1993; Avcioglu and Soya, 1994; Polat and Avcioglu, 1995; Simic, 2009) also affect the seed yield; results on characteristics such as lying, plant height, spike height, number of stem (vegetative and generative), seed number and yield in a single spike, green and hay yield, biomass yield, thousand seed weight, harvest index, hectolitre weight and germination (fertility) rate have reported.

This research; Esquire variety (Palmiye Seed, Izmir), which is one of the most sold perennial ryegrass (*Lolium perenne* L) varieties in our country, was carried out in order to determine the seed yield performance of different doses of fertilizer applications and in different row spacings in Sakarya/Pamukova ecological conditions with a cool climate.

MATERIAL and METHODS

Material

The study was conducted in the research area of the Pamukova Vocational School of Sakarya University of Applied Sciences University (N 40° 30’ 20,462, E 30° 10’ 9,263 and 80 m above sea level) for a 3-year period between 2013-2017.

The research area’s long term climatic data and data for the period between November 2013-July 2017 are given in Table 1.

Table 1. The climate dates of Geyve district for 2013-2015 years and long term average (L.T.A.)*

Climatic factors	Years					
	2013	2014	2015	2016	2017	LTA*
Total precipitaion (mm)	84.4	697.2	721.3	633.7	289.6	685.9
Average temperature (°C)	5.9	15.2	14.5	14.6	11.7	14.7
Moisture (%)	83.3	77.7	77.6	76.1	77.5	77.0

*: The Official Directoryship of Meteorological Bulletion for Geyve/Sakarya.

Climate data by years are 2013 (last two months), 2014, 2015, 2016 and 2017 (first 6 months). Total precipitation in the 2014 and 2015 year of the research was higher than long term average, but was lower in the 2016 year. The amount of precipitation in the first 6 months of the 4th year is also close to the average of many years. Average temperature data for the 2015 and 2016 year was similar to long term data, but was relatively higher for the 2014 year. Relative humidity values for all three years were very close to long term average.

Soil samples taken from 0-20 and 20-40 cm depths of the research area were analyzed in the Sakarya University of Applied Sciences University Pamukova Vocational School laboratory (Brohi and Aydeniz, 1991) and results were listed in Table 2.

Table 2. Soil properties of the research area

Soil depth (cm)	Properties							
	Struc-ture	pH	Total salt (%)	$CaCO_3$ (%)	Organic matter (%)	Nitrogen (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
0-20	Loamy	6.70	0.024	5.61	1.61	1.12	10.5	205.0
20-40	Loamy	7.61	0.023	7.50	1.14	0.65	8.5	255.0

(Brohi and Aydeniz, 1991).

According to analysis results, soil at 0-20 cm depth was determined as loamy-textured, having medium acid reaction; at middle range in terms of salinity, lime and organic matter, insufficient in total nitrogen and available phosphorus, and rich in potassium. Soil at 20-40 cm depth was identified as slightly alkaline and was in the same group in terms of other values.

The seed used in the research was the "Esquire" variety of *Lolium perenne* L., a variety released to market by the private sector.

Method

The research was conducted in a two-factor structure with two different row spacings (20 and 40 cm) and four different nitrogen fertilizer doses (0, 10, 20, 30 g m^{-2}). The experiment was set up in the randomized block design with 3 replications. Plot dimensions were arranged to form 20 cm row spacings of 5 m×1,60 m = 8 m^2 and 40 cm row spacings of 5 m×3,20 m = 16 m^2, The plots were established in accordance with the Technical Instructions Concerning Experiments on Value for Cultivation and Use (Anonymous, 2014).

Ammonium Nitrate (33% N) fertilizer was used as the source of fertilizer. The annual nitrogen fertilizer amount was separated into 3 equal parts and was administered every year during the period of tillering (March 25), before (April 25) and after (May 25) the period of heading. Soil analyses revealed insufficient phosphorus, thus triple superphosphate (P_2O_5 42%, TSP) fertilizer was applied on an annual basis starting with the first year of sowing and continuing in later years around October at a rate of 10 g m^{-2} and, in this way, the phosphorus amount was kept steady.

The seeds were sown on 21 November 2013 into 2 cm depth in accordance with the 3 g m^{-2} calculation (Hope, 1983; Genckan, 1983; Cockerham et. al., 1989; Acikgoz, 2001). Irrigation was implemented using the sprinkler irrigation system. Weeds were combated using the hoeing method. Seed harvest was performed when the seeds on spikes reached maturity; which was on 29 June 2014 for the first year, 10 July 2015 for the second year, 21 June 2016 for the third year and 25 June 2017 for the fourth. All spikes were dried at room temperature, grinded manually for separation of seeds, and sturdy seeds were isolated from empty seeds and glumes.

The properties examined in the study were lodging rate (none, slight, half-way, excessive, total), plant height (cm), spike length (cm), generative shoot number (count m^{-2}), weight of seed per spike (g), seed yield (g m^{-2}), 1000 seed weight (g), hectolitre weight (g) and germination rate (%) (Anonymous, 2014).

Statistical analyses for the research data were carried out in a two-factor randomized blocks design, using the TARIST program (Acikgoz et. al., 2004) and according to row spacing, fertilizer dose and row spacing × fertilizer dose interactions. The resulting LSD (5%) values were given in the tables.

RESULTS and DISCUSSION

Statistically significant differences were observed in terms of row spacing, fertilizer dose and row spacing × fertilizer dose interactions for all features examined in the study and the LSD (5%) values were indicated under the Tables.

Lodging rate

The lodging degree of plants in the plots were assessed as none, slight, half-way, excessive and total lodging, and relevant observations were listed in Table 3.

Table 3. Observations regarding lodging rate

Years	Row Spacings (cm)	Fertilizer Doses (g m^{-2})			
		0	10	20	30
1st	20	None	Slight	Slight	Half
	40	None	None	None	Slight
2nd	20	None	Slight	Slight	Half
	40	None	None	None	Slight
3th	20	None	Slight	Slight	Half
	40	None	None	None	Slight
4th	20	None	Slight	Slight	Half
	40	None	None	None	Slight

As can be understood from the Table 3 examination, plants in the 20 cm and 40 cm row spacing of the plots that were not applied a fertilizer dose were fully erect in all years. 10 g m^{-2} and 20 g m^{-2} nitrogen fertilizer applied plots with 20 m row spacing have been observed to slight lying for all years while the plants in 40 cm row spacing did not lie down. Plants with row spacing of 20 cm in plots treated with 30 g m^{-2} nitrogen fertilizer showed slight lying throughout all years, while all plants with 40 cm row spacing were observed to have a lying rate of approximately 50%.

As the nitrogen dose increases, plants' resistance for staying erect decreases and their tendency to load grows (Genckan, 1983; Kelly, 1988; Acikgoz, 2001). Plants in the 20 cm row spacing are more inclined to lodging than those in the 40 cm row spacing, and this situation can be explained with these plants having a thinner stem structure. The reason for lying may be the excessive amount of rainfall and the plants, which had reached greater plant heights, could not withstand the wind. Lodging, which generally has a negative effect on seed yield, occurred not as a total lodging but rather as a mass lodging in this study and did not have a negative effect on seed harvest or yield. The results support statements by Beard (1973), Genckan (1983) Kelly (1988) and Acikgoz (2001) who reported that extensive nitrogen fertilizer encourages lodging in turfgrasses.

Plant height

10 plants from each plot were measured in cm before the harvest and the obtained data was presented in Table 4 and Figure 1. Upon assessment of the data with regard to row spacing distance, it was determined that the 20 cm row spacing showed highest value with 88,3 cm in 1st year. Highest values in terms of nitrogen were obtained from the 30 g m^{-2} dose (81,4 cm). Greatest plant height, with regard to row spacing × fertilizer dose interactions, was measured in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the first year as 96,5 cm.

It is known that narrow row spacings hold a lot of plants and these plants grow taller than those in wider row spacings because they are in an intense competition for nutrient elements, water and space (Genckan, 1983; Acikgoz, 2001).

Table 4. Values of plant height (cm)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m⁻²) 0	10	20	30	Mean
1st	20	73.1	90.2	93.3	96.5	88.3
	40	71.3	85.5	89.8	91.2	84.5
2nd	20	65.2	79.2	87.5	88.7	80.2
	40	61.7	73.4	82.6	83.8	75.4
3th	20	55.5	68.6	74.5	78.5	69.3
	40	51.6	63.3	71.2	72.6	64.7
4th	20	50.8	61.1	66.5	71.4	62.5
	40	48.7	58.1	60.2	68.4	58.9
Mean	20	61.2	74.8	80.5	83.8	75.0
	40	58.3	70.1	76.0	79.0	70.8
General Mean		59.7	72.4	78.2	81.4	---
LSD 5%	*RS: 1st 5.41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

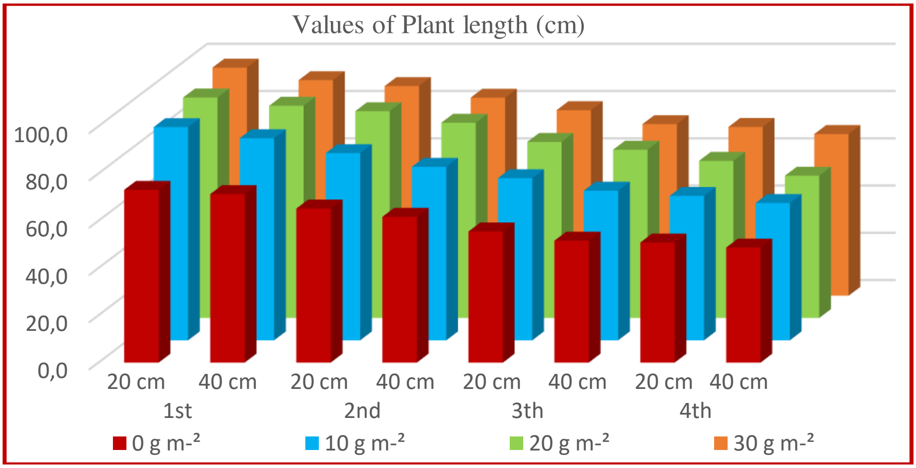

Figure 1. Values of plant height (cm)

The collected data was higher than the findings of Polat and Avcioglu (1995), Sılbır et. al., (1996), Acikgoz et. al., (1996), Nizam (2009) and Salman et. al., (2017) while they were close to the findings of Tükel (1993) and Yılmaz and Avcıoğlu (2002; 2009).

Spike length (cm)

The spike length of the 10 plants harvested from each plot was measured in cm, these values were averaged and obtained data was presented in Table 5 and Figure 2.

Table 5. Values of spike length (cm)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m⁻²) 0	10	20	30	Mean
1st	20	16.20	21.40	24.50	25.60	21.93
	40	14.60	17.20	21.40	23.20	19.10
2nd	20	15.50	18.50	22.30	23.85	20.04
	40	14.10	14.30	17.60	20.40	16.60
3th	20	11.10	12.10	14.20	16.40	13.45
	40	9.30	10.40	11.10	13.20	11.00
4th	20	8.50	9.30	9.40	10.30	9.38
	40	6.10	7.20	7.30	7.30	6.98
Mean	20	12.83	15.33	17.60	19.04	16.20
	40	11.03	12.28	14.35	16.03	13.42
General Mean		11.93	13.80	15.98	17.53	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

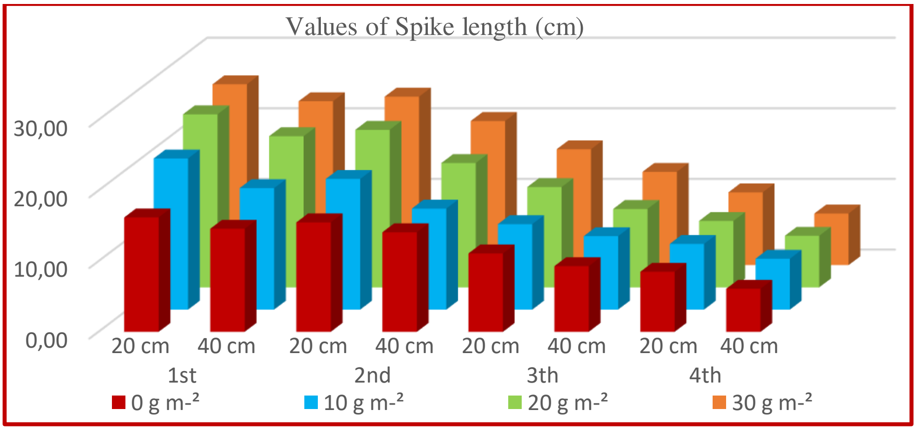

Figure 2. Values of spike lenght (cm)

In terms of row spacing distance, the results showed that the 20 cm row spacings had higher values than the 40 cm row spacings for all years of the research and for average values, and the highest value was seen in the 20 cm row spacing in the first year with 21,93 cm. Highest values with regard to nitrogen doses were observed in the 30 g m^{-2} dose (17,53 cm). Assessment in terms of row spacing × fertilizer dose interactions revealed that greatest plant height was measured in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the second year as 25,60 cm. Lowest spike length was detected in the 40 cm row spacing within the control plot in the fourth year, with a length of 6,10 cm. Spike length data was in parallel with plant height data and generated relatively higher results than those of Salman et. al. (2017).

Generative shoot number

Seed-containing generative shoot found in 5 different 10-cm unit areas in every plot were counted, this number was then multiplied with 10 to find the number in 1 meter and multiplied with area to obtain data for count m^{-2}. The resulting data was listed in Table 6 and Figure 3. When results were examined with regard to row spacing distance, higher values were obtained from the 20 cm row spacing than the 40 cm row spacing for all years of the research and for average values. The highest value was measured in the 20 cm row spacing with 466,1 count m^{-2} in the first year. Assessment in terms of nitrogen doses revealed that highest values were identified in the 30 g m^{-2} dose, with a result of 406,5 count m^{-2}. Analysis of results for row spacing × fertilizer dose interactions showed highest generative stem number values in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the first year.

Table 6. Values of generative shoot number (count m^{-2})

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2}) 0	10	20	30	Mean
1st	20	301.5	455.2	551.6	556.1	466.1
	40	255.2	415.2	458.7	465.4	398.6
2nd	20	265.4	435.2	525.2	528.8	438.7
	40	235.1	405.2	448.4	455.4	386.0
3th	20	218.3	334.6	348.8	345.5	311.8
	40	201.7	315.4	315.6	320.5	288.3
4th	20	141.7	185.7	188.4	195.5	177.8
	40	121.6	165.6	168.4	175.3	157.7
Mean	20	231.7	352.7	403.5	406.5	348.6
	40	203.4	325.4	347.8	354.2	307.7
General Mean		217.6	339.0	375.6	380.3	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

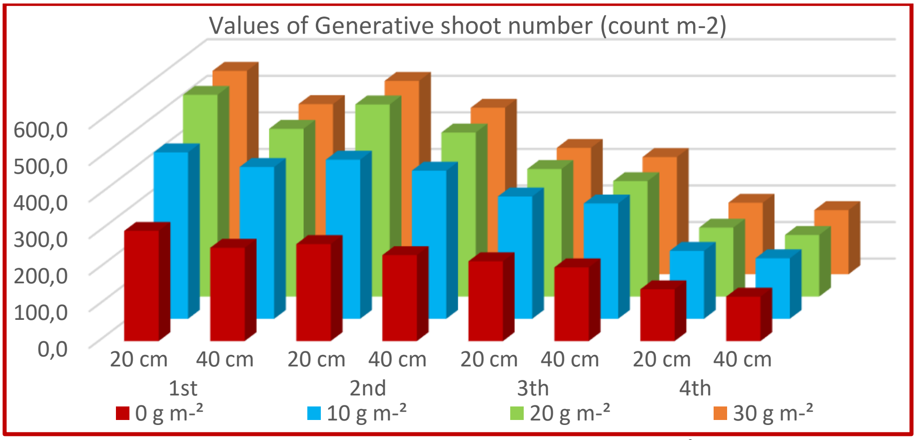

Figure 3. Values of generative shoot number (count m^{-2})

In grasses, each germinated seed produces more than one shoot and this process is called “tillering”. A some of the tillers grow spikes, but do not produce seeds. These are called a “Vegetative Shoot”. On the other hand, those that do produce seeds are defined as “Generative Shoot” (Kun, 1983). If the generative spike number in a unit area is high, seed yield for grasses is affected positively (Beard, 1973; Genckan, 1983; Acikgoz, 2001). An increase in the generative shoot number is aimed by encouraging tillering with the use of nitrogen fertilizer when producing seed (Kelly, 1988). These results support the reports of many researchers (Yılmaz and Avcıoğlu (2002; 2009, Nizam, 2004;2009, Salman et. al., 2017).

Weight of seed per spike

The seeds taken from 10 spikes collected from each plot were separately weighed, these measurements were averaged and the obtained values were listed in Table 7 and Figure 4.

Table 7. Values of weight of seed per spike (g)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2}) 0	10	20	30	Mean
1st	20	0.128	0.169	0.185	0.187	0.167
	40	0.122	0.161	0.174	0.177	0.159
2nd	20	0.123	0.164	0.178	0.181	0.162
	40	0.112	0.153	0.171	0.174	0.153
3th	20	0.098	0.121	0.152	0.161	0.133
	40	0.085	0.114	0.143	0.158	0.125
4th	20	0.072	0.102	0.113	0.121	0.102
	40	0.061	0.089	0.101	0.114	0.091
Mean	20	0.105	0.139	0.157	0.163	0.141
	40	0.095	0.129	0.147	0.156	0.132
General Mean		0.100	0.134	0.152	0.159	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

When these figures are evaluated in terms of row spacing distance, it can be seen that the 40 cm row spacings gave higher values than the 20 cm row spacings for all years of the research and in average results. The highest value was reported in the 20 cm row spacing in the first year with a record of 0,167 g.

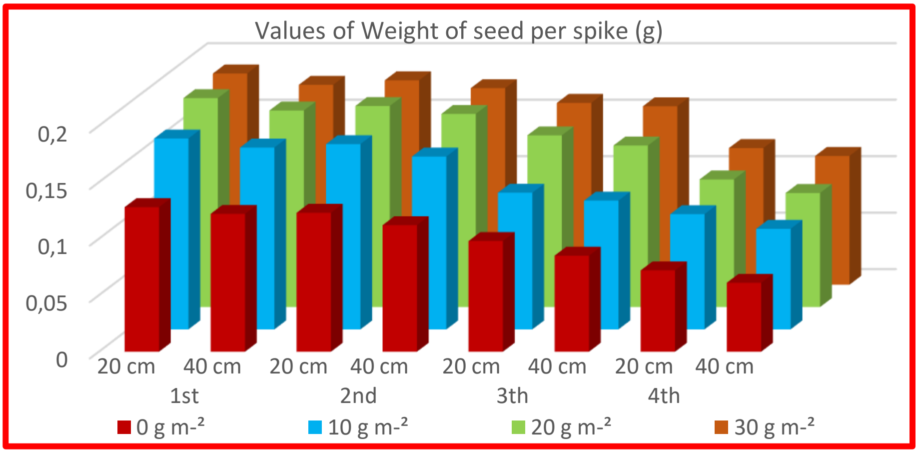

Figure 4. Values of weight of seed per spike (g)

Highest values in relation to nitrogen doses were observed in the 30 g m^{-2} dose, with 0,159 g. In terms of row spacing × fertilizer dose interactions were showed that highest weight of seed per spike yields (0,187 g) were measured in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the first year. The lowest value (0,061 g) was detected in the 40 cm row spacing within the control plot in the fourth year.

One of the main objectives in using nitrogen fertilizer for seed production is to enhance tillering and in this way increase the number of generative shoot (Genckan, 1983; Kelly, 1988; Acikgoz, 2001) Increasing fertilizer doses increased the seed yield of a weight of seed per spike. The findings of this study were higher than those recorded by Yılmaz and Avcıoğlu (2002;2009), Nizam (2004;2009) and Salman et. al. (2017).

Seed yield

The average values for the amounts of seed taken from an area of 1 m^2 in each plot were presented in Table 8 and Figure 5.

Table 8. Values of seed yield (g m^{-2})

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2})				Mean
		0	10	20	30	
1st	20	36.2	122.1	145.2	147.5	112.8
	40	34.3	114.4	133.5	138.2	105.1
2nd	20	35.1	97.3	125.2	128.4	96.5
	40	30.2	72.8	118.5	122.2	85.9
3th	20	11.6	35.2	49.2	51.3	36.8
	40	8.7	24.3	36.2	37.4	26.7
4th	20	5.7	9.8	13.2	13.4	10.5
	40	5.1	8.8	9.5	9.8	8.3
Mean	20	22.2	66.1	83.2	85.2	64.2
	40	19.6	55.1	74.4	76.9	56.5
General Mean		20.9	60.6	78.8	81.0	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

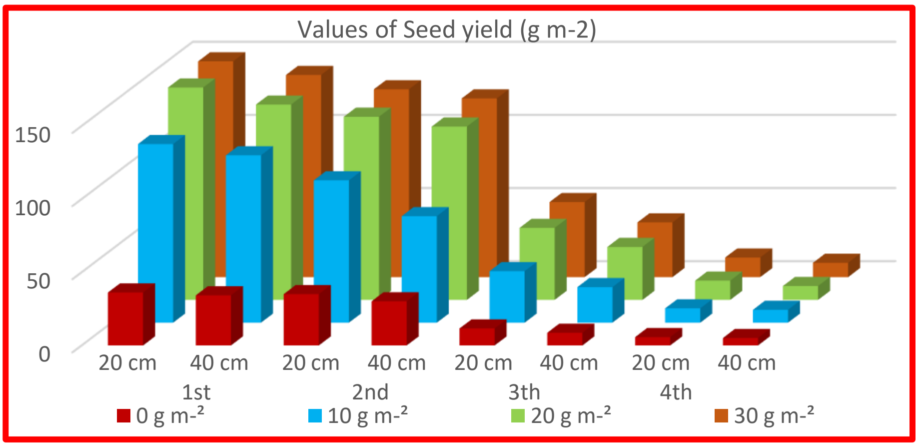

Figure 5. Values of seed yield (g m^{-2})

Review of the data in terms of row spacing distance shows that higher values were obtained from the 20 cm row spacing in comparison to the 40 cm row spacing, for all years of the research and for average values. The highest value was determined in the 20 cm row spacing in the first year with a measurement of 112,8 g m^{-2}. The study conducted by Simic et. al., (2009) also achieved higher seed yield in the 20 cm row spacing and their values were similar to the results of our study. Highest values with respect to nitrogen doses were observed in the 30 g m^{-2} dose, with a value of 81,0 g m^{-2} in average. Analysis of results for row spacing × fertilizer dose interactions revealed highest seed values (147,5 g m^{-2}) in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the first year.

Application of higher doses of nitrogen created a positive effect on seed yield. Similar studies carried out in different ecological conditions (Genckan, 1983; Cockerham et. al., 1989; Young III et. al., 1999; Acikgoz, 2001; Yılmaz and Avcıoğlu, 2002;2009, Nizam, 2004;2009 and Salman et. al., (2017). emphasized that the application of nitrogen fertilizer increased seed yield, Seed yields achieved in this study were higher than the values of numerous researchers.

The most important issue to be considered here is that the characters that affect the seed yield of the *Lolium perenne* plant begin to decrease rapidly from the second year. Perennial grass is not a plant that can be seeded for many years. Therefore, the seed production area should be replanted for seed production (Beard, 1973; Genckan, 1983; Kelly, 1988; Acikgoz, 2001.

The collected data was higher than the findings of Heblethwaite and Ahmet (1978), Riewe and Mondart (1985), Acikgoz and Karagoz (1987), Tan et. al., (1991), Acikgoz et. al., (1996), Nizam (2004;2009), Salman et. al., (2017), and Rolston et. al., (2005) while they were close to the findings of Fisakov (1984), Incesu and Avcioglu (1991), Polat and Avcioglu (1995), Balasko et. al., (1995), Rowarth et. al., (1998), Young III et. al., (1999), Yilmaz and Avcioglu, (2002;2009).

1000 seed weight

For four times, 100 pure seeds were selected among the seeds taken from each plot, and these were then counted and weighed using a sensitive scale. Each consequent data was multiplied with 10 to calculate the 1000 seed weight and these figures were listed in Table 9 and Figure 6.

Table 9. Values of 1000 seed weight (g)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2})				Mean
		0	10	20	30	
1st	20	1.543	1.828	2.161	2.196	1.932
	40	1.555	1.974	2.283	2.274	2.022
2nd	20	1.542	1.775	2.158	2.176	1.913
	40	1.547	1.975	2.261	2.229	2.003
3th	20	1.485	1.788	2.112	2.119	1.876
	40	1.498	1.798	2.119	2.128	1.886
4th	20	1.342	1.728	2.078	2.081	1.807
	40	1.355	1.798	2.095	2.096	1.836
Mean	20	1.478	1.780	2.127	2.143	1.882
	40	1.489	1.886	2.190	2.182	1.937
General Mean		1.483	1.833	2.158	2.162	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

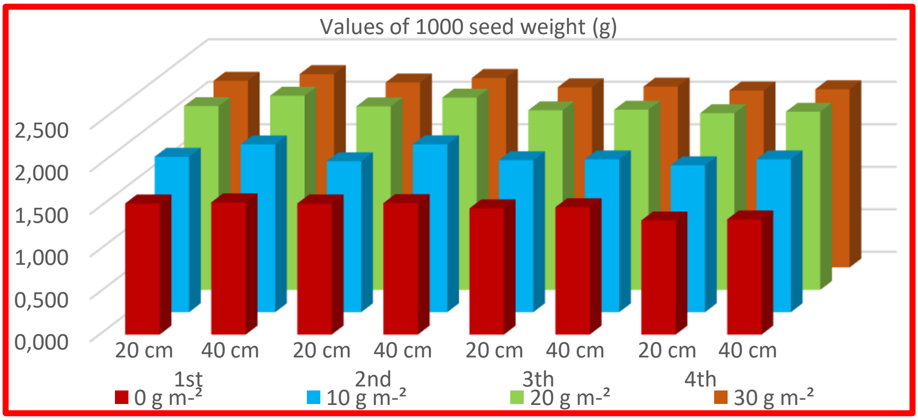

Figure 6. Values of 1000 seed weight (g)

The highest value with reference to row spacing distance was seen in the 40 cm row spacing in the first year with 2,022 g. Canode (1967) stated that the 1000 seed weight of 5 cool-season turfgrass was heavier in the 90 cm row spacing when compared to the 30-60 row spacings, and showed results which were in line with the findings of this study. Topal (1993) concluded that, in late sowing, the number of plants in the unit of area decreased and that the existing plants had developed in an environment with less competition for water and nutrients, resulting in a higher 1000 seed weight and were similar to our findings. Highest values in terms of nitrogen doses were observed in the 30 g m^{-2} for mean with a measurement of 2,162 g. Highest 1000 seed weight data (2,283 g) with regard to row spacing × fertilizer dose interactions were measured in the 40 cm row spacing and 20 g m^{-2} fertilizer dose in the second year. The lowest value (1,342 g) was detected in the 20 cm row spacing within the control plot in the fourth year.

While some researchers (Nizam, 2004; Salman et. al., 2017). expressed that increasing amounts of fertilizer had no effect on 1000 seed weight, some others (Young III et. al., 1999; Yılmaz and Avcıoğlu, 2002;2009) asserted that it did. According to data from this study, application of nitrogen fertilizer affected 1000 seed values, and results were higher than those of Yılmaz and Avcıoğlu (2002;2009), Nizam (2004;2009) and Salman et. al., (2017).

Hectolitre weight

The obtained seeds were weighed using the ¼-liter hectolitre device and resulting data was multiplied with 400 to calculate (Kun, 1983). These values were presented in Table 10 and Figure 7.

Table 10. Values of hectolitre weight (kg)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2}) 0	10	20	30	Mean
1st	20	39.81	40.53	41.08	41.11	40.63
	40	39.57	40.41	41.01	41.03	40.51
2nd	20	39.85	40.61	41.09	41.12	40.67
	40	39.61	40.41	41.01	41.05	40.52
3th	20	39.91	40.65	41.11	41.14	40.70
	40	39.66	40.44	41.06	41.07	40.56
4th	20	39.92	40.68	41.13	41.17	40.73
	40	39.69	40.47	41.09	41.09	40.59
Mean	20	39.87	40.62	41.10	41.14	40.68
	40	39.63	40.43	41.04	41.06	40.54
General Mean		39.75	40.53	41.07	41.10	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*		*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*	

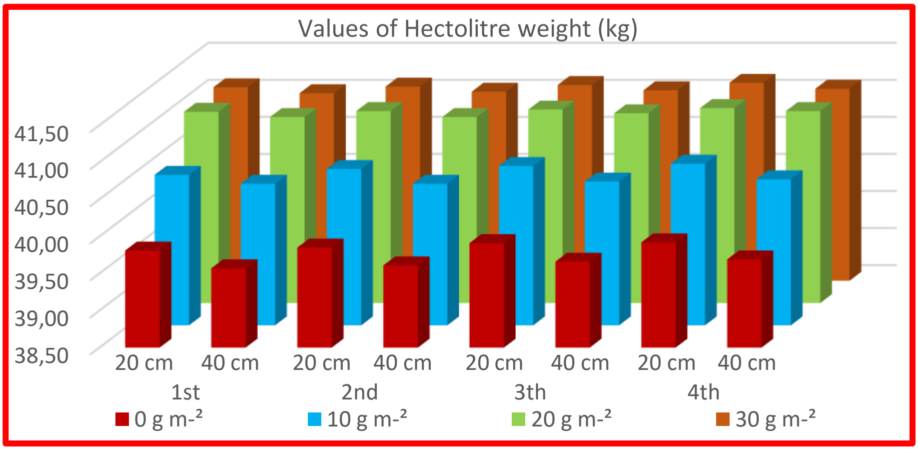

Figure 7. Values of hectolitre weight (kg)

Regarding row spacing data, higher values were obtained from the 20 cm row spacing when compared to the 40 cm row spacing for all years of the research and for average values. The highest value was detected in the 20 cm row spacing in the fourth year with a measurement of 40,73 kg. Highest value among the nitrogen doses was seen in the 30 g m^{-2} dose, which gave the result of 41,10 kg. Highest hectolitre weight values (41,17 kg) with regard to row spacing × fertilizer dose interactions were measured in the 20 cm row spacing and 30 g m^{-2} fertilizer dose in the fourth year. The lowest value (39,57 kg) was determined in the 40 cm row spacing and the control plot in the fourth year in the first year of the study.

Hectolitre weight signifies the weight of a seed within 100 liters of volume in kilograms and is related to the coarseness of seeds. According to Genckan (1983) and Acikgoz (2001), seeds cultivated in narrow row spacings are generally more fine-textured than those from wide row spacings, and it is normal for more fine seeds to fall inside a volume of 100 liters and result in greater weight under such circumstances. A striking matter of importance seen in this study was that, although seeds in the control plot had finest structure, they did not yield highest values in terms of weight. This can be explained with the fact that seeds, which could not take in sufficient nutrients, were unable to produce satisfactory endosperms and thus had poor quality seed. The results of the present study are higher than that of Young III et. al., (1999), Yılmaz and Avcıoğlu (2002;2009), Nizam (2004;2009) and Salman et. al., (2017).

Germination rate

Four batches of 100 seeds, selected from the seeds collected from plots, were counted and tested for germination inside petri dishes in a laboratory setting. All observations and measurements were conducted fallowing ISTA regulations and notifications (Anonymous, 2014).

Germination percentage values, obtained by taking the arithmetic average of the 4 repetitions, were listed in Table 11 and Figure 8.

Table 11. Values of germination rates (%)

Years	Row Spa-cings (cm)	Fertilizer Doses (g m^{-2}) 0	10	20	30	Mean
1st	20	87.35	92.35	94.36	94.27	92.08
	40	87.44	92.52	94.88	94.66	92.38
2nd	20	86.25	92.11	94.18	94.12	91.67
	40	86.42	92.26	94.24	94.21	91.78
3th	20	85.35	92.08	93.78	93.75	91.24
	40	85.48	92.14	93.85	93.81	91.32
4th	20	84.75	91.86	93.55	93.51	90.92
	40	84.88	91.92	93.61	93.58	91.00
Mean	20	85.93	92.10	93.97	93.91	91.48
	40	86.06	92.21	94.15	94.07	91.62
General Mean		85.99	92.16	94.06	93.99	---
LSD 5%	*RS: 1st 5,41, 2nd 6,25, 3th 6,25, 4th 0,00, M, 5,17*	*FD: 1st 6,61, 2nd 6,76, 3th 5,42, 4th 0,00, M, 5,23*		*RS×FD: 1st 4,32, 2nd 4,11, 3th 5,22, 4th 0,00, M, 4,23*		

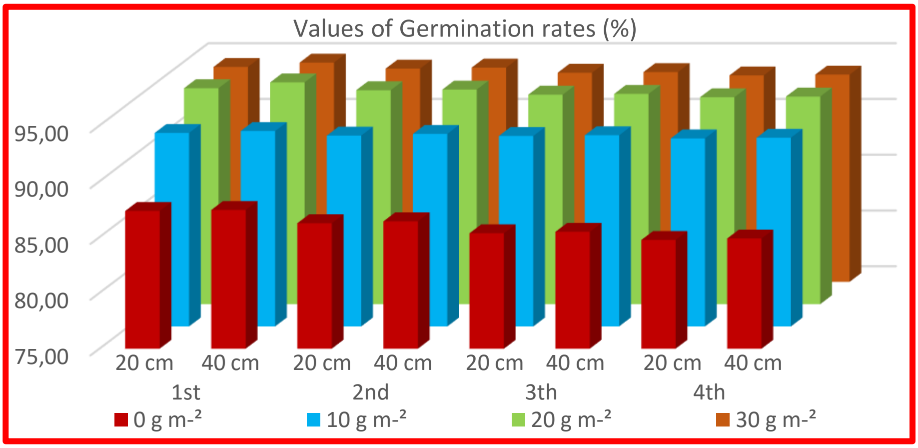

Figure 8. Values of germination rates (%)

Regarding row spacing data, higher values were obtained from the 40 cm row spacing when compared to the 20 cm row spacing for all years of the research and for average values. The highest value was reported in the 40 cm row spacing in the first year with a percentage of

92,38%. High values in relation to nitrogen doses were observed in the 30 g m^{-2} dose, with 94,06%. Assessment in terms of row spacing × fertilizer dose interactions showed that highest value (92,5%) were measured in the 40 cm row spacing and 20 g m^{-2} fertilizer dose in the first year. The lowest value (84,75%) was detected in the 20 cm row spacing within the control plot in the fourth year.

It was observed that increasing fertilizer doses had an effect on the germination percentage. A healthily developed embryo and endosperm are the most important factors to determine germination rate in turfgrass varieties which are being harvested as a new product. Another important matter to consider when establishing a new lawn area with turfgrass plants is the vitality of the seed to be used. Establishment of the area with fresh turf species and varieties which have a high germination rate will provide a higher chance for its success. Germination percentages obtained in fertilizer applications were over 85%, thus the desired values were obtained (Genckan, 1983; Acikgoz, 2001). This data was higher than Yilmaz and Avcioglu (2002), and was close to the values by Young III et. al., (1999), Yılmaz and Avcıoğlu (2009), Nizam (2004;2009) and Salman et. al., (2017).

CONCLUSION

The following results were reached with a holistic analysis of the values obtained in this study in consideration of the effect of different row spacings (20 and 40 cm) and different nitrogen fertilizer doses (0, 10, 20 30 g m^{-2}) on the seed yield and certain botanical characteristics of the "Esquire" variety of *Lolium perenne* L.

When data was examined in terms of row spacings; higher values were obtained from the 20 cm row spacing for lodging rate, plant height, spike length, generative shoot number, seed per spike, seed yield and hectolitre weight, while the 40 cm row spacing resulted in higher values for 1000 seed weights and germination rate. Seed yield for narrow row spacings increases in places where annual rainfall is sufficient, and where rainfall is evenly distributed among seasons and even months; as there are generally a great number of plants in a unit area of the narrow row spacings established in such places (Genckan, 1983; Acikgoz, 2001).

With regard to nitrogen dose applications; the data showed that highest values for plant height, spike length, generative shoot number, weight of seed per spike, seed yield, 1000 seed weight and germination rate were achieved in the 30 g m^{-2} nitrogen dose; while this dose also caused decrease in lodging rate and hectolitre weight.

Many researchers (Genckan, 1983; Kelly, 1988; Cockerham et. al., 1989; Acikgoz, 1994;2001, Young III et. al., 1999, Yılmaz and Avcıoğlu, 2009, Nizam, 2004;2009, Avcioglu, 2014; and Salman et. al., 2017). indicate that increasing doses of nitrogen fertilizer application increases seed yield, and the results of this study validate this thesis.

Row spacing distance and fertilizer doses, components applied to data obtained in this study, were not the only factors affecting the performance of sown plants; the climate also played an important role. Long term average climatic data for the research area showed total annual precipitation at a value of 685,9 mm and annual average temperature at 14,7 ºC (Table 1). Furthermore, the research area had

128,6 days of rain and cool temperatures (average 14,7 °C) in a year, according to long term data. It is possible to say that climatic date pertaining to the years of the research revealed close to ideal conditions especially in terms of the precipitation and temperature required to cultivate cool-season turf plants, among which *Festuca arundinacea* can be counted, with the purpose of producing seed and also a suitable ecology for the plants to enhance in full performance (Genckan, 1983; Acikgoz, 2001). Climatic differences between the years is a totally natural and unpreventable reality, which was also reflected onto the data of the research. Except for the hectolitre weight, all the properties have the highest values in the first year.

In the research, very satisfactory seed yield was obtained, but genetically perennial grass plant is not capable of giving seeds for many years. As explained on the seed yield, the most important issue of the perennial grass plant is that the seed yield decreases rapidly after the second year. Therefore, the seed production area should be replanted for seed production (Beard, 1973; Genckan, 1983; Kelly, 1988; Acikgoz, 2001).

The fact that only 5,9% of turf seeds annually used in our country are domestically produced further emphasizes the importance of seed production. With an overall evaluation of the characteristics examined in the study, and in consideration of the seed yield and some important characteristics of the *Lolium perenne* L. plant; it can be said that this plant is suitably cultivated in the 20 cm row spacing and 30 g m^{-2} nitrogen dose; which provided a seed yield of 147,5 g m^{-2} in the 1st year, 128,4 g m^{-2} in the 2nd year, 51,3 g m^{-2} in the 3rd year and 13,4 g m^{-2} in average according to our study results. However, there is no knowledge concerning the effects of higher doses than those administered in this research on the examined properties, particularly on seed yield. For this reason, it is clear that more research needs to be conducted with different row spacings, different doses and different fertilizer types in order to obtain reliable healthy and explanatory results.

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CHAPTER XIV

RELATIONS AMONG GRASS-FUNCTIONAL PLANT GROUPS

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INTRODUCTION

Plant communities coexist and form through many complicated relationships. It is known that Clements was the first one who investigated the relationships amongst plants and termed as competition (Clements et al., 1929). In the 20th century, plant-plant relationships were defined as competition under limited resource conditions (de Wit, 1969; Braakhekke, 1980; Odum, 1983; Wilson, 1988) but later, researchers revealed many other interactions amongst the plant species and classified them within the groups of positive, negative or neutral interactions (Wilson and Agnew, 1992; Bertness and Leonard, 1997). Today, the interactions amongst the plant species are mostly examined in the perspectives of facilitation, competition, and neutral effects. When facilitation is termed as at least one species gain benefits but cause no harm to any other (Bruno et al., 2003), competition is defined as the negative effects of competing of neighbored species for one or more resources (Tow and Lazenby, 2001). These interactions have many effects on species coexistence (Wootton, 2001), plant reproduction (Hatipoglu and Tukel, 1997; Bertness and Leonard, 1997), root development (Venterink, 2011; Poorter et al., 2012), structuring plant communities (Manier and Hobbs, 2006; Osem et al., 2007), conserving diversity (Milchunas and Noy-Meir, 2002), photochemical efficiency (Cavieres and Sierra-Almeida, 2012).

The competitive and facilitative interactions occur and could shift from competition to facilitation or vice versa depending on many biotic and abiotic factors. For example, competitive relation could shit to facilitation after the death of neighbor plants and according to the tress gradient hypothesis, plants facilitate each other under stressful conditions but the relationship shifts to competition in the absence of stress (Callaway and Walker, 1997; Callaway et al., 2002). Facilitation is prevailed over competition mostly under increasing environmental stress conditions or in poor habitats (Bowker et al., 2010; Cavieres and Sierra-Almeida, 2012; Ehlers et al., 2014) and contrarily, competitive relations are reported under benign environments (Ibanez and Schupp, 2001; Kelemen et al., 2015). Drought and high temperature are the most observed environmental stresses affecting the interactions amongst the species (Tielborger and Kadmon, 2000; Kaisermann et al., 2017; Ploughe et al., 2019). For example, some large species could facilitate small herbaceous species under high-temperature stress by sheltering radiation and creating a microclimate area beneath them (Moro et al. 1997). Temperature differences could reach up to 7°C between such sheltered canopy and outside (Pugnaire et al., 2011) and this difference could be adequate to alleviate heat stress in many species. Shade area of a large species also decrease evaporation and the water content of the soil could be better for the survival of the other seedlings (Pugnaire et al, 2004; Callaway, 2007) which is called the effect of nurse plant in such cases (Tewksbury and Lloyd, 2001; Flores and Jurado, 2003). On the contrary, the shadow of the larger species may inhibit the growth of the small herbaceous plants if heat stress is not present (Gundel et al., 2014). Similar interactions are also observed under drought stress (Garcia-Fayos and Gasque, 2002; Resco de Dios et al., 2014). Besides, Grant et al. (2014) observed a facilitative effect by neighbor plants of *Arrhenatherum elatius* under drought stress but the effect shifted into competition for *Lotus corniculatus* in the same conditions and this indicates that the nature of the shift in an interaction could change under drought depending on the species.

Universally no species are assumed as the ultimate competitors or facilitators because there is an ongoing balance of nature between the species (Kerr et al., 2002; Rojas-Echenique and Allesina, 2011; Soliveres et al., 2015a). Plant-plant interactions are varied due to environmental changes such as CO_2 (Bazzaz and McConnaughay, 1992; Johnson et al., 1993), nutrient availability (Erkovan et al., 2008b; Allesina and Levine, 2011), light quality (Gundel et al., 2014), presence of a third species (Borer et al., 2007; Koc et al., 2013), etc. The photosynthetic activity of the plants shows different responses under changing CO_2 levels (Ainsworth and Long, 2005) and depending on the light quality (Poorter et al., 2012; Gundel et al., 2014), which in turn affects the growth and competitive ability of plants (Brooker, 2006). Higher growth rates also provide a rapid resource acquirement ability to plants in the community and that could make species a superior competitor (Venterink, 2011). These reports indicate that CO_2, light quality, and nutrient availability affect the interactions among the plants through plant growth, niche differentiation, or stress amelioration. The magnitude of the interaction shapes the vegetation dynamics by increasing species richness (Cavieres and Badano, 2009; Ehlers et al., 2014) or disturbing the vegetation equilibrium due to extinction of species (Butterfield, 2009; Bowker et al., 2010).

Biotic factors have a significant role in plant-plant interactions. Rangeland plant communities are shaped in a dynamic equilibrium between the plant-plant relations and disturbance factors as grazing (Gullap et al., 2013). Grazing is the most common biotic pressure on the rangeland plant communities, especially due to extensive animal husbandry. Many researchers are indicating the effect of grazing on the interactions among the plants (Choler et al., 2001; Anthelme et al., 2009; Erkovan et al., 2011; Suzuki and Suzuki, 2011; Ward and Esler, 2011). Herbivores primarily consume the aboveground biomass of the plants by selecting due to some characteristics as palatability, large height, and availability (May et al., 2009; Gullap et al., 2011). Therefore, some species challenge the grazing pressure while others do not and this could affect the competitive power of the species. Light or moderate grazing positively affects the plant regrowth (Erkovan et al., 2009) and species richness (Erkovan et al., 2011), and these changes are stated as responsible especially for positive and negative relations among the species due to heterogeneity (Huisman et al., 2001; Soliveres et al., 2015b). On the other hand, species are suppressed and most of the productive tissues of the plants are consumed under heavy grazing pressure (Lemaire and Agnusdei, 2000; Koc, et al., 2008). They could not have any competitive ability under these circumstances and more likely their coexistence will be under threat especially in arid and semi-arid rangelands.

In some cases, large and unpalatable species, which have defensive traits on grazing, could protect the palatable herbaceous species from grazing through their canopy (Suzuki and Suzuki, 2011; Soliveres et al., 2012; Catorci et al., 2016). This is a good example of the facilitative interaction of plants against grazing and the same mechanism is also processed through new community formation and spread (sometimes in seconder succession) after the disturbance of long-term heavy grazing on rangelands (Manier and Hobbs, 2006; Osem et al., 2007; Catorci et al., 2012). Besides, large and unpalatable species sometimes suppress the small species in ungrazed vegetation (Alberti et al., 2008; Veblen, 2008) and this example presents how facilitation could shift into competition if the stress factor is removed. Also, the density of unpalatable species causes remarkable effects on the formation of light or moderately grazed rangelands via plant-plant facilitation (Kelemen et al., 2019). Grazing disturbance may co-occur in association with any abiotic stress as drought on rangelands and some researchers examined how plant-plant interactions could shape under such environments. It was revealed that species show facilitative effect under abiotic stress as long as grazing continues but the relation shift to the competition if grazing removed at both wetlands (Boughton et al., 2021), and drylands (Veblen, 2008).

Plant formation has an important role to determine the plant-plant relationships in various environments. Neighbor species that have similar formation could compete for any resource as water, nutrient, light, space, and CO_2, which is termed symmetric competition (Gomez-Aparicio, 2009; Pan et al., 2013), but some larger plants (especially shrubs) facilitates the smaller herbaceous species by providing a benign micro-environment due to their canopy (Cavieres et al., 2007; Holmgren et al., 2012). Besides, woody plants may cause both facilitative (Ludwig et al., 2001) and competitive (Ludwig et al. 2003) effects on grasses depending on the availability of light, nutrients, and water. These relations should be well-analyzed on vegetation for proper rangeland management.

Rangelands are unique fodder sources in extensive animal husbandry and mostly occurred at elevations from 1000 to 2000 meters in the world. These areas receive the annual precipitation in a range of 250-800 mm and the vegetation mostly consisted of grass species due to many advantages of this family under limited water availability (Thilenius, 1979; Holechek et al., 2011). Transient summer precipitations could moisten only a few cm depths of the soil surface especially in the arid and semi-arid rangelands and fibrous root systems of the grass species are perfect to utilize this limited water resource (Holechek et al., 2011). This makes the grass species become the dominant family in most rangelands. Indeed, grass species coexist with many other forbs, shrubs, and woody species in the vegetation and therefore, interactions should be understood well among these plant forms (Erkovan et al., 2008a). Therefore, the relations among grasses and different functional plant groups were discussed in detail.

Grass-grass relations

Grass species widely spread throughout the world and they could exist in environments varied from warm deserts to cold tundra (Holechek et al., 2011; Koc et al., 2015). The widespread domination of the grass species in natural vegetation is making them an important functional group. Moreover, a considerable amount of the grasslands consist of mostly grass species and in turn, grass-grass interactions, both intraspecific or interspecific, play a crucial role in the functioning of these wide areas.

Resource competition is one of the most important relation among the grass species and superior competitors mostly suppress the inferior competitors hereby (Sheley and James, 2014; Yin et al., 2018). Phenological root characteristics are significantly determinant in shaping the grass-grass competition for resources (Herben et al., 2007; James, 2008). Superior competitors are indicated to have more fibrous roots and therefore, they could reach and effectively take up soil resources like water and nutrients more than weaker competitors (Liu et al., 2013). In the case of nutrient addition (e.g. fertilization of rangelands), grass species facilitate each other due to vertical space partitioning (Gross et al., 2007; Pontes et al., 2012). However, Hautier et al. (2009) reported this positive effect is not observed, even may go worse if there is light competition among the species. Therefore, rangeland fertilization should be carried out considering the undergoing relations among the species, especially for grass-dominated vegetation.

The size of the grass species may affect interspecific competition. Larger grasses generally compete with small grass species for light (Murrel and Law, 2003; Fridley, 2003) but this effect could shift into neutral or facilitation especially at alpine ecosystems, where harsh environmental conditions prevail (Yin et al., 2018). The high elevation of alpine ecosystems might be effective on this shift in interaction because it was known that grass-grass interactions may shift to positive with increasing altitude (Callaway et al., 2002). The positive interactions among large and small grasses on alpine ecosystems are also related to space partitioning (Fridley, 2002), and therefore, overyielding increases (Yin et al., 2018). This is consistent with the stress gradient hypothesis of Bertness and Callaway (1994). Mowing and heavy grazing reduce these positive interactions by reducing the plant size (Geijzendoiffer et al., 2011; Yin et al., 2018; Koc et al., 2020). Besides the size of species, priority is another effective factor, increasing the competitive ability (Liu et al., 2013; Young et al., 2015). Earlier germination and emergence is an advantage for the species, which might be suppressed by a neighbor and superior competitor grass species in equal conditions (Herben et al., 2007; Abraham et al., 2009). DiVittorio et al. (2007) reported early emerged winter grass species gain a size advantage over late emerged grasses and thus, could compete with them.

Grass-grass relations are species-specific and greatly change due to the lifespan of species (Leger and Espeland, 2010). For example, annual grass species *Bromus tectorum* and *Taeniatherum caput-medusae* were facilitated from neighboring perennial grass species as *Elymus elymoides* and *Pseudoroegneria spicata* (Blank, 2010), but another perennial grass, *Agropyron desertorum* could strongly suppress *Taeniatherum caput-medusae* (Davies et al., 2010). These variations in resource use dynamics of species (Arredondo and Johnson, 2002), and the availability of soil nutrients, especially N (Monaco et al., 2003; Adair et al., 2008). Besides, the distance among the species has a significant impact on interspecific competition (Liu et al., 2013; Rayburn and Schupp, 2013) and this is called a competition kernel (Schneider et al., 2006). The number of species could also affect interspecific relations and facilitation is higher when there are more species in the neighborhood (Wright et al., 2014). The interspecific relations among grasses could shape the vegetation dynamics (Sheley and James, 2014; Koyama et al., 2015) and could be used for ecosystem restoration as providing biotic resistance against annual invasions (James et al., 2008; Davies et al., 2010).

Perennial grass species could facilitate annual grasses as a nurse plant, or grazing refuge (Blank, 2010; Kakinuma et al., 2013). However, the grazing refuge effect may disappear under continuous heavy grazing similarly as in grass-shrub interactions (Figure 1). Tussock-formed perennial grasses also increase soil nutrients via litter accumulation (Koyama et al., 2015) and this might positively affect the growth of neighbor grass species through facilitation. Contrarily, some research results indicate the suppressive effect of perennials on annual grasses (Davies, 2008; James et al., 2008; Davies et al., 2010). Moreover, exotic grass species may also suppress the native perennials and this creates a barrier to ecosystem restoration (Young et al., 2015).

Figure 1. Continuous heavy grazing reduces the facilitative effect of grazing refuge

The grass-grass interactions do not only occur among species (interspecific), intraspecific relations could also have considerable effects on vegetation. Even, they are more effective than interspecific relations, especially in competition (Herben et al., 2007; Liu et al., 2013). One of the most important intraspecific interactions for grass species is self-thinning, which is caused by significant root competition for soil resources and increases with drought stress (Li and Zhou, 2011; Zhu et al., 2015). In stressed environments, root competition increases and is generally, stated to be more important than the aboveground competition (Haugland and Tawfiq, 2001; Ramirez et al., 2009). Increased root competition may cause facilitative aboveground interactions and therefore, could affect the performance of plants (Murrel and Law, 2003; Herben et al., 2007).

Intraspecific relations are also species-dependent. Some species are suppressed by intraspecific competition (Blank, 2010; Zimmermann et al., 2015) but it could also be positive, which means that species could ameliorate their habitat for themselves, mostly for soil nutrients (Sheley and James, 2014). The ameliorating of its environment is termed as soil engineering (Blank and Young, 2004) and most of the annual grasses have the soil-engineering ability (Blank, 2010). Therefore, they could quickly invade natural vegetation especially after a heavy disturbance as heavy grazing (Surmen et al., 2013).

Grass-forb relations

Forbs are a functional plant group, which have a wide variation in species on natural vegetation along with grasses. Some forb species have weedy characteristics and commonly consist of undesired species in the vegetation especially after heavy disturbance but many positive effects were also revealed on the dominant functional group of natural vegetation throughout the world "e.g. grasses" (Perry et al., 2009; Hulet et al., 2010; Leger et al., 2014). Forbs and grasses could significantly interact with each other (Sasaki et al., 2011; Mariotte, 2014; Mulhouse et al., 2017). These interactions might have transitionary effects on communities (Leger et al., 2014), and have many positive effects on the function of the ecosystem, for example, they provide important forage resources even in summer (Yoakum and O'Gara, 2000; Warne et al., 2010) and therefore their relations should not be underestimated.

Grass species use shallow water more efficiently than any other species via the dense and fibrous root system and therefore, could compete strongly with forb species for water and nutrients (Fargione et al., 2003; Andersen et al., 2004; Temperton et al., 2007). Besides, there are some reports indicating competition of the light and belowground space between forbs and grasses (Marty et al., 2009; Smilauer and Smilauerova, 2012). Some annual forbs have highly competitive relations with annual grass species (Leger et al., 2014) due to overlap in phenology (Forbis, 2010; Abella et al., 2012) but contrarily, forbs and perennial grass species could go into facilitative interactions via niche complementarity (Smilauer and Smilauerova, 2012) or partitioning (Nippert and Holdo, 2015). The relationship is highly determined by the similarity of root phenology of forbs with grasses, and generally facilitative (Figure 2) for species, which have vertical root growth as taproots (Leger et al., 2014; Nippert and Holdo, 2015). These interactions were stated to provide the balance of vegetation (Cox and Allen, 2011; Parkinson et al., 2013).

Figure 2. Unpalatable forbs protects palatable grasses from grazing

Soil nitrogen is one of the most important limiting factors for plant growth in natural vegetation and especially grass species are highly dependent on soil nitrogen (Venterink and Gusewell, 2010). This limited nitrogen is another factor, which grasses and forbs compete for (Paynel et al., 2001; Marty et al., 2009). Legumes, as a family within the forbs functional group, can fix atmospheric N_2 and thereby, could facilitate the growth of grass species (van Ruijven and Berendse, 2003; Erkovan et al., 2008c). This positive effect of legumes is due to both N sparing and N transfer but mostly N sparing (Temperton et al., 2007; Marty et al., 2009). Besides, the litter of legumes could also facilitate grasses because legume litter is rich in N, but this process needs more time, even years, considering N transfer (Andersen et al., 2004; Xiao et al., 2004). Apart from N, a niche complementary between legumes and grasses was also reported to cause facilitative interactions (Smilauer and Smilauerova, 2012). Grass species could take soil minerals more efficiently than legumes (Xiao et al., 2004) and therefore, they could compete and generally suppress legumes for other limiting soil nutrients (Andersen et al., 2004; Corre-Hellou et al., 2006). Additionally, competition for light, water, and even belowground space were also reported between grasses and legumes under limited resource conditions (Fargione et al., 2003; Tan et al., 2004; Marty et al., 2009).

Figure 3. Thyme species on natural vegetation

Some forb species are highly allelopathic and therefore, could affect the grass-forb relations in natural plant communities. For example, thyme species (Figure 3) significantly inhibit the germination and growth of grasses via allelopathy (Ehlers et al., 2014). Thymes could reduce the survival rate of the neighboring grasses by about 80 % via their allelopathic secondary compounds (Ehlers, 2011). Some other forb species as *Heracleum mantegazzianum, Impatiens glandulifera,* and *Lupinus polyphyllus* were also reported to suppress the grasses via allelopathy (Loydi et al., 2015), and therefore might decrease their competitive abilities. The competitive effects of forbs on grasses may also increase by fungal endophyte (Aschehoug et al., 2014).

In general, competitive or facilitative interactions among forbs and grasses are species-specific (Parkinson et al., 2013), and significantly affected by environmental factors, mostly precipitation (Hallett et al., 2019).

Grass shrub relations

Until the end of the 20th century, grass-shrub interactions had been known as competition mostly but later, researchers (Maestre et al., 2003; Bonanomi et al., 2011; Pierce et al., 2019b) reported many facilitative interactions between these functional groups. The balance between the competitive and facilitative relations among grass and shrub species determines the functioning of semi-arid ecosystems (Sankaran et al., 2004; Higgins et al., 2010; Cipriotti et al., 2014) and could shape the transitions between grassland and shrubland (Pierce et al., 2019a). Water and water-related factors have a major role in grass-shrub interactions especially in arid and semi-arid environments, but temperature, nutrients, light, fire, grazing, species, functional groups such as legumes, and even the growth stage of the plants significantly affects the state of interactions (Callaway et al., 1996; Holzapfel et al., 2006; Bechtold and Inoge, 2007; Cipriotti et al., 2008; Saccone et al., 2009; Goldstein and Suding, 2014; Gullap et al., 2018).

Grass and shrub species have niche differentiation and they use soil water from different layers (Cipriotti et al., 2008). Shallow water is mostly used by grass species and this makes them superior competitors especially in semi-arid regions but in some cases, both grass and shrub species may compete for soil water between 20-40 cm depth

(Kambatuku et al., 2013; Cipriotti et al., 2014). The competition for shallow water resources has vital importance for new shrub establishment because grass species could suppress the shrub seedlings by utilizing most of the near-surface water resources (Pierce et al., 2019a). Contrarily, facilitative interactions of some grass species (e.g. *Stipa tenacissima*) on shrub seedlings have been revealed in semi-arid areas (Maestre et al., 2003). The inconsistent results might be indicating the occurrence of species-dependent relations among grasses and shrub seedlings. Some researchers reported the competitive effects of invasive-annual grass species are more efficient on shrub establishment because of higher growth rates and water demand (Cavaleri and Sack, 2010; van Kleunen et al., 2010; Edwards et al., 2019). By the way, annual grasses are being suppressed in arid environments and thereby, the negative effect might be alleviated but remains (Eliason and Allen, 1997; Seifan et al., 2010). Grass species could also reduce the water percolation into the deeper zones, where it is available for adult shrubs (Wiegand et al., 2005). The negative effects of water competition are more important between grass and shrub seedlings than the competition for light, nutrients, and even the water limitation itself (Casper and Jackson, 1997; Esch et al., 2018).

Grass species are often assumed as a competitor for shrub seedlings with some exceptions in water-limited environments (Maestre et al., 2003; Mazzola et al., 2011), but once shrubs are established, they could suppress invasive-annual grasses beneath their canopy (Goldstein and Suding, 2014). On the contrary, adult shrubs generally facilitate the grass species in natural vegetation especially as a biotic refuge or nurse plant in water-limited environments (Brooker et al., 2008; Xu et al., 2010; Bonanomi et al., 2011), and the positive effects of shrubs include both native and invasive-annual species (Davies et al., 2007; Rayburn and Schupp, 2013). The facilitative effects increase with increasing environmental stress (Pierce et al., 2019b), which is consistent with the stress gradient hypothesis of Bertness and Callaway (1994).

Canopy shade of the shrubs could be as effective as tree species and may cause temperature differences more than 10°C between under and out of shrub canopy (Xu et al., 2010). Thus, they reduce the water loss through evapotranspiration in arid and semi-arid environments (Maestre et al., 2003; Davies et al., 2007) and ameliorate the stress in microclimate for understory grasses (Callaway, 2007). Besides the shade effect, shrub species also could provide available water for grasses via hydraulic lift (Priyadarshini et al., 2016). Moreover, they increase litter accumulation beneath their canopy and in turn, soil moisture could be preserved efficiently (Bechtold and Inogue, 2007; Poulos et al., 2014), which facilitates the grass species. Litter accumulation facilitates understory grasses also through elevation of the nutrient content (Throop and Archer, 2008; Ward et al., 2018) but there is evidence of allelopathy at some shrub species (e.g. *Artemisia tridentata* and *Lepidaploa aurea*) that suppressing the grass species via their litter (Kelsey et al., 1978; Lopes et al., 2018).

Figure 4. Facilitative effect of a shrub via biotic refuge effect

Some shrubs, especially spiny, unpalatable or toxic species protect palatable grasses from herbivory through their dense and/or thorny canopy (Rebollo et al., 2002; Howard et al., 2012; Erkovan et al., 2015). This is termed as the refuge effect (Milchunas and Noy-Meir, 2002) which is assumed as another facilitative effect of shrubs on grasses. Shrubs could increase species heterogeneity (Figure 4) by serving as biotic refuges (Pihlgren and Lennartsson, 2008) and facilitate the growth of understory grasses even under heavy grazing (Pazos et al., 2007). It is well-known that grass-shrub interactions may alter under grazing activities (Kidron and Gutschick, 2013; Cipriotti et al., 2014). Heavy grazing primarily suppresses grass species and therefore, increases shrub establishment but later, established shrubs facilitate the establishment and growth of grass species by ameliorating the micro-environment or protecting the grass seedlings from grazing (Howard et al., 2012; Pierce et al., 2019b). This is a good example indicating the dynamic structure of natural vegetation.

Figure 5. Grass-legume shrub coexistence in a natural vegetation

A considerable amount of the shrubs in natural vegetation consists of legume species (Figure 5), which have the nitrogen-fixing ability (Eldridge et al., 2011; Lang et al., 2017). The amount of N is critically important especially in nutrient-poor soils, and legume shrubs significantly increase soil nitrogen (Michalet et al., 2015; Lang et al., 2017) and thereby, facilitates the growth of grass species (Zhang et al., 2016). Precipitation positively increases the facilitative effect of legume shrubs on grass species beneath or near the canopy (Aranibar et al., 2004; Armas et al., 2011). The positive effect of the precipitation is related to increment in soil organic carbon (Zhang et al., 2017) because nitrogenase activities are dependent on carbohydrate supply to nodules and precipitation increases the supply (Marino et al., 2007; Arfin-Khan et al., 2014). Nitrogen transfer of the grasses from rhizodeposition might increase nearly 47 % within a 500 cm distance to legume shrubs (Gubsch et al., 2011) and this N_2 supply by legume shrubs also disrupts the competitive interactions of grasses (Hellman et al., 2011), but increase their forage quality (Zhang et al., 2017)

Grass-woody relations

Grass and woody species widely coexist as a neighbor in natural vegetation. Vegetation of some herbivore-grazing areas mostly consisted of grass and woody species as savannas, which cover 20 % of the world land surface (House et al., 2003; Riginos et al., 2009). Both plant forms are important for the ecosystem concerning production, water balance, and nutrient cycle (Mordelet and Le Roux, 2006), and the effects of environmental factors on the coexistence of tree and grass species as a neighbor are known as the “savanna question” (Sarmiento, 1984; Sankaran et al., 2004). Numerous studies reported positive, negative, or neutral relationships between grass and woody species (Ludwig et al., 2001; House et al., 2003; Riginos, 2009; Manea and Leishman, 2015) but it has not been revealed yet due to the complicated nature of the relations. Besides, densities of woody plants are in change over the world, declining or increasing due to direct human-related reasons, grazing, fire, or CO_2 elevation (Smit, 2004; Morgan et al., 2007; Riginos et al., 2009; Acacio et al., 2009; Buiterwerf et al., 2012; Pinto-Correira et al., 2018). The consequences of these changes on grass species or herbivores therefore should be well-understood. Relations between grass and woody species are generally shaped due to the availability of light, temperature, and water in their neighbor area, which is termed as micro-environment. The differences in these factors in their micro-environment are mostly caused by their different growth formation that causes niche separation but the direction of the relationship may also change in wet/dry seasons, depending on the canopy density, soil nutrients, or grazing (Riginos et al., 2009; Blaser et al., 2013; Dohn et al., 2013).

Figure 5. Shade effect of trees facilitates the understory grasses

Light is one of the most important factors that plants compete for and the variations on shade, temperature, and evapotranspiration are mostly caused by the availability and the intensity of light. Dense and low canopy formed trees compete for light and therefore, negatively affect the photosynthetic activity of understory grass species (Milton and Dean, 1995; February et al., 2013) but the facilitative relations observed (Figure 5) if enough light could be penetrated from tree canopies to the understorey grasses (Blaser et al., 2013). Besides, trees even with dense canopy could facilitate the growth of grass species by alleviating the heat stress under high light density (Mussery et al., 2016; Barron-Gafford et al., 2017) and by reducing the understory evapotranspiration (Mordelet and Le Roux, 2006; Ludwig et al., 2008). Indeed, light density has an important role in water availability as in evapotranspiration, but water-based gradients significantly shape the tree-grass interaction even it is related to light or not. For example, dense tree canopy intercepts the rainfall (Scholes and Archer, 1997; Smit, 2005) and cause competitive relations under high rainfall conditions of savanna but it could easily shift to facilitation for understory grasses when the precipitation is low and drought prevails (Simmons et al., 2008; Blaser et al., 2013; Dohn et al., 2013). This indicates how fluxional is the relationship depending on the environmental conditions and the results are consistent with the stress gradient hypothesis of Bertness and Callaway (1994).

The effects of water on tree-grass interactions are mostly discussed over precipitation or evapotranspiration, but the hydraulic lift is another important water-related concept which is firstly observed by van Bavel and Baker (1985) and termed firstly by Richards and Caldwell (1987) on woody species (Mendel et al., 2002). Tree species could transfer water from deep and wet soils to the dry shallow surface, where grass roots are intense. Ludwig et al. (2003) showed that Acacia may lift and leaching between 75 and 225 L of water each night to the shallow layer of a 300 m^2 area and water is effectively used by grass species due to their fibrous root system at the shallow area and they are facilitated (Simmons et al., 2008; Priyadarshini et al., 2016). Soil water is the limiting factor according to the Walter hypothesis (Walter, 1971) which assumed grass species as a superior competitor but the root niche separation avoids the competition as in the hydraulic lift especially in dry seasons (Moustakas et al., 2013; Ward et al., 2013). Therefore, the interaction shifts depending on the precipitation, which is mostly facilitative in dry and competitive in the wet season (Kikvidze et al., 2006; Priyadarshini et al., 2016). Besides water, the nutrient availability also affects the tree-grass relationships (Treydte et al., 2007; Ludwig et al., 2008; Blaser et al., 2013; Whitecross et al., 2017). Tree species enrich the soil by N_2 fixing i.e. Acacia species (Treydte et al., 2007; Riginos et al., 2009; Erkovan et al., 2016), below-crown litter accumulation (Ludwig et al., 2001; 2008), leaching or attracting animals (Gea-Izquierdo et al., 2009) and therefore, increases the biomass and nutrient content of understory grasses through facilitation (House et al, 2003; Riginos et al., 2009). Additionally, the facilitative effect of trees on grasses through N-fixation is higher under dry conditions (Sitters et al., 2013) and this may suggest any of these effects may not be effective singularly but in a complicated relationship with many biotic and abiotic factors.

Grass-tree relation is a two-way phenomenon including the effect of grass species on trees also. Few researches are revealing the competitive effect of grasses on large trees (Smit and Rethman, 2000) but generally, they could suppress the growth of tree seedlings and saplings as much as herbivory and fire (Jeltsch et al., 1997; Riginos and Young, 2007; Riginos, 2009; Morrison et al., 2019). The suppression is mostly at water-limited environments such as arid and semi-arid savannas (Davis et al., 1998; Ward and Esler, 2011) because grass species are superior competitors for water near the shallow soil layers but the competitive effect decreases in the wet season even in arid savannas (February et al., 2013; Kulmatiski and Beard, 2013). Moreover, nitrogen fertilization could also increase the competition between grasses and tree seedlings because of increased biomass (Trubat et al., 2011; Shekede et al., 2018; Tilman, 2020) especially if invader grass species coexists (Gordon et al., 1989; Flory and Clay, 2010).

The competitive effects of grass species on tree establishment are the most common under increased CO_2 conditions in C_3 grass-dominated vegetation (Manea and Leishman, 2015) because the biomass of C_3 grasses tends to increase under elevated CO_2 conditions (Lara and Andreo, 2011) and thus, water consumption increases also. Generally, it should be concluded that water availability is the most important factor on grass-tree relations but some other biotic (herbivory and human impact) and abiotic (fire, nutrients, etc.) factors may also cause significant differences in these effects along with water.

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CHAPTER XV

A VALUABLE FODDER TREE FROM EAST AFRICA: Chibha *(Ficus thonningii)*

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INTRODUCTION

Ficus thonningii is an important multipurpose fodder tree providing economic and ecological benefits across arid and semi-arid areas in Africa. Its name is Chibha in Africa and produces browsable biomass yield within two years of age. During the dry periods, this fodder plant remains green for longer period because of deep rooting system. This tree has high biomass yield, adaptability, feed value. Also it is easy to propagate, has multipurpose values and utilized for livestock feed, food, latex, timber production, medicine, soil and water conservation, fence, fuel wood, windbreak and fiber.

Fresh leaves of Chibha trees are used as dry season supplement to the livestock after wilting or fresh. *F. thonningii* leaves are a good source of nutrients (proteins, fats, carbohydrates and minerals) as well as fibre and are within the recommended range for ruminant livestock growth and development.

Here in this review, we present the major properties of this species with special focus on feed and fodder value more to be evaluated to be utilised in temperate climatic zones where same family crops (Figs) may be grown like Mediterranean regions.

Over 200 000 smallholder farmers plant fodder trees in East Africa. Fodder trees require little land, labor or capital but are knowledge-intensive. Fodder trees reduce the cost of meeting dairy cows' protein requirements (Franzel et al., 2014).

Finding alternative feed supplements for livestock is an important step to sustain livestock production. Ficus thonningii leaf is one of the potential feed resources for ruminants (Mekuriaw and Asmare, 2018).

In a questionnaire survey participated by 240 farmers from Ethiopia for selecting, evaluating and comparing fodder trees for climate-resilient silvopastoral systems, 20 criteria of three categories (animal-based, plant-based and multipurpose) asked and *Ficus thonningii* was ranked first among the top 10 species of trees followed by *Cordia africana*, *Eucalyptus cameldulensis* and *Rhus natalensis (*Balehegn et al., 2015*)*.

Ficus thonningii is an important multipurpose fodder tree providing economic and ecological benefits across arid and semi-arid areas in Africa. In a study of Balehegn et al., (2014), it is found that *F. thonningii* can be used to replace commercial concentrate mixture up to 50% with improvements in feed intake and productivity at Ethiopian highland goats. *F. thonningii* leaf meal had adequate levels of crude protein, neutral detergent fiber and tannins which results with body weight increases. But, increases its ratio in meal more than 50% resulted in decreased body weight gain and other carcass parameters.

Chibha (*Ficus thonnighii*) is a very popular indigenous multipurpose fodder tree in Ethiopia where annual rainfall is 750-2000 mm. The plant could be propagated by seed, seedlings and cuttings and adopts a wide range of soil types and fertility levels in which brown soil is the most suitable soil type for establishment. It produces adequate biomass yield in two years after plantation but three years of age is better to utilize as feed. Female Chibha produces seed in 5 years and continues producing seeds every year. During dry periods, it remains green for extended period by the help of its deeper rooting system compared to grasses. Due to latex content, farmers cut leaves and twigs in the morning and put them in the sun throughout the day, wilt and then feed different types of animals. It is an excellent feed for dry period supplementation and can be potential protein supplement for ruminants. This tree has high biomass yield, adaptability, feed value and easy of propagation compared to other indigenous and improved fodder trees. Generally, the plant has multipurpose values and it is utilized for livestock feed, food, latex, timber production, medicine, soil and water conservation, fence, fuel wood, windbreak, fiber source etc. Farmers prefer this fodder especially due to its high biomass level, multi-functionality, long life span of the tree, high adaptation to cropping systems and high feed value compared to other indigenous fodder trees (Mengistu et al., 2017).

Uses of *F. thonningii* tree by smallholder farmers from northwestern Ethiopia was analysed from December 2014 - March 2015 to determine the management and utilization options of these trees as livestock feed and to identify major production and utilization constraints. As the result of the study, it was observed that, *F. thonningii* were fed by cattle (54.2%), sheep (24.1%) and goats (21.7%). Leaves of trees were used in fresh form as a dry season supplement to livestocks by the farmers in the study districts, followed by wilting or both fresh and wilting. Assessment indicated that the tree has valuable benefits to mitigate critical livestock feed scarcity in the dry season (Asmare and Mekuriaw, 2019)

Fodder quality of *Ficus thonningii* Blume in Ethiopia were evaluated by Berhe and Tanga, (2013). They showed that the tree diameter size was effective on foliar nitrogen, phosphorus, potassium, dry matter, crude protein, digestible crude protein, ether extract, crude fibre content, but was ineffective on ash content and nitrogen free extract values. The results also showed that *F. thonningii* leaves are a good source of nutrients (proteins, fats, carbohydrates and minerals) as well as fibre and placed within the recommended range for ruminant livestock growth and development. So, use of *F. thonningii* as a supplement/substitute livestock feed to low-quality grasses during the periods of feed scarcity should be widely considered.

Following investigations of the roots of *Ficus thonningii* Blume, two new flavonoids, thonningiol (qq) and thonningiisoflavone (qp) along with nineteen known compounds were isolated by Fongang et al., (2015). Also, β-Isoluteone (qt) was isolated for the first time from a natural source. Thonningiisoflavone (qp) and hydroxyalpinumisoflavone (qr) showed strong radical scavenging activity. The methanolic extract taxifolin (qt), conrauiflavonol (qw) and shuterin (qz) exhibited moderate antimicrobial activity against six micro-organisms.

F. thonningii [Moraceae] stem-bark extracts may be useful in the control of diabetes mellitus. Its stem-bark ethanolic extract possesses reno- and cardio-protective effects in diabetes mellitus (Musabayane et al., 2007).

The dendrometric parameters total height (H), crown height (CH), crown diameter (CD), diameter at stump height (DSH), diameter at breast height (DBH), crown depth (CDp), crown area (CA) and crown volume (CV) were measured from 12 sampled trees comprising three age ranges in northern Ethiopia. Leaves and edible twigs of the sampled trees were clipped, oven dried, weighed and recorded as dry weight (DW). Results showed that only CV, CA, CD, CDp and DSH showed a strong correlation with DW. It was observed that *F. thonningii* produces a very high amount of browsable biomass at all ages compared to common fodder species (Balehegn et al., 2012).

Berhe and Tanga (2013) evaluated the fodder quality of *F. thonningii* Blume in the Ahferom district of Tigray, Ethiopia. The results also showed that its leaves are a good source of proteins, fats, carbohydrates, minerals, fibre and are within the fit range for ruminant livestock growth and development. It amy serve as a supplement/substitute livestock feed to low-quality grasses during the feed scarcity periods. Data on foliar nitrogen (N), phosphorus (P), potassium (K), dry matter (DM), crude protein (CP), digestible crude protein (DCP), ether extract (EE), crude fibre (CF), ash content and nitrogen free extract (NFE) revealed that the tree diameter size had an effect on foliar N, P, K, DM, CP, DCP, EE and CF, whereas it had no effect on ash content and NFE.

Pollinator wasp of *Ficus thonningii* is *Elisabethiella stuckenbergi* (Vovlas et al., 1998*).*

The FRIN (Forestry Research Institute of Nigeria) herbal garden is established for conservation of endangered medicinal plant species in Nigeria and the identification number of *Ficus thonningii* is “FRIN 110160” (Morenike et al., 2019).

F. thonningii is used in ethnomedicine for the treatment of ailments like diarrhoea, dysentery, diabetes mellitus, gonorrhoea, etc. In the study of Egharevba et al., (2015), the leaves were observed elliptic or obovate, rarely slightly oblanceolate. The presence of lignin, tannin, protein, and oval and round shape starch grains was observed. Oils glands were on parenchymatous cells. Microscopic examination of the leaf powder revealed straight-walled epidermal cells with thick cuticle. Palisade cells and group of fibers and spiral vessels were also detected. Some unicellular trichomes were also realised. Prisms of calcium oxalate crystals were observed. The phytochemical screening revealed the presence of carbohydrate, saponin, tannin, and flavonoids.

A feed mixture study including *Ficus thonningii* and *Panicum maximum* showed that *F. thonningii* is higher in crude protein (20.5%) and lower in NDF (55.8%) than *Panicum maximum* (CP = 8.3%, NDF = 76.2%). Dry matter (DM), organic matter (OM), CP intakes improved significantly with more *F. thonningii* in diet and were best in 75% *F. Thonningii* and lowest in solely *P. maximum*. Weight gain were best in 50% and 75% *F. thonningii* and least in sole *P. maximum*. Digestibility values were generally good, but highest in 50% *F. thonningii*, and least in sole *P. maximum*. As a result *F. thonningii* displayed no limitations utilization in ruminant feeding solely or in mixture with P. Maximum grass. It was well consumed and can be used in alleviating feed scarcity problem for ruminant animals in the dry seasons (Bamikole and Ikhatua, 2010).

F. thonningii is an important fodder species with multipurpose benefits to rural communities and many desirable qualities such as drought resistance, absence of allelopathic effects, lower anti-nutritive contents, easy propagation and fast growth rate. Most nutritive parameters: dry matter, crude protein, non-fibrous carbohydrates, nitrogen free extract, crude fiber and neutral detergent fiber, but Calcium and Magnesium varied significantly among three edible parts (leaves, twigs and bark) and two maturity groups (younger than 6 months including new out growths or older than 1year old plant parts). Most of the values were within the acceptable or tolerable range for ruminant and non-ruminant herbivores. Leaves were the most nutritious parts and bark was the least. It is concluded that *F. thonningii*, an ever green drought resistant tree, can be used as a ruminant fodder source during critical seasons (Balehegn and Hintsa, 2015).

The phytochemical screening revealed the presence of alkaloids, cardenolides, terpenoids, saponins, tannins and flavonoids. Crude extracts showed inhibitory activity on moulds and yeast. Hexane leaf extract was the most active inhibiting for all strains of *Aspergillus niger*, *Candida albicans*, *Penicillum chrysogenum* and *Rhizopus nigricans*. The study showed that *Ficus thonningii* Blume is a good source of various phytochemicals including antimicrobial compounds (Coker et al., 2015).

CONCLUSION

High dry adaptation due to deep roots and aerial roots, high leaf biomass yield, easy to propagate, multipurpose utilization (feed, food, latex, timber, medicine, fence, fuel wood, windbreak, fiber etc)

Special focus is needed on this tree as a feed and fodder crop to be evaluated to be utilised in temperate climatic zones where same family crops (Figs) may be grown like Mediterranean regions.

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CHAPTER XVI

THE IMPORTANCE OF NATURAL RANGELANDS FOR SEDIMENT MOVEMENT

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INTRODUCTION

Rangelands are a type of land on which the natural vegetation is dominated by grasses, forbs and shrubs, characterized by low and irregular precipitation, diverse topography, highly variable soils, and often low soil fertility. Soil is the primary component of natural rangelands and it regulates forage production in a region with particular climate. Surface cover is the key to erosion control in grazing lands In rangelands, sedimentation is the direct result of the loss of sediments from soil surface. Sediment yield is the total quantity of sediment transported from a location in a given period of time. Low sediment yields can be attributed to, among other factors, a region's low erosion rate. Sedimentation activities can be land-based (i.e., agriculture, forestry, urbanization) and water-based (i.e., dams, port activities, drag fishing, channelization). Both erosion and sediment transport processes are sensitive to changes in climate, changes in land use and human activities. Overgrazing has a number of negative impacts on rangelands, often including an increase in undesirable vegetation or a loss in vegetation cover and biomass. Also, heavy grazing has negative effects on soil physical and chemical properties. Proper grazing management on rangelands is higly important to manipulate the vegetaions. Properly managed vegetation is not only to provide feed for grazing animals but also to hold soil in place againist to eroding forces

Erosion and sedimentation

Erosion and sedimentation are two different processes that caused different types of environmental damage (Engler, 2001). Erosion is the wearing away of soil materials, caused by the action of wind and water, through detachment and transport of materials from one location to another, usually at a lower elevation (Sawatzky, et al., 2005). It can be classified into many types due to different eroding forces. The surface runoff erosion is the commonest erosion type and the slope gradient is one of the most important factors affecting the surface flow erosion (Lui et al., 2001). Sedimentation is the direct result of the loss of sediments from soil surface (Engler, 2001). Sediment yield is the total quantity of sediment transported from a location in a given period of time. Low sediment yields can be attributed to, among other factors, a region's low erosion rate (Atkins, 2007). Sedimentation activities can be land-based (i.e., agriculture, forestry, urbanization) and water-based (i.e., dams, port activities, drag fishing, channelization). Both erosion and sediment transport processes are sensitive to changes in climate, changes in land use and human activities (Atkins, 2007; Abubakari, 2014). These natural physical processes will continue whether or not they are influenced by the activities of humankind (Engler, 2001).

Rangelands

Rangelands are a type of land on which the natural vegetation is dominated by grasses, forbs and shrubs, characterized by low and irregular precipitation, diverse topography, highly variable soils, and often low soil fertility (Anonymous, 2014).

Figure 1. Beauty of a natural rangeland

Benefits of rangelands

Rangelands provide natural beauty, a diversity of wildlife, recreational opportunities like hunting, hiking, and camping, and economic values, including ranching, mining, and electrical power. Also it serves as important watersheds for production of clean abundant water (Anonymous, 2014).

Figure 2. Rangelands produce clean water

The soils, vegetation, and water of rangelands are important to the health of the ecosystem. Rangelands also provide important habitat for domestic and wild animals. Most of the world's livestock live and feed on rangelands (Anonimous, 2014).

Figure 3. Using of rangelands for recreational opportunities like hunting, fishing, hiking, and camping

Water coming from rangelands generates hydroelectric power. Mining and extraction of coal, oil, and natural gas are important energy resources gained from rangelands. Rangelands can also serve as suitable sites for attaining solar power, and wind power from turbines (Anonymous, 2014).

Rangeland areas of the world

Rangeland areas occupy 47% of the earth's surface (Heitschmidt and Stuth, 1991; Greiner et al. 2009; Holechek et al., 2011) and mainly used for domestic livestock grazing. Also, these natural vegetations are main food source of wild animals.

Figure 4. Domestic and wild animal grazing on rangelands

Erosion and sedimentation problems on rangelands

Soil is the primary component of natural rangelands and it regulates forage production in a region with particular climate (NRC, 1994; Holechek et al., 2011). Surface cover is the key to erosion control in grazing lands (Carey and Silbum, 2006) and the vegetations are vital for the protection of the soil against to the erosive forces. Plant roots help to hold soil in place and above ground biomass and crop residues reduce the movement of surface water and increase its infiltration into the soil (NRC, 1994; Wall, 1987; Livingstone, 1991). However, there are several factors causing grassland degradation, grazing intensity is one of the most important causes of degradation in the world's arid and semiarid rangelands (Snyman, 2005; Altin et al., 2005; Holechek et al., 2011).

Changing in land use and mismanagement may caused to soil erosion and land degradation in many rangelands of the world (Lal, 1990; Ravi et al., 2010). Natural erosion rates vary across rangelands as a function of climate, topography, vegetation composition and structure (Gillette, 1999). Soil characteristics impact runoff and erosion from rangeland. Organic matter, bulk density, texture, structure, aggregate stability, porosity, and moisture conditions influence soil runoff and erosion by controlling the amount of infiltration and runoff from a soil surface.

Sediment, resulting from geologic erosion is a natural component of rangelands and their fresh water streams, and high sediment concentrations may occur naturally (Wood and Blackburn, 1981). On the other hand erosion and sediment production may related with grazing, at different stocking rates, compared to no grazing (Renner, 1936; Dunford, 1949; Aldon and Garcia, 1973; McGinty et al., 1979; Coskun et al., 2016). Intensive grazing can initially decrease plant cover, cryptogamic crusts, and soil aggregate stability. If continued long term periods, it can do alter plant composition, which may seriously affect the hydrology of a watershed (NRPH, 2003). But, grazing intensity can affect sediment loss at different levels depending on plant species composition of rangeland (Johnston, 1962). Sediment production may also increase with decreasing standing phytomass and soil depth of rangeland sites (McGinty et al., 1979).

Figure 5. Examples for intensive grazing rangelands and sediment movement

Overgrazing has a number of negative impacts on rangelands, often including an increase in undesirable vegetation or a loss in vegetation cover and biomass (Herbel and Pieper, 1991; Tongway et al., 2003; Holechek et al., 2011) and it leads not only to a decline of biodiversity (Wu, 1997), grass and animal production, increases the sediment movement and leads to losing of productive topsoil (Coskun et al., 2016) but also to the deterioration of the environment (Ash et al. 1994; Zhang, 1995). Also, heavy grazing has negative effects on soil physical and chemical properties (Beukes and Cowling, 2003) and lead to transport of sediment and nutrients from rangelands (Ciotti et al., 2010). It is important to maintain enough vegetation cover to protect the soil and nutrient transportation because as the vegetation cover of plants or crop residues decrease, by the effects of heavy grazing or other factors such as fire and drought, soil erosion potential increases (NRC, 1994; McIvor et al., 1995; Holechek et al., 2011; Sanjari, 2011). If the rangelands are degraded by the effects of environmental forces the restoration of these areas may take too long period because soil formation processes work slowly (NRC, 1994; Gokkus and Koc, 1996; Holechek et al., 2011).

Proper grazing management on rangelands is higly important to manipulate the vegetaions. Properly managed vegetation is not only to provide feed for grazing animals but also to hold soil in place againist to eroding forces. If conducted improperly, grazing can affect ecosystem structure negatively, hydrologic cycle by decreasing plant cover, which can increase raindrop impact on the soil surface, decrease soil organic matter, and accelerate surface runoff and soil erosion.

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CHAPTER XVII

CROP SALINE TOLERANCE IN RELATION TO NITRATE/AMMONIUM RATIO IN FERTILIZERS

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INTRODUCTION

Soil applied nutrients enhances metabolic processes in plant roots, change rhizosphere conditions, modify uptake of ions, change activities of enzymes and affect growth patterns. Nitrogen is a major nutrient for crop growth and yield formation. Many studies on plant nitrogen relations consider only the total amount of nitrogen available in the soil and the total amount of nitrogen in the plant tissues but the source of nitrogen is also vey important.

Global agricultural productivity is under pressure of environmental problems like drought and salinity as primary abiotic stress factors limiting crop production especially in arid and semi-arid areas. The ability of crops to tolerate salt is determined by many factors where an easily managable part is related to the form of nitrogen applied by fertilizers. Plants acquire nitrogen from soil mainly in nitrate and ammonium froms. These two dominates high-yield crop production nitrogen fertilization.

Here in this review, effect of nitrogen fetilizer form on salinity stress mitigation or tolerance is analysed based on different plant species types.

Fertilisers in agriculture are key inputs for the production of sufficient food and fodder (Lawlor et al., 2001). Conventional cropping systems must supply adequate nitrogen (N) to soil needed for high crop productivity and ensure high N utilization by fertilizer N rate, timing and application methods (Meisinger, 1984). N nutrition enhances metabolic processes in physicochemical environment at the soil-root interface, change rhizosphere conditions, modify uptake of cations/anions, enhances or represses the several enzyme activities, affects growth patterns (Fernandes and Rossiello, 1995).

Many studies on plant N relations consider only the total amount of N available in the soil and the total amount of N in plant tissues. But source of N is increasing its importance. Nitrate ($NO3^-$) is a major N source for higher plants (Bloom, 2015). Plant acquire N from soil mainly in the form of $NO3^-$ and ammonium (NH_4^+). These two dominates high-yield crop production N fertilization. The mechanisms of root adaptation to altered supply of N forms and concentrations is well characterized. The N supply may alter the timing and duration of the transition from the vegetative to the reproductive growth phase of crop. This in turn generally affect crop architecture especially the structures for grain yield. So correct regulation of plant architecture by N can increase crop yield and N use efficiency (Luo et al., 2020). Nutrition with NH_4^+ increases anion uptake, free amino-N/protein ratios, acidify root free space, reduces carbohydrate amounts in plant tissues. NO_3^- nutrition results with higher cation uptake, higher carbohydrate content in tissues and alkalinized root free space. N assimilation interferes with the allocation of dry matter and energy, which changes growth rates of different plant parts (Fernandes and Rossiello, 1995).

Global agricultural productivity is facing with increasing environmental problems like drought and salinity (Bartels and Sunkar, 2005). Salinity is a primary stress limiting crop production, especially in arid and semi-arid areas (Ibrahim et al., 2019). 20% of irrigated agricultural land is adversely affected by soil salinity (Chinnusamy et al., 2005). Soil salinity stress reduces the growth, survival and physiological functions of many plants (Shao et al., 2020). Crop loss due to this problem is an increasing threat to agriculture worldwide (Van Zelm et al., 2020). Salt tolerance of plants varies considerably among species but the cultural conditions varies in soil, water, and environmental factors which influence the salt tolerance of crops (Maas, 1987).

The ability of plants to tolerate salt is determined by multiple biochemical pathways like retention and/or acquisition of water, protecting chloroplast functions and maintaining ion homeostasis (Parida and Das, 2005). Control of ion homeostasis and N metabolism madifies salt tolerance in crops (Yu et al., 2016). Low cytosolic (intracellular) sodium (Na) concentration is essential for cells to grow in high salt concentrations (Blumwald, 2000).

The effect of N source for nutrition (NH_4^+ or NO_3^-) of pea plants under moderate salt stress was studied by Frechilla et al., (2001). Growth declined under salt stress. NO3- fed pea plants were more resistant to salinity compared to NH_4^+ fed plants. This difference was mainly sourced from better maintenance of root growth in NO3- fed plants. It is concluded that the N source (NH_4^+ or NO3-) is a major factor affecting pea responses to saline stress, plants being more sensitive when NH_4^+ is the source used.

Salt-tolerant and sensitive sweet potato (*Ipomoea batatas* L.) varieites exogenously supplied with NaCl, NH4+ and NO3− at adventitious root stage. NH4+ inhibited Na+ influx and K+ efflux under salt shock condition. Moreover, a salt-enhanced NO3− net influx was also detected in mature Xu 22 root region (Yu et al., 2016).

Forage sorghum plants respond contrasting under salinity under different N sources. NH_4^+ protects photosynthetic machinery of sorghum plants from salt damage by modulating structural and carbon assimilation pathways. Sorghum plants fed with NO3 were failed to activate the defense mechanisms and displayed elevated salt stress. Good performance of NH_4^+ under salinity was sourced from low amount of hydrogen peroxide accumulation, improved CO2 assimilation and K+/Na+ homeostasis (de Oliveira et al., 2020).

Hhydro-morph and salted marginal lands originated plant namde Smooth cordgrass (*Spartina alterniflora*) (Poaceae) strongly inhibit nitrification and promote denitrification under hypoxic and salt stressed conditions. Distribution and yield of this species depend on its capacity to tolerate salinity and to use NH_4^+ as the predominant source of nitrogen. *S. alterniflora* is one of the scarce species which prefered NH_4^+ as N source. The addition of 500 mol m−3 NaCl affected plant growth in both $NO3^-$ and mixed-media, but did not affect when NH_4^+ was supplied. Secretion of Na+ by shoots was increased by NH_4^+ treatment. NH_4^+ treatment probably improved salt tolerance of S. alternifloraby increasing secretion activity of salt glands leading to a decrease in salt content of leaves mesophyll and consequently to avoiding toxic buildup of Na+ in the apoplastic tissues of the leaves (Hessini et al., 2009).

N sources induced differences in *Pisum sativum* plant growth, ion accumulation, ion distribution that affect salt tolerance. In non-salty conditions, the largest biomass accumulation was obtained with NH_4NO_3. In the presence of NaCl, plants fed with NO experienced less salt toxicity than plants supplied with other N sources. This indicated lower Na+ and Cl– and higher K+ concentrations in the shoot. It was also seen that it is possible to establish an effective symbiosis under saline conditions with a salt-tolerant Rhizobium with good N2-fixing ability. N-fertilizer selection can enhance the growth of *Pisum sativum.*

A greenhouse experiment was conducted to assess if salt stress on sunflower can be mitigated by foliar applied potassium $NO3^-$. KNO3 increased the photosynthetic rate and leaf turgor which in turn resulted in enhanced growth and yield in sunflower plants subjected to salt stress (Akram and Muhammad, 2009). 1% K+ and 1.6% $NO3^-$ (from KNO3) were most effective under saline conditions.

Increasing N applications under NaCl stress promoted poplar growth by improving the efficiency of light energy utilization (Wang et al., 2019).

Supplementary KNO3 and proline treatments significantly ameliorated the adverse effects of salinity on melon (*Cucumis melo*) plant growth, fruit yield and the physiological parameters examined (Kaya et al., 2007).

Potassium $NO3^-$ application alleviated NaCl stress in winter wheat cultivars differing in salt tolerance where KNO3 was more effective in the salt-tolerant than in the salt-sensitive cultivar (Zheng et al., 2008).

Supplementary $KNO3^-$ improved salt tolerance in bell pepper (*Capsicum annum*) plants with high salt treatment, before supplementing the soil with KNO3 at 1 g kg−1. The K and N levels were similar to those of the control which meant that supplementary KNO3 can overcome the effects of high salinity on fruit yield and whole plant biomass in pepper plants (Kaya and Higgs, 2003).

Application of nitric oxide and calcium $NO3^-$ enhanced the tolerance of wheat seedlings to salt stress (Tian et al., 2015).

Cerium $NO3^-$ improved the salt tolerance of wheat seedlings by regulating the antioxidant capacity of chloroplasts (Chen and Shan, 2019).

N enhanced salt tolerance by modulating the antioxidant defense system and osmoregulation substance content in cotton (*Gossypium hirsutum*). N supplementation increased the plant water status, photosynthetic pigment synthesis, gas Exchange and accumulation of osmolytes (soluble sugars, soluble proteins and free amino acids). And decreased the generation of hydrogen peroxide, lipid peroxidation and electrolyte leakage ratio. Also antioxidant defense system was upregulated in both saline and non-saline growth media as a result of N application. N application was found as a potential strategy to overcome the salinity-mediated impairment of cotton (Sikder et al., 2020).

An effective strategy for re-establishing K+ and Na+ homeostasis is a challenge for the improvement of plant performance in saline soil. Understanding the mechanisms of Na+ extrusion from plant cells, the control of Na+ loading in the xylem and the partitioning of the accumulated Na+ between different plant organs are in core of studies (Miranda et al., 2017).

To see how external N affect Na^+ accumulation under saline conditions, $NH4^+$ supplied to *Sorghum bicolor.* It improved salt tolerance of the plant by restricting Na^+ accumulation and increasing K^+/Na^+ homeostasis in shoots, resulted with low Na^+ load to the xylem. Here, $NH4^+$ acted as a signal for the regulation of Na^+ homeostasis in sorghum under salt stress and increased salt tolerance (Miranda et al., 2017).

Study of Ibrahim et al., (2019) revealed that N was successful for alleviating the adverse effects of NaCl. Furthermore, similar effects were observed by applying 86 kg ha-1 and 210 kg ha-1 N on wheat seedling based on observations of emergence and seedling growth. Moreover, results revealed that N fertilizer at moderate salinity exerted a positive affect on wheat plants while at high salt concentration it was negative affecting or ineffective. Therefore, it is concluded that fertilizer management is required in the salt-affected areas to sustain yield and to decrease the degradation of soil.

Exogenous application of silicon and $KNO3^-$ reduced Na uptake, increased potassium and consequently improved plant weight, 100-seed weight, seed yield, ear length, and photosynthesis rate of wheat (*Triticum aestivum* L.). This study suggested that utilization of a salt-tolerant cultivar combined with foliar application of KNO3- (2 mmol L−1) and silicon (4 mmol L−1) at the wheat booting stage might help to obtain higher grain yields on saline soils (Ahmad, 2014).

Effects of NaCl and $NO3^-$ on the root morphologic characteristics and N accumulation in the shoot of the seedlings of the halophyte species *Suaeda physophora* were investigated by Yuan et al. (2009). Increasing $NO3^-$ levels in the high NaCl solution increased the Na^+, $NO3^-$ and organic N concentrations and $NO3^-$ reductase activities, but also decreased Cl^- and K^+ concentrations. Positive response of seedlings under high NaCl stress may be attributed to N application which increased root growth and improved Na^+ and N accumulation in the shoots of the seedlings.

Salt tolerance of Chinese Iris (*Iris lactea* Pall.) and the osmoticum in leaves at different levels of exogenous $NO3^-$ were observed by Zhang and Li, (2011). Increasing concentrations of exogenous NO_3^- decreased Cl^-, Na^+ and K^+ contents but increased proline and NO_3^- contents. Growth under NaCl stress was better after exogenous NO3- at medium concentrations.

Rice is a salt sensitive cultivar. Cha et al. (2010) studied the possibility of improving its osmotic potential, pigment stabilization, photosynthetic efficiency and growth characteristics of rice plant under salinity stress by $KNO3^-$ application. Na ion accumulation in root and leaves of KNO3 applied plants declined compared to control plants. In control plants, due to decline in potassium ion content, the Na+/K+ ratio increased significantly. A positive relation between Na+ accumulation and osmotic potential was observed. The photosynthetic ability of plants with KNO3 application was positively related to plant dry weight. Exogenous KNO3 application to rice crops may improve their salt tolerance.

In their work, Çavuşoğlu et al. (2017) studied the effects of KNO_3^- on the seed germination, seedling growth (radicle length, radicle number and fresh weight), mitotic activity and chromosomal aberrations of *Allium cepa* L. germinated under both normal conditions and salt stress. The detrimental effects of salt on the seed germination, seedling growth, mitotic activity and chromosomal aberrations was sharply declined by KNO_3 applications.

CONCLUSION

The ability of crops to tolerate salt is partially managable by the form of nitrogen applied with fertilizers. Plants acquire nitrogen from soil mainly in nitrate and ammonium froms.

Low intracellular sodium concentration is essential for cells and crops to grow in high salt concentrations.

- NO_3^- fed pea, wheat, sunflower, rice, sweet potato, melon, bell pepper and onion plants were more resistant to salinity compared to NH_4^+ fed plants.
- NH_4^+ fed forage sorghum, smooth cordgrass plants were more resistant to salinity compared to NO_3^- fed plants.

Mechanismns used by plants to cope with salinity by shifts from one fertilizer nitrogen source type to another were mentioned in studies as 1) better maintenance of root growth, 2) inhibited Na+ influx and K+ efflux under salt shock 3) protection of photosynthetic machinery, 4) modulating structural and carbon assimilation pathways, 5) low amount of hydrogen peroxide accumulation, 6) improved CO2 assimilation, 7) improved K+/Na+ homeostasis 8) decrease in salt content of leaves mesophyll by secretion of Na+ by shoots salt glands, 9) increased leaf turgor, 10) photosynthetic pigment synthesis, 11) improved gas

Exchange, 12) accumulation of osmolytes (soluble sugars, soluble proteins and free amino acids), 13) decreased lipid peroxidation 14) decreased electrolyte leakage ratio 15) upregulated antioxidant defense system

Reactions to salinity are also change among varieties. So these parameters may be analysed in a similar study on varieties of major crop species to approve in saline land zones before real field trials to escape from high labour requirements but also to learn more from different plant species, varieties, metabolic processes etc.

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CHAPTER XVIII

PROPOSAL OF A COMPLEX INTERCROP SYSTEM INCLUDING DURUM WHEAT (*Triticum durum)* FOR FORAGE PRODUCTION

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INTRODUCTION

Drought, heat waves, high temperature, salt, weeds, diseases, insects, high light stress, nutrient losses in soils are problems in monoculture crop production. Intercropping, especially in forage production, spesifically complex intercropping, may reduce many negative effects of monoculture and may improve yield and quality with cost reductions.

As a partner of legumes in an intercrop, durum wheat may be very helpful with its stress tolerating properties. Barley has a fast early growth phase, wheat has a late speedy growth phase with very high variety option, triticale has advanced adaptation capacity to poor soils etc. Here in this review, a complex intercrop including many different cereals and legumes in the same time, is proposed, which are rising on the shoulders of currently published research articles of many researchers mentioned in this analysis.

Grain protein content is one of the most important quality traits for wheat, defining the end-use and rheological characteristics (Nigro et al., 2019). Globally, durum [*Triticum turgidum* L. ssp. durum (Desf.)] is still considered a minor wheat crop and typically much of the research effort on durum is mostly conducted in relation with bread wheat. Durum wheat is used largely for pasta, bulgur and couscous production (Beres et al., 2020). Grain protein content is an important factor in pasta and breadmaking quality for human nutrition which is also determining grain prices of wheat with high grain protein content (Olmos et al., 2003).

It is frequently assumed that durum wheat is more tolerant to stress than bread wheat. In their research, Marti and Slafer (2014) re-classified a variety database based on decades they released. Researchers conduct field trials and found that bread wheat varieties outyielded durum wheat in almost any comparison in 1960s. But in the 2000s, durum wheat outyielded bread wheat in most comparisons; grain weight was constitutively higher in durum than in bread wheat. Differences in yield were also related to differences in water and nitrogen use efficiencies. Under low-yielding conditions, bread wheat was more efficient than durum. But with high-yielding conditions durum wheat was more efficient.

The unstable Mediterranean climate causes fluctuations in wheat yield and quality, but offers opportunity for obtaining high-quality durum wheat in terms of grain protein content (Rharrabti et al., 2001). Durum wheat accounts for more than 50% of the total wheat growing area in the Mediterranean region (Guzmán et al., 2016). Comparatively to bread wheat, the photosynthetic performance of durum wheat is more tolerant to heat stress, as stomatal conductance and transpiration are less affected (Dias et al., 2011).

Mixed cropping of barley and durum wheat was a common practice of smallholder farmers in some drylands of Ethiopia. Because barley is more competitive at early stages than wheat which dominates the canopy towards the reproductive stage. Fast growing nature of barley at early growth stages helps intercropping system by its belowground and areal resources faster, while wheat grows slowly and demands less resource at the earlier growth stages. At later stages, wheat is becoming dominant and resource demanding. Therefore, mixed cropping of these two crop species helps combine important characters in a cropping system to enhance productivity through complementary resource uses in drylands (Molla and Sharaiha, 2010).

Barley aerial biomass and grain yields were higher than durum wheat cultivars in well watered conditions. In a study of Carvalho et al., (2014), grain yield decrease by drought at barley was 47% compared to 30% in durum wheat. Root to shoot dry matter ratio was increased for durum wheat under drought but not for barley. Also root weight was increased for wheat in response to drought but decreased for barley.

Cover crops and mulches can be used for increasing sustainability in winter cereal cropping systems (Campiglia et al., 2014). Intercropping is a farming practice that fights pests and diseases and improves plant growth (Bechtaoui et al., 2019). Intercropping cereals and legumes could be an option for obtaining forage suitable for ensiling and reduced N fertilization (Mariotti et al., 2012).

Intercropping durum wheat and chickpea increase rhizosphere phosphorus availability in a low P soil (Betencourt et al., 2012). Bedoussac and Justes (2010) observed in a study that the efficiency of durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration was found dependant on N availability during early growth.

Grain protein concentration of durum wheat is low particularly in low-N-input systems but wheat-winter pea intercrop may improve yield and durum wheat grain protein concentration. To test this, durum wheat (*Triticum turgidum* L.) and winter pea (*Pisum sativum* L.) were grown as sole crops or intercrops in France with different fertilizer N levels by Bedoussac and Justes (2010). Without or late applied N fertilizer (less than 120 kg N ha^{-1}), yields of intercrops were up to 19% higher than sole crops and up to 32% for accumulated N, but were less efficient with large fertilizer N applications. Wheat grain protein concentration was significantly higher in intercrops than in sole crops. Also fewer ears were observed per square metre in intercrops.

Durum wheat and subclover (*Trifolium subterraneum* L.) were sown as a living mulch system to provide a high cereal grain yield and a sufficient subclover reseeding following the wheat harvest in a study in Central Italy which was conducted by Campiglia et al., (2014). Durum wheat yield was not reduced when two species were sown in rows 10 cm apart. Nitrogen fertilization increased durum wheat yield but decreased subclover performance. Durum was dominant, its aggressivity increased with proximity to subclover. Subclover was able to improve weed control in intercropped compared to sole durum.

Two experiments were performed in central Italy for intercropping durum wheat and field bean (*Vicia faba* L. var. minor) at row ratios of cereal/legume (1:1 and 2:1) at different N rates (20 and 50 kg ha−1) in a study of Mariotti et al., (2012). Intercropping reduced N fertilizer requirement and led to forage yield improvement with better quality compared to sole croppings. Land equivalent ratio was 26% up with intercropping compared to sole crops. Field bean was the dominant species at intercrop, but N fertilization reduced it and increased wheat in mixture. In intercrop fertilized with 50 kg N ha^{-1}, the proportion of the wheat in the herbage (0·34–0·41 of the total dry matter) was sufficient for ensiling of the forage mass. N uptake of durum was greater at intercrop compared to sole durum.

Efficiency of rhizobial symbiosis was higher with intercropped durum with faba bean compared to sole faba bean in a study of Kaci et al., (2018). Also shoot dry weight and nitrogen nutrition index were significantly higher for intercropped than for the sole cropped wheat. Whereas there was no significant difference on shoot dry weight between the intercropped and sole cropped faba beans. Intercropping increased the N nutrition of durum wheat by increasing the availability of soil-N for durum wheat. This increase may be sourced from a lower competition between legume and durum wheat than competition between plants of durum wheat.

In a two year trial in two locations in Italy, three "durum wheat"-"field pea" intercropping systems with rates of 25/75, 50/50, 75/25 and 100/100 were tested in interaction with two N fertilizer levels by Carrubba et al., (1996). Analysis showed that 50/50 and 100/100 (crowded) intercropping systems mantained high yield performances also in stressed environments. The higher weed control conferred by intercropping showed to be a sure tool to enhance competitivity as regards production and ecological aspects.

Sarno et al., (1998) studied the efficiency of intercropping durum wheat and field pea (*Pisum sativum* L.) by comparing 1) two pure stands (350 and 60 seeds m-2 for durum wheat and field pea, respectively); 2) intercrops at a rate of 25:75, 50:50 and 75:25. Plots were recieved two diferent nitrate fertilizer levels (0 and 50 kg ha-1). Field pea showed a lower competitive ability than durum wheat. Fertilization rates did not affect yield and land equivalent ratio. Durum wheat presence in intercrop was improved efficiency of weed control.

Selection of appropirate and correct “intercrop evaluation index” that will be employed in intercrop value evaluation is very important to correct understanding of interactions between species and comparison to values of sole crops. Available indices to evaluate the potential advantages of intercrops and interactions are Aggressivity, “Cumulative Relative Efficiency Index”, “Land Equivalent Ratio”, “Change in Contribution”, “Interspecific and Intraspecific Interaction Index”, “Comparative Absolute Growth Rate Index” (Bedoussac and Justes, 2011).

Bedoussac and Justes (2011) were suggested to use the intraspecific and interspecific interaction indices, which can reveal possible facilitation phenomena and allow description of species change in the contribution index for durum-legume interacrops. Interspecies interaction dynamics that determine the resultant balance and the outcomes of competitions between crops may be evaluated with precision by “Comparative Absolute Growth Rate Index”. However, the results must always be related to actual data values (yield, dry weight or N accumulated) because the indices used cannot support evaluation of intrinsically quantitative performance but only the relative performance of intercrops compared with that of sole crops.

CONCLUSION

Durum wheat has advantages over barley and wheat in terms of stress tolerance in Mediterranean conditions. Higher acreages of durum compared to bread wheat in Mediterranean region reflects this situation. To benefit from crop diversification, it may be a good option to intercrop “bread wheat”-“durum wheat”-“barley”-“legume” intercrop for forage production not just under Mediterranean conditions but also for other regions of world to escape from stress and to improve forage quality. Different speed of different growth stages of different crop species may also support this system in forage production which transfers advantages of diversification to biomass production for animal feding pusposes but is not feasable for grain production for bread. Also triticale and rye may be added in this cereal cocktail for intercroppings between legumes. This may result with adoption of forage production more to stressful conditions (especially to the multiple stressed conditions). By this way, salt, heavy metal, deficit or excess nutrients and elements in soils, pests and diseases problems may be reduced more at forage production. To improve syncronisation of its elements more, nitrogen fertilization studies for possible mixtures may be conducted under different conditions. Yield and quality stability may be high compared to sole and few diversified mixtures with this system.

As legume partner in the complex mixture, again, diversification may add complex interactions and advantages. Winter pea, chickpea, subclover, field bean, faba bean and field pea may be good partners for cereals according to exsisting literatures. As an example of a mixture, each of these species may share 8% of total seed number in mixture: 1) durum 2) alfalfa 3) barley 4) soybean 5) tritiacale 6) field bean 7) wheat 8) field pea 9) rye 10) subclover 11) oat 12) pea.

The ultra high diversified starting mixture may fit to very different fields and/or individual field's local parts with different local combinations of species and different dominancies in narrow localites to keep biomass yield and quality higher than ever an escape from monoculture to ancient / archaic grasslands…

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CHAPTER XIX

SWEET CLOVERS (*Melilotus* sp.) AS AN ALTERNATİVE FORAGE CROP

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INTRODUCTION

Increasing population, economic developments, and awareness about diet increase the demand for animal products day by day and require more efficient use of limited production resources such as water and soil. Selecting the right forages and suitable management practices are the most effective strategies for reasonable forage production under limited natural resources and also against climate change.

Agriculture, from sowing to harvest, is mainly shaped by climatic conditions. Therefore, climate change is expected to directly impact crop production systems at varying levels from region to region with the degree of warming (Wheeler and Reynolds 2013). All these changes and risks push humanity to search for new alternatives in plant production, including forage crops. Increasing feed requirement of animal production and insufficiency of production resources have increase interest in plants with economical and satisfactory yields in different climate and soil conditions. In this context, neglected and underutilized plants have been gaining attention recently, such as sweet clovers (*Melilotus* sp.).

Melilotus is a genus Fabaceae, and is common in grassland or as a weed in fields. The most known and common species are *Melilotus officinalis* L. (yellow sweet clover) and *Melilotus alba* L. (white sweet clover). Mueller and Stewart, (1980) reported that *Melilotus officinalis* is a biennial species, and it is considered as palatable roughage of high quality both for animals and natural flora. Strong and deep penetrating taproots make it a suitable candidate as a nurse crop in derelict land compacted soils (Stevens and Monsen, 2004).

Total land size and structure of Turkey

The actual area it covers, including lakes and islands, is 814.578 km², and the projection area is 783.562 km² in Turkey. The difference between these two surface measurements is due to the mountainous and topography. The 83% of its area has a slope of 8% and higher, while half of it has a slope of 45% and above (Anonymous, 2021a).

More than half of Turkey's territory consists of mountains. The remaining areas are lowland, plateau, and hilly areas. Turkey's 190.000 km^2 area, showing the plain covered with silt property consists of flats of different heights. The lowland and plateaus are a total of 270.000 $km^2$and these two areas consist of 1/3 of Turkey's surface area. Flat areas are 370,000 km^2 (FAO, 2003).

According to data from 2018, the total agricultural area in Turkey was 37 802 million ha. The total cultivation area is 23.185 million ha, and the areas of cereals and other crops are 15.421 million ha. Fallow lands are 3.513 million ha and constitute 15% of the total agricultural lands. The grassland and pasture is 14.167 million ha, while the forest is 22.3434 million ha (Acar et al., 2020).

The situation of forage crops in Turkey

The quality roughages are provided by grassland, pastures and, forage crops produced in field agriculture. The yield and quality of pastures have decreased due to unconscious use for years and after all the production of forage is very low. Therefore, the quantity and quality of roughages supplied from these two sources are insufficient to meet the needs of livestock.

According to the data from 2018, Turkey has also 2 million ha of forage crop area that the most produced forage crops are alfalfa, sainfoin, vetch and silage corn. The amount of hay obtained from forage crop cultivation is 16.373 million tons. A total of 14.617 million tons of hay is produced from the meadow, pastures. The total amount of hay yield is 31 million tons. There are 19 million animal units in our country, and they need annually 86 million tons of good quality hay. The amount of roughage deficit is 55 million tons (Acar et al., 2020).

Marginal agricultural lands

Marginal agricultural land is lands opened for agriculture due to the needs. It has little or no agricultural or industrial value. Marginal land has little potential for profit and often has poor soil or other undesirable characteristics. The slope of the land is more than 12% in places where precipitation is below 640 mm, and more than 18% in places where it is 640 mm or more, and the depth of the soil is less than 50 cm. Generally, the crops yield is below the local average. These lands are not suitable for irrigation with conventional methods, but their irrigated can be using controlled techniques.

It is possible to say that people have direct negative effects on the agricultural areas that have been used for years to meet the food needs of the increasing world population. Agricultural lands, water resources, and many plant resources are been destroyed due to unconscious practices for years. Many agricultural areas in the world have faced abiotic factors such as drought and frost due to factors such as excessive irrigation and fertilization. While agricultural lands in the world are faced with 26% of drought, 20% mineral, and 15% cold and frost, only 10% of them are not faced with any stress factor (Mut and Sezer, 2008). There are 1.5 million hectares of barren land in Turkey. Their 1.100.000 ha is salty, 390.000 ha is salty-alkaline and 10.000 ha is alkaline (Anonymous, 2021b).

Sweet clover (*Melilotus* sp.)

Sweet clovers (*Melilotus* sp.) are a member of the Fabaceae family and are originated native to Eurasia. Smith and Gorz (1965) and Goplen and Gross (1984) reported that sweet clovers were established in North America early in the 18th century. Sweet clover is represented by 24 species worldwide, distributed in the Mediterranean countries, Asia and North America, Central and Eastern Europe (Hoppe, 1975) There are 11 species depending on the Melilotus genus in Turkey, and these are endemic (*Melilotus albus (M. alba), Melilotus bicolor, Melilotus elegans, Melilotus indicus, Melilotus italicus, Melilotus officinalis, Melilotus siculus, Melilotus spicatus, Melilotus sulcatu, Melilotus sulcatus, Melilotus tauricu and Melilotus urbanii)* (Anonymous, 2015). The two most common species in Turkey are *Melilotus alba* Desr. (white sweet clover) and *Melilotus officinalis* Desr. (yellow sweet clover).

M. officinalis and *M. alba* are found throughout the lowlands and on lower mountainous stands. They do not have special requirements regarding climate and soil conditions; therefore, they occur on balks, roadsides, wastelands, ditches, and railway embankments. They prefer sunny sites, and if they grow in shaded spots, they are less vital and the seeds production is limited. The studies on the agricultural character of sweet clover are very few. For this reason, sweet clovers grow spontaneously in natural flora or are evaluated pasture plants.

The *Melilotus alba* (white sweet clover) and *Melilotus officinalis* (yellow sweet clover) for the livestock to meet roughage in spring. Because they start growing early in the spring. Also, they can be evaluated grazing, hay, silage, and pasture plant. Besides, in the summer period, sweet clovers keep green and so, utilized their hay.

Sweet clovers native and distribution

Sweet clovers are typically a biennial or annual herbaceous plant and is native to Europe and Asia (Europe: France, Greece, Ukraine, Hungary, Lithuania, Austria, Slovakia, Moldova, Estonia, Spain, Germany, Czech Republic, Bulgaria, Romania, Belarus, Latvia, Poland, Italy, and Cyprus, Turkmenistan, Azerbaijan, Kyrgyzstan, Georgia Afghanistan, Iran, Pakistan, Tajikistan, Jordan, Armenia, Turkey, Russian, Uzbekistan, Iraq, Israel, India, , Federation, Bhutan, Kazakhstan, China) (Turkington et al., 1978).

Morphological traits of white sweet clover

It stem is smooth and hairless, erect, and branched, grooved or channeled. The height of stem ranged between 30-150 cm. White Sweet Clover leaves have 3 leaflets, and each leaflet is fully toothed. Their leaves are usually smooth, sometimes hairy. The length of leaves ranges from 1 to 7 cm. White Sweet Clover has pile roots and they can grow up to 1.5 m. The plant flowers appear between June and October relative to region and altitude. They are white, size of 4-5 mm, and the flower stalks each have between 20 and 65 flowers. The white sweet clover fruits are black to dark grey and each contains a single seed. Their seeds are yellow and oval to kidney-shaped and a plant can produce up to 350.000 seeds (Dölarslan and Gül, 2017).

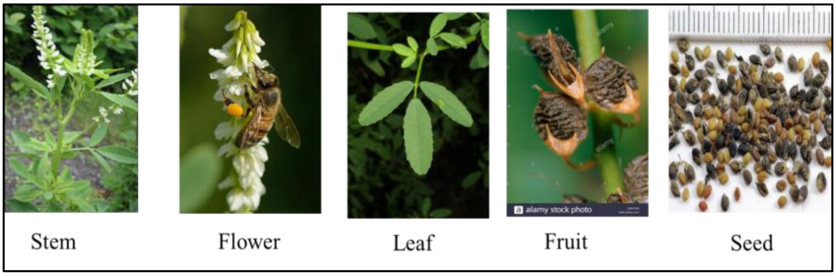

Figure 1. *M. alba* morphological traits (Anonymous, 2021c, d, e, f, g)

Requirements of climate and soil of white sweet clover

Melilotus alba can grow in soils that are inefficient for other plants It is one of the plants that have been the most discussed on the global scale because of not only growing in this kind of marginal areas without irrigation but also has resistance to drought and heat and has sustained its growth during the summer months and protect its greenery. It can be seen on the roadsides and in forest areas. The plant, which can be growing in areas with low organic matter, and it is usually spreading in coarse-textured soils with high sand content. The pH value of the soil where it is located range between 6.70-6.75, while it shows slightly acidic properties (Wolf and Rohrs, 2001; Barnes et al., 2003; Dölarslan and Gül, 2017).

Figure 2. Spread of *M. alba* Desr.

Morphological traits of yellow sweet clover

Yellow sweetclover is generally biennial plant, an erect, stem height ranged between 40-250 cm. Stems are coarse with alternate, 3 pinnate leaves and axillary flowers. Leaflets are small, 1 to 2.5 cm, and the pea-like, perfect flowers occur in 30- to 70-flowered racemes that measure 4 to 12 cm long. It is flowering from May to September, and up to 7 mm long; calyx with 5 unequal teeth, yellow petals whose banner is longer than the wings, themselves longer than the keel (Harrington, HD, 1964).

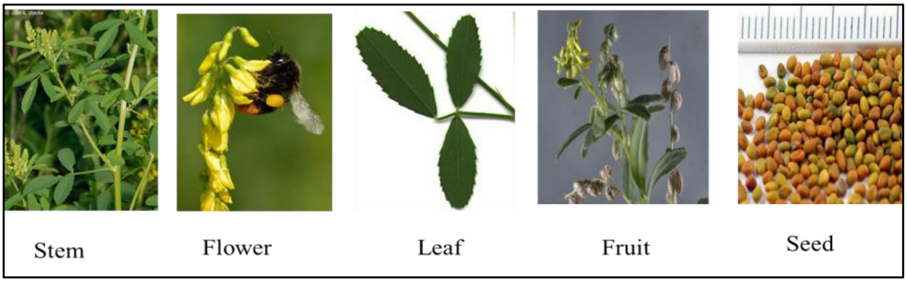

Figure 3. *M. officinalis* morphological traits (Anonymous, 2021h, ı, i, j)

Requirements of climate and soil of yellow sweet clover

Yellow sweet clover can be grown in degraded lands and seen at altitudes of 1750 m (Davis, 1965-1988). It has resistance to drought and heat and has sustained its growth during the summer months and protect its greenery. It can be seen on the roadsides and in forest areas. The plant, can grow in areas with low organic matter. The pH value of the soil where it is located ranges between 7.26-7.39, while it shows alkali properties (Wolf and Rohrs, 2001; Dölarslan and Gül, 2017).

Figure 4. Spread of *M. officinalis* (Anonymous, 202k)

Sowing of *Melilotus* sp.

The best suitable planting time of sweet clovers is spring. Early season moisture conditions are more favorable for rapid seed germination and seedling establishment. Late summer and fall seedings are not recommended because young sweet lover seedlings usually will not develop enough to survive the winter. Sweet clover grows slowly for the first 60 days after planting. They must develop an extensive root system and store high levels of plant food in the roots during the fall growth period. These stored food reserves are essential in overwintering their and to assure a vigorous, productive stand the following year (Meyer, 2005).

Sweet clover is a small-seeded legume and requires a uniform, shallow seeding into a firm seedbed for successful seedling emergence and adequate stand establishment. The recommended planting depth is 0.6-1.20 cm deep on medium- to heavy-textured soils and 1.2-2.5 cm on sandy soils. Seeding too deep is one of the most common causes of poor stand establishment. Sowing rates of sweet clovers range between 0.5 to 2. kg da^{-1}.

Using as a forage crop

Sweet clovers have high palatability and nutritional value in the first year. Therefore, its hay is benefited in the first year. Sweet clovers are of lower quality in the second year, and as they mature their palatable decreases. Previous researchers reported that sweet clovers crude protein, crude ash, ADF, NDF, K, P, Ca and Mg ratios were ranged between 15.0-24.0%, 4.4-16.2 %, 29.0-52.6% and 41.52-57.94%, 1.48-2.88%, 0.18-0.33%, 0.44-1.50%, and 0.11-0.39%, respectively (Özyiğit and Bilgen, 2006; Canbolat ve Karaman, 2009; Gülümser et al., 2020). Zabala et al. (2018) reported sweet clovers are recognized of the species with greatest potential as a forage source for ruminants in saline rangelands. The ideal cutting height is 45-60 cm, while the cutting time is the budding period. Since the quality of the plant in the second year is lower than the first year, it is more appropriate to use it as silage. Sweet clover two-year types are used to increase the quality of short-term pastures to be established in barren and poor soils. The swelling problem of sweet clover is less than compared to the alfalfa and trefoil species (Manga et al., 2003).

Sweet clovers have condensed tannins. The low level of tannins (2-3%) in ruminant feeding has a beneficial effect as it reduces protein degradation in the rumen (Barry, 1987), while the high level of tannin negatively affects protein digestion, microbial and enzyme activities (Kumar and Singh, 1984). On the other hand, approximately 21-25% of anthropogenic CH_4 release worldwide is produced in the animal digestive system. In the rumen, this tannin protects proteins from degradation and ruminants excrete less urinary N. The N of the urinary is quickly converted to ammonia. and induces environmental problems. Thus, the amount of greenhouse gas emitted to the environment is also decreasing. In this respect, if sweet clovers use in the feeding of ruminants they can reduce the methane gas emission that may occur with feeding.

Sweet clover poisoning

The stems of sweet clover plants should be exam-ined to make sure that they are properly cured (thoroughly dry) before being baled as hay. If conditions are right for hay to become moldy, they are right for coumarin to convert to dicoumarin. Although the measures are taken to reduce the toxic effect of the plant, coumarin can be seen in the plant. Generally, the coumarin content in sweet clovers ranges between 2-2.5%. Coumarin is found in different parts of the plant in different proportions. Young leaves contain more coumarin than old leaves. Coumarin is higher in the bud. The period when coumarin is most intense is the beginning of budding and the end of the flowering of the plant (Slatensek, 1947; White and Honer, 1940; Barnes et al., 2003).

Sweet clover contains a substance called coumarin, which is converted to dicoumarol by mold in hay. Dicoumarol is an anti-clotting agent that will cause livestock to hemorrhage. When the plant is not stored under proper conditions or spoiled, coumarin is converting to dicumarol, a toxic substance. Dicumarol prevents the intake of vitamin K1. Vitamin K1 is important in blood clotting and causes toxic effects such as bruising or disease. Therefore, dicumarol can cause bleeding, disability, and even death in animals (Smith, 1962). The toxic effect can be passed to the calves of animals that eat sweet clover through milk. Since vitamin K1 is decreased or consumed in the body, this situation may occur in 2 or 3 weeks or longer. The toxic effect can be seen in the whole herd that is constantly consuming sweet clover hay throughout the winter. Young animals are more sensitive to the toxin than older animals.

Using as a silage or haylage

Sweet clovers can be evaluating as silage or haylage. The suitable harvest time for sweet clover silage is early flowering. The good quality silage should contain 25 - 40% dry matter. If the silage contains more than 40% dry matter, palatability decreases with the high cellulose and hemicellulose content. Besides, if the silage contains low dry matter content (< 25%), most of the carbohydrate source may be leached. Sweet clover can be using as haylage. If sweet clovers are stored as haylage, they should dry matter content of 35% to 65%.

Grazing of sweet clovers

Sweet clovers are nutritious and palatable. Livestock including sheep, cattle, and horses can graze on young sweet clover and sweet clover hay. Animals can be grazing sweet clover during May, June and July (60-90 days). Grazing is most effective when plants are 30 cm tall and continues throughout the growing season. Older plants become woody and have higher levels of coumarin, a chemical that causes a bitter taste in them, decreasing palatability as the plant age. Edward et al. (2002) reported that livestock will be consuming sweet clovers less at first, however, they graze without difficulty after become accustomed to the taste.

On the other hand, sweet clovers are not tolerated close grazing or mowing during the first year of growth because regrowth occurs from stem buds rather than crown buds. Therefore, a large amount of shoot and root growth can be produced during the second year and they are a prolific producer. Clark (2007) reported that sweet clovers have feed value similar to alfalfa in the first-year, and lesser quality because of greater volume in the second year.

Using for soil improving

Sweet clovers are one of the few plants that can be used for soil improvement. They loosen the lower parts of the soil and provides aeration due to their pile roots. After its roots mature, it quickly breaks and decays, so it leaves the organic matter in the soil. Besides, it provides nitrogen to the soil by bacterial inoculation (Manga et al., 2003). Sweet clover is plowed under the year following seeding when the plants are 15-25 cm height. Late plowing adds more organic matter to the soil, but the additional growth period tends to dry out the soil to deeper depths and decomposition of the plant material will be slower. Viil and Võsa (2005) reported that sweet clovers are providing 247 kg/ha of nitrogen to the soil. Sweet Clovers can be grown as a green manure plant. When it is grown as a green manure plant, it saves 20-30 kg N per decare (Gençkan, 1983). Besides, sweet clovers are grown in moderately saline areas where traditional forage legumes cannot be grown. Therefore, they can be used in the improvement of salty soils (Bowman et al., 1998; Maddaloni, 1986; Smith and Gorz, 1965).

Using for nectar source for bees

Sweet clovers are a source of nectar for bees. Sweet clovers give a large yield of nectar, and if early and late flowering varieties are avaliable nectar can be gathered over a long period. Howes (1979) indicated that sweet clovers are always attractive to bees and important honey- producing plant in many parts of the world, and has been renowned as a bee plant from classical times. The name of the plant derives from the words Mel (honey) and lotus (flower). The quality of sweet clover honey is good, and it is of medium density, with a pleasantly mild flavor, slightly vanilla–like.

Using as a medicine

The flowering branches and leaves of sweet clover are used to make medicine. Sweet clover is used to increase the loss of water from the body through urine. It is also used for varicose veins and to relieve symptoms of poor blood circulation including leg pain and heaviness, night cramps, itchiness, and fluid retention.

Sweet clover is sometimes used along with regular medicines for the treatment of blood clots in the veins. Other uses include treatment of hemorrhoids and blockage of the lymphatic system. The lymphatic system drains fluid from tissues. Some people apply sweet clover directly to the skin for bruises (Anonymous, 20211).

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CHAPTER XX

INVESTIGATION OF THE EFFECT OF CHROMIUM (Cr) TREATMENT ON CHROMIUM ACCUMULATE IN PLANT ORGANS AND MORPHOLOGICAL CHARACTERISTICS IN *Sorghum spp* VARIETIES

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INTRODUCTION

The term heavy metal appears for metals with a density higher than 5 g/cm^3. These include elements such as Cd, Cr, Hg, Zn and Cu. The average Cr rate in the earth's crust is 100 mg kg^{-1}. Although the main use of Cr is in the metallurgy, refractory and chemical industries, it is widely used as a pigment due to its yellow color and in the production of green shades for paints, varnishes, glazes and inks. In the chemical industry, Cr (+3 and +6) is mainly used in pigments, metal plating and wood preservatives for stainless steel and chromate plating purposes. In addition, significant amounts of Cr compounds are used in leather tanning (the main source of Cr contamination) and in various stages of paper production. Industrial and residential wastewater treatment plants emit significant amounts of Cr into the environment. Chromite ore processing residue (COPR) is the biggest environmental risk in some regions (Kabata-Pendias, 2011).

The average Cr content of the world soils has been determined as 60 mg kg^{-1} (Hedrick, 1995; Reimann and De Caritat, 1998). Soils, especially those consisting of serpentines, sometimes contain Cr over 100,000 mg kg^{-1}. The highly variable oxidation states of Cr allow the formation of organic complexes as well as anionic and cationic species. Naturally occurring Cr compounds have values of +3 (chromic) and +6 (chromate). Cr + 3 only moves slightly in very acidic environments and precipitates almost completely at pH 5.5, on the other hand, Cr + 6 is very unstable in soils and is easily mobilized in both acid and alkaline soils (Bartlett, 1999).

Easily soluble in soil, Cr + 6 is toxic to plants and animals. Therefore, variability in the oxidation state of Cr in soils is a major environmental problem. Chromium exists in small amounts for plants and does not easily migrate within the plant, mainly because of the tendency of Cr3 + to bind to cell walls, it concentrates in the roots (Zayed et al., 1998).

S. bicolor, (sorghum) is the fifth most important grain crop in the world after *Oryza* spp. (rice), *Triticum* spp. (wheat), *Zea mays* L. (maize) ve *Hordeum vulgare* L.(barley) and is widely grown in more than 120 countries across Africa, Asia, Australia and Europe in tropical, semi-tropical, arid and semi-arid climates (FAO, 2015). The endurance of sorghum to different stress conditions, as well as its use in silage production in animal feeding gains importance in today's changing and increasing adverse environmental conditions.

The aim of this study is to examine the effect of different doses of Cr treatment on morphological properties and to detect Cr accumulation in plant organs in some sorghum varieties.

MATERIAL and METHODS

This research was conducted between April 28 - September 10, 2017 in research greenhouses of Kahramanmaras Sutcu Imam University Faculty of Agriculture. The soil used for the experiment was obtained from the Avsar Campus area of Kahramanmaras Sutcu Imam University and the soil analysis results are as in Table 1.

Table 1. Some properties of experiment soil

Saturation (%)	pH	Salinity (%)	$CaCO_3$ (%)	Organic matter (%)	K (mg/kg)	P (mg/kg)	Total Cr (mg/kg)	Available Cr (mg/kg)
58.3	7.33	0.1	0.71	0.6	275.2	8.12	247.7	0.12

The grain sorghum varieties used in the study were Akdari, Beydari and Ogretmenoglu and were obtained from the Batı Akdeniz Agricultural

Research Institute. Chromium (K_2CrO_4) is commercially available. The study was established according to the split plots experimental design (3 varieties x 1 element x 6 doses x 3 replication) for the chromium element. The soil obtained from the campus area was sifted through a 4 mm sieve, then waited for dry (air) weight in the greenhouse, then weighed in 10 kg volumes and placed in pots. 5 seeds (separately for each pot) were planted in a controlled greenhouse environment on the soil that was sieved and placed in pots of 10 kg volume on April 28, 2017. After germination, weak seedlings were diluted and a single strong sorghum seedling was left. Fertilization; (20 kg N and 10 kg P_2O_5) was calculated according to the amount of soil used, weighed and applied.

No heavy metal treatment was applied until the plants were 20-25 cm tall, and irrigation (drinking / mains water) was carried out according to the field capacity. Disease and pest control has been done. Cr concentrations (0, 50, 100, 200, 400 ppm) determined for each variety were calculated and weighed, dissolved in 100 ml of water and applied. Ppm in calculation; It was determined according to the volume of soil used. All irrigations until the harvest time after the treatment were made with drinking water quality water according to the field capacity and heavy metal washing was tried to be prevented. At the end of the 130-day growing period, the morphological characteristics of the plant were measured; leaves, stem and roots are separated and made ready for analysis. The samples were burned in CEM-MARS 6 microwave device and the chromium (Cr) element contents of the obtained solutions were determined in the ICP-MS device. In addition, element determination was made in soil samples taken after harvest. DTPA method was used for this determination. The data belonging to the investigated features were subjected to variance analysis in accordance with the split plot design. The results obtained were compared with the LSD test (SAS, 1999).

RESULTS and DISCUSSION

Examined morphological features

Plant height (cm)

The average of Cr doses, varieties and dose-variety interactions and LSD test groups are given in Table 2. Variety, dose and variety x dose interaction of Cr doses according to plant height variance analysis results were found to be very significant ($p < 0.01$).

When the effect of grain sorghum varieties in Cr stress on plant height was examined, it was seen that the highest plant height (48.23 cm) in the average of the varieties was in the Akdari variety and the smallest plant height (44.32 cm) in the Ogretmenoglu variety. When we look at the average of the doses, it is observed that increasing doses inversely proportional to the increase of Cr doses cause a decrease in plant height. The smallest plant height (24.40 cm) was obtained from 400 ppm Cr treatment, while the highest plant height (96.34 cm) was obtained from control group plants. When we look at the variety x dose interaction, it was seen that the highest plant height in Cr treatment was obtained from 0 ppm Cr (control) treatment of Akdari, Beydari and Ogretmeoglu cultivars, while the smallest plant height was obtained from 400 ppm treatment, which is the highest Cr dose in all varieties.

Table 2. Mean values of the effect of different Cr doses on plant height (cm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	**Mean**
0	96,75±5,16 B**	104,51±2,05 A	87,77±2,35 C	96,34 a**
50	66,00±30 D	65,00±5,00 D	52,50±5,50 E	61,167 b
100	44,03±9,89 F	27,97±5,14 GH	46,00±00 F	39,33 c
200	30,47±2,70 G	25,00±00 GH	30,67±3,51 G	28,71 d
300	27,93±2,06 GH	25,00±00 GH	25,00±00 GH	25,98 d
400	24,2±1,93 H	25,00±000 GH	24,00±00 H	24,40 d
Mean	48,23 a**	45,41 b	44,32 b	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

In all varieties used in the study, chromium stress negatively affected the plant height and plant height decreased regularly with increasing dose. Kasmiyati et al. (2016) tried the $CrCl_3$ and KCr (SO_4) 2 form of chromium in the sorghum plant in the soil and reported that the plant dyes were negatively affected in both chromium forms. Wallace et al. (1977) stated that the addition of a Cr_2O_7 at a concentration of 10−5 N in string beans reduced plant growth by 25%. Gupta et al. (2009) 0-500 µ M Cr +6 treatment of *Brassica juncea* cv. They stated that for Varuna, the plant height decreased by about 50%.

The results obtained in these studies are consistent with the results of this study.

Plant stem diameter (mm)

The mean of Cr doses, varieties and dose-variety interactions and LSD test groups are given in Table 3. According to variance analysis results of plant stem diameters of Cr doses, variety, dose and variety x dose interaction were found to be very significant ($p < 0.01$).

It was determined that the plant stem diameters of grain sorghum varieties under Cr stress varied between 7.80 mm and 6.67 mm. It was observed that the thickest stem diameter appeared in Ogretmeoglu variety and the thinnest stem diameter appeared in Akdari variety.

It was determined that stem diameters decreased inversely with increasing Cr doses. On average, the thinnest stem diameter was obtained from 300 ppm (4.24 mm) and 400 ppm (3.89 mm) Cr treatment, while the thickest stem diameter (11.78 mm) was obtained from 0 ppm/control group plants. Increasing the Cr doses negatively affected the plant stem thickness.

In Cr treatment, the thickest plant stem diameter was obtained from 0 ppm doses (control) of Beydari and Ogretmeoglu varieties, while the thinnest stem diameter was obtained from 300 and 400 ppm Cr treatments of Beydari variety.

Chromium treatment caused a decrease in plant stem diameter in all varieties used in the study. Vajpayee et al. (2001) reported that biomass production of Cr above 2.5 µg/mL level was negatively affected in his study where he applied Cr to *Vallisneria spiralis* plant and investigated its toxicity.

Tablo 3. Mean values of the effect of different Cr doses on stem diameter (mm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	**Mean**
0	10,44±1,17 B**	12,35±0,37 A	12,53±1,37 A	11,78 a**
50	8,40±0,66 C	10,75±0,05 B	11,63±1,33 AB	10,26 b
100	5,94±0,34 D-F	6,48±0 DE	6,7±1,27 D-F	6,37 c
200	5,67±0,44 D-F	5,65±1,16 D-F	6,09±0 D-F	5,80 c
300	5,23±0,98 E-G	2,5±0 H	5±0 FG	4,24 d
400	4,31±0,82 G	2,5±0 H	4,86±0 FG	3,89 d
Mean	6,67 b**	6,71 b	7,80 a	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

Turner and Rust (1971) stated that in their study they added 0.5 mg kg^{-1} Cr to the nutrient medium and 60 mg kg^{-1} Cr to the soil environment, that almost all macro nutrients decreased in the root region; It was thought that the decrease of these macro nutrients as well as chromium toxicity might have negatively affected the plant growth/stem diameter development.

Stem raito (%)

The mean of Cr doses, varieties and dose x variety interactions and LSD test groups are given in Table 4. According to the variance analysis results of the stem ratios of Cr doses, the type, dose and variety x dose interaction were found to be very important (p <0.01). Stem ratios of the varieties varied between 52.55% and 44.78%. While the highest stem ratio was in Akdari variety, the lowest stem ratio was determined in Ogretmeoglu variety.

Increasing Cr doses caused different changes on stem proportions. While the control plants were forming clusters, the failure of other Cr-treated plants to form clusters caused irregular changes in stem-leaf-cluster ratios. However, the highest body ratio (58.02%) was obtained from 50 ppm Cr treatment, while the lowest stem ratio was obtained from 100, 200 and 300 ppm Cr treatments.

Considering the variety x dose interaction, the highest stem ratio was obtained from 50 and 100 ppm Cr treatment of Akdari variety and 400 ppm Cr treatment of Beydari variety. The lowest stem rate was obtained from Ogretmeoglu variety in 100 ppm Cr treatment.

Tablo 4. Mean values of the effect of Different Cr doses on stem raito (%)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	**Mean**
0	48,79±1,02 B-E**	49,62±1,64 B-D	43,65±0,8 DE	47,35 b**
50	62,27±0,58 A	55,94±6,19 A-C	55,85±1,04 AB	58,02 a
100	62,34±3,32 A	41,03±3,39 DE	37,88±3,87 E	47,08 b
200	50,15±10,06 B-D	41,05±7,1 DE	44,02±7,61 DE	45,08 b
300	44,01±11,83 DE	48,4±4,69 B-E	44,27±15,57 C-E	45,56 b
400	47,75±9,04 B-E	67,22±5,54 A	42,99±6,8 DE	52,65 ab
Mean	52,55 a**	50,55 a	44,78 b	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

The doses of Cr used in the study are 0-50-100-200-300 and 400 ppm. The death of the plants treated with 300 ppm and 400 ppm Cr in all varieties occurred shortly after the treatment. In addition, since the Cr treatments were made when the healthy plants were 20-25 cm tall, the plants died 24-72 hours after this high dose Cr treatment. While it is still in a very small growth phase, the separation of leaves and stems is not very clear, since deaths occur and it is drying. In addition, plants could not form clusters at any dose, except the control group. It is not correct to say that the stem ratio decreases or increases in parallel with the dose increase among the three varieties used; Because while clusters were taken into account in the control group at these rates, both the absence of clusters and the lack of clear stem/leaf separation and the death of the plants at other doses affected the stem ratio parameter. Karunyal et al. (1994) applied wastes containing different doses of Cr on 25-50-75% and 100% to black lentil, cotton, cowpea and tomato plants in a study using leather industry wastes and stated that the plants died in 75% and 100% treatments.

Leaf raito (%)

The mean of Cr doses, varieties and dose-variety interactions and LSD test groups are given in Table 5. According to the variance analysis results of Cr doses and leaf ratios, the variety was significant ($p < 0.05$), while the dose and dose x variety interaction was found to be very important ($p < 0.01$).

Leaf rates of the varieties varied between 42.31% and 48.71%. While the highest leaf ratio was in Increasing Cr doses caused different changes on leaf ratios. While the control plants were forming clusters, the failure of other Cr-treated plants to form clusters caused irregular changes in stem-leaf-cluster ratios. However, the highest leaf ratio was obtained from 100, 200 and 300 ppm Cr treatment, while the lowest leaf ratio (18.94%) was obtained from 0 ppm Cr/control treatment.

When we look at the variety x dose interaction, the highest leaf ratio was obtained from 100 ppm Cr treatment of Ogretmeoglu variety, while the lowest leaf ratio was obtained from 0 ppm Cr/control treatment in all varieties.

Tablo 5. Mean values of the effect of Different Cr doses on leaf raito (%)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	**Mean**
0	20,37±0,58 F**	19,17±0,64 F	17,29±0,9 F	18,94 c**
50	37,73±0,58 E	44,06±6,19 C-E	44,15±1,04 DE	41,98 b
100	37,66±3,32 E	58,97±3,39 AB	62,12±3,87 A	52,92 a
200	49,85±10,06 B-D	58,95±7,10 AB	55,98±7,61 AB	54,92 a
300	55,99±11,83 AB	51,6±4,69 A-D	55,73±15,57 A-C	54,44 a
400	52,25±9,04 A-D	32,78±5,54 E	57,01±6,8 AB	47,34 ab
Mean	42,31 b*	44,25 b	48,71 a	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

The conditions mentioned for the stem ratio were valid for the leaf ratio; While the cluster could be calculated in the control group, the lack of clusters at other doses and the fact that the stem/leaf separation was small and dried at the doses at which the plant died, and the plant death affected the leaf ratio parameter. Along with this situation, studies on the effects of Cr toxicity on leaves; In a study conducted with wheat plant, 0.5 mM Cr added to the nutrient medium caused a 50% reduction in the total number of leaves in each plant, it was reported by researchers that this could be caused by many mechanisms and mostly due to the decrease in water use (Sharma and Sharma, 1993). Vernay et al. (2007) reported that with the increase of Cr +6 level in the nutrient solution, CO_2 assimilation and other parameters related to the photosystem in the leaves of the *Lolium perenne* plant decreased. Karunyal et al. (1994) applied leather industry wastes containing different doses of Cr to 25-50-75% and 100% of black lentil, cotton, cowpea and tomato plants made using leather industry wastes and observed an increase in leaf area in 25% treatment. Gupta et al. (2009) 0-500 μ M Cr + 6 treatment of *Brassica juncea* cv. They reported that the wet weight of the plant decreased with increasing Cr doses in the Varuna plant, but the dry weight of the plant was 57% higher than the control plants.

Distribution of chromium among plant organs

The variation graph of the accumulation of the chromium element in the grain sorghum varieties in the organs of the plant is given in Figure 1. The graph was created with the data obtained from the average of all applied doses. Percentage (%) rates were calculated over the total average values in all doses taken by the grain sorghum variety, independent of the amount of Cr remaining in the soil.

Looking at Figure 1, it is seen that the highest Cr accumulation occurs in the leaf of the plant in all varieties. While accumulation is in a direction in the form of leaf> root> stem in millet variety, this situation differed in Beydari and Ogretmeoglu varieties. In Beydari and Ogretmeoglu varieties, this situation occurred as leaf> stem> root. The most important issue here is whether Cr is transported to the organs other than the root of the plant. This study shows that the plant carries chromium to its stems and leaves.

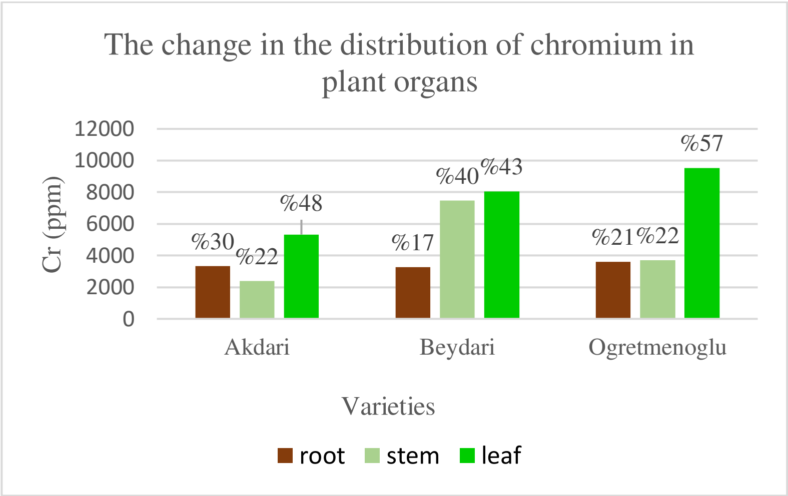

Figure 1. Distribution of chromium (Cr) among the organs of grain sorghum types

Cr concentrations of roots (ppm)

According to the results of variance analysis of Cr amounts of Cr doses in the root region, dose, variety and dose x cultivar interaction was found to be very important ($p < 0.01$). The mean of Cr doses, varieties and dose x variety interactions and LSD test groups are given in Table 6. Looking at the amount of Cr accumulated in the roots of grain sorghum varieties, Ogretmeoglu variety showed the highest Cr accumulation (3608.35 ppm), while the lowest Cr accumulation was shown by the Beydari variety (3258.80 ppm). The Akdari variety followed the Beydari variety in the second place as the amount of Cr accumulation in its roots (3328.49 ppm).

With the increase of the Cr doses, an increase in the amount of Cr was observed in the root region in direct proportion. While the highest Cr amount was observed in 400 ppm Cr treatment, the lowest Cr accumulation was obtained from 0 ppm Cr/control treatment.

When we look at the variety x dose interaction, the highest Cr accumulation in the root region was obtained from 200 ppm Cr treatment of Ogretmeoglu variety, while the lowest Cr accumulation was obtained from 0 ppm Cr/control treatments of all varieties.

Tablo 6. Cr concentration in roots of sorghum varieties (ppm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	Mean
0	32,46±0,34 M**	44,91±7,22 M	66,20±5,97 M	47,86 f**
50	1721±36,17 K	2078,43±61,13 J	1790,49±8,05 K	1863,30 e
100	1614,24±1,14 L	2399,17±49,68 I	2734,33±52,21 H	2249,25 d
200	5342,15±70,57 D	6405,62±29,39 B	7235,34±51,74 A	4895,67 c
300	6150,89±118,92 C	4008,66±19,88 G	4527,48±24,56 F	5007,47 b
400	5110,18±53,54 E	4615,99±108,64 F	5296,24±46,74 D	6327,70 a
Mean	3328,49 b**	3258,80 b	3608,35 a	

**$P < 0.01$, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

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With the increase of Cr doses, Cr concentration increased in the plant root area as well. In addition, when looking at the varieties, it is seen that Cr accumulation varies in different organs of the plant. The order of Cr density for the millet variety was as leaf> root> stem, while for the Beydari and Ogretmeoglu varieties it was leaf> stem> root. Vernay et al. (2008) stated that *Datura innoxia* plant accumulates a much higher amount of Cr (VI) in its roots compared to the stem. Simon et al. (1998) reported that in a study they conducted in Cr-contaminated soil (247 mg kg^{-1} Cr) around an old galvanizing facility, they observed a high rate of Cr accumulation in the roots (up to 160 mg kg^{-1}) especially in the forage radish in the plants grown in this area. Golovatyj and Bogatyreva (1999) stated for a study they conducted that regardless of the soil properties and chromium concentration of Cr uptake, there was more accumulation in the roots compared to other plant organs. In general studies, it is stated that the accumulation is in the root region of the plant, so the results of our study are not similar to these studies. The reason for this is that the chromium doses are very high and the plant dies/completely dries out before it can grow, shortly after the treatment (24-48 hours). That is, the plant took a heavy intake of Cr, transferred it to the leaves and stem, and then died; If the plant could continue to survive, perhaps it would tend to dilute the Cr concentration in these above-ground organs or the plant roots could accumulate more chromium, and in these possibilities, as in studies, the highest accumulation could be detected in the roots of the plant. Petrunina (1974) stated that the addition of Cr to the soil affects the Cr content of the plants and the rate of Cr uptake by plants varies depending on various soil and plant factors.

Cr concentrations of stems (ppm)

According to the results of variance analysis of Cr amounts of Cr accumulated in the stem, dose, variety and dose x variety interaction were found to be very important ($p < 0.01$). The mean of Cr doses, varieties and dose x variety interactions and LSD test groups are given in Table 7.

Considering the amount of Cr accumulated in the stems of grain sorghum varieties, Beydari variety showed the highest accumulation (7458.39 ppm), while Akdari variety showed the lowest accumulation

(2386.92 ppm). Ogretmeoglu variety was the second lowest variety (3704.01 ppm) accumulating Cr in its stem.

With the increase of Cr doses, the amount of Cr accumulated in the stem increased in direct proportion. The highest Cr accumulation (18061.14 ppm) was obtained at 400 ppm Cr treatment, while the lowest Cr accumulation (7.32 ppm) was obtained from 0 ppm Cr/control treatment.

Looking at the variety x dose interaction, the highest Cr accumulation in the stem was given by the Beydari variety in the treatment of 400 ppm Cr, while the lowest accumulation was given by 0 ppm treatment of all varieties.

Tablo 7. Cr concentration in stems of sorghum varieties (ppm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	Mean
0	10,96±0,78 K**	7,38±1,19 K	3,62±0,34 K	7,32 e**
50	264,23±5,27 J	274,65±3,69 J	528,88±5,97 I	355,92 d
100	285,97±5,06 J	769,48±18,56 H	982,22±30,35 G	655,86 c
200	317,63±23,75 J	1086,15±23,51 G	563,79±23,94 I	679,22 c
300	6862,65±41,16 E	7216,85±211,7 D	7938±28,59 C	7339,16 b
400	6580,06±78,37 F	35395,81±347,75 A	12207,56±21,66 B	18061,14 a
Mean	2386,92 c**	7458,39 a	3704,01 b	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

Increasing Cr doses in all sorghum varieties used in the study caused an increase in the amount of Cr accumulated in the stem. Plants have realized the transfer of Cr from the root to the stem. In our study, Cr accumulation in the Beydari and Ogretmeoglu varieties was more in the stem than in the root. In the Akdari variety, the lowest accumulation occurred in the stem. Vernay et al. (2008) stated in their study that there is a difference in terms of chromium accumulation according to different organs of the plant. Karuppanapandian and Manoharan (2008) stated that the toxicity of Cr^{+6} for plants is at the same level in root and stem.

Cr concentrations of leaves (ppm)

According to the results of variance analysis of Cr amounts of Cr accumulated in leaves, dose, variety and dose x variety interaction were found to be very important ($p < 0.01$). The mean of Cr doses, varieties and dose x variety interactions and LSD test groups are given in Table 8.

The amount of Cr accumulated in the leaves of grain sorghum varieties varied between 5323,31-9524,36 ppm. While the highest accumulation showed the Ogretmeoglu variety, the lowest accumulation showed the Akdari variety and these two varieties formed two different average groups. The Beydari variety, on the other hand, formed the third average group as the second highest variety that accumulated Cr in its leaves.

With the increase of Cr doses, an increase was observed in the amount of Cr accumulated in the leaves up to 400 ppm treatment. The highest Cr accumulation was obtained at 300 ppm treatment (29814.5 ppm), while the lowest (29.0 ppm) Cr accumulation was obtained from 0 ppm/control treatment. While 100 and 200 ppm treatments formed the same average group, all other doses formed different mean groups.

Looking at the variety x dose interaction, the highest Cr accumulation was observed in the Ogretmeoglu variety in the treatment of 300 ppm, while the lowest accumulation was observed in 0 ppm/control treatment of all varieties.

Tablo 8. Cr concentration in leaves of sorghum varieties (ppm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	**Mean**
0	32,96±8,89 J**	40,15±4,86 J	13,97±1,38 J	29,00 e**
50	340,14±15,70 IJ	516,55±13,21 I	355,47±5,73 IJ	404,10 d
100	934,31±33,15 H	1062,36±10,15 H	965,49±15,97 H	987,40 c
200	944,31±14,79 H	2295,77±70,83 G	354,57±18,79 IJ	1198,20 c
300	23272,55±33,4 C	24984,87±151,78 B	41186,12±819,53 A	29814,50 a
400	6415,59±519,84 F	19458,65±84,93 D	14270,53±100 E	13381,60 b
Mean	5323,31 c**	8059,72 b	9524,36 a	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

Chromium was transferred to the leaves of the plants in all sorghum varieties used in the study. With increasing doses, chromium concentration in plant leaves also increased. Howe et al. (2003) reported that Cr^{+6} cannot be completely reduced to Cr^{+3} and chromium can pass through vascular tissues. In addition, they stated that Cr^{+6} and Cr^{+3} can be transported to plant leaves easily.

Cr concentrations of soils (ppm)

According to variance analysis results of Cr doses and Cr amounts available in the soil where the varieties are grown, dose, variety and dose x variety interaction were found to be very important (p <0.01). The mean of Cr doses, varieties and dose x variety interactions and LSD test groups are given in Table 9.

It was determined that the amount of Cr remaining in the soil where the varieties were grown varied between 18.38 ppm and 32.22 ppm, the highest Cr amount was found in the soil where the Akdari variety was grown, and the lowest Cr amount was found in the soil where the Ogretmeoglu variety was grown. This variety was followed by the soil where the Beydari variety was grown. Considering the amount of Cr remaining in the soil, it can be said that the varieties that remove the most Cr from the soil are Ogretmeoglu and Beydari.

When the effect of Cr doses on the amount of Cr remaining in the soil was examined, the amount of Cr remained in the soil increased in parallel with the dose increase and the lowest Cr amount (0.033 ppm) was obtained from the control treatment, while the highest Cr amount (61.75 ppm) was obtained from 400 ppm Cr treatment has been.

Table 9. Cr concentration in soils of sorghum varieties (ppm)

Cr dose (ppm)	Varieties			
	Akdari	Beydari	Ogretmeoglu	Mean
0	0,04±0,02 N**	0,02±00 N	0,04±0,01 N	0,03 f**
50	6,98±0,14 JK	6,32±0,11 K	2,36±0,26 M	5,22 e
100	15,69±0,16	7,9±0,13 J	3,55±0,08 L	9,05 d
200	28,04±0,52 F	19,5±0,30 G	10,42±0,32 I	19,32 c
300	61,36±0,37 B	35,39±1,99 E	36,11±0,12 E	44,29 b
400	81,18±0,78 A	46,3±1,21 D	57,78±1,06 C	61,75 a
Mean	32,22 a**	19,24 b	18,38 b	

**P < 0.01, level of significance; capital letters show significant differences between the interactions of varieties and doses; small letters show significant differences between the averages of varieties and doses

When we look at the interaction of variet x dose, Akdari variety gave the highest Cr amount in the soil at 400 ppm Cr treatment, while the lowest Cr amount was given by 0 ppm Cr/control treatment of all varieties.

As the amount of Cr treatment to the soil where the plants were grown increased, the amount of Cr available in the soil also increased. It was determined that not all of the chrome in the soil was used in all varieties, but Beydari and Ogretmeoglu varieties removed more Cr from the soil than Akdari variety. Kasmiyati et al. (2016) in their study that treatment Cr to different sorghum varieties, they stated that the growth responses and Cr uptake rates of sorghum varieties to Cr+3 stress differed both in the germination phase and in the early seedling period. Two varieties were evaluated as sensitive. Petrunina (1974) stated that the Cr content in plants is mainly dependent on the soluble Cr content of the soils; However, he stated that the addition of Cr to the soil affects the Cr contraction of plants and the rate of Cr uptake by plants varies depending on various soil and plant factors.

CONCLUCSION

As the amount of Cr applied to the soil where the plants are grown increased, the amount of Cr available in the soil increased. It has been determined that all the chromium in the soil is not used in all varieties, but the Beydari and Ogretmeoglu varieties remove more Cr from the soil than the Akdari variety. Kasmiyati et al. (2016), in their study where they applied Cr to different sorghum varieties, stated that the growth responses and Cr uptake rates of sorghum varieties against Cr^{+3} stress differed both in the germination phase and in the early seedling period, and while they classified four sorghum varieties as very strong tolerant under Cr^{+3} stress conditions, They evaluated the two varieties as sensitive. Petrunina (1974) stated that the Cr content in plants depends mainly on the soluble Cr content of the soils. Most soils contain significant amounts of Cr, but its availability in plants is rather limited; however, he stated that the addition of Cr to the soil affects the Cr content of the plants and the rate of Cr uptake by plants varies depending on various soil and plant factors.

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CHAPTER XXI

A NEW FORAGE CROP TEDERA (*Bituminaria bituminosa* L): GROWN WITH LOW INPUTS IN POOR CONDITIONS

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INTRODUCTION

The emission of greenhouse gases, which are found naturally in the atmosphere and prevent the extreme cooling of the Earth, has increased as a result of human activities, especially carbon dioxide, methane and nitrogen oxide since the Industrial Revolution. The agricultural sector is one of the areas where the effects of global warming will be widely felt. It is expected that especially individual farmers and consumers will be affected by global and regional climate changes (Karaca et al., 1995). As it is known, annual precipitation and temperature distribution in agriculture is of great importance for which crop to grow. With global warming, both annual precipitation and temperature distribution will change all over the world. Therefore, which crop will be grown will be determined accordingly (Pittock, 2005). In recent years, in terms of food security, it is seen that plants with high adaptability have started to come to the fore in the stress environments brought about by global climate change. In addition, although alfalfa is grown in fertile lands irrigated in summer and sainfoin in regions with high altitude, there is a need for drought and temperature resistant legume forage plants that we can grow in low-yield, low soil depth, sloping and stony areas. As a matter of fact, in the experiments conducted in Australia, it was determined that tedera adapted to extremely hot and dry conditions better and was more productive than clover, and showed rapid regrowth after grazing with sheep (Real, 2012). Some hopeful plants belonging to the legume family, which are neglected or rarely used, stand out not only with their importance in animal nutrition, but also with their improvement of soil properties and resistance to extreme conditions.

Very few forage species and varieties are cultivated in Turkey. The country, which has very different climate and soil characteristics, it is not easy to develop forage crops agriculture with existing plants. Therefore, it is important and necessary to include new species and varieties in forage crop farming as well as existing ones.

Bituminaria bituminosa L. (syn: *Psoralea bituminosa* L.) is also popularly known as orman üçgülü, katran yoncası, demir otu, katranlı yaban üçgülü, kayışkıran in Turkey. Intensive research has been carried out on *Bituminaria* species, especially in recent years. Tedera is intensely grazed by animals in the Canary Islands. The plant is very resistant to intense pressure and grazing of animals. In addition to being consumed fresh, it is also fed to animals as hay.

Adaptation

The plant, whose homeland is the Mediterranean basin, is widely distributed in some natural vegetation such as Turkey, Southern Europe, Crimea, Western Syria, Cyprus, Caucasus, Israel, North Africa, Portugal, Spain (Davis, 1965). Spain, Israel and Australia have developed national Tedera research programs (Gintzburger and Le Houerou, 2002; Sternberg et al., 2006; Real et al., 2008; Fernandez et al., 2010; Real et al., 2014). It has been cultivated in the Canary Islands and Morocco for many years. Its cultivation is gradually becoming widespread in the arid western regions of Australia with using new cultivars.

Tedera, a plant belonging to the legume family, is resistant to drought and heat, can continue to grow during the summer months and preserve its greenness. It is one of the most emphasized plants because it can be grown without irrigation at a pH between 4.7 and 8.5 in sloping, stony, soil that has lost the upper soil layer, in wooded and forested areas defined as marginal area. It is an important green feed source for animals.

Despite the fact that Turkey constitutes one of the important natural spreading areas of this species, studies as a forage crop in arid pastures have just begun. However, it is seen that the latest researches are concentrated in Spain, Italy, Israel and some North African countries, which have similarities with Turkey. In Australia, intensive researches are carried out within the scope of a national program with genotypes brought from Mediterranean countries to develop new cultivars suitable for the hot and arid regions of the country. Positive results have begun to be obtained from these studies, and a new variety named Lanza has recently been registered.

All these features make the Tedera an important fodder plant. It is important to work more on this plant, which has a wide spread in the flora of Turkey and has high resistance to poor conditions, and to develop cultivars using in agricultural system.

Taxonomy and morphologıcal features

Kingdom: Plantae

Phylum: Magnoliophyta

Class: Angiospermae

Order: Fabales

Family: Leguminosae

Subfamily: Papilionoideae

Genus: Bituminaria (Psoraleae)

Species: *Bituminaria bituminosa*

There are approximately 150 species in the genus *Bituminaria,* which belongs to the legume family (Hooker and Jackson, 1960). *Bituminari bituminosa* is a perennial species included in this genus. Although the most common species in Turkey is *Bituminaria bituminosa* (Tedera), there are also *Bituminaria acualis* and *Bituminaria jaubertina* species in a limited area (Altun and Tanker, 2000).

When the geographical distribution in the world is examined, there are *B. bituminosa var. bituminosa* (250-1000 mm), *B. morisiana* (Pignatti and Metlecics) Greuter, *B. bituminosa subsp. pontica* A.P. Khokhrjakov, *B. bituminosa var. brachycarpa* (Feldman) A. Danin and *B. bituminosa var. palaestina* (Gouan) Ralf Jahn, *B. bituminosa var. hulensis* (Hula Valley, Israel), *B. bituminosa* (L.) Stirton *var. bituminosa* (300-1000 mm), *B. bituminosa var. crassiuscula* Méndez et al (400-500 mm), *B. bituminosa var. albomarginata* Méndez et al (150-300 mm) (Macaronesian Region) in the Mediterranean Basin.

Bituminaria bituminosa var. bituminosa (L.) Stirton distributed in the Mediterranean Basin is resistant to winter cold. It grows easily in 200-800 mm rainfall regime and alkaline soils. *B. bituminosa var. albomarginata* is more sensitive to winter cold but more resistant to drought. It can be grown easily in 150-300 mm rainfall, its leaves remain green throughout the year. *B. bituminosa var. crassiuscula* has a wide adaptability from humid regions to high altitude regions. It is resistant to winter cold. In cold weather, the plant goes into dormancy.

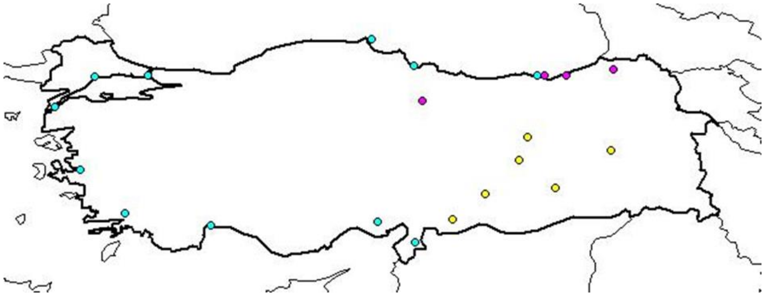

Figure 1. Distribution area of tedera in Turkey (Tubives, 2021)

Bituminaria bituminosa

Bituminaria acaulis

Bituminaria jaubertina

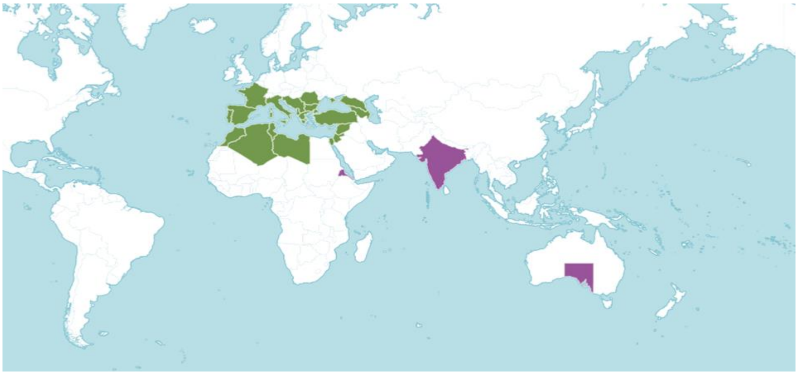

Figure 2. Distribution area of tedera in world (Green: Native; Purple:Introduced) (Anonymous 1)

Bituminaria bituminosa has taproots that can go deep. Its deep roots increase the resistance of the plant to many extreme conditions, especially drought (Beard et al., 2014). It grows easily in soils that have lost the upper soil layer, have a stony problem and are unproductive. It binds the free nitrogen in the air to the soil thanks to the *Rhizobium* bacteria living in its roots (Finlayson et al., 2012; Oldham et al., 2013). Environmental benefits include better use of deep ground water compared to other types, prevention of secondary salinity, and reduction of soil erosion risk (Beard et al., 2014). *Bituminaria bituminosa* can be grown easily in acidic soils where alfalfa does not perform well.

Figure 3. General apperance and root system of *Bituminaria bituminosa*

In *Bituminaria bituminosa* plant, leaves consist of 3 leaflets. The middle petiole stalk is longer than the other petiole stalks. The outside of the leaflets are straight and covered with hairs. Although the shape of the leaflets is lanceolate or oval, they vary depending on the genotype. The number of leaves in the plant 50-596, leaflet width 1.4-3 cm, leaflet length 3.4-5.4 cm are varied (Gulumser et al., 2010). One of the most important features of the tedera is that its leaves can remain green all year. Especially in dry periods, the drying up of many plants in the pastures and their yield decrease, increases the importance of this plant in meeting the need for green feed of livestock. Another important feature is that it does not shed its leaves when used hay, unlike alfalfa. As a result, besides being a better quality feed source, it can easily meet the feed needs of animals in dry periods.

Figure 4. *Bituminaria bituminosa* leaves

Tedera has a purple-violet flower color. Flower community is head, flower state is terminal. It is a long day plant and completes flowering and seed formation in spring. The plant begins to bloom in May, with even a small number of flowers throughout the year. According to Gulumser et al. (2010), the number of head in per plant varied between 3-177, and the number of flowers in per head varied between 5-32. *Bituminaria bituminosa* is a self-fertilizing plant and its chromosome number is 2n = 20 (Nelson et al., 2020). Although it is a self-fertilizing plant, the presence of bees in the environment increases the chance of seed production (Correal et al., 2008).

Figure 5. *Bituminaria bituminosa* blossoms

A seed is formed in each flower whose pollination and fertilization processes are completed. The average seed weight of seeds is 25-33 grams (Gulumser et al., 2010). The seeds have a beak-like structure and feathers. The beak is easily removed by mechanically harvesting and crushing the seed, leaving the oval-shaped seed left behind. Seeds are large compared to many other legumes. Seeds show optimum germination at 15-25 0C. The seeds have a hard seed feature that forces the radicle to exit the seed coat. This hard seed feature can be alleviated by mechanical abrasion or chemical application. If seeds harvested at the beginning of summer are sown in autumn, this hard seed effect is not seen much (Beard et al., 2014).

Figure 6. Beaked and non-beaked seeds of Tedera

Yield and feedıng value

The vegetation of Turkey's pastures is largely composed of cool season forage crops. These plants either dry out completely or go into a dormant period due to the high temperature and drought during the June-August period. For this reason, the productivity of pastures decreases considerably in summer. In this period when other species dry up and forage quality decreases, tedera remains green and increases the yield and nutritional value of pastures. In addition, as the plant continues to develop throughout the year in temperate regions where it adapts, it also provides green forage continuously (Gutman et al., 2000).

Tedera is traditionally used as a fodder for ruminant animals, mainly in Spain and North African countries. In recent studies, it has been determined that tedera has a positive effect on poultry feeding, and that it is a good alternative especially for regions with tropical climates and / or lack of access to cheap protein sources, improving the growth performance of chicks (Barbara et al., 2019). *Bituminaria bituminosa* L. plant is important in providing alternative feed sources for animals with its nutritious feature (Sternberg et al., 2006). It is reported that Bituminaria bituminosa contains more protein and digestible energy compared to *Medicago arborea*, and has similar chemical content with some bush legumes (*Chamaecytisus palmensis*) (Ventura et al., 2009).

Acar et al. (2001) determined that *Bituminaria bituminosa* L., which grows naturally in the OMÜ Kurupelit campus, blooms between the middle of May and the first week of July, grows upright and 100-150 cm height. In the same study, it was determined that the crude protein content of the plant was 15.00% and the crude ash content was 9.50%.

The green organs of the plant have different nutritional properties. Sternberg et al (2006) reported that the leaves of the tedera are good in terms of nutrition. It has been reported that in the tedera plants collected from 16 different locations, the protein ratio in leaf + flower varies between 22.35% and 25.60% (Gulumser et al., 2010).

The yield and nutritional characteristics of the plant change according to the development period. In tedera genotypes collected from different ecological places, as average, some characteristics varied as below; plant height 26.32 - 118.65 cm, dry weight 58.40 - 205.07 g / plant, leaf ratio 59.87 - 78.47%, crude protein ratio 7.28 - 23.41%, ADF ratio%,19.80 - 47.14%, NDF ratio 27.37 - 56.38%, and the relative feed value (RFV) 86.08 - 249.75. In the same study, it was determined that calcium content was 1.28 - 1.87%, magnesium content was 0.36 - 0.40%, phosphorus content was 0.18 - 0.42%, Ca/P ratio was 3.10 - 7.98%, potassium content was 0.51-2.75% and K/(Ca+Mg) ratio was 0.29 - 1.70% in tedera hay (Kumbasar, 2015; Kumbasar et al., 2018). While the ratio of crude protein and leaf decreases with the development of the plant, the ratio of ADF and NDF increases, when only the leaves are considered, the decrease of protein ratio was very limited. Since the accumulation of cellulose in the leaves is very low, the digestibility rate and nutrient accumulation are higher compared to the stem. In a study in which Ventura et al. (2004) examined the mineral content of tedera plants at different growth stages, the Ca content was 0.86-1.13%, the P content was 0.25-0.32%, the Mg content was 0.18-0.26%, and the Na content was 0.22-0.30%. and the K content was 0.26-0.33%.

In a study conducted on 42 tedera genotypes, the plants were harvested at four different times (January, April, July, November). Morphological characteristics, feed quality and mineral substance balance were examined in the study. Even if there are seasonal fluctuations, the crude protein ratio is determined to be high and the ratio of ADF and NDF to be low in every period (Tuzen Şahin et al., 2020). It was stated by the researchers that there was no irrigation and fertilization in the study area, and no diseases and pests were detected. Therefore, tedera can be used as pasture and forage crops in low-yielding areas that cannot be irrigated when suitable varieties are developed.

It was determined that the protein content of tedera hay ranged from 10.3% to 20.4%, the ADF content between 23.8% and 41.9%, the NDF content between 38% and 56.3%, and the digestibility rate between 46% and 51% (Ventura et al., 2004; Alvarez et al., 2004; Sternberg et al., 2006; Pecetti et al., 2007; FAO, 2010). Acar et al. (2016 a, b) stated that the hay yield per plant varied between 83-994 g, and the average crude protein in the early vegetative period was 23%, ADF 20%, NDF 30% and RFV value 150.

It has a winter dormancy feature similar to alfalfa. Plants slow down their growth before entering winter and are least affected by winter cold. In a study carried out with tedera genotypes collected from different altitudes, it was found that there was a very important relationship between altitude and plant height, number of harvest and yield, genotypes adapted to high altitudes entered the dormant phase in autumn and started to develop late in the spring, so the plant height, harvest number and yields were lower (Acar et al., 2020).

Gutman et al. (2000), in a study they conducted, determined that *Bituminaria bituminosa* L. plant is highly resistant to intense grazing pressure.

Considering the vegetative component and mineral content of the tedera plant and its ADF, NDF and Relative Feed Value, we can say that it has the potential to be a very important forage plant and pasture plant in non-irrigated, barren, hot and arid regions. Of course, there must be continuity of research in order to get more benefits from this plant.

Cultivation

Tedera is resistant to many adverse conditions, especially drought, due to its deep root system and other physiological and morphological features. Being a legume plant and performing symbiotic nitrogen fixation thanks to the *Rhizobium* bacteria living in its roots provides the improvement of the soil structure (Foster et al., 2012). A wide variety of soil types and the fact that it can be cultivated easily in regions where rainfall is limited has enabled tedera to be recognized as a promising species (Real and Verbyla, 2010). Although the cultivation of many plants is difficult in areas with salinity problems, tedera can be cultivated easily. In a study conducted on genotypes collected from 85 different places, it was reported that some genotypes were resistant to salinity and these genotypes could be used in the evaluation of salty areas (Kaymak and Acar, 2020).

Unlike many other plants, tedera plant does not have soil selectivity. It grows easily on roadsides, under forests and trees, at pH between 4.7 and 8.5, on stony, low-depth soils with lost upper soil layer (Kaymak and Acar, 2020).

The seed of tedera is larger than alfalfa and clover types. In a study, the appropriate planting depth was determined as 2-8 cm. In shallower sowing, the seeds died before germination or showed low seedling output as they had less contact with the soil. Although there was a delay in cotyledon formation at 10 cm sowing depth, 65% of the seeds germinate and seedlings emerged (Beard et al., 2014).

Although the optimum germination temperature for tedera seeds is between 15-25 ° C, it easily germinates at temperatures ranging from 5 °C to 35 °C. Its slow growth and low water use increase its role in areas where alfalfa farming is limited. Growing in areas such as South Australia and similar climatic zones where alfalfa is not well-adapted and especially in soils with low P levels or in mixed farming systems such as the Mediterranean where there is a need for green fodder in summer and autumn, increases the potential of this plant (Ward et al., 2017).

The hard seeding feature limits the agriculture of the tedera. In recent years, studies have been carried out especially on removing this hard seed. Approximately 70% of freshly harvested forest clover seeds are hard and cannot absorb water (Real et al., 2009). They exhibit primary dormancy approximately three months after maturation (Beard, 2009). After this time, the seeds will generally germinate at 100%. The exact cause of this dormancy is unknown and is an obstacle to rapid hybrid seed production in the breeding program. After this restriction is lifted, germination is possible. Natural and artificial softening of the seed coat are ways to overcome this dormancy. Natural smoothing; It includes variable temperature applications, forest fires, grazing by animals and then excretion with faeces (Baskin and Baskin, 2004). Artificial softening can be made by mechanically or chemically. These processes allow water absorption and root formation by eroding the seed coat from its weak point (Vilela and Ravetta, 2001; Koornneef et al., 2002; Finch-Savage and Leubner-Metzger, 2006).

Other usage areas

In addition to being a fodder plant, tedera is also a medicinal plant. It contains some secondary metabolites. The amount of secondary metabolites that give the plant a unique odor varies significantly according to the genotype and ecological conditions (Pecetti et al., 2007; Real, 2012; Correal, 2012). While these metabolites play a role in the plant's defense mechanism, they also have beneficial effects on human physiology and healing of diseases due to their bioactive molecules. Secondary metabolites with pharmacological effects in *B. bituminosa* plant can be counted as furanocoumarins, isoflavonoids and pterocarban (Martinez-Fernandez et al., 2010). These substances are used in the cosmetic industry and treatment of diseases such as vitiligo, psoriasis, fungus, eczema, sunburn, skin cancer and colon cancer, as well as Mediterranean anemia, anti-inflammatory, sedative, and allergenic diseases (Pistelli et al., 2003; Pazos-Navarro et al., 2012). The secondary metabolites and antioxidant substances in the plant not only positively affect animal health, but also increase the quality of animal products (Pecetti et al., 2007).

In a study conducted on 12 tedera genotypes, plants were harvested in three different periods (growth initiation, budding and flowering initiation) and plant extracts were obtained. In the study, the effect of the extracts obtained from the leaves on the growth performance of wheat was examined, the best development was determined in the extract obtained during the budding period, as a result, the tedera plant showed a positive allellopathic effect (synergistic) in wheat (Acar et al., 2019). In the same study, secondary metabolites of psoralen, angelicin, daidzein and genistin were determined in tedera, and the density of these compounds differed according to the development period of the plants and their genotypes.

Regarding the content of *B. bituminosa* plant, Tava et al. (2007), psoralen and angelicin furanocoumarins were detected in essential oil obtained from leaves and stems. Furanocoumarin (psoralen and angelisin) contents were also investigated during different growth stages of tedera plants (Pazos-Navarro et al., 2012). Furanocoumarin analyzes were performed on samples taken in April, August and November, and the highest values were found in samples taken in August (Walker et al., 2006). Increased temperature and UV light intensity increase the plant's furanocoumarin content (Bourgaud et al., 1995).

Daidzein, a compound used in pharmacology, reduces the risk of breast cancer, provides protection against bowel cancer, promotes estrogen secretion in the body, and is used in alcohol treatment (Sun at al., 2016). Psoralen is used in the treatment of vitiligo disease. Vitiligo is a disease that progresses with the whitening of the skin due to the loss of the substance (pigment) that dyes the skin. Coumarin that is a plant chemical present in the plant in free form or combined with glucose. It has blood thinning, antifungal and anti-tumor effects. It increases the amount of blood in the veins and decreases capillary permeability. It can be toxic when used in high doses for a long time (Smith, 1962).

CONCLUSION

More researches should be done on tedera because of its wide adaptation ability, resist to extreme conditions where many plants cannot grow, especially drought, and its superior nutritive value in terms of animal husbandry. The severity of global warming, which threatens the world and our country, is increasing day by day. For this reason, it becomes necessary to cultivate plants that need less water. Tedera, which grows and stays green throughout the year without the need for irrigation, is a promising plant for years to come.

In areas where alfalfa farming is difficult, tedera can be grown easily. It is consumed fondly by sheep, goats and cattle in Morocco, Canary Islands and Australia where it is cultivated and where it grows naturally. Since it is a perennial species, tedera can be used both in field agriculture and in pasture mixtures. Thanks to being a legume plant, it causes improvement in the soil structure with the help of bacteria living in its roots, leaving a nitrogen-rich soil for the next plant.

In addition to all these properties, secondary metabolites in its leaves and stems are used in the treatment of many diseases. These secondary metabolites provide benefits on both animal health and human health.

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CHAPTER XXII

SILAGE ADDITIVES

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INTRODUCTION

The most important nutritional problem of the country's livestock breeding is the lack of quality roughage, as well as the inability to meet the need for green and juicy roughage throughout the year. In order to meet this need, silage production has gained importance in our country in recent years. When it comes to silage, the first plant that comes to mind is corn. In our country, forage crops such as corn, alfalfa, vetch, barley, wheat are used alone or as a mixture (Seydoşoğlu, 2019a,b; Seydoşoğlu and Gelir, 2019; Görü and Seydoşoğlu, 2021) . Many studies have shown that cereals are fermented more easily and are more suitable for silage making than legumes. Low soluble carbohydrate ratio and high protein ratio negatively affect the growth of lactic acid bacteria. In this case, fermentation cannot be performed successfully in legumes (Özbay 2007, Davies et al., 1998, Singh, 1996, Pitt, 1990; Raquse and Smith, 1966). Fermentation is the first condition for a quality silage. Otherwise, the silage will deteriorate and mold. Three days after silage is very important. Lactic acid bacteria production should increase and accordingly the pH should be lower than 4. Lactic acid production depends on the sufficient level of water-soluble carbohydrate in the environment (Kılıç, 1986; Kung, 2010). If pH does not fall to the desired level, it causes a condition called "proteolysis". In other words, it is the breakdown of the real proteins in the feed up to ammonia (Atalay, 2009). This means that some of the real protein, one of the most valuable nutrients, is wasted by enzymes. In addition, nitrogen excreted in the urine poses a significant threat to the environment (Winters et al., 2000). As a result; The higher the lactic acid production rate, the lower the pH and the less proteolysis.

Dry matter amount, shape length and additives used are the most important factors determining the silage quality (Haigh, 1988). How to apply it is important in the use of additives. First of all, it should be suitable for the characteristics of the plant to be silaged. It is important to use it in a timely and correct manner. The silage additives used should be allowed to mix homogeneously with the silaged material. The additives can be added to the material to be sieved during the shredding process or during the filling of the shredded material into the silo. However, additives used in small amounts should be added to the material during the shredding process (Dumlu, 2007). Studies have shown that adding additives to silages generally increases silage quality. As a matter of fact, additives are needed to overcome some of the generally known deficiencies for species other than maize.

The researcher named Kaiser (1999) classified the additives, which can be examined under different groups according to their mechanism of action, structure and purpose of use, as follows.

Fermentation stimulants

a) Fermentable carbohydrates Sugar sources such as molasses, sucrose, glucose, citrus pulp, pineapple pulp, sugar beet pulp

b) Enzymes such as cellulases, hemicellulases, amylases

c) Inoculants such as lactic acid bacteria (LAB)

Fermentation inhibitors

a) Mineral acids (eg hydrochloric), acids such as formic acid, acetic acid, lactic acid and organic acid salts,

acrylic acid, calcium formate, propionic acid, propionates

b) Other chemical inhibitors such as formaldehyde, sodium nitrite, sodium metabisulfite

Aerobic spoilage inhibitors

Some inoculants such as propionic acid, propionates, acetic acid, caproic acid, ammonia

Nutrients

Such as urea, ammonia, grains, minerals, sugar beet pulp

Absorbents

Such as cereal, straw, bentonite, sugar beet pulp, polyacrylamide

Commonly used silage additives to improve crop protection and feeding value are described below.

Fermentation stimulants

One of the most used additives to enrich the carbohydrate ratio of silage is melast. Molasses is known to be an effective silage additive in terms of promoting lactic fermentation, lowering silage pH, preventing clostridial fermentation and proteolysis, and generally reducing organic matter losses (Yitbarek and Tamir, 2014). It is added at a rate of 1-6% depending on the type of the feed. For the same purpose, ground corn, barley, oat seeds, corn cobs can be added at a rate of 50-100 kg per ton. Whey, beet and citrus pulp, potato and turnip pieces can also be added to increase the carbohydrate content of the silage. In a study investigating the effects of different withering times and additives on silage in alfalfa, silage made from clover using molasses + crushed barley additives was the best quality silage (Gül et al., 2015).

Lactic acid bacteria have been used as silage additives in recent years in order to facilitate silage fermentation and prevent spoilage. These additives, which contain the frozen dry and powdered cultures of live lactic acid bacteria, are considered as biological silage inoculants (Pahlow, 1986). Various improvements have also been achieved in important performance criteria such as milk yield, live weight gain and feed efficiency of silages made with lactic acid bacteria (Harrison, 1989; Muck, 1993; Kung and Muck, 1997; Kung et al., 2003).

Fermentation inhibitors

The use of formic acid is commonly used to stimulate the growth of lactic acid bacteria. While molasses is used as an energy source in lactic acid formation, bacterial inoculants are used for the formation of organisms that should be in the silo material. Studies show that the use of formic acid has a generally positive effect on fermentation (Singh et al., 1996; Haigh, 1988; O'kiely, 1992). It has been determined that bacterial inoculants reduce the pH and positively affect the lactic acid bacteria. The use of organic acid as an additive has a positive effect on the feed and energy values of silages (Filya and Sucu, 2003). Many acids such as formic, propionic, acetic, lactic, kapoic, sorbic, benzoic acid are preferred as silage additives in order to increase the quality and consequently animal yield in silages. The most used of these is formic acid (Kılıç, 1986; Coşkun et al., 1998). It is recommended to use formic acid diluted to a level of 1:20 (McDonald et al., 1991). The salt additive used to prevent the growth of unwanted bacteria in the silage technique increases the silage quality (Kılıç, 1986; Koç et al., 1999; Dumlu, 2007).

Aerobic spoilage inhibitors

Although propionic acid is weak compared to formic acid and mineral acids, they are more useful additives for silage (Yitbarek and Tamir, 2014). For corn silage, it is recommended to use propionic acid at 0.2% to 0.5% usage rates (Beck, 1975). They are preferred to improve fermentation, enrich and sterilize the silage and prevent unwanted growth. Bacteria inoculation (lactic acid bacteria), enzyme (amylase, protease), sugar (glucose, sucrose, dextrose, acid propionic, lactic, sulfuric, hydrochloric), ammonium, urea, CO_2, sodium sulfate and minerals are examples (Liu and Guo, 2010).

Nutrients

They are used to facilitate the formation of silage in low sugar content and protein-rich products such as legume forage crops. There is no need for grain for corn silage. However, it increases energy in grass silage. If there is not enough withering, it increases the dry matter. As a carbohydrate source, they facilitate fermentation and help silage to be successful by lowering the pH. In a study where salt and grains were used as additives, the dry matter ratio increased from 31.44% to 39.16% in general. The silage pH has decreased from 5.43% to 5.02% (Dumlu, 2007). Sugar beet pulp has highly digestible fibers. Crude protein value is approximately 10% (Yörük et al., 2014). It is also used as pulp, but it is more convenient to consume it by silage. Its dry matter ratio is very low. In a study, wheat straw, alfalfa straw and vetch were separately silosed. In this study where molasses was used as an additive, high quality silages were obtained in all groups (Yörük et al., 2014). Similarly, Deniz et al. (2001) stated that sugar beet pulp should be supplemented with molasses and dry matter due to its low dry matter and soluble carbohydrate content. Urea and ammonia are used to increase the nutritional value of silages. It has been reported that ammonia can be used in making silage of low protein plants due to late harvesting (Magno et al., 1986; Moore et al., 1986). However, since their positive effects on silage quality are not very evident, they are not used much today (Kılıç, 1986).

Absorbents

Low dry matter makes it difficult to ferment. Ph and butyric acid increase. Loss of nutrients occurs with leakage (Etgen et al., 1987; Miller, 1992). Withering is the first application to reduce dry matter. Its purpose is to prevent nutrient loss due to respiration (Etgen et al., 1987; Spoelstra and Hindle, 1989). The withering time should be adjusted well. If the plants wither for a long time, the carbohydrate in the feed decreases. Ph cannot reach the desired level (Pitt, 1990; Açıkgöz, 1995). In addition to withering, additives that increase the dry matter level should also be used. The most preferred are straw and ground grain feeds. In addition, dried sugar beet pulp, dried citrus pulp, oat pods and cotton seed pods are also used (Coşkun et al., 1998; Kılıç, 1986; Courtin, and Spoelsra, 1989; Kamphues et al., 1983).

Things to Consider When Using Additives

-It should not be dangerous for the health of the employees

- It should not have a negative effect on the productivity of the animals.

-It should be equally distributed to all sides of the feed.

-It should increase the durability of silage

-It should be easy to apply and should not require a high level of knowledge.

The addition rates of additives to silage are given in Table 1 (Tan, 2016; Tan, 2018).

Table 1. Rates

Molasses	%2-5
Beet pulp	%15-20
Beet	%8-20
Crushed grain	%5-10
Salt	%1-3

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