ALTERNATIVE FORAGE CROPS- II

EDITOR: Assoc. Prof. Dr. Gülcan DEMİROĞLU TOPÇU

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PREFACE

One of the most important problems of the enterprises is to provide the quality roughage required for livestock activities in a healthy way. Demand of Increasing the feed production required by the animals and on the other hand reducing the increasing costs push the producers to search for many alternatives. Their expertise in forage crop production and their access to the necessary tools to grow alternative forage crops suggest that many producers can implement the idea of diversifying their production. Legumes and grasses are generally used in the production of forage crops. However, many plant species from other families are also used as fodder plants. Many annual and perennial species, which are among these plants that can be used both as cultivated and as they are found in nature, and which we can define as alternative forage crops, will help livestock enterprises by supporting legumes and grasses used primarily in forage production. Alternative forage crops, on the one hand, provide diversity to the producers, on the other hand, they will also support the planting plans of the producers with different vegetation periods In this book, there is information such as climate and soil requirements of some other alternative forage crops that are not included in the ALTERNATIVE FORAGE CROPS- I, Cultivation and utilization areas of some alternative forage crop species.

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CHAPTER 1

SUNN HEMP (*Crotalaria juncea* L.)

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1. INTRODUCTION

Livestock farming in Türkiye encounters economic, technical, and certain cultural constraints, impeding the progress of cultivating forage crops, a crucial source for fulfilling the high-quality forage needs of farm animals. Despite the acknowledged significance of advancing forage crop cultivation and the emphasis on new research for the future of national animal husbandry, desired advancements have not been realized due to a variety of challenges. Ensuring the supply of high-quality forage stands as one of the most critical challenges for fostering healthy livestock activities within livestock operations. Given that approximately 70% of expenses in livestock farming are attributed to feed costs, coupled with the current state of meat prices in our country, the significance of producing high-quality forage becomes unmistakable.

Although there exist numerous alternative forage crops that could be cultivated in our country, the cultivation of these crops remains limited. In contrast, many other countries, especially those with advanced animal husbandry practices, employ a variety of forage crops. In regions of our country characterized by the Mediterranean climate, successful cultivation of well-known and widely used plants worldwide is feasible. Sunn hemp (*Crotalaria juncea* L.), an annual summer legume, has been identified as having promising potential in our country due to its various usage opportunities. Therefore, experiments with *Crotalaria juncea* L. have been conducted since 2016 in the fields of the Department of Field Crops at Ege University, located in Bornova/Izmir, representing the typical Mediterranean climate. The results obtained indicate the successful cultivation of this plant in our country (Demiroglu Topcu and Ozkan, 2019; Demiroglu Topcu and Ozkan, 2021; Ozkan, 2022).

2. SYSTEMATIC AND MORPHOLOGY

The genus *Crotalaria*, a member of the Genisteae tribe within the Papilionoid Legumes (Papilionoideae), encompasses a diverse array of approximately 600 species. The nomenclature "*Crotalaria*" derives from the evocative notion of "rattle" symbolizing the audible emanations produced by seeds within mature pods (White and Haun, 1965). These species exhibit a broad distribution, thriving in tropical, subtropical, and selectively temperate zones, with adaptability to regions maintaining elevations below 600 meters from sea level in temperate climates.

Crotalaria juncea L., belonging to the Fabaceae family, stands out as an annual plant with versatile applications and global cultivation. Noteworthy counterparts within the genus include *Crotalaria striata*, *Crotalaria spectabilis*, *Crotalaria intermedia*, and *Crotalaria lanceolata*. These species have been cultivated over extensive periods, particularly in the United States and various nations, serving dual roles in soil conservation and amelioration, alongside their utility as forage crops (Ahlgren, 1956).

The paramount species within the *Crotalaria* genus, recognized as *Crotalaria juncea* L. or Bengal Hemp/Bombay Hemp, is commonly acknowledged as indigenous to India. Its deployment extends to soil reclamation, fiber production, and as a forage crop. Within tropical realms, notably in Indonesia, Malaysia, Taiwan, Thailand, and China, it finds prominence as a robust green manure crop. In South Asian territories, it has sustained historical significance as a pivotal fiber crop, contributing to the production of ropes and paper (Rotar and Joy, 1983).

Systematic (Anonymous, 2023)

Kingdom Plantae	: Plants
Subkingdom Tracheobionta	: Vascular plants
Superdivision Spermatophyta	: Seed plants
Division Magnoliophyta	: Flowering plants
Class Magnoliopsida	: Dicotyledons
Subclass	: Rosidae
Order	: Fabales
Family Fabaceae	: Pea family
Genus	: *Crotalaria* L. (rattlebox)
Species	: *Crotalaria juncea* L. (sunn hemp)

Crotalaria juncea L. is an herbaceous plant that typically thrives in tropical regions, exhibiting an upright growth habit with a potential height range of 2.5 to 4 meters. Its lance-shaped leaves, arranged spirally along the stem, are structurally simple, featuring a width spanning from 0.5 to 3.0 cm and a length of 4 to 12 cm, displaying a vibrant green hue.

The plant is characterized by a robust taproot and well-developed lateral roots, while the stem can attain a diameter of up to 2 cm. When cultivated under conditions with a shorter daylight duration, the flowering process commences approximately eight weeks after the initial planting

Figure 1: Leaves and flowers of Sunn hemp (original)

The flowers form clusters, measuring 8-20 cm in length, featuring hairy sepals measuring 1.5 cm in length and petals measuring 2-5 cm in length, presenting a striking yellow color. The fruit takes the form of a cylindrical pod covered in short velvety hairs, enclosing 6-12 seeds. These curved, heart-shaped seeds have dimensions of 6-7 mm in length and may vary in color from dark brown to black. The weight of a thousand seeds is approximately 35-50 grams (Rotar and Joy, 1983; Chaudhury et al., 1997; Mosjidis and Wang, 2011; Al-Snafi, 2016; Demiroğlu Topçu and Özkan, 2018).

Figure 2. Illustration of sunn hemp (*Crotalaria juncea* L.) (Anonymous, 2023)

3. ADAPTATION

Crotalaria juncea L., commonly known as sunn hemp, is the fastest-growing species within the *Crotalaria* genus and exhibits high adaptability to both tropical and subtropical climates. Successful cultivation is feasible in regions with elevations below 600 meters from sea level, particularly in temperate zones (Rotar and Joy, 1983). Moreover, it exhibits adaptability to diverse soil conditions, thriving in soils with an average annual temperature ranging between 15.0-37.5°C and a soil pH between 5.0-8.4. For fiber production, it is advisable to cultivate *Crotalaria juncea* L. in very light and well-drained soils with a sandy or loamy structure that retains sufficient moisture.

For optimal seed germination, it is advised to sow in a well-prepared seedbed with soil moisture levels not falling below 30%. The timing of sowing significantly influences the vegetative growth and development of *Crotalaria juncea* L. Despite

being a short-day plant, vegetative growth is more advantageous during longer daylight periods, making April and May the optimal sowing months. Late sowings result in a shortened vegetative growth period, reduced plant height, decreased internode count, and narrowed stem diameter.

Recommended practices include sowing *Crotalaria juncea* L. in rows, with seeds typically sown at a depth of 2-3 cm. Research indicates that narrow-row planting yields higher seed production compared to wide-row planting, with an ideal row spacing of 20-30 cm. The inter-row distance should be maintained between 5-10 cm if necessary. Germination is epigeal, occurring within approximately three days. Plant growth is significantly affected by the sowing date and early-season rainfall.

Figure 3: Seeds of Sunn hemp (original)

The seeding rate depends on germination and soil moisture, with a minimum germination rate of 80%. For row planting, 20-30 kg per hectare of seeds is recommended, while for broadcast planting, 40-50 kg per hectare should be used (Chaudhury et al.,1997). As a leguminous plant, *Crotalaria juncea* L. does not necessitate nitrogen fertilization, but applying a small amount of nitrogen fertilizer at planting can enhance yield. For green manure purposes, planting can occur in any month, with subsequent burial of plants around the 30th or 45th day of the growing season. Weeds are generally left unmanaged, except for *Ipomoea* spp., which may grow concurrently with sunn hemp.

Figure 4: Sunn hemp epigeal germination and stem diameter(original)

Figure 5: Pods of Sunn hemp (original)

Harvest timing varies based on ecological conditions and cultivation goals. The recommended harvest time for fiber production is during flowering or when the seed pods are fully ripe. It is noteworthy that there is little discrepancy in strength and fiber quality during this period. Additionally, in certain regions, the upper part of the plant (approximately 30 cm) is initially mown and utilized for fodder. Following harvest, the plants are categorized based on their height and thickness, bundled into approximately 20-25 cm bundles, and left in the field for 2-3 days to facilitate leaf shedding. Subsequently, the leaves are manually removed, and the stems are directly sent for retting. In some parts of India, the plants are left on the ground for 10-15 days, and the separation of fibers takes place overnight with sufficient dew, which can be quite substantial (Duke, 1981).

For green forage or silage production, the optimum harvest period is around 50% flowering and early pod stages. Harvesting can be performed at ground level using a sickle or a machine. Moreover, during this period, it is also utilized for grazing in some countries around the world.

The seed yield of sunn hemp exhibits considerable variation, influenced by factors such as planting time, variety, and the impact of diseases and pests. Ideally, in the chosen region for seed production, the latitude should not exceed 24°N, temperatures should not drop below 10°C, ample sunlight should be available, and there should be no precipitation during the fruiting period. Cultivation areas in India typically range between 17-30°N. In Brazil, it is feasible to cultivate the plant in the equatorial zone up to 22.5°N, under conditions of moderate to heavy rainfall. Under optimal conditions, the average seed yield is in the range of 300-700 kg per hectare.

4.YIELD AND QUALITY

4.1. Nutritive value of forage

Crotalaria juncea L. is recognized as the most aggressive species within its genus (Mosjidis and Wang, 2011). Furthermore, it can achieve a green forage yield of 27 t ha^{-1} in 60 days (Warren et al., 2012), and the rapidly growing plant attains a height of 1.2 meters 60 days after sowing and 1.8 meters after 90 days (Rotar and Joy, 1983; Mansoer et al., 1997). The leaves of the plant are known to contain 30% protein (Warren et al., 2012). Additionally, Mansoer et al. (1997) reported in their study that the ratios of lignin, cellulose, and hemicellulose in the leaves were lower at each harvest time than the ratios in the stem. Sheep and goats have been observed to prefer the leaves and upper parts of the plant (Burke et al., 2011).

Figure 6: General appearance of the Sunn hemp (original)

Grazing can be initiated when the plants reach approximately 45-90 cm in length. Despite having high leaf quality (about 4-5% N equivalent, 25-30% protein, 22-28% NDF, 22-27% ADF), the stem quality is low (about 1.3-1.7% N equivalent, 8-10% protein, 74-76% NDF, 64-65% ADF). However, the stems can provide the roughage needed by ruminants. Intensive growth until flowering may lead to the loss of some lower leaves and a decrease in forage quality. When the plant is 80% flowered, approximately 35-40% of the biomass consists of leaves. Consequently, early harvest is preferable for forage use because the plants are less mature, leading to an increase in leaf proportion and improved forage quality. Additionally, *Crotalaria juncea* L. has demonstrated successful results in silage production (Coutinho et al., 2011; Demiroglu Topcu and Ozkan, 2021; Ozkan, 2022). In some regions of the world, such as South Africa, Brazil, and Hawaii, it is also cultivated as a green manure and cover crop (Romin and Fitt, 1938; National Academy of Science, 1979; Rotar and Joy, 1983; Stallings, 2015; Meagher et al., 2017).

4.2. Green manure and crop rotation

In animal production, leguminous forage crops serve as the primary source for providing the crucial input of feed, playing a vital role in enhancing feed quality. These plants not only contribute to animal nutrition but also, through the *Rhizobium* bacteria in their roots, fix atmospheric nitrogen into the soil. This process not only improves soil structure but also enhances the yield and quality of subsequent crops in crop rotation. The nitrogen fixed by leguminous forage crops becomes a significant nitrogen source for non-nitrogen-fixing plants in mixed plantings (Duke, 1981; Lindemann and Glover, 2003). Research indicates that common vetch (*Vicia sativa*) can fix 180 kg ha^{-1} of nitrogen, and hairy vetch (*Vicia villosa*) can fix 110 kg ha^{-1} of nitrogen (Erkovan, 2007).

Crotalaria juncea L. is widely grown as green manure worldwide (Diamond, 2006). Under suitable soil conditions, *Crotalaria juncea* L. can provide sufficient fertilizer to meet the nutritional requirements of many plants for N, P, and K (Phatak et al., 2002). *Crotalaria juncea* L., known for its soil improvement capability and suitability as a summer crop, provides approximately 165 kg ha^{-1} of nitrogen to the soil (Rotar and Joy, 1983). This value is considered quite satisfactory for a rapidly developing summer crop. As most nitrogen and other macro-nutrients are present in its leaves, the early or mid-flowering period is the most suitable for incorporating

Crotalaria juncea L. into the soil as green manure or organic mulch (Marshall, 2002).

The organic matter of *Crotalaria juncea* L. decomposes rapidly in tropical climates (approximately 2 weeks), with the highest nitrogen mineralization rate occurring during this period (Wang et al., 2004). Therefore, producers should plan to seed and fertilization practices to ensure that nutrients are readily available in the soil within the first 2 weeks after incorporating *Crotalaria juncea* L. residues.

Crotalaria juncea L. residues can be left on the soil surface as organic mulch. This mulch decomposes much more slowly over an extended period. The use of *Crotalaria juncea* L. plant residues as surface mulch in strip-tillage systems allows some residues to be incorporated into the soil, releasing nutrients immediately, while others remain on the soil surface, gradually releasing nutrients as mulch (Reeves et al., 1996).

The most significant advantage of *Crotalaria juncea* L. in crop rotation systems is its ability, as a leguminous plant, to fix atmospheric nitrogen in its root nodules, thereby meeting its nitrogen needs and having a good potential for soil improvement. Additionally, it is beneficial in rotations for areas exposed to nematode infections (Wang et al., 2002; Kamil et al., 2009). Rotation trials have been conducted with crops such as sugar cane, rice, wheat, and jute (Barros Salgado et al., 1972). In Cuba, it is rotated with kenaf, and in the U.S., it is rotated with cotton. In Brazil, it is rotated with wheat, sorghum, sugar cane, and beans. It has been determined that planting *Crotalaria juncea* L. before beans increases yield by an average of 41%. In India, suitable cropping patterns include rotations such as sunn hemp-wheat, sunn hemp-potato, sunn hemp-rice-wheat, sunn hemp-mustard, and sunn hemp-mustard-wheat. Studies on various combinations have shown that planting sunn hemp as a preceding crop increases wheat yield by 10-15% (Chaudhury et al., 1997).

4.3. Toxicity

Research on *Crotalaria juncea* L. in the United States commenced in the 1930s (Cook and White, 1996). *Crotalaria juncea* L., with its rapid growth potential, has been included in the breeding program by the National Academy of Science (1979) to increase its potential uses and benefits. Previous studies on this plant have frequently expressed concerns about potential toxic effects in animal nutrition,

particularly regarding its seeds or green tops used as fodder (National Academy of Science, 1979; Purseglove, 1981; Rotar and Joy, 1983; Williams and Molyneux, 1987; Strickland et al., 1987; Hess and Mosjidis, 2008; Mosjidis et al., 2012). However, recent research and the development of new varieties have demonstrated the absence of toxic effects (National Academy of Science, 1979; Purseglove, 1981; Rotar and Joy, 1983; Williams and Molyneux, 1987; Strickland et al., 1987; Hess and Mosjidis, 2008; Mosjidis et al., 2012). However, some researchers have conclusively determined that only certain species within the same genus, such as *Crotalaria spectabilis*, *Crotalaria retusa*, and *Crotalaria pallida*, are toxic (Ritchey et al., 1941; Martin et al., 1976; Hooper and Scanlan, 1977; Williams and Molyneux, 1987).

Purseglove (1981) reported that the seeds of *Crotalaria juncea* L. can be utilized as feed for farm animals in certain countries without inducing toxic effects. Rotar and Joy (1983) determined that the seeds of the "Tropic Sun" variety, developed in Hawaii, were non-toxic to animals. In a study conducted by Williams and Molyneux (1987) to ascertain the toxic effects of seeds from various *Crotalaria* species on chicks, it was found that there were no toxic effects of *Crotalaria juncea* L. seeds in chickens fed with 10 mg g^{-1} body weight. Mosjidis et al. (2012) concluded, in their study investigating whether the seeds and forage of *Crotalaria juncea* L., a widely cultivated annual plant in tropical regions, exhibit toxic effects, that this plant serves as a valuable forage source (non-toxic). It was determined that the seeds do not cause acute toxicity in domestic animals, despite the detection of trace amounts of pyrrolizidine alkaloids. Therefore, it was reported that there is no issue in utilizing it as fodder.

4.4. Biofuel and Bio-oil

In global plant production, the emphasis is not only on food supply but also on energy production from plants, particularly focusing on the feasibility of cultivating crops in marginal areas. This approach aims to contribute to the economy by utilizing non-arable lands. Currently, there is a goal to increase forage crop farming to 30% and energy crop farming to 20% of total agricultural production (Eser et al., 2007). Clean biodiesel can be produced from biomass-based agricultural oils. *Crotalaria juncea* L., being a versatile plant belonging to the legume family and capable of being evaluated as a green manure or forage crop, can also be used

to produce biodiesel through transesterification using methanol and different catalysts (Sadhukhan and Sarkar, 2016). Although the energy content of *Crotalaria juncea* L. oil (34.128 MJ kg^{-1}) is slightly lower than that of gasoline (47 MJ kg^{-1}) and diesel fuel (44.8 MJ kg^{-1}), its other characteristics indicate significant potential for use. This biological oil may have the possibility of being used as fuel for a diesel engine with some modifications (additives) (Demiroğlu Topçu et al., 2017).

REFERENCES

Ahlgren, H.G. 1956. Forage Crops. Department of Farm Crops Rutgers University, Mc. Graw-Hill Book Company Inc., 2nd Edition, New York-USA.

Al-Snafi, A.E. 2016. The contents and pharmacology of *Crotalaria juncea*-A review. Volume 6, Issue 6 Version. 2, PP. 77-86.

Anonymous, 2023. https://plants.usda.gov/home/classification/78574

Anonymous,2023a. http://www.cuniculture.info/Docs/Elevage/Figur-Tropic/chapitre3/pl-61-CrotalariaJuncea-1.jpg

Barros Salgado, A.L., Lovadini, L.A.C., Pimental, M., Gimenez, W. 1972. Instrucoes para a cultura da *Crotalaria juncea*. Instituto Agronomico, Campinas, Brazil. Secao de Plantas Fibrosas Boletim 198.

Burke, J.M., Mosjidis, J.A., Miller, J.E., Casey, P. 2011. Sunn hemp with chicory or pearl millet to minimize gastrointestinal nematode infection in weaned goats. J. Anim. Sci. 89(E-Suppl.2):17-18 (Abstr.).

Chaudhury, J., Singh, D.P., Hazra, S.K. 1997. Sunn Hemp (*Crotalaria juncea* L.). Central Research Institute for Jute and Allied Fibres (ICAR), Tech. Bull. No. 5, pp 1-50.

Cook, C.G., White, G.A. 1996. *Crotalaria juncea*: A potential multipurpose fiber crop. p. 389-394. In J. Janick (ed.), Progress in new crops. ASHS Press, Arlington, VA.

Coutinho, J.J.O., Coura, R.A.N., Athayde, A.A.R. 2015. Effect of additives in the forage legumes silage. Ciência et Praxis, V. 8, N. 15., 53-57.

Demiroğlu Topçu, G., Özkan, Ş.S. 2018. A preliminary study on the adaptation of sunn hemp (*Crotalaria juncea* L.) in Mediterranean climatic conditions. 2nd International Vocational Science Symposium, 26-29 April 2018, Abstract Book, Pp:199, Antalya/Turkey.

Demiroğlu Topçu, G., Özkan. Ş.S. 2019. Effects of different growing stages on the yield and some forage quality characteristics of sunn hemp (*Crotalaria juncea* L.) grown as second crop in Mediterranean climate condition. COMU J. Agric. Fac., 7(1), 119-126.

Demiroğlu Topçu, G., Özkan, Ş.S., Özçelik, A.E., Acaroğlu, M. 2017. Investigation of agronomic techniques of sunn hemp (*Crotalaria juncea* L.) as an alternative forage and energy crop in Turkey. 1st International Conference on Energy and

Thermal Engineering, 25-28 April 2017, Proceedings Book, Pp:333, Istanbul/Turkey.

Demiroglu Topcu, G., Ozkan, S.S. 2021. Quality properties of sunn hemp (*Crotalaria juncea* L.) and maize (*Zea mays* L.) silages. Tropical Grasslands-Forrajes Tropicales, 9(3), 315-320.

Dempsey, J.M. 1975. Fibre Crops. The University Press of Florida. Gainesville.

Diamond, H. 2006. Traits of Crotalaria used as a green manure legume on a sustainable cropping system. JARQ, 40(4): 299-305.

Duke, J.A. 1981. Handbook of Legumes of World Importance. Plenum Press: New York, NY.

Erkovan, H.İ. 2007. Determination of symbiotic nitrogen fixation and transfer in legume-wheat forage crop mixtures. 7th Congress of Field Crops, Vol:2, 268-271, Erzurum.

Eser, V., Sarsu, F., Altunkaya, M. 2007. Current status and future of plants used in biofuel production. Biofuels and Biofuel Technologies Symposium, 51, 61. Ankara.

Field, D. 1992. Papermaking in India, Bangladesh and the Himalayas–An overview. Hand Paper Making. 7(2):9-15.

Gilbert, M. 1966. Servant of India. A Study of Imperial Rule, Longmans; First Edition, 377-378.

Hess, J.B., Mosjidis, J.A. 2008. Effect of sunn hemp seed inclusion in broiler starter diets on live performance attributes. J. Appl. Anim. Res. 33:105-108.

Hooper, P.T., Scanlan, W.A. 1977. *Crotalaria retusa* poisoning of pigs and poultry. Aust. Vet. J. 53:109-114.

Javaid, M.M., Bhan, M., Rathinasabapahi, B., Chase, C.A. 2012. A non-protein amino acid from *Crotalaria juncea* foliage with allelopathic potential. American Society for Horticultural Science, Abstract.

Kamil, D., Kumar, R., Asha, S. 2009. Effect of green manuring of *Crotalaria juncea* L. on some soil borne pathogens. Indian Phytopath, 62(3), 304-309.

Lindemann, W.C., Glover, C.R. 2003. Nitrogen fixation by legumes. New Mexico State University Cooperative Extension Guide A-129.

Mansoer, Z., Reeves, D.W., Wood, C.W. 1997. Suitability of sunn hemp as an alternative late-summer legume cover crop. Soil Sci. Soc. Am. J. 61:246-253.

Marshall, A.J. 2002. Sunn hemp (*Crotalaria juncea*) as an organic amendment in crop production. University of Florida, 310p.

Martin, J.H., Leonard, W.H., Stamp, D.L. 1976. Principles of field crop production. Macmillan Publishing Co. New York.

Meagher, R.L., Nagoshi, R.N., Brown, J.T., Fleischer, S.J., Westbrook, J.K., Chase CA 2017. Flowering of the cover crop sunn hemp, *Crotalaria juncea* L. HortScience, 52(7), 986-990.

Morris, J.B., Chase, C., Treadwell, D., Koenig, R., Cho, A., Morales-Payan, J.P., Murphy, T., Antonious, G.F. 2015. Effect of sunn hemp (*Crotalaria juncea* L.) cutting date and planting density on weed suppression in Georgia, USA. Journal of Environmental Science and Health, Part B, 50(8), 614-621.

Mosjidis, J.A., Burke, J.M., Hess, J.B. 2012. The Facts about Sunn Hemp Toxicity. Crop Sci. 52:1469-1474.

Mosjidis, J.A., Wang, M.L. 2011. Crotalaria. In: C. Kole, editor, Wild crop relatives: Genomic and breeding resources, Industrial Crops. Springer-Verlag Berlin Heidelberg. p.63-69. doi:10.1007/978-3-642-21102-7_3

National Academy of Science, 1979. Sunn Hemp. In: Advisory committee on technology innovation, tropical legumes: Resources for the future. National Academy of Science, Washington, DC. p. 272-278.

Ozkan, S.S. 2022. Silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixtures at different ratios in the Mediterranean climate. Emirates Journal of Food and Agriculture, 34(7), 612-619.

Phatak, S.C., Dozier, J.R., Bateman, A.G., Brunson, K.E., Martini, N.L. 2002. Cover crops and conservation tillage in sustainable vegetable production. In E. van Santen (ed.) Making Conservation Tillage Conventional: Building a Future on 25 Years of Research. Proceedings Annual Southern Conservation Tillage Conference for Sustainable Agriculture 25: 401-403.

Pilbeam, D.J., Bell, E.A. 1979. Reappraisal of the free amino acids in seeds of *Crotalaria juncea* (Leguminosae). Phytochem., 18, 320-321.

Purseglove, J.W. 1981. Leguminosae. In: J.W. Purseglove, editor, Tropical crops: Dicotyledons. Longman Group, Essex, UK. p. 250-254.

Reeves, D.W., Mansoer, Z., Wood, C.W. 1996. Suitability of sunn hemp as an alternative legume cover crop. Proceedings of the New Technology and

Conservation Tillage 96, 125-130. University of Tennessee Agricultural Experiment Station, Jackson, TN, U.S.A.

Ritchey, G.E., McKee, R., Becker, R.B., Neal, W.M., Arnold, P.D.D. 1941. Crotalaria for forage. Fla. Agric. Exp. Stn. Bull. 361:72.

Romin, A.E., Fitt, R.H. 1938. The feeding of sunn hemp hay (*Crotalaria juncea*) as compared with cowpea hay (*Vigna catjang*) in a fattening ration for bullocks. Rhod. Agric. J. 35:15-19.

Rotar, P.P., Joy, R.J. 1983. 'Tropic Sun' sunn hemp, *Crotalaria juncea* L. Research Extension Series 036 University of Hawaii, Honolulu

Sadhukhan, S., Sarkar, U. 2016. Production of Biodiesel from *Crotalaria juncea* (Sunn-Hemp) Oil Using Catalytic Trans-Esterification: Process Optimisation Using a Factorial and Box–Behnken Design. Waste Biomass Valor, 7:343-355.

Sarkar, S.K., Hazra, S.K., Sen, H.S., Karmakar, P.G., Tripathi, M.K. 2015. Sunn Hemp in India. Central Research Institute for Jute and Allied Fibres (ICAR), Barrackpore, West Bengal. pp.140.

Schomberg, H.H., Martini, N.L., Diaz-Perez, J.C., Phatak, S.C., Balkcom, K.S., Bhardwaj, H.L. 2007. Potential for using sunn hemp as a source of biomass and nitrogen for the Piedmont and Coastal Plain regions of the southeastern USA. Agronomy Journal 99: 1448-1457.

Stallings, A. 2015. Sunn hemp (*Crotalaria juncea* L.) as a Cover Crop for Winter Wheat. Graduate Faculty of Auburn University, Master thesis, 144p.

Strickland, R.W., Lambourne, L.J., Ratcliff, D. 1987. A rat bioassay for screening tropical legume forages and seeds for palatability and toxicity. Aust. J. Exp. Agric. 27:45-53.

Wang, K., Sipes, B.S., Schmitt, D.P. 2002. Crotalaria as a cover crop for nematode management: a review. Nematropica 32: 35-57.

Wang, K.H., McSorley, R., Marshall, A.J., Gallaher, R.N. 2004. Nematode community changes following decomposition of *Crotalaria juncea* amendment in litterbags. Appl. Soil Ecology 27:31-45.

Warren, J., Wilson, T., Edwards, J. 2012. Using sunn hemp as a cover crop in Oklahoma. Oklahoma Cooperative Extension Service, PSS-2273.

White, G.A., Haun, J.R. 1965. Growing *Crotalaria juncea*, a multi-purpose fiber legume, for paper pulp. Econ. Bot. 19:175-183.

Williams, M.C., Molyneux, R.J. 1987. Occurrence, concentration, and toxicity of pyrrolizidine alkaloids in Crotalaria seeds. Weed Sci. 36:476-481.

CHAPTER 2

EBUCEHİL (*Calligonum polygonoides* L. *subsp. comosum* (L' He'r.)

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1. INTRODUCTION

For both animal health and high animal production, the roughage included in the rations must be cheap and of high quality. This also ensures that animal husbandry is profitable and sustainable. In fact, approximately 70% of the costs in animal production go to feed expenses, and 78% of this goes to roughage expenses (Demiroğlu Topçu and Özkan, 2017; Bıçakçı and Açıkbaş, 2018; Harmanşah, 2018,). On the other hand, in Turkey, as in the world, areas within meadow-pasture and field agriculture are one of the most important sources from which roughage is supply. However, the amount of quality forage provided from these areas is not at the desired levels due to unconscious cultural practices and inadequate management-breeding efforts along with unsuitable environmental conditions. As a result, the desired animal product performances cannot be obtained from farm animals that are exposed to inadequate and unbalanced nutrition, or animal husbandry becomes unprofitable due to additional feed costs. For this reason, in order to ensure sustainable animal production and increase the quantity and quality of animal products, a search was made for cheap and high-quality roughage that can be an alternative to conventional feed sources to meet the the roughage deficit. In this sense, halophyte and xerophyte species that grow naturally in marginal areas (salty and arid) that have lost their productivity and can adapt to the conditions of that region have been seen as an important advantage (Kuria et al., 2005; El-Amier and Abdullah, 2015; Temel, 2015, 2018; 2019a, 2019b; Temel et al., 2015a; Abdullah et al., 2017; Paydaş et al., 2018; Temel and Sürmen, 2018; Altay and öztürk, 2020; Iqbal et al., 2022; Pirasteh-Anosheh et al., 2021; Pirasteh-Anosheh et al., 2023). In fact, thanks to their physiological and vegetative properties, xerophyte and halophyte species can grow in extreme environmental conditions and maintain their greenery throughout their vegetation period. As a result, these species, which can continue their productivity without suffering much loss of yield and quality, provide an important alternative forage material in the nutrition of ruminants.

The genus Calligonum, a member of the Polygonaceae family, is mostly distributed in deserts in the arid and semi-arid climate regions of the world (North Africa, Western and Central Asia, Southern Europe) and contains 153 species (Brandbyge, 1993; Kerven et al., 2004; Abdurahman et al., 2012; Vyas et al., 2012). One of these species is *Calligonum polygonoides* L. *subsp.*

comosum (L'Hér.). However, in Turkey as in the world, the pressure on this species (removal as fuel, overgrazing and extreme environmental conditions) is increasing day by day and as a result, the areas where it grows are narrowing and their density per unit area is decreasing (Tadevosyan, 2001; Altundağ, 2009; Gültekin, 2011). Like other species in the same genus, this species, which forms a habitat only in the Iğdır-Aralık wind erosion area (13.542 ha) in Türkiye, offers important ecological and social benefits by developing in marginal areas where many cultivated plants cannot grow. For example, they play an important role in retaining sand dunes, increasing soil fertility and erosion control with their strong roots and wide-spreading canopies. The local community also uses its branches and thick roots as fuel (Tao, 2000; Gyssels et al., 2005; Altundağ, 2009; Gültekin, 2011; Oktay, 2014; Artan and Temel, 2018; Afefe, 2020). However, it should be noted that these intensive removal and cutting practices increase the severity of erosion in the region. It also provides shelter and feeding habitat for wildlife.

On the other hand, like other halophyte and xerophyte species growing in extreme environmental conditions, Ebucehil shrub produces secondary compounds (terpenoid, steroid, glycoside, alkaloid, flavonoid and phenolic) as a protective measure in order to survive and maintain its vital functions properly. As a result, leaves, flower buds, succulent fruit, seeds, bark and flowers rich in these compounds are an excellent natural source of estrogenic, antimicrobial, cardioprotective, lipoxygenase-inhibiting, anti-ulcer, anti-inflammatory, hypoglycemic, cytotoxic and antioxidant. And these plant parts are widely preferred in the health and nutrition (food) sector (Singh et al., 1996; Samejo et al., 2011; Zouari et al., 2012; Samejo et al., 2013; Gomes et al.,, 2015; Ahmed et al., 2020; Berwal et al., 2021; Iqba et al., 2022). *Calligonum polygonoides*, which can maintain its greenness and productivity throughout the vegetation period in arid, semi-arid and desert conditions, also provides an important feed source for grazing animals due to its desired chemical, nutritional and mineral content (Bhandari, 1990; Koocheki and Mohalati, 1994; Goyal and Sharma, 2008; Abdurahman et al., 2012; Abdullah et al., 2013; Oktay and Temel, 2015a, 2015b; Temel ve Temel, 2018; Temel, 2019c; Alzarah, 2022).

2. SYSTEMATIC AND MORPHOLOGY

The genus Calligonum (Polygonaceae), which comes from the Greek words kalli "beautiful" and gony "knee joint", includes 153 species. One of these is *Calligonum polygonoides* L. *subsp. comosum* (L'He'r.). This species, known as "arta", "Phog", "Phogala" and "Phogaro" in the countries where it is distributed around the world, is known as Ebucehil shrub in Turkey. Ebucehil shrub is a perennial species with a slow growing and phanerophyte life form. It has a taproot system and sometimes an underground stem with a taproot system. Depending on the ecological conditions in which it grows and grazing pressure, its height varies between 0.85-3.0 m and the number of branches per tuft varies between 12-19 (Jussieu, 2001; Oktay, 2014; Temel and Temel, 2018) (Figure 1).

Kingdom	:Plantae
Phylum	:Tracheophyta
Class	:Magnoliopsida
Order	:Caryophyllales
Family	:Polygonaceae
Genus	:*Calligonum sp.*
Species	:*Calligonum polygonoides* L.
Subspecies	:*Calligonum polygonoides* L. *subsp. comosum* L' Her.
Synonym	:*Calligonum comosum* L'Hér.

Figure 1: Habitat, Plant Height and Crown Diameter of Tufts of Ebu Cehil shrub (Original)

While the young branches (shoots) formed during the vegetation period (April-August) are green in color and soft in structure, the old branches are in a hard structure, white to grayish-white, and sometimes light brown. In addition, young and old branches (shoots) are hairless, fragile, with swollen nodes and long internodes. Since there is a lot of branching, the canopy diameter of each tuft can be 2.70-3.90 m (Oktay and Temel, 2015b), sometimes up to 10 m (Burdak, 1982). In the Ebucehil shrub, leaves are usually absent or very small (8-16 mm long), sessile, distinct or united with short membranous ochreae (Fifure 2). For this reason, photosynthesis is carried out by green shoots (young branches) and the photosynthetic pathway they follow is C4.

Figure 2: Young and Old Shoots (Steam), Flower Buds, Flowers and Fruits (Original)

Bisexual flowers pedicellate, pedicel 3-8 mm long, slightly accrescent in fruit, articulate in the centre or near the base, Perianth segments 3-4 mm long, 2-3 mm broad, broadly oblong, white, reflexed in fruit. Pedicellate bisexual flowers, consisting of a 5-piece perianth 3-4 mm long and 2-3 mm broad, are mostly found in pairs or triplets (single or in loose clusters) in the axils where the leaf and branch joint. The flower pedicel is 3-8 mm long and hairless. Its white petals with green stripes are hairless. It has 10-18 stamens with filaments

that joint at the base and is dark red in color. The ovary is tetragonous. Flower buds form in mid-April. Flowering begins at the end of April and continues until the beginning of August (Table 1).

Since flowering continues for a long time during the vegetation period, it can provide an important nectar-pollen source to bees. The fruit, 12-17 mm long and 10-14 mm broad, is surrounded by numerous filiform bristles, 10-12 mm long, 2-3 times or more bilaterally branched. The fruits are light pink when newly formed, then dark red and bright brown when mature. The fruits matured between June and August depending on the climatic conditions, and most of them fall between mid july and early September (Table 1). The germination rates of seeds with a weight of 27-34 g per 1000 grains are between 60-77%. Additionally, seeds or fruits can be stored in sealed containers at 1-4 ^{0}C conditions for at least 5 years (Gültekin, 2011; Oktay and Temel, 2015b; Purohit and Kumar, 2020).

Table 1: The phenological Periods of Ebucehil Shrub (Oktay and Temel, 2015b)

	Months																							
	Emr	Mmr	Mre	Ea	Ma	Ae	Em	Mm	Me	Ej	Mj	Je	Ejl	Mjl	Jle	Eag	Mag	Age	Es	Ms	Se	Eo	Mo	Oe
Dp	+																							
Sbb		+																						
Sbp			+																					
Sb				+	+																			
Sp					+	+	+	+	+	+	+	+	+	+	+	+								
Bfb					+	+	+	+	+	+	+	+	+	+	+	+								
Fbp						+	+	+	+	+	+	+	+	+	+	+								
Bf							+	+	+	+	+	+	+	+	+	+								
Fp								+	+	+	+	+	+	+	+	+								
Ef									+	+	+	+	+	+	+	+	+							
Fs										+	+	+	+	+	+	+	+							
Bfr											+	+	+	+	+	+	+	+						
Frp												+	+	+	+	+	+	+						
Ff														+	+	+	+	+	+					
Esp																				+	+	+		
Tdp																								+

Dp: Dormant period	Sbp: Shoot bud period	Sp: Shoot period	Esp: End of shoot period
Bfb: Beginning of flower bud	Bf: Beginning of flowering	Ef: End of flower	Bfr: Beginning of fruit ripening
Sbb: Shoot bud beginning	Sb: Beginning of shoot	Fs: Fruit stage	Frp: Fruit ripening period
Fbp: Flower bud period	Fp: Flowering period	Ff: Fruit fall	Tdp: Transition to dormant period

Emr: Early March	Ea: Early April	Em: Early May	Ej: Early June
Mmr: Mid-March	Ma: Mid- April	Mm: Mid-May	Mj: Mid- June
Mre: End of March	Ae: End of April	Me: End of May	Je: End of June
Ejl: Early July	Eag: Early August	Es: Early September	Eo: Early October
Mjl: Mid- July	Mag: Mid- August	Ms: Mid- September	Mo: Mid- October
Jle: End of July	Age: End of August	Se: End of September	Oe: End of October

3. ADAPTATION

The genus *Calligonum* (Polygonaceae) is distributed mainly in China, Southern Europe, North Africa and Asia. *Calligonum polygonoides* L. *subsp. comosum* (L'He'r.), which is included in this genus, grows naturally on sandy, loamless, desert or semi-desert areas where arid climate prevails in Naxchivan, Syria, Iraq, Iran, Yemen, Azerbaijan, Mauritania, Palestine, Libya, Algeria, Bahrain, India, Tunisia, Egypt, Pakistan, Armenia and Kuwait in world, and is the dominant species of these areas (Koocheki and Mohalati, 1994; Khan, 1997; Abdurahman et al., 2012; Vyas et al., 2012; El-Amier and Abdullah, 2015; Kumar et al., 2015; Abdullah et al., 2017; Afefe, 2020; Dahiya, 2023). In Türkiye, it is distributed only in a narrow area (13,542 ha) on the slopes of Mount Ararat overlooking the Iğdır-Aralık plain, 30 km East-west and 4-5 km North-south (Davis, 1965-1985; Temel et al., 2017). This area is also the second largest wind erosion area in Turkey, and the wind speed can reach 102 km per hour. Its main distribution altitude is 800-1000 m. The average annual rainfall in the distribution area is between 100-300 mm. The average temperature is 12.9 ^{o}C, the highest and lowest temperatures are +42 ^{o}C and -30 ^{o}C, respectively. Relative humidity in the region is low and the annual evaporation rate is 1094 mm. These data show that the plant is quite resistant to drought and frost. Since the plant follows the C4 photosynthetic pathway, it can grow in intense light and high temperature conditions and use soil water and nitrogen more efficiently. It also reduces shoot development as a tolerance mechanism in drought conditions and accelerates the aging of adult shoots (Dhief et al., 2009). For this reason, their net photosynthetic production is higher and their

adaptation to arid and infertile areas is better compared to C3 plants (Pearcy and Ehleringer, 1984).

Although the plant grows in clay and saline soils, it is mainly found on sandy and volcanic soils. Therefore, this species can easily grow in sandy areas where annual rainfall and soil fertility are low (because its water requirement is low). It also plays an important role in soil conservation by holding the dunes with its strong roots and branches that spread on a large area. As a matter of fact, in a study, the amount of soil accumulated by the Ebucehil shrub per tuft was determined as minimum 697.65 kg, maximum 5 082.53 kg and average 2 383.19 kg (Oktay, 2014). Since the Ebucehil shrub accumulates the sand dunes carried by erosion in the canopy, it forms tuft and spreads in natural vegetation in tufts. This also causes the Ebucehil shrub to have a large crown diameter on the soil surface and to increase its density per unit area.

In addition, it contributes significantly to the development and spread of other herbaceous and shrub species in the vegetation by positively improving the physical and chemical properties of the soil. Accordingly, it increases the species composition and density of the vegetation. As a matter of fact, in previous studies, it was reported that the Ebucehil shrub increased the water holding capacity, organic carbon, organic matter, lime, available nitrogen and phosphorus content of the soil under the canopy, and decreased the salinity content (Rathore et al., 2015; Artan and Temel, 2018; Mashizi and Sharafatmandrad, 2019; Abd-ElGawad vd., 2020; Ahmed et al., 2020b). For these reasons, it has been revealed that Ebucehil has a potential soil ameliorating factor and ecological importance. However, in the geographies where it grows, its density per unit area is decreasing day by day due to reasons such as intensive grazing of the plant by animals and its removal as fuel by local community. Similar pressure applies to other geographies where it grows, and it has been reported that this species is under threat (Dahiya, 2023). Considering that many species have no or low adaptation to such areas with extreme ecological conditions, it is of great importance to protect Calligonum polygonoides, which can adapt to these conditions, and to take propagation measures into consideration. In this way, marginal areas can be vegetated and natural vegetation can be developed. For propagation (planting), seeds, scions (branches/shoots), root shoots or dipping techniques can be preferred and used in planting sand dune areas. Although Ebucehil shrub is well adapted to desert

or semi-desert dune areas, measures such as windbreaks or shelterbelts that will stop or minimize dune movements must be taken into consideration for the formation of a healthy establishing in the first year (initially).

4. YIELD AND QUALITY

In order for a species to be recommended as an alternative feed material, the yield obtained per unit area must be high and the feed quality must be at the desired levels. A forage material with these properties can be provided with the known forage plant species and varieties under appropriate ecological conditions and correct agronomic practices. However, it is difficult or impossible to achieve this goal with known forage plant species in marginal areas where extreme ecological conditions prevail and the diversity of species that can be grown is limited. In this sense, species and varieties (especially shrub and tree formations) that grow in marginal areas and have the desired productivity and feed quality have been seen as an alternative solution to meet the required quality roughage needs (Gökkuş et al., 2011; Özaslan Parlak et al., 2011; Temel and Tan 2011a, 2011b; Kökten at al., 2012; Tan and Temel, 2012; Dökülgen and Temel, 2015, 2019, 2020). As a matter of fact, thanks to their superior properties, these formation types can provide important forage material to animals, especially in periods when herbaceous species turn yellow and their nutritional value decreases or there is no feed material to graze in the environment (habitat).

As in other geographies of the world with marginal ecological conditions, the extreme climate and soil conditions prevailing in the Iğdır-Aralık wind erosion area significantly restrict the plant diversity and productivity of existing areas. Especially in summer and autumn, when herbaceous species are in dormant period, feed material cannot be produced in sufficient quantity and quality in the environment. This results in low animal products and unprofitable animal husbandry due to inadequate and unbalanced nutrition of grazed animals. For this reason, xrephyte and halophyte species that grow naturally in arid and infertile (dune) areas have been seen as an important advantage in closing the quality roughage gap and meeting the daily nutritional requirements of animals. (Temel et al., 2015; Keskin, 2018; Temel and Sürmen, 2018; Temel, 2015; 2019a, 2019b; Temel and Keskin, 2019a, 2019b). In this sense, the Ebucehil shrub, which grows widely in the wind erosion area with

dune soil structure and arid climate, maintains its greenness and productivity for a long time and provides an important alternative forage source for grazing animals in the region (Oktay and Temel, 2015b). However, depending on the animal species, the grazing plant parts and densities of each species vary. These differences may arise from the development periods, size, palatability and feed quality of the species. As a matter of fact, since there are no leaves in the Ebucehil shrub, the parts that are used as fodder material or grazed by animals are the young shoots formed during the vegetation period. On the other hand, since the plant is not tall enough, all accessible parts of the plant, especially its shoots, are grazed by cattle, sheep and goat during the vegetation period (from April to October) (Figure 3) and it is in the frequently preferred group (more than 76%) (Temel and Temel, 2018). Similar results were also revealed by Abdullah et al. (2017). Researchers have stated that Ebucehil shrub, which grows naturally in the arid pastures of the Cholistan desert, is a palatable species moderately preferred by free-grazing mixed herds (sheep, goat, cattle and camel) and has a good feed potential for ruminants. In addition, its flower buds, flowers and fruits are moderately palatable and are grazed by camels, cattle and sheep.

Figure 3: Ebucehil Shrub Being Grazed by Sheep and Cattle (Original)

Since the soils in the wind erosion area have a sand dune and volcanic sediment structure, their water holding capacity and productivity are very low. In addition, the annual rainfall in the region is low and the evaporation rate is very high. Accordingly, since the number and density of species growing in the wind erosion area is low, grazing pressure is concentrated on the Ebucehil shrub. In addition, the local community occasionally remove the Ebucehil shrub

and use it as fuel. As a result of all these, the development, height, density and yield per unit area of the Ebucehil shrub vary. As a matter of fact, in a study conducted in the region, it was reported that the fresh shoot yield per tuft of Ebucehil shrub varied between 19.17-67.13 kg, and the fresh herbage yield per decare ranged between 345.06-1208.34 kg. The average fresh herbage and dry hay yields of the plant were determined as 697.14 kg and 184.14 kg, respectively (Temel and Temel, 2018; Table 2). However, it is thought that the forage yield to be obtained from unit area during the year is higher. Because these values belong to the results obtained from a single harvest period. As a matter of fact, the Ebucehil shrub is constantly grazed during its vegetation and forms new shoots following grazing (Oktay and Temel, 2015b; Table 1).

Table 2: Some Yield Characteristics of Ebucehil Shrub (Oktay and Temel, 2015a)

Characteristics	Minimum	Maximum	Mean
Fresh shoot yield per tuft (kg)	19.17	67.13	38.73
Dry shoot yield per tuft (kg)	5.49	16.20	10.23
Fresh shoot yield (kg da^{-1})	345.06	1208.34	697.14
Dry shoot yield (kg da^{-1})	98.82	291.6	184.14
Shoot length (cm)	45.10	68.25	58.65
Plant height (m)	1.20	2.25	15.88
Number of branches per tuft (number)	12.0	19.0	15.65

In order to obtain high quantity and quality animal products, it is of great importance to know the quality content as well as the amount of feed produced per unit area of the plants used as feed sources. Because animals provide the organic and inorganic nutrients that they need daily for survival and productivity through the feed they eat. Therefore, it is important that they obtain the nutrients needed for profitable livestock farming from the roughage they graze. In a study, some nutritional and chemical composition contents of Ebucehil shrub shoots were determined according to months during the vegetation period (Oktay and Temel, 2015a; Table 3).

Table 3: Nutrient and Chemical Composition of Ebucehil Shrub According to Months during Vegetation Period (Oktay and Temel, 2015)

Month	CP	NDF	ADF	ADL	DMD	DMI	DE	ME	RFV
	(%)						(Mcal kg^{-1})		
April	25.29	38.48	20.90	8.31	76.98	3.12	3.56	2.92	186.09
May	17.09	45.72	28.41	9.97	67.34	2.62	3.15	2.58	137.01
June	16.40	47.86	30.95	10.10	64.96	2.51	3.04	2.50	126.26
July	12.46	49.83	33.59	10.73	61.13	2.41	2.88	2.36	114.12
August	11.87	51.53	34.50	11.19	60.13	2.33	2.84	2.33	108.55
September	8.60	53.81	36.19	11.66	57.37	2.23	2.72	2.23	99.18
October	7.54	59.97	39.32	12.78	54.35	2.00	2.59	2.13	84.31
Mean	14.18	49.60	31.98	10.68	63.18	2.42	2.97	2.44	118.49

CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, ADL: Acid detergent lignin, DMD: Dry matter digestibility, DMI: Dry matter intake, DE: Digestible energy, ME: Metabolic energy, RFV: Relative feed value

It can be said that this feed value of Ebucehil shrub is higher than many cultivated forage plant species, especially straw, which is used as a roughage source. According to 7-month average data, it was observed that Ebucehil shrub produced a feed material of good quality in terms of crude protein, NDF, DMI and RFV, and high quality in terms of ADF and DMD (Table 4). Although there has been a decrease in forage quality values with maturation, especially after June, the Ebucehil shrub constantly produces new (young) shoots following grazing. Accordingly, grazing animals have the opportunity to consume higher quality feed material for a long time. As a matter of fact, it has been shown that the Ebucehil shrub produces the best quality forage material in April, when it produces young shoots intensively, and the high quality forage material in May (Table 3; Table 4). When these data were compared with NRC (2007) values, it was seen that Ebucehil shrub has chemical and nutritional potential that can provide daily live weight gain in addition to the survival requirement of grazing ruminates without the need for a supplementary feeding. In addition, it has been reported that samples consisting of a mixture of leaves, shoots and flowers collected in the spring of the Ebucehil shrub, which grows naturally in the arid rangelands of the Pakistan-Cholistan desert, produce a medium quality feed material (Abdullah et al., 2017). As a result of this research, the dry matter ratio, crude protein, crude fiber, total ash, NDF, ADF, hemicellulose and lignin contents of the plant were determined as 93.64%, 11.54%, 23.37%, 9.48%,

43.67%, 33.67%, 10.00% and 8.80%, respectively. In another study (on the Deltaic Mediterranean coast of Egypt), they reported that naturally growing *Calligonum polygonoides* shoots had a content of 6.12% ash, 7.02% fiber, 1.88% fat, 18.94% protein, 4.58 mg/g glucose and 5.89 mg/g sucrose (El-Amier and Abdullah, 2015).

Table 4: Roughage Quality Standards for Farm Animals (Rivera and Parish, 2010)

Quality standard	CP	NDF	ADF	DMD	DMI	RFV
The best quality	>%19	<%40	<%31	>%65	>%3.0	≥151
High quality	%17-19	%40-46	%31-35	%62-65	%3.0-2.6	125-151
Good quality	%14-16	%47-53	%36-40	%58-61	%2.5-2.3	103-124
Medium quality	%11-13	%54-60	%41-42	%56-57	%2.2-2.0	87-102
Poor quality	%8-10	%61-65	%43-45	%53-55	%1.9-1.8	75-86
Very bad quality	≤%8	>%65	>%45	<%53	<%1.8	<75

CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, DMD: Dry matter digestibility, DMI: Dry matter intake, RFV: Relative feed value

In addition to the healthy nutrition of animals, although nutrients such as protein, fat, carbohydrates and vitamins are important in providing high quantity and quality animal products, mineral requirements must also be met. Because minerals (macro and micro) have an important role in supporting the rumen activities of ruminants, increasing feed utilization efficiency, stimulating the neuromuscular systems and metabolite activities of animals. (Kutlu et al., 2005; Spears, 1994). However, mineral substances that play an important role in the metabolic activities of animals cannot be synthesized in the animal body (Kutlu et al., 2005) and the required minerals are mostly met by the plants that the animals graze (Gökkuş et al., 2013). Therefore, it is important to know the mineral composition contents of the plants that will be considered as feed sources and to have their mineral values at the desired levels. Mineral composition contents of plants may vary depending on the species of plants in the vegetation, their density, grazed plant parts, growing conditions and the grazing time of animals on these species. Depending on these, the mineral composition values that should be included in the daily rations of animals may be less or more than necessary. As a result, in case of deficiency or excess of minerals, it can have negative effects on the reproduction, development,

immune systems and productivity of animals (McDowell, 1992; Altıntaş, 2013).

As a matter of fact, it was reported that the mineral contents (P, K, Ca, Mg, Mn, Fe, Zn and Cu) of *Calligonum comosum* growing in the eastern province of Saudi Arabia varied according to months (January, February, March and April) and plant parts (whole plant, leaves, and stem) (Alzarah, 2021). In the current study, while nitrogen, phosphorus and potassium contents were found to be highest in the whole plant part, calcium, magnesium, manganese, zinc and copper elements were determined to be higher in the leaves compared to other plant parts. According to months, the highest nitrogen, potassium and zinc contents were recorded in March, but phosphorus, calcium, iron and copper contents in February. The lowest magnesium and highest manganese were determined in April. However, the results obtained from this study showed that mineral contents (except Zn and Mn) according to both months and plant parts were above the maximum tolerable levels of the animals (NRC, 2005). In another study conducted in a different geography, only shoot mineral contents of *Calligonum polygonoides* were determined (El-Amier and Abdullah, 2015). As a result of the study, it was seen that the P, Na, Fe, Cu, Mn and Zn contents of the shoots were at the tolerable levels of the animals and the K, Ca and Mg contents were above (NRC, 2005). Mineral contents of especially halophyte and xerophyte species growing in arid and saltine conditions are generally high. This is due to the fact that they remove large amounts of salt ions from the environment in which they grow and store them in their bodies. On the other hand, although not as much as halophyte and xerophyte species, grass and legume species that grow naturally in meadow-pasture areas can generally have higher mineral content than most cultivated forage plant species. In a study on the subject, the mineral contents of 12 legume and 8 grass forage plant species growing naturally in meadow-pasture areas were determined (Gürsoy and Macit, 2017). When the results obtained from this study were compared with NRC (2005) values, it was shown that some mineral substances could not meet the daily requirements of animals and some mineral substances were above the maximum tolerable levels of animals. However, it has been determined that the Ebucehil shrub, which grows naturally in extreme climate and soil conditions, can easily meet the daily mineral requirements of animals

and its mineral contents are below the maximum tolerable level (except Mg) for animals (Table 5; Table 6).

Table 5: Some Mineral Values of Ebucehil Shrub according to Months during the Vegetation Period (Temel, 2019)

Month	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
			(%)				(ppm)		
April	0.33	1.68	1.81	0.99	0.30	190.43	2.31	26.20	37.97
May	0.49	1.83	1.52	0.87	0.20	138.30	2.35	25.90	41.37
June	0.54	2.03	1.49	0.82	0.21	125.66	2.47	29.33	34.16
July	0.53	1.84	1.33	0.81	0.24	111.30	2.67	28.03	35.60
August	0.63	1.93	1.37	0.79	0.22	115.16	2.43	31.83	34.63
September	0.59	1.98	1.39	0.74	0.23	100.97	2.00	24.77	41.12
October	0.47	1.45	1.32	0.65	0.25	99.73	2.70	28.60	45.56
Mean	0.51	1.82	1.46	0.81	0.24	125.93	2.42	27.85	38.63

In this study, during the 7-month vegetation period, it was reported that P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn contents of Ebucehil shrub varied between 0.33-0.63%, 1.45-2.03%, 1.32-1.82%, 0.65-0.99%, 0.20-0.30%, 99.73-190.43 ppm, 2.00-2.70 ppm, 24.77-31.83 ppm and 34.16-45.56 ppm, respectively. In addition, it was determined that Ca, Na, Mg and Fe contents were relatively higher in the early development period, and P and K contents were relatively higher in the late development period (Temel, 2019c).

Table 6: Maximum Tolerable Levels of Minerals in the Rations (% or mg/kg of the DM) of Animals according to İndexes Of Animal Health (NRC, 2005)

	P	K	Ca	Mg	Na	Mn	Cu	Zn	Fe
			(%)				(ppm)		
Cattle	0.70	2.00	1.50	0.60	4.50	2000	40	500	500
Sheep	0.60	2.00	1.50	0.60	4.00	2000	15	300	500

In addition to having the desired nutritional, chemical and mineral content, Ebucehil shrub is also rich in secondary compounds such as carotenoids, tannins, terpenoids, steroids, glycosides, alkaloids, flavonoids and phenolics. These compounds have a great impact on the usefulness of other

feedstuffs eaten by animals, animal health, rumen microbial population, and the quantity and quality of animal products. As a matter of fact, studies have shown that these compounds have estrogenic (Ahmed et al., 2015), anticarcinogenic (Sak, 2014), antimicrobial (Riadh et al., 2011; Alkhalifah, 2013; Khan et al., 2015; Al-Hammouri et al., 2018), cardioprotectiv (Abushouk et al., 2017), lipoxygenase-inhibiting (Yawer et al., 2007), antiosteoporotic (Sabry et al. 2013), anti-ulcer, anti-inflammatory (Liu et al., 2001; Shalabi et al., 2015), hypoglycemic (El-Hawary and Kholief 1990; Abdo et al., 2015), antihelmentic (Degheidy et al. 2013), cytotoxic and antioxidant (Badria et al. 2007; Ahmed et al., 2020) activity. However, it should not be forgotten that when these compounds are included in high amounts in the diet of animals or when animals are fed with plants containing these compounds for a long time, these secondary compounds may inhibit the growth of the animal and disrupt its normal metabolism.

As a result, it has been observed that the Ebucehil shrub growing in arid and infertile conditions to which most species cannot adapt is an important alternative forage source for grazing animals because it has the desired feed quality characteristics. Although feed quality values decrease with maturation, it is at a level that can meet the needs of ruminants without the need for supplementary feeding during the vegetation period. In addition, when most herbaceous species growing in marginal areas dried out or entered the dormant period, the Ebucehil bush can produce a significant amount of feed material, and this should be seen as an important advantage in terms of meeting the daily feed requirement of the animals grazing in the region. It is also thought that the Ebucehil shrub can make important contributions to the profitable and sustainable of the animal husbandry.

REFERENCES

Abd-ElGawad, A.M., Rashad, Y.M., Abdel-Azeem, A.M., Al-Barati, S.A., Assaeed, A.M., Mowafy, A.M., 2020. *Calligonum polygonoides* L. shrubs provide species-specific facilitation for the understory plants in coastal ecosystem. Biology, 2020, 9(8): 232. doi: 10.3390/biology9080232.

Abdo, W., Hirata, A., Shukry, M., Kamal, T., Abdel-Sattar, E., Mahrous, E., Yanai, T. 2015. *Calligonum comosum* extract inhibits diethylnitrosamineinduced hepatocarcinogenesis in rats. Oncology Letters, 10(2):716-222. doi: 10.3892/ol.2015.3313.

Abdullah, M., Khan, R.A., Yaqoob, S., Ahmad, M. 2013. Mineral profile of browse species used as feed by grazing livestock in Cholistan Rangelands, Pakistan. Pakistan Journal of Nutrition, 12(2): 135-143. doi: 10.3923/pjn.2013.135.143

Abdullah, M., Rafay, M., Hussain, T., Ahmad, H., Tahir, U., Rasheed, F., Ruby, T., Khalil, S., 2017. Nutritive potential and palatability preference of browse foliage by livestock in arid rangelands of Cholistan desert (Pakistan). The Journal of Animal and Plant Sciences, 27(5): 1656-1664.

Abdurahman, M., Sabirhazi, G., Liu, B., Yin, L., Pan, B., 2012. Comparison of five *Calligonum* species in Tarim Basin based on morphological and molecular data. EXCLI Journal, 11: 776-782.

Abushouk, A.I., Ismail, A., Salem, A.M.A., Afifi, A.M., Abdel-Daim, M.M. 2017. Cardioprotective mechanisms of phytochemicals against doxorubicininduced cardiotoxicity. Biomedicine and Pharmacotherapy, 90(Suppl. 10 (4)):935-946. doi: 10.1016/j.biopha.2017.04.033.

Afefe, A.A. 2020. Composition and changes in the spontaneous flora of the WadiEl Rayan Ramsar site, Fayoum, Egypt, in the last 20 years. Limnological Review, 20(3): 109-121. doi: 10.2478/limre-2020-0012.

Ahmed, H.S., Moawad, A.S., Owis, A.I., AbouZid, S.F. 2020. Antioxidant capacity and HPLC determination of phenolic in different organs of *Calligonum polygonoides subspecies comosum*. The Journal of Reports in Pharmaceutical Sciences, 9(2): 251-255. doi: 10.4103/jrptps.JRPTPS_23_19.

Ahmed, H.S., Moawad, A.S., Owis, A.I., AbouZid, S.F., Abdel-Rahman, R.F. 2015. Phytochemical screening and evaluation of biological activity of *Calligonum polygonoides* L. *subsp. comosum*. Journal of Applied Pharmaceutical Science, 5 (Suppl 3): 022-026. doi:10.7324/japs.2015.510.S4.

Al-Hammouri, A.A.N., Salman, A.K., Ibbini, J., Abusmier, S., Sanogo, S. 2018. Effect of biofumigation by *Calligonum polygonoides*, dry olive leaves, and ash of olive leaves on chilli pepper growth and recovery of Rhizoctonia solani. Acta agriculturae Slovenica,111 (1): 41-9. doi: 10.14720/aas.2018.111.1.05.

Alkhalifah, D.H. 2013. In-vitro antibacterialactivity of ethanol extract of *Calligonum comosum* plant against four human pathogens in Saudi Arabia. International Journal of Plant, Animal and Environmental Science, 3: 170-175.

Altay, V., Özturk, M. 2020. The genera *Salsola* and *Suaeda* (Amaranthaceae) and their value as fodder. Handbook of Halophytes. Editör: Grigore, M. N. Springer, Cham.

Altıntas, A. 2013. Mineral materials. Disability-Overdose Diseases. Ankara: Ankara University Lecture Notes on Biochemistry Department.

Altundağ, E. 2009. Uses of the Wild Plants in Iğdır Province (East Anatolia). İstanbul University, Institute of Health Science, Department of Pharmaceutical Botany. Phd. Thesis. İstanbul. 2009.

Alzarah, M.I. 2021. Macro and micro-elements concentrations in *Calligonum comosum* wild grazing plant through its growth period. Saudi Journal of Biological Sciences, 28 (1): 6992-6999. doi: 10.1016/j.sjbs.2021.07.084.

Artan, G., Temel, S. 2018. The effect of Ebu cehil (*Calligonum polygonoides* L.) shrub used as forage resource in Igdir-Aralık on some soil properties. Igdir International Conference on Multidisciplinary Studies 1: 242-249.

Badria, F.A., Ameen, M., Akl, M.R. 2007. Evaluation of cytotoxic compounds from *Calligonum comosum* L. growing in Egypt. Zeitschrift fur Naturforschung C, 62 (9-10): 656-660. doi: 10.1515/znc-2007-9-1005.

Berwal, M.K., Haldhar, S.M., Ram, C., Shil, S., Kumar, R., Gora, J.S., Singh, D., Samadia, D.K., Kumar, M., Mekhemar, M. 2021. *Calligonum polygonoides* L. as novel source of bioactive compounds in hot arid

regions: evaluation of phytochemical composition and antioxidant activity. Plants, 10: 1156. doi: 10.3390/ plants10061156.

Bhandari, M.M. 1990. Flora of the Indian Desert. Revised Edition. Jodhpur: MPS Reports.

Bıçakçı, E., Açıkbaş, S. 2018. Determination of roughage production potential for farm animals in Bitlis Province. BEU Journal of Science, 7(1), 180-185.

Brandbyge, J. 1993. Polygonaceae. In K. Kubitzki, J.C. Rohwer & V. Bittrich (eds.). The families and genera of vascular plants, Springer-Verlag, Berlin.

Burdak, L.R. 1982. Recent advances in desert afforestation, Dehradun, p.56

Dahiya, K.S. 2023. Eco-morphology and economic importance of *Calligonum polygonoides* Linn. An endangered plant of Indian Desert. Madhav Research and Review, 5(1): 109-112.

Davis, P.H. 1965-1985. Flora of Turkey and the East Aegean Islands. 1-9. Edinburgh: Edinburgh University Press.

Degheidy, N.S., Sharaf, E.M., Fathi, S.M. 2013. Field evaluation of anthelmentic efficacy of *Calligonum comosum* against fasciolosis in sheep at Taif, KSA. Global Veterinaria, 11 (4): 377-384. doi: 10.5829/idosi.gv.2013.11.4.7691.

Demiroğlu Topçu, G., Özkan, Ş. S. 2017. General View to Meadow-Rangelands and Forage Crops Cultivation of Aegean Region and Turkey,. *ÇOMÜ Journal of Agriculture Faculty*, *5*(1), pp:21-28.

Dhief, A., Gorai, M., Aschi-Smiti, S., Neffati, M. 2009. Comparative phenological and water potential patterns of three *Calligonum* species in the eastern Great Erg of Tunisia. Flora, 204 (8): 581-592. doi: 10.1016/j.flora.2008.07.007.

Dökülgen, H., Temel, S. 2015. Seasonal nutrient content changes of leaf and leaf + shoots in deciduous Christ's thorn (*Palirus spina-christi* Mill.). Journal of the Institute of Science and Technology, 5(3): 57-65.

Dökülgen, H., Temel, S. 2019. Determination of nutritional value of terebinth and styrax tree according to the grazed plant parts and seasons. Harran Journal of Agricultural and Food Science, 23(2): 178-188. doi: 10.29050/harranziraat.425602.

Dökülgen, H., Temel, S. 2020. Determination of seasonal nutrient contents of plant parts and kermes oak, mock privet and wild olive maquis species. KSU Journal of Agriculture and Nature, 23(4): 986-993. doi: 10.18016/ksutarimdoga.vi.688648.

El-Amier, Y.A., Abdullah, T.J. 2015. Evaluation of nutritional value for four kinds of wild plants in northern sector of Nile Delta, Egypt. Open Journal of Applied Sciences, 5 (7): 393-402. doi: 10.4236/ojapps.2015.57039.

El-Hawary, Z., Kholief, T. 1990. Biochemical studies on some hypoglycemic agents (II) effect of *Calligonum comosum* extract. Archives of Pharmacal Research, 13 (1): 113-116.

Gomes, S.M.C., Fernandes, I.P.G., Shekhawat, N.S., Kumbhat, S., Oliveira-Brett, A.M. 2015. *Calligonum polygonoides* linnaeus extract: HPLC-EC and total antioxidant capacity evaluation. Electroanalysis, 27 (2): 293-301. doi: 10.1002/elan.201400555.

Goyal, M., Sharma, S.K. 2008. Traditional wisdom and value addition prospects of arid foods of Desert region of North West India. Indian Journal of Traditional Knowledge, 8 (4): 581-585.

Gökkuş, A., Parlar, A.O., Baytekin, H., Hakyemez, B.H. 2013. Change of mineral composition of herbaceous species at the Mediterranean shrublands. Journal of Tekirdag Agricultural Faculty, 10 (1): 1-10.

Gökkuş, A., Özaslan Parlak, A., Parlak, M. 2011. Change of mineral element content in the common shrubs of Mediterranean zone. I. Macronutrients. Žemdirbystė-Agriculture, 98(4): 357-366.

Gültekin, H.C. 2011. Ebucehil shrub (*Calligonum polygonoides* L.), the green cover of the deserts. Forest and Hunt, (3): 43-47.

Gürsoy, E., Macit, M. 2017. Determination of mineral contents of some legume and cereal forages grown as naturally in pastures of Erzurum Province. Alınteri Journal of Agricultural Sciences. 32(1): 1-9. doi: 10.28955/alinterizbd.279756.

Gyssels, G., Poesen, J., Bochet, E., Li, Y. 2005. Impact of plant roots on the resistance of soils to erosion by water: A review. Progress in Physical Geography, 29 (2): 189-217. doi: 10.1191/0309133305pp443ra.

Harmanşah, F. 2018. Quality roughage production in Turkey, problems and suggestions. journal of TÜRKTOB, 25: 9-13.

Iqbal, J., Shaheen, A., Ghani, M.A., Iqbal, Q., Azam, M., Ali, B., Noor, A., Anwar, A., Bibi, M., Iqbal, R., Anwar, I., Aslam, M., Mahmood, I. 2022. Nutritional and mineral composition analysis of desert plants: A case study. Emirates Journal of Food and Agriculture, 34 (10): 882-887. doi: 10.9755/ejfa.2022.v34.i10.2926.

Jussieu, A.L. 2001. Polygonaceae, No. 205. Flora of Pakistan, Karachi University, Karachi.

Kerven, C., Alimaev, I.I., Behnke, R., Davidson, G., Franchois, L., Malmakov, N., Mathijs, E., Smailov, A., Temirbekov, S., Wright, I. 2004. Retraction and expansion of flock mobility in Central Asia: Costs and Consequences. African Journal of Range and Forage Science, 21 (3): 91-102. doi: 10.2989/10220110409485848.

Keskin, B. 2018. Determination of monthly changes in mineral content of Spiny *Atraphaxis* (*Atraphaxis spinosa* L.) as an alternative fodder crop. Progress in Nutrition, 20(3): 318-322. doi: 10.23751/pn.v20i3.6817.

Khan, A., Khan, R.A., Ahmed, M., Mushtaq, N. 2015. In vitro antioxidant, antifungal and cytotoxic activity of methanolic extract of *Calligonum polygonoides*. Bangladesh Journal of Pharmacology, 10 (2): 316-20. doi: 10.3329/bjp.v10i2.22448.

Khan, T.I. 1997. Conservation of biodiversity in western India. Environmentalist, 17: 283-287.

Koocheki, A., Mohalati, M.N. 1994. Feed value of some halophytic range plants of arid regions of Iran. Squires, V.R., Ayoub, A.T. (eds.). Halophytes as a resource for livestock and for rehabilitation of degraded lands. 249-253.

Kökten, K., Kaplan, M., Hatipoğlu, R., Saruhan, V., Çınar, S. 2012. Nutritive value of mediterranean shrubs. The Journal of Animal and PlantSciences, 22(1): 188-194.

Kumar, M., Tiwari, M., Mohil, P., Vivek, B., Jain, U. 2015. *Calligonum polygonoides* Linn.: An important rare shrub species in Thar desert of India. Indian Journal of Plant Sciences, 4(2): 63-66.

Kuria, S.G., Wanyoike, M.M., Gachuiri, C.K., Wahome, R.G. 2005. Nutritive value of important range forage species for camels in marsabit district, Kenya. Tropical and Subtropical Agroecosystems, 5(1): 15-24.

Kutlu, H.R., Görgülü, M., Celik, L.B. 2005. General animal feeding. Adana: Cukurova University Faculty of Agriculture Department of Animal Science Department of Feed and Animal Nutrition.

Liu, X.M., Zakaria, M.N., Islam, M.W., Radhakrishnan, R., Ismail, A., Chen, H.B., Chan, K., Al-Attas, A. 2001. Anti-inflammatory and anti-ulcer activity of *Calligonum comosum* in rats. Fitoterapia, 72 (5): 487–491. doi: 10.1016/S0367-326X(01)00271-4.

Mashizi, A.K., Sharafatmandrad, M. 2019. Assessing the efects of shrubs on ecosystem functions in arid sand dune ecosystems. Arid Land Research and Management, 34 (12): 1-17. doi: 10.1080/15324982.2019.1634655.

McDowell, L.R. 1992. Minerals in animals and human nutrition. San Diego New York, USA: Department of Animal Science, University of Florida, Gainesille, Academic Press.

NRC, 2005. Mineral Tolerance of Animals. National Research Council, Vol. 2nd rev. ed. Natl. Acad. Press, Washington, DC.

NRC, 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. National Research Council of the National Academies, Washington DC, 362 p.

Oktay, G. 2014. Determınation of the change of annual nutritional value and some properties of Ebu cehil (*Calligonum polygonoides* L. *ssp. comosum* (L'Hér.)) shrub growing in Igdır ecological conditions. Master's Thesis, Iğdır University Graduate Education Institute, Iğdır, s.43.

Oktay, G., Temel, S. 2015a. Determination of annual fodder value of Ebu cehil (*Calligonum polygonoides* L. *ssp. comosum* (L'Hér.)) shrub. Journal of Agricultural Faculty of Gaziosmanpasa University, 32(1): 30-36.

Oktay, G., Temel, S. 2015b Determination of the growth patterns of Ebu cehil (*Calligonum polygonoides* L. *ssp. comosum* (L'Hér.). shrub in terms of grazing management. Journal of Agricultural Faculty of Gaziosmanpasa University, 32 (2), 1-6. doi: 10.13002/jafag773.

Özaslan Parlak, A., Gökkuş, A., Hakyemez, B., Baytekin, H. 2011. Shrub yield and forage quality in Mediterranean shrublands of West Turkey for a period of one year. African Journal of Agricultural Research, 6(7): 1726-1734.

Paydaş, E., Şelli, M.Ş., Demir, R. 2018. Use of *Atriplex spp*. treatment plants in cattle and small head animal husbandary as animal feed. Çukurova Journal of Agricultural and Food Sciences, 33(1): 19-28.

Pearcy, R.W., Ehleringer, J. 1984. Comparative ecophysiology of c3 and c4 plants. Plant Cell and Environment, pp. 1-13.

Pirasteh-Anosheh, H., Mirhosseini, A., Akram, N.A., Hasanuzzaman, M. 2021. Forage potential of *Salsola* species in arid-saline rangelands. Doga, Turkish Journal of Botany, 45(3): 203-215. doi: 10.3906/bot-2010-36.

Pirasteh-Anosheh, H., Ranjbar, G, Akram, N.A., Ghafar, M.A., Panico, A. 2023. Forage potential of several halophytic species grown on saline soil in arid environments. Environmental Research, 219 (3): 114954. doi: 10.1016/j.envres.2022.114954.

Purohit, C.S., Kumar, R. 2020. A review on genus *Calligonum* L. (Polygonaceae) from India and report *Calligonum crinitum* an addition for Flora of India. Journal of Asia-Pacific Biodiversity, 13 (2): 319-324. doi: 10.1016/j.japb.2020.03.002.

Rathore, V., Singh, J., Bhardwaj, S., Nathawat, N., Kumar, M., Roy, M. 2015. Potential of native shrubs *Haloxylon salicornicum* and *Calligonum polygonoides* for restoration of degraded lands in arid western Rajasthan, India. Environmental Management, 55(1): 205-216. doi: 10.1007/s00267-014-0372-1.

Riadh, H., Imen, F., Abdelmajid, Z., Sinda, F. 2011. Detection and extraction of anti-Listerial compounds from *Calligonum comosum*, a medicinal plant from arid regions of Tunisia – compounds *Calligonum*, medical from regions Tunisia. African Journal of Traditional, Complementary, and Alternative Medicines, 8 (3): 322-327. doi: 10.4314/ajtcam.v8i3.65299.

Sabry, L., Sattar, M.A., Amin, H.A., Sattar, E.A. 2013. Antiosteoporotic effect of some herbal extracts versus alendronate on an animal model of osteoporosis. Life Science Journal, 10 (4):177-187.

Sak, K. 2014. Cytotoxicity of dietary flavonoids on different human cancer types. Pharmacogosy Review, 8(16):122-146. doi: 10.4103/0973-7847.134247.

Samejo, M.Q., Memon, S.M.I., Bhanger, K., Khan, M. 2011. Preliminary phytochemical screening of *Calligonum polygonoides* Linn. Journal of Pharmacy Research, 4(12): 4402-4403.

Samejo, M.Q., Memon, S.M.I., Bhanger, M.I., Khan, K.M. 2013. Chemical composition of essential oil from *Calligonum polygonoides* Linn. Natural Product Research, 27(7): 619-23. doi: 10.1080/14786419.2012.686904.

Shalabi, M., Khilo, K., Zakaria, M.M., Elsebaei, M.G., Abdo, W., Awadin, W. 2015. Anticancer activity of *Aloe vera* and *Calligonum comosum* extracts separetely on hepatocellular carcinoma cells. Asian Pacific Journal of Tropical Biomedicine, 10(5): 375-381. doi: 10.1016/S2221-1691(15)30372-5.

Singh, U.R., Wadhwani, A.M., Johri, B.M. 1996. Dictionary of Economic Plants in India. ICAR, New Delhi.

Spears, J.W. 1994. Minerals in forages. Forage Quality, Evaluation, and Utilization. Editörler: Fahey, G. C. J., Moser, L. E., Martens, D. R., Collins, M.. Madison, USA: ASA. CSSA. SSSA.

Tadevosyan, T.L. 2001. On the ecology of the joint weed-like *Calligonu*m (*Calligonum polygonoides* L., Dicotyledones, Polygonaceae). In: Proceedings of republican youth scientific conference: The future of ecological science in Armenia. Yerevan. Center for Ecological-Noosphere Studies NAS RA Council of the Young Researches, Yerevan State University Student Scientific Society, p. 35-42

Tan, M., Temel, S. 2012. Alternative forage crops. Ataturk University, Faculty of Agriculture Publications No: 246, 195-207, Erzurum/Türkiye.

Tao, L. 2000. Genetic diversity and systematical taxonomy of genus *Calligonum* L. PhD Thesis, Environment and Engineering Institute of Cold and Arid Regions, The Chinese Academy of Sciences, PR China, 281 p.

Temel, S. 2015. Determination of fodder quality parameters in vegetative and seed maturity stages of *Salsola tragus* L. and *Noaea mucronata* (Forssk.) Asch. & Schweinf. International Journal of Agriculture and Wildlife Science, 1(1): 23-30.

Temel, S. 2018. Determination of nutritional contents at the different development stages of *Puccinellia distans* and *Aeluropus littoralis*

commonly growing in saline-alkaline pastures. International Journal of Agriculture and Wildlife Science, 4(2): 237-246. doi: 10.24180/ijaws.440309.

Temel, S. 2019a. The determination of changes in monthly mineral contents of thorny saltworth (*Noaea mucronata subsp. mucronata*). Fresenius Environmental Bulletin, 28: 2421-2425.

Temel, S. 2019b. Variations in nutrient composition during *Noaea mucronata*'s active growth as a source of roughage. International Journal of Agriculture and Wildlife Science, 5(1): 117-123. doi: 10.24180/ijaws.487284.

Temel, S. 2019c. Changes in seasonally mineral content of *Calligonum polygonoides* L. shrub and its capacity of meeting daily mineral requirements of grazing small ruminant. Turk Journal of Field Crops, 24: 195-201. doi: 10.17557/tjfc.643548.

Temel, S., Keskin, B. 2019a. Annual evaluation of nutritional values of *Salsola ruthenica* evaluated as a potential feed source in arid-pasture areas. Fresenius Environmental Bulletin, 28(10): 7137-7144.

Temel, S., Keskin, B. 2019b. Determination of some phenological properties of goat's wheat shrub growing in Igdir erosion areas in terms of grazing management. Umteb 6. International Vocational and Technical Sciences Congress. 11-12 April 2019, Iğdır University, Iğdır-Türkiye.

Temel, S., Keskin, B., Akbay Tohumcu, S., Tan, M., Unal, M., Yılmaz, I.H. 2017. Iğdır province meadow and pasture plants guide (Iğdır İli Çayır Mera Bitkileri Kılavuzu). Öncü Printing Publication Promotion limited company, I. Edition, p:180, ISBN: 978-605-9028-57-8.

Temel, S., Sürmen, M. 2018. Mineral content changes of some halophyte species evaluated as alternative forage crops for ruminants' nutrition. Fresenius Environmental Bulletin, 27(11): 7340-7347.

Temel, S., Sürmen, M., Tan, M. 2015. Effects of growth stages on the nutritive value of specific halophyte species in saline grasslands. The Journal of Animal and Plant Sciences, 25: 1419-1428.

Temel, S., Tan, M. 2011a. Fodder values of shrub species in maquis in different altitudes and slope aspects. The Journal of Animal and Plant Sciences, 21(3): 508-512.

Temel, S., Tan, M. 2011b. Determination of the leaf yields and leaf ratios per plant depending on altitude and slope aspects of shrub species in mediterranean region maquis. Journal of the Faculty of Veterinary Medicine, Kafkas University, 17(2): 257-262. doi: 10.9775/kvfd.2010.3192.

Temel, S., Temel, I. 2018. Determination of some plant and yield characteristics with preference conditions in grazing of endemic *Calligonum polygonoides* L. *ssp. comosum* (L'Her.) shrub for Turkey. Ataturk University Journal of the Agricultural Faculty, 49(1): 7-13. doi: 10.17097/ataunizfd.346142.

Vyas, G.K., Kumar, V., Sharma, R., Sharma, R.A., Sharma, S., Singh, J.P., Kumar, S., 2012. Chemical and genetic diversity among some wild stands of *Calligonum polygonoides* (Polygonaceae) from the Thar Desert of Rajasthan. Revista de Biología Tropical, 60 (3): 1097-1108.

Yawer, M.A., Ahmed, E., Malik, A., Ashraf, M., Rasool, M.A., Afza, N. 2007. New lipoxygenase-inhibiting constituents from *Calligonum polygonoides*. Chemistry Biodiversity, 4(7):1578-1585. doi: 10.1002/cbdv.200790137.

Zouari, S., Dhief, A., Aschi-Smiti, S. 2012. Chemical composition of essential oils of *Calligonum comosum* cultivated at the South-Eastern of Tunisia: a comparative study between flowering and fructification stages. Journal of Essential Oil Bearing Plants, 15(2): 320-327. doi: 10.1080/0972060X.2012.10644054.

CHAPTER 3

FORAGE TURNIP (*Brassica rapa* L.)

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1. INTRODUCTION

Brassica species are cultivated around the world as alternative forages to close feed deficits when forage production is limited. Forage turnips (*Brassica rapa* L.), forage rapes (*Brassica napus* ssp. *oleifera*) and fodder cabbages are some of the main *Brassica* species. An annual plant in the cruciferous group, forage turnip is a winter vegetable. Nutrients that are digestible and high in protein are found in it (Olmstead, 2006; Denen and Malayoğlu, 2022).

In the *Brassica* genus, *Brassica rapa* is one of the most important species, cultivated across Europe for centuries and eventually spreading to Central and East Asia, but its origin is in the Mediterranean Basin (De Candolle 1886; Del Carpio et al, 2011; Aissiou et al, 2018; Shankar et al 2019). Widely consumed crops from *Brassica rapa* include fodder turnip, heading and non-heading leafy vegetables, oilseed crops, and vegetable turnips. These crops are produced through a combination of genetic and epigenetic variation (Cartea et al, 2011a; Zhang et al, 2013; Zheng et al, 2015; Cheng et al, 2014, 2016b;). As a result, multiple phenotypically diverse morphotypes were produced, meaning that morphological variety (such as leafy, root, fodder, and oilseed types) within a species population corresponded to distinct groups or subspecies.

The cultivation of this species is very old. It is estimated that it has been cultivated in Europe for 8000 years. *Brassica* species, which are native plants of the Mediterranean region, are used all over the world mainly for edible and industrial oil production, vegetables and spice crops (Al-Shehbaz et al, 2006). Among these, forage turnip is the most widely used species as a forage crop.

Turnip contains significant amounts of vitamin C, dietary fiber and minerals such as calcium, magnesium, riboflavin and iron. It is also rich in glucosinolates and phenolic compounds, which are secondary metabolites found in plants. It has been reported that it can prevent the risk of developing high blood pressure, diabetes and various types of cancer due to these antioxidant substances (Li et al, 2018). But at the same time, their presence in the plant can also cause some diseases in livestock.

2. SYSTEMATIC AND MORPHOLOGY

The forage turnip, scientifically known as *Brassica rapa* subsp. *rapa*, belongs to the *Brassicaceae* family. Its place in systematics is indicated below (Paul et al., 2019).

Order: *Brassicales*
Family: *Brassicaceae (Cruciferae)*
Genus: *Brassica*
Species: *Brassica rapa*
Subspecies: *Brassica rapa* subsp. *rapa*

The forage turnip is a subspecies of *Brassica rapa* and is specifically cultivated for use as forage for livestock. The plant is known for its fleshy taproot, which is commonly consumed by grazing animals.

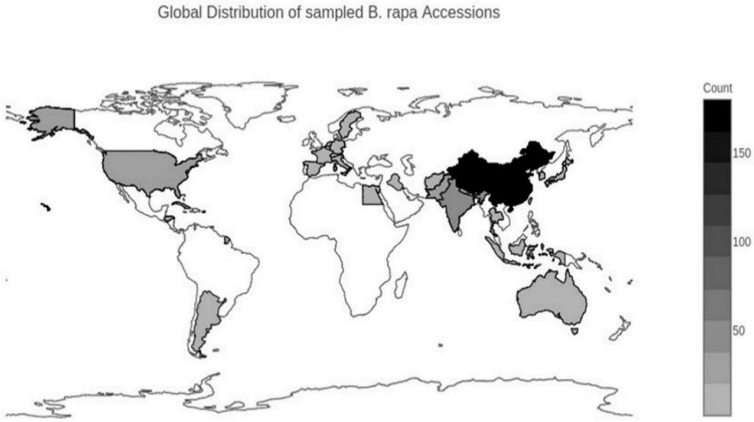

Figure 1. Global geographic distribution of different Brassica rapa L. accessions. A higher proportion of B. rapa accession from that nation is indicated by darker hues. The USDA GRIN-Global database identified the nation of origin (Bird et al, 2017)

In Europe, Asia, and North Africa, turnip (*Brassica rapa* subsp.. *rapa*, 2n = 2x = 20 AA), popularly referred to as white turnip, is one of the most widely grown winter taproot forage crops. Succulent store roots, expanded hypocotyls, and increased upper root and stem base tissues are its most typical growth characteristics (Lu et al, 2008; Solaiman et al, 2008). When autumn-germinated seeds are exposed to vernalization throughout the following winter, the plants—which are normally biennial—can be grown as annuals (Heenan et al, 2004; Zhang et al, 2014a, b). Turnip is grown from true seed, much like sugar beet. Its above-ground storage organ, the hypocotyl, is formed from this stage, and the proportions of its stem and root tissues vary (Zhang et al, 2014a, b; Liu et al, 2019). Depending on the cultivar, turnips develop a long,

cylindrical root or a swelling, spherical, slightly fattened root as a reservoir organ.

The morphology of forage turnips includes various features of the plant's structure and appearance. Leafy-type fodder turnip is a productive forage crop with large leaves and a height of up to 3-4 m. It can be used for hay and silage production (Açıkgöz, 2021).

Forage turnips have a large, fleshy taproot, which is the edible part of the plant. This taproot can be white or purple depending on the variety.

Figure 2. Leafy type and taproot type forage turnips (Missouri Southern Seeds, 2023; Johnny Seeds, 2023)

The plant produces broad, lobed leaves that are typically green in color. The leaves are attached to the stem by petioles.

Figure 3. Forage turnip leaves (Gardener's Path, 2023).

The stem of forage turnips is usually smooth and can vary in height depending on the growth stage and specific cultivar.

Forage turnips, like many members of the *Brassicaceae* family, produce small, four-petaled flowers. These flowers are typically white or yellow and form in clusters.

Figure 4. Forage turnip flowers (Honey Plants, 2023).

Fruits: After flowering, forage turnips develop seed pods containing small seeds. However, forage turnips are often grown as an annual crop for their roots and are not typically cultivated for seed production.

Figure 5. Forage turnip seeds (Cotswold Seeds, 2023).

Habit: Forage turnips are herbaceous plants with an annual growth habit. They are commonly grown as cover crops, green manure, or as a forage crop for livestock.

Lifecycle: Forage turnips complete their life cycle in one growing season. They are often planted in the late summer or early fall and harvested in the fall or early winter.

Understanding the morphology of forage turnips is important for cultivation and management practices, especially when used as a forage crop for livestock or as part of a rotational cropping system.

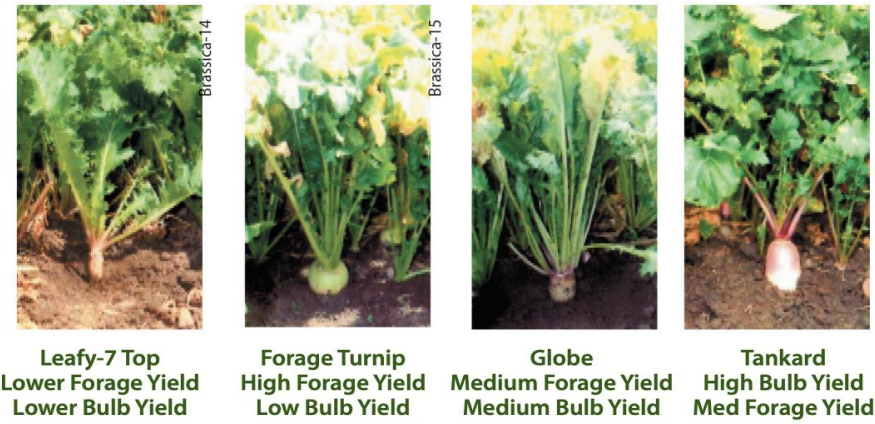

Figure 6. Forage turnip types (USDA, 2003).

3. ADAPTATION

Brassica species grow well in humid and cool regions with regular rainfall. In regions with these climatic characteristics, they can be grown throughout the year and in regions with mild winters, they can be grown in winter. Plants that are sown in early fall and grow well into rosettes withstand winter well. Especially in regions with mild winters, they are not damaged by short-term frosts (Barnes and Miller, 1995).

Widely grown in Europe, Asia and the Americas, turnip is a tuberous vegetable that can be found all year round. *Brassicaceae*, which includes approximately 338 genera and 3709 species, is spread all over the world except Antarctica. It grows naturally in a wide area extending from the Mediterranean region and the Middle East to Central Asia (Açıkgöz, 2021). The tuber is

usually white in color, spherical, with a fleshy reddish purple crown (Tindall, 1983).

Small, crisp varieties are used for human consumption, while larger varieties are used as feed. Turnip, one of the cultivated plants, has been consumed since prehistoric times (Haliloğlu et al, 2012). It is widely used in cold regions and especially in Europe. It can be stored for several months after harvest without spoiling and grows well in cold climates (Haliloğlu et al, 2012).

Turnips need well-drained soil, and their ideal pH range is between 5.5 and 6.8. Turnips that have been glyphosate-killed can be no-tilled into a sod. As a result, bug issues are decreased. Additionally, they can be sown into wheat stubble. Although clean till sowing is effective, there could be more insect pressure. Herbicide residues from herbicide carryover are a major concern for turnips when sowing following crop farming. Turnip establishment and growth can be impacted by certain frequently used herbicides for a maximum of 24 months. Carry-over label instructions meant for sugar beets often apply to the majority of turnip types as well. For turnips, use 2 to 4 pounds of seed per acre. Turnips can be planted aerially, no-till, or conventionally. Because turnip seeds are tiny, they must be sown in a firm, fine seedbed that is sufficiently moist for them to germinate. Plant the seed at a depth of no more than ½ to ¼ inch, spacing the seeds 6 to 8 inches apart. Aerial seeding of turnips and small grain crops into standing maize in mid-August has proven successful for certain producers. Once more, before using this seeding technique, review your herbicide program for any potential carryover and grazing restrictions (USDA, 2003).

4. YIELD AND QUALITY

Forage turnip yields can vary based on several factors, including environmental conditions, soil fertility, cultivation practices, and the specific cultivar planted. Generally, forage turnips are known for their rapid growth and can produce high biomass within a relatively short period, especially when planted in the late summer or early fall. Adequate spacing and appropriate soil moisture contribute to optimal yields. Harvesting at the right stage, typically before the plant bolts and the root becomes woody, ensures maximum yield. Forage turnip yields can vary based on several factors, including environmental conditions, soil fertility, cultivation practices, and the specific cultivar planted.

Generally, forage turnips are known for their rapid growth and can produce high biomass within a relatively short period, especially when planted in the late summer or early fall. Adequate and appropriate soil moisture contributes to optimal yields. Harvesting at the right stage, typically before the plant bolts and the root becomes woody, ensures maximum yield.

Although Brassicas have low dry matter content, they can have higher herbage yields than many forage crops. Crude protein content levels are around 15-20% in leaves and 6-15% in roots. They are delicious because they are juicy and sugary. However, when fed too much, it may cause diarrhea and sour milk. In crops with leafy stems such as collards and cabbage, the crude protein ratio is around 20-25% in the leaves and 10% in the stem. Forage turnip; It is stated that it has a ratio of 45% roots and 55% leaves, and the dry matter ratio is 8.5% in the roots and 5.5% in the leaves (Kır et al, 2007). Geren et al (2002) stated in their study that it is possible to cultivate fodder turnip as a winter second crop in the cotton-cotton or wheat-cotton cropping system in the Ödemiş Plain, which represents the Mediterranean climate zone, in the fields that remain empty after cotton until the spring of the following year, and that it is possible to obtain a total yield of over 12 tons/ha of wet matter and over 1 ton/ha of dry matter. They concluded that important feeding problems, especially in dairy cattle breeding, can be solved by providing a succulent feed source such as fodder turnip at a time when animals are fed dry.

In the Black Sea Coastal Area, Albayrak ve Candaş (2006) assessed four forage turnip cultivars for root and leaf yields, as well as their yield components and the recovery of applied N under five different degrees of N fertilization. The amount of N administered had a direct impact on the yields of roots and leaves, with most cultivars exhibiting larger yields at higher N rates. The variation in cultivars and N application rates resulted in varying degrees of increase. The cultivar Volenda yielded the highest results across all application levels. All cultivars' crude protein content rose when nitrogen fertilizer was applied. Crude protein yields in the roots and leaves were highest for the Volenda cultivar.

Ayan et al., (2006) examined the yield performance of some forage turnip varieties in the Central Black Sea Region. They reported that the highest fresh leaf yield (3833.0 kg/da) was obtained from Polybra variety in Samsun and 4778.0 kg/da was obtained from Silogonova variety in Suluova. The

highest total protein yield was obtained from Polybra variety in Samsun (70.38 kg/da) and Agressa variety in Suluova (191.03 kg/da). According to these results, they decided that this variety should be tried more in this ecology.

Türk et al., (2009) investigated the effects of fertilization on foliage and root of fodder turnip in a Mediterranean climate in Isparta. Their study's findings demonstrated a strong correlation between the amount of N applied and the yields of roots and leaves. P treatments increased leaf yield, leaf DM yield, root CP content, and leaf CP yields. N doses increased root length, root diameter, root yield and DM yield, leaf yield and DM yield, root CP content and yield, and leaf CP content and yield. The amount of ADF and NDF in the forage turnip's root and leaf was reduced by nitrogen and phosphorus treatments.

Tiryakioğlu and Türk (2012), investigated whether sowing and harvesting times affect forage turnip under Isparta conditions. They found that planting and harvesting times had different effects on yield and quality in forage turnip, which is used as a second crop. It is understood from the statements they wrote that the yield will increase and the quality will decrease with the harvest made at later times.

Bilgili et al., (2003) examined the effects of seed rate and row spacing on seed performance under Bursa conditions. As a general result of their experiments, they obtained that fodder turnip can be grown successfully in fall sowing under Mediterranean climate rain-fed conditions. They stated that they were able to grow the highest seed yield in the combination of 35 cm row spacing and 200 seed m sowing rate without any serious lodging problems.

Since leaves are more nutritious than roots, newly developed turnip varieties have a high leaf-to-stem ratio. For example, the Cyclon turnip variety has a leaf-to-stem ratio of 4:1 and the Tyfon turnip has a leaf-to-stem ratio of 9:1. The highest root dry matter yield in turnip is reached 90-95 days after sowing in spring sowing and 80-85 days after sowing in fall sowing. It is a very suitable plant for the need for irrigated feed in the fall. Due to the short growing season, turnip is suitable for use as a main crop. In some European countries, it can also be grown as a second crop (Altınok and Karakaya, 2003; Özaslan Parlak and Sevimay, 2005).

Nutritional value is generally higher in the fall than in the spring. There are two reasons why plants sown in the fall retain their nutritional value. The

first one is that dry matter accumulation is low after reaching maximum yield. The second reason is that the weather is cool in the fall (Tan and Temel, 2012).

Despite their high nutritional value, Brassicas contain anti-quality substances and mineral concentrations that negatively affect animal performance. Concentrations of Ca, Mg, K, Cu, Fe and Mn are higher in summer growing plants than in fall growing plants. Ca:P ratios of herbages may be at risky values for ruminants. These values are slightly lower in roots but still carry a risk. Mg content and its usefulness to ruminants depends on K, N and Ca ratios. Generally, high levels of these elements in grasses can cause magnesium deficiency for ruminants. The imbalance between these elements can often lead to tetanus. It is known that the K/MCa + Mg ratio (Tetani value) in turnip increases to 5.2 (Guillard and Allison, 1989; Tan and Temel, 2012). This situation affects the feed value. Feed value corresponds to the primary and secondary components of the plant and their benefits to ruminant animals.

The definition of forage feeding value (FV) is the animal's response to grazing fodder when its availability does not limit its ability to function. In growing animals, it is commonly expressed as liveweight gain (LWG) or milk yield in lactating animals, frequently when the animals are grazing a single feed. This is the case for many sheep-based brassica grazing trials. The three components of feed value (FV) are apparent digestibility, efficient use of nutrients that have been digested, and voluntary feed intake (VFI). It is widely acknowledged that a high ratio of structural to rapidly fermentable carbohydrates (CHO) will result in faster rumen clearance, higher VFI, and higher FV when comparing FV among forages. This is accurate in situations when plant secondary chemicals do not pose a threat, which brassicas used as forage do not (Barry, 2013). The secondary chemicals found in pasture brassicas, their breakdown and metabolism in the ruminant digestive system, and the absorbed products that may have adverse effects on grazing animals are depicted in Figure.7.

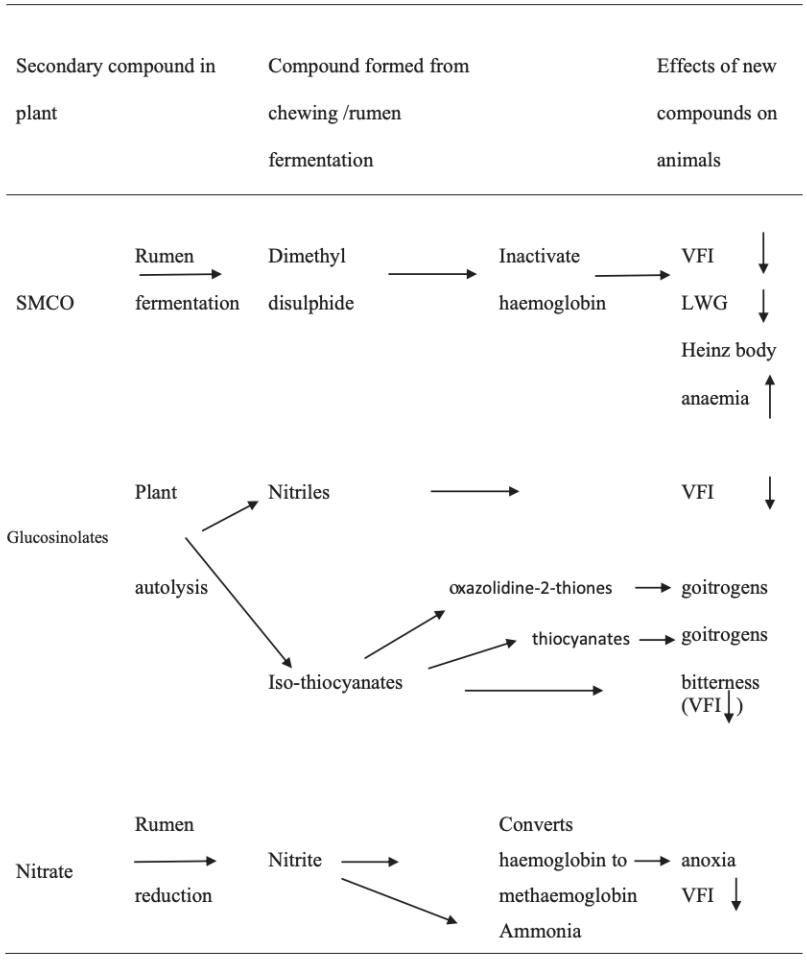

Figure 7. Compounds formed from secondary compounds in brassica plants and their effects upon grazing ruminants (Barry, 2013).

Figure 8. Flowering stage of forage turnip (Original).

Despite all the positive and negative characteristics of forage turnip, it is a plant that has the potential to contribute to closing the quality forage deficit. However, there is a lack of research on this subject. At the same time, it should not be ignored that there should be some approaches to expand this species in crop rotations in Türkiye.

REFERENCES

Açıkgöz, E. 2021. Forage Crops (Vol 1.) Ministry of Agriculture and Forestry Publications, General Directorate of Crop Production, Ankara, 448p.

Albayrak, S., Çamaş, N. 2006. Performances of forage turnip (*Brassica rapa* L.) cultivars under different nitrogen treatments. Anadolu Journal of Agricultural Sciences, 21(1), 44-48.

Altınok, S., & Karakaya, A. 2003. Effect of growth season on forage yields of different Brassica cultivars under Ankara conditions. Turkish Journal of Agriculture and forestry, 27(2), 85-90.

Ayan, İ., Önal, Ö., Özlem, Başaran, U., Mut, H. 2006. Qualıty characters of some turnıp (*Brassica rapa* L.) cultıvars. J. of Fac. of Agric., OMU, 21(3), 310-313.

Barnes, R. F., Miller, D. A., Nelson, C. J. 1995. Forages (Volume 1). Ames, Iowa: Iowa State University Press.

Barry, T. N. 2013. The feeding value of forage brassica plants for grazing ruminant livestock. Animal Feed Science and Technology, 181(1-4), 15-25.

Bilgili, U., Sincik, M., Uzun, A., Acikgoz, E. 2003. The influence of row spacing and seeding rate on seed yield and yield components of forage turnip (*Brassica rapa* L.). Journal of Agronomy and Crop Science, 189(4), 250-254.

Bird, K. A., An, H., Gazave, E., Gore, M. A., Pires, J. C., Robertson, L. D., Labate, J. A.2017. Population structure and phylogenetic relationships in a diverse panel of *Brassica rapa* L. Frontiers in plant science, 8, 321.

Cotswold Seeds. 2023. Turnip. (https://www.cotswoldseeds.com/species/61/stubble-turnip accessed: 30.11.2023).

Denen, M., Malayoğlu, H. B. 2022. The effects of wilting and different additives on fermentation and aerobic stability in forage turnip (*Brassica rapa* L.) silage. Journal of Agriculture Faculty of Ege University, 59(2), 297-312.

Gardener's Path. 2023. Turnip. (https://gardenerspath.com/plants/vegetables/health-benefits-turnip-greens/ accessed: 30.11.2023).

Geren, H., Demiroğlu, G., Avcıoğlu, R. 2002. Investigations on the yield characteristics of some forage turnip (*Brassica rapa* L.) cultivars. Journal of Agriculture Faculty of Ege University, 39(1).

Guillard, K., Allinson, D. W.1989. Seasonal variation in chemical composition of forage Brassicas. I. Mineral concentrations and uptake. Agronomy Journal, 81(6), 876-881.

Haliloğlu, H. İ., Arslan, M., Lee, B. J., Dabrowski, K. 2012. The effects of dietary turnip (*Brassica rapa)* and biofuel algae on growth and chemical composition in rainbow trout (*Oncorhynchus mykiss*) juveniles. Turkish Journal of Fisheries and Aquatic Sciences, 12(2).

Heenan, P. B., FitzJohn, R. G., Dawson, M. I. 2004. Diversity of brassica (*Brassicaceae*) species naturalised in Canterbury, New Zealand. New Zealand Journal of Botany, 42(5), 815-832.

Honey Plants. 2023. Turnip (https://www.honey-plants.com/calendar/mississippi/forage-turnip/ accessed: 30.11.2023).

Johnny Seeds. 2023. Purple top forage turnips. (https://www.johnnyseeds.com/growers-library/farm-seed-cover-crops/brassicas/forage-crops-brassica-rapa-key-growing-information.html accessed: 30.11.2023).

Kır, B., Demiroğlu, G., Soya, H. 2007. An Investigation on Yield Characteristics of some Forage Turnip (*Brassica rapa* L.) Cultivars. Journal of Agriculture Faculty of Ege University, 44(1), 87-97.

Li, X., Li, B., Yang, Y. 2018. Effects of foliar selenite on the nutrient components of turnip (*Brassica rapa* var. rapa Linn.). Frontiers in Chemistry, 6, 42.

Lu, K., Wei, L., Li, X., Wang, Y., Wu, J., Liu, M., ... Li, J.2019. Whole-genome resequencing reveals *Brassica napus* origin and genetic loci involved in its improvement. Nature communications, 10(1), 1154.

Lu, G., Cao, J., Yu, X., Xiang, X., Chen, H. 2008. Mapping QTLs for root morphological traits in *Brassica rapa* L. based on AFLP and RAPD markers. Journal of applied genetics, 49, 23-31.

Missouri Southern Seeds. 2023. Forage turnips (https://www.missourisouthernseed.com/product/jackpot-forage-turnips/ accessed: 30.11.2023).

Özaslan- Parlak, A., Sevimay, C. S. 2005. Effect of seeding after barley and wheat harvest on yield components of forage turnip *Brassica rapa* L. Cultivars. Journal of Agricultural Sciences, 11(03).

Paul, S., Geng, C. A., Yang, T. H., Yang, Y. P., Chen, J. J. 2019. Phytochemical and health-beneficial progress of turnip (*Brassica rapa*). Journal of food science, 84(1), 19-30.

Solaiman, A. H. M., Hasanuzzaman, M., Uddain, M. J. 2008. Performance of turnip (*Brassica rapa* sub sp. *rapifera*) under different manuring package at mulched and non-mulched condition. Am Eurasian J Bot, 1(3), 78-84.

Tan, M., Temel, S. 2012. Alternative forage crops. Atatürk University, Faculty of Agriculture, Offset Facility, Erzurum, Turkey.

Tindall, H. D. 1983. Vegetables in the tropics. Macmillan Press Ltd.

Tiryakioğlu, H., Türk, M. 2012. Effects of different sowing and harvesting times on yield and quality of forage turnip (*Brassica rapa* L.) grown as a second crop. Turkish Journal of Field Crops, 17(2), 166-170.

Türk, M., Albayrak, S., Balabanli, C., Yüksel, O. 2009. Effects of fertilization on root and leaf yields and quality of forage turnip (*Brassica rapa* L.). J. Food Agric. Environ, 7, 339-342.

USDA. 2003. Illinois grazing fact sheet: Turnips for forage. (https://nrcs.usda.gov/sites/default/files/2022-12/TurnipsForForage.pdf accessed 29.11.2023).

Zhang, N., Zhao, J., Lens, F., de Visser, J., Menamo, T., Fang, W., ... Bonnema, G. 2014a. Morphology, carbohydrate composition and vernalization response in a genetically diverse collection of Asian and European turnips (*Brassica rapa* subsp. *rapa*). PLoS One, 9(12), e114241.

Zhang, X., Lu, G., Long, W., Zou, X., Li, F., Nishio, T. 2014b. Recent progress in drought and salt tolerance studies in Brassica crops. Breeding Science, 64(1), 60-73.

CHAPTER 4

HOPS (*Humulus lupulus* L.)

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1.INTRODUCTION

Population growth, economic advancements, and dietary awareness all contribute to rising demand for animal products, which calls for more effective use of scarce production resources such as soil and water. The best methods for achieving decent fodder production with scarce natural resources in the face of climate change are proper forage selection and appropriate management techniques.

Climate conditions have a significant impact on agriculture from sowing to harvest. Therefore, depending on the degree of warming, different levels of direct climate change influence on crop production systems are anticipated from region to region (Wheeler and Reynolds, 2013, Demiroğlu Topçu et al., 2019). As a result of all these modifications and dangers, people are looking for new ways to produce plants, especially alternative forage crops.

On the other hand, in the search for new feed sources, in addition to efficiency, the quality of the source and its effects on animal health are also taken into consideration. Recent studies on the nutrition of ruminants have revealed that the secondary metabolites (such as flavonoids, isoflavonides, phenolic compounds, and tannins) contained in plants are very important for rumen health and animal productivity (Rochfort et al., 2008; Patra et al., 2006; Lee et al., 2017). Some researchers emphasize that these substances increase feed intake and efficiency in animals (Dohi et al., 1997; Robbins, 2003), and have antioxidant and antimicrobial effects (Santos Neto et al., 2009; Frozza et al., 2009). Flavonoids and phenolic compounds found in the plant control nutritional stresses such as rumen fermentation, bloating and acidosis (Seradj et al., 2014; Paula et al., 2016) and reduce mortality (Martin et al., 2016). Condensed tannins have an anthelmintic effect, reducing animal internal parasites and increasing productivity in animals. In addition, condensed tannins suppress organisms that cause methane release from the rumen and therefore reduce the greenhouse effect. It is estimated that 1/4 of global warming is caused by methane gas produced in the digestive systems of ruminants and released into nature (Lascano and Cardenas, 2010).

Hop is also known as “yeastwort” or “beer flower” among the public. This plant is grown mainly for brewery as a bittering, flavouring, and stability agent in beer. However, its yield and nutritional properties offers opportunities to use its animal feeding. The plant is a perennial herb with climbing stems and belongs to the hemp family. The young shoots of the plant, whose general purpose is beer, yeast,

and bread, are also consumed as vegetables (Incekara, 1964). Besides, the hop is simple to digest and includes high amounts of polyphenols, crude protein, and crude ash. These characteristics help to improve the quality, yield, and health of the animals. Accordingly, the plant can also be grown as forage. However, even with its current production form, it is already a potential feed source. Brewers use only the cones of hops, therefore, after the hop harvest, a non-negligible amount of waste suitable for animal feeding is released.

2. SYSTEMATIC AND MORPHOLOGY

The hop (*Humulus lupulus* L.) is a dioecious, anemophilous, perennial climbing plant arising from a rhizome with large numbers of adventitious roots (Miller, 1958). Hops species are native in temperate climate zones, between a latitude of 35° N and 55° N. Hops have pistillate and staminate flowers on different plants, but are cultivated only for their mature unfertilized female inflorescence called cones (strobiles) (Kondić et al., 2021).

Team: Urticales

Family: Cannabaceae

Genus: Humulus T.

Species: *Humulus lupulus* L. (2n=20)

Root: The perennial parts of the plant are the underground roots and rhizomes. Its underground parts can survive for up to 100 years. But its economic life is about 15-25 years.

Figure 2.1. Root of hop (Anoymous, 2023b; 2023c)

Hops are a tap-rooted plant that can penetrate as far as 4 meters. The soil's composition directly affects how far down the roots can grow. There are numerous

side roots because the main root's thickness varies from 5 to 10 cm. Main root thickness is directly proportional to the age of the plant. Side roots connected to the main root extend horizontally underground. In addition, it shoots (rhizomes) develop from the main root and rise above the soil, and these form the above-ground body of the plant. These shoots, thanks to their hard hairs, form the trunk by wrapping themselves around a point from left to right (Anonymous, 2023a) (Figure 2.1).

Hops is a dioecious plant. It is a group of female flowers (cones) resembling a pine cone or a large ear on female plants. There are between 20 and 60 flowers in each cone. Each flower consists of two bracts and four bracteole leaves. There are plenty of yellow lupulin glands in the bracteole leaves. It is a perennial plant and has a climber trunk structure that can grow 7-9 m. The above-ground organs die in winter, but many shoots, each 0.5–1 cm thick, 6-cornered, and covered with hairs, are formed from the perennial underground rhizomes. On the stems are arranged leaves that resemble vine leaves, usually with segmented, long stems and toothed edges. There are hairs on the petiole and underside of the leaf that make climbing easier. Fruit branches and branchlets emerging from the leaf axils end in cones formed by female flowers. When mature cones are crushed, dark yellow, gray, and black seeds fall out. In hop plantations established with only female plants, males are the pollen source. Since there are no seeds in cones, they rarely form seeds. The weight of seedless cones is 30% less than that of those with seeds. However, cones with seeds have low aroma and taste quality. For this reason, male plants are given little or no space in plantations (Anonymous, 2023a).

Stem:Its wrapping stems, which can grow up to approximately 8-10 meters, die with their leaves in winter, and new stems grow from the underground parts the following year. Plants cling to a vertical support, and if there is no object to cling to, they grow by crawling on the ground. The main stem has a 6-cornered structure, is 0.5–1.0 cm thick, and is covered with hard hairs. The trunk and branches have a gnarled structure.

Figure 2.2. Stem of hop (Anoymous, 2023d; 2023e; 2023f)

Leaf: The stipule leaves, which are opposing leaves, grow at each node of the stem, whereas the main leaves develop from their axles. Stipulate leaves are small, thin, long, and pointed. New branches and fruit branches that form flowers develop from the main leaf axils.

Figure 2.3. Leaf of hop (Anoymous, 2023g)

The main leaves grow from the nodes opposite each other, and their edges are toothed. The main leaves grow from the nodes opposite each other, and their edges are toothed. The lower leaves have a 5-piece structure, a 3-piece structure in the middle parts of the plant, and a single heart-shaped structure at the top. The leaf is attached to the stem with a very long petiole and is covered with hard hairs.

Flower: Hop is generally a dioecious plant, with male and female flowers on different plants. However, plants with monecian characteristics are also encountered in some cases. The flowers of the male plant are in a cluster and are not used to obtain lupulin. Each male flower has 5 sepals, 5 petals, and 5 stamens. The female flower state is called "cone," and each cone consists of the union of 20 to 60 flowers.

Figure 2.4. Flower of hop (Anoymous, 2023h)

The cone is connected to the main stem with a stem. The female flowers that make up the cone are connected to the main axis of the cone with a short stem. The cone axis is actually an extension of the cone stem. On the contrary, it has a zigzag structure. The cone resembles an umbrella or a wide spike. The length of the cones varies between 2 and 6 cm, and the width varies between 1.5 and 3.5 cm. The arrangement of female flowers on the spike axis can be dense or loose.

There are 4 bracteoles (perigon leaves), 4 ovaries, and 2 bracte leaves (covering leaves) at each bending point of the zigzag spike axis. This structure is called a spikelet or flower group. The ovary is located at the base of the bracteole leaf. Bracteole leaves contain yellow lupulin glands. These glands form the substance lupulin. Bracted leaves are very low in lupulin. The female flower group in hops is called the cone and is the most used part of the plant. The cones to be used in brewing must not be pollinated. Because the amount and quality of lupulin decrease significantly during seed formation. A male hop plant emits pollen powder for 15–20 days. When these pollens reach the pistil on the female plant, fertilization occurs and the seed is formed (Figure 2.4).

Seed: Hop seeds are grayish-black in color, 3–4 mm long, 2.5 mm wide, and 1.5 mm thick, and have a slightly angular structure. Hop seed does not require pre-application for germination. However, seeds planted when the weather is still cool germinate faster. It is necessary to be patient, as its germination is irregular (30–90 days). The soil should be kept moist throughout this process.


Figure 2.5. Seed of hop (Anoymous, 2023i; 2023j)

3. ADAPTATION

Propagation of hops is usually done vegetatively and new fields are also established this way. Generative units are used only for breeding purposes. For this reason, its production is usually done with claws and cuttings. Only female hops are cultivated. Males are not grown and are not allowed to grow near females. Because the quality of the cones deteriorates, female hops are unable to produce seeds. The winding branches grow every year, and their length is 8–10 m. Even though the flowers it blooms resemble the cones of cone-bearing plants, these are its flowers (İncekara, 1964).

The hop plant is a pleasure plant. The hops grow naturally in the temperate regions of the Northern Hemisphere, and the cultivate is grown between 30 and 50 latitudes in the Northern and Southern Hemispheres of the world. Its wild form can be seen in the natural flora of Bolu, Zonguldak, Adapazarı, Bilecik, Edirne, Kırklareli, and Istanbul, but it is cultivated only in Bilecik province in Turkey (İncekara, 1964; Öztürk et al., 2020)

To get good yields from hop, the climatic conditions and soil properties of the place must be well known. Although annual average temperatures of 7.5–8.5 °C are ideal for hops, it can grow well at average temperatures of 13–14 °C. Hop is a plant that requires plenty of sun. On average, more than 15 hours of light are needed. It is resistant to freezing in the winter. It likes the hot weather at the end of March and the beginning of April (İbrik, 2020).

Hops require 600–700 mm of rainfall during vegatation period. Water is essential, especially in May. May's chilly, rainy weather aids in the growth of the

hop plant. After mid-June, warm weather is optimal for growing hops. It is known to suffer harm at temperatures higher than 30 °C, though. Occasionally, in extremely hot and dry weather, flowers drop, which has a negative impact on the alpha acid characteristic. Between May and August, temperatures rise and precipitation falls, necessitating irrigation. Because of the plant's numerous leaves, which transpire a lot of water, it has a high water requirement (İbrik, 2020).

Hop plants are sensitive to the physical and chemical properties of the soil, such as pH, salinity, body, lime, and organic matter (Çakıcı et al., 2005). Since the hop plant remains in the soil for many years, the soil must be rich in plant nutrients. Bottom and alluvial soils with a depth of around 2 meters and good drainage are ideal for hop cultivation. It is also important that the topography is smooth. Poor and shallow soils are not suitable for hops. The ideal soil for hops is deep-structured, well-drained, humus-containing, sandy-clayey, clayey, and sandy soil. Soil pH should be between 6.5 and 7.0.

Figure 2.6. Growing of hop (İbrik, 2020)

4. YILED AND QUALITY

It is known that hops were used in ancient Egypt, Rome, and ancient Greece before Christ. However, it was first cultivated and produced around Bohemia in Europe in the 14th century. Later, hop cultivation spread in various ways to European countries such as England, Austria, Hungary, Poland, Ukraine, Switzerland, and different countries of the world in the 16th century.

Table 2.1. Distribution of world hop production by country (2009) (Başkaya, 2012)

Countries	Production (ton)	Countries	Production (ton)	Countries	Production (ton)
ABD	42.945	**Turkey**	1.650	**S. Africa**	360
Germany	42.00	**Ukraine**	1.330	**Russia**	330
Ethiopia	30.281	**Spain**	900	**Slovakia**	249
Chinese	10.000	**Australia**	890	**Bulgaria**	129
Poland	3.924	**N. Zeland**	800	**Other**	12.938
Slovenia	2.669	**Argentina**	450	**Total**	151.850

The United States, Germany, Ethiopia, and China are the nations that produce the most hops worldwide. Among the top generating nations are the USA and Germany, whose combined output exceeds 40.000 tons. The USA produces 27.6% of the world's output, followed by Germany with 28.3%. Approximately 56% of global production is made up of the output quantities produced in these two nations. With 30,281 tons of output and 10.000 tons of production, respectively, Ethiopia and China come next to these nations. The nations that utilize hops the most are also those with high output levels. Turkey is one among the top ten producing nations. Regarding the species cultivated, 55% of the hop area in European nations is devoted to aromatic species, while the remaining 45% is devoted to bitter species.

Türkiye started real hop production within the Ministry of Agriculture in 1955. The 24 hops brought from different countries were tested in 22 different locations during five years, and Late Cluster, Brewers Gold, and Tardif Janune de Bourgogne varieties gave good results in provinces of Bilecik and Edirne (Bağcı, 2005). Today, the hop cultivation is carried out only in the Pazaryeri district of Bilecik province.

Studies conducted in Turkey since 1992 have resulted in the development of several hop varieties. Older cultivars like Late Cluster and Brewers Gold have been replaced with four new bitter and three aromatic kinds. Names including Aegean, Erciyas, Güney, Pazaryeri, Tarbes, and Anadolu were registered for these kinds. In actuality, super-alpha cultivars of Brewer's Gold and Northern Gold have begun to replace the more conventional bitter kinds in European nations. The varieties registered in Turkey are given in Table 2.2. The most cultivated varieties today are Brewers Gold and Efes Aroma. While Brewers Gold is a bitter-type variety, Efes Aroma is an aroma-type hop.

Table 2.2. Local hop varieties and characteristics (Başkaya, 2012).

Variety	Type	Registration year	Maturity
Efes Aroma	Aroma	1992	Middle-Late
Ege	Bitter	1997	Early
Erciyas	Bitter	1997	Late
Güney	Bitter	1997	Early
Tarbes 99	Aroma	1999	Middle-Late
Anadolu 99	Aroma	1999	Middle-Late
Pazaryeri 2001	Bitter	2001	Middle-Late

Figure 2.7. Bilecik provinces and districts (İbrik, 2020)

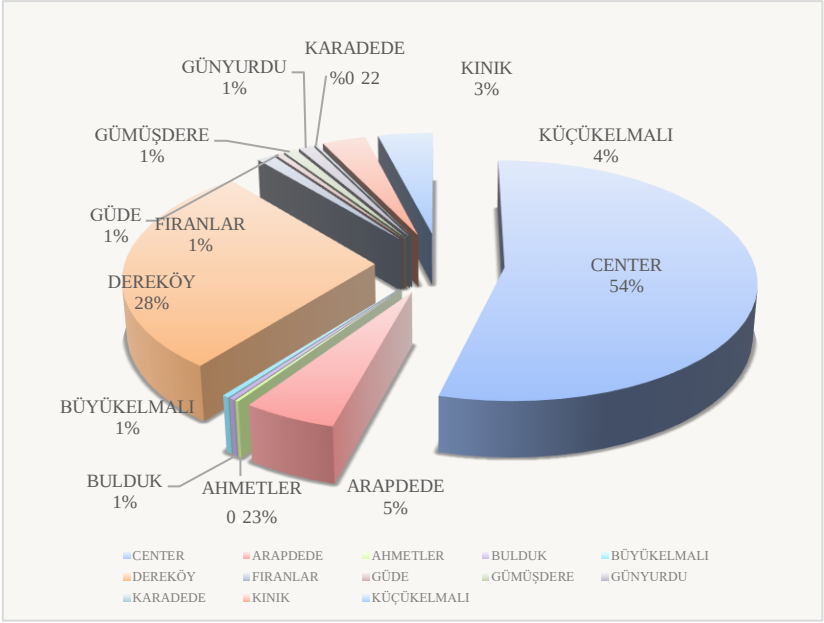

Figure 2.8. Pazaryeri villages hops area distribution (%) (İbrik, 2020)

The cultivation of the hop plant has spread over a wide area in Europe. In Turkey, it is cultivated only in the Pazaryeri district of Bilecik province. Bilecik is located at the intersection points of the Marmara, Black Sea, Central Anatolia, and Aegean Regions. Bilecik is one of the small provinces of Turkey, with an area of 4.307 km^2. It consists of 8 districts, 3 towns, and 245 villages, including the central district (Anonymous, 2018). Pazaryeri is among the smallest districts in the province.

Hops were produced in an area of 3.230 decares in 1994; it is believed that until the 2000s, both the size of the production area and the number of hops produced were at good levels (Table 2.3). There has been a notable decline in hop growing regions since the 2000s. Hop output has declined as a result of factors like rising production costs, unfavorable weather patterns, and a rise in emigration from rural areas. Because there were more producers in the province in 2015, there was a rise in the quantity of cones produced. Because of the good climatic circumstances, there was no substantial decline in the volume of output in 2016 despite the fall in the number of producers. In comparison to prior years, it was noted that in 2018, productivity in 3.300 decare areas with 547 producers remained low. Hailstorms,

which have been common in our city, have had a detrimental effect on hop output, particularly in recent years (Anonoymousi 2023k) (Table 2.3).

On the other hand, relative to the cost of manufacturing, hops are expensive to buy. Hop cultivation brought in a healthy income for many growers and improved their social life in rural regions. A well-manicured hops crop may offer an average output of 500 kg per decare, earning a producer up to 6.000 TL if the projected climatic conditions are met during the production season.

Table 2.3. Hop production by year in the Pazaryeri district (İbrik, 2020)

Year	Number of producers	Planting area (da)	Cone yield (ton)	Yield (kg da^{-1})
1995	-	3.230	1.308	404,95
1996	-	3.330	1.280	384,38
1997	-	3.330	1.309	393,09
1998	-	3.330	840	252,25
1999	-	3.330	743	223,12
2000	-	3.180	554	174,21
2001	-	2.120	709	334,43
2002	-	2.120	933	440,09
2003	-	2.140	965	451,03
2004	-	2.130	1.000	469,00
2005	469	2.250	1.140	507,00
2006	500	2.397	1.244	519,00
2007	482	2.410	1.253	520,00
2008	442	2.415	1.385	573,00
2009	479	2.835	1.474	520,00
2010	505	3.050	1.617	530,00
2011	510	3.050	1.525	500,00
2012	505	3.100	1.581	510,00
2013	708	3.200	1.680	525,00
2014	722	3.180	1.685	530,00
2015	733	3.150	1.732	550,00
2016	397	3.100	1.783	575,00
2017	359	3.000	1.725	575,00
2018	547	3.000	1.725	575,00
2019	595	3.050	1.750	573,00

Hop is useful against internal restlessness and insomnia in addition to being a sedative, sleep aid, and treatment for some issues relating to the genital system.

Additionally, it is a useful herb for treating minor depression, cardiac rhythm abnormalities, and nervous heart diseases. The plant's female cone is mostly used to make beer, but in recent years, it has also begun to be employed in the cosmetic and pharmaceutical sectors. In tiny amounts, it has sedative, urinary-enhancing, and appetizing properties (Akpınar Borazan and Andoğlu, 2012).

Numerous illnesses affecting humans, including cancer, diabetes, osteoporosis, inflammation of the bones and surrounding joints, and cardiovascular disorders, can be prevented or treated with hops. According to Cleemput et al. (2009), the α- and β-acids are linked to inflammation and cancer, while the iso-α-acids, dihydro-iso-α-acids, tetrahydro-iso-α-acids, and hexahydro-iso-α-acids can effectively prevent fat and sugar metabolism as well as inflammatory illnesses. Hops' impact on the central nervous system (CNS) and its potential advantages for treating sleep problems have been investigated in lab animals; however, the findings are not always consistent and need more testing (Zanoli and Zavatti, 2008).

The unused parts of hops, such as stems and leaves, are much more numerous than the cones used in beer production. There are 5.000 hops in one hectare. The average weight of a hop is 2.5 kg. While the 20% of the plant is used in beer-making, the remaining 80% is not used. Therefore, 10 tons of fresh yield and 3 tons of hay yield are obtained from one hectare of land. This figure shows how important the plant is in terms of being used as roughage and filling the gap.

Hops were first used for their antimicrobial properties, possibly due to the fact that injured animals rub their wounds on the plant. It has been observed that animals whose birth is approaching are calmer after eating the plant, their birth is easier, and milk yield is increased. In addition, it has been determined that hops have anticonvulsant and hypnotic effects, and therefore animals that eat hops are less restless than other animals. This situation reveals that the plant has an estrogenic and calming effect. Additionally, hops attract attention because they contain ionophore antibiotics, which are important in terms of their potential to reduce ammonia production (Flythe, 2009; Narvaez et al., 2013).

Hops is one of the many plants that have therapeutic qualities. Therapeutic plants are crucial for animal production, health, and product quality. Recent research on ruminant nutrition has concentrated on the secondary metabolites found in these plants and how they affect animals (Rochfort et al., 2008; Patra et al., 2016; Lee et al., 2017). These components, which include tannin, flavonoids, and phenol, are the

most significant. When animals are fed plants containing these compounds, their feed intake and, therefore, their live weight rise (Dohi et al., 1997). These chemicals possess antioxidant and antibacterial characteristics, as shown by Santos Neto et al. (2009) and Frozza et al. (2013). As a result, nutritional problems in animals, such as bloating and acidosis, can be managed (Paula et al., 2016; Seradj et al., 2014). Hops' total phenolic content was found to be 33.93 mg GAE g^{-1}, its flavonoid content was 54.47 mg QE g^{-1}, and its DPPH content ranged from 15.6 to 81.7% by Aline et al. (2020) and Vitalini et al. (2023). However, certain plants prevent protozoa that make hydrogen in the rumen and methane-producing organisms that use the condensed tannins in them directly to produce hydrogen, which helps lower the quantity of greenhouse gasses derived by animals. Öztürk and Gülümser (2023) found that the condensed tannin content of hops ranged between 1.38% and 5.42%. Hops' feed quality is also crucial for the health, productivity, and quality of animals. Gülümser et al. (2022) reported that the crude protein, ADF, NDF, K, P, Ca, and Mg ratios of the hop ranged between 15.76-20.8%, 35.76-44.09%, 48.63-59.80%, 2.12-2.20%, 0.30-0.37%, 15.76-20.8%, 0.87-1.16% and 0.46-0.54%, respectively.

After the harvest, hops are taken to the factory to separate the cones. The remaining parts of the plant, whose cones are separated in the factory, are thrown out of the cone separation machine as very small particles. The remaining parts of the plant are more suitable to store by making silage than hay, especially since it breaks into small pieces. In this way, animals can consume the plant easily, and the compression process of the plant can be done more easily. By using the plant as silage, fresh grass will be offered to the animals during the winter period when the green feed chain is broken. In addition, hops promote fermentation in silage thanks to the phenolic compounds they contain, while giving it an aromatic taste and increasing its palatability (Al-Mamun et al., 2011). Kaymaz (2023) reported that silage of hops lactic, acetic, oxalic, succunic and citric acid contens ranged between 1.69-4.10%, 0.037-0.371%, 0.054-0.067%, 0.072-0.122%, and 0.066-0.204%, respectively. Kaymaz (2023) reported that silage of hops lactic, acetic, oxalic, succunic, and citric acid contents ranged between 1.69–4.10%, 0.037–0.371%, 0.054-0.067%, 0.072-0.122%, and 0.066-0.204%, respectively. It is possible to use the plant as silage by mixing it with different species. In the study carried out to determine the silage quality of hops, maize, and forage soybean mixtures of 75+25%,

50+50%, and 25+75%, respectively, it was found that hops improve silage quality (Öztürk et al., 2020).

Figure 2.9. Processing of hops (İbrik, 2020).

Hops have numerous portions that are not used in beer making, such as stems and leaves. It has a high crude protein, crude ash, and polyphenol content. Because it inhibits the synthesis of ammonia. This highly digestible plant helps minimize greenhouse gas emissions coming from animal sources while also promoting animal development through the extracts of lupulone and b-acid. Hops have hypnotic and anticonvulsant properties that help animals become calmer. Also, it is an excellent feed source thanks to its high nutritional content. Accordingly, utilizing the remaining parts of hops from the brewery and/or growing it mainly as forage may have an important role in closing the forage gap.

REFERENCES

Aline Da Rosa, A., Matheus Vinícius De Oliveira, B.M., Machado, M.H., Bazzo, G.C., Rafael Dutra De, A., Vitorino, V.B., Vitali, L., Block, J.M., Barreto, P.L.M. 2020. International Journal Of Food Science And Technology, 55: 340–34.

Al-Mamun, M., Saito, A.,& Sano, H. 2011. Effects of ensiled hop (*Humulus lupulus* L.) residues on plasma acetate turnover rate in sheep. Animal Science Journal, 82: 451-455.

Akpınar Borazan, A., Andoglu, E.M. 2012. Phenolic content and their antiradical activity of the hops (*Humulus lupulus* L.) varieties cultivated in Turkey. New Biotechnology, 23-26: 121-122.

Anonymous. 2018. http://www.tuik.gov.tr.

Anonymous, 2023a. file:///C:/Users/Erdem/Downloads/SERBETCI_OTU.pdf.

Anonymous, 2023b. http://www.greenroadfarm.com/cider_hops_grapes/?page_id=18.

Anonymous, 2023c. https://tettnanger-hopfen.de/en/everything-about-hops/the-botany-of-hops/

Anonymous, 2023d. https://www.jekkas.com/products/hops

Anonymous, 2023e. https://www.minnesotawildflowers.info/flower/common-hops

Anonymous, 2023f. https://garden.org/plants/photo/360364/

Anonymous, 2023g. https://www.dreamstime.com/photos-images/hop-leaf.html

Anonymous, 2023h. https://en.wikipedia.org/wiki/Hops

Anonymous, 2023i. https://www.etsy.com/listing/1136492532/common-hops-seeds-free-shipping-humulus.

Anonymous, 2023j. https://bestnavosk.live/product_details/119392167.html.

Anonymous. 2018. http://www.tuik.gov.tr.

Bağcı, İ. 2005. Hop Farming. Agricultural Products and Livestock Industry and Trade Joint Stock Company Publication, Pazaryeri, Bilecik, Turkey.

Çakıcı, H., Yener, H., Aydın, Ş. 2005. Nutritional status of hops plantations in Pazaryeri-Bilecik. Journal of Agriculture Faculty of Ege University, 42(3): 123-134.

Demiroğlu Topçu, G., Özçelik, A.E., Tutar, T. 2019. Possible effects of climate change on energy fossil fuels and agricultural production, Engineering and Multidisciplinary Approaches, Güven book publication p:8-29

Dohi, H., Yamada, A., Fukukawa, T. 1997. Intake stimulants in perennial ryegrass *(Lolium perenne* L.) fed to sheep. Journal of Dairy Science, 80: 2083–2086.

Flythe, M.D. (2009). The antimicrobial effects of hops (*Humulus lupulus* L.) on ruminal hyper ammonia producing bacteria. Letters in Applied Microbiology, 118: 242-248.

Frozza, C. O.S., Garcia, C.S.C., Gambato, G., De Souza, M.D., Salvador, M., Moura, S., Padilha, F.F., Seixas, F.K., Collares, T., Borsuk, S., Dellagostin, O.A., Henriques, J.A., Roesch-Ely, M. 2013. Chemical characterization, antioxidant and cytotoxic activities of Brazilian red propolis. Food and Chemical Toxicology, 52: 137-142.

Gülümser, E., Mut, H., Başaran, U., Çopur Doğrusöz, M. 2022. Hop (*Humulus lupulus* L.) as a roughage source. BSEU Journal of Science, 24(4): 9(1), 609-615.

İbrik, C. (2020). Hops Growing in Pazaryeri District of Bilecik Province Contribution to District Economy and Development. Master's Thesis, Graduate School Of Natural and Applied Sciences, Ankara University, Ankara.

İncekara, F. (1964). Industrial Plants And Their Breeding: Pleasure Plants And Their Breeding. Republic of Turkey Ministry of Agriculture and Forestry Central Library.

Kaymaz, Z. 2023. Silage yield and quality of hops (*Humulus lupulus* L.). Master Thesis, Bilecik Şeyh Edebali University, Graduate School of Education, Bilecik, Turkey.

Kondi´c, D., Cerenak, A., Košir, I.J., Ocvirk, M., Krmpot, T., Đuri´c, G. 2021. Morphological and biochemical characterization of wild hop (*Humulus lupulus* L.) populations from Banja Luka area (Bosnia and Herzegovina). Agronomy, 11: 239

Lascano, C.E., Cárdenas, E. 2010. Alternatives for methane emission mitigation in livestock systems. Rev Bras Zootec, 39: 175-182.

Lee, S. H. Y., Humphries, D. J., Cockman, D. A., Givens, D. I., Spencer, J.P.E. 2017. Accumulation of citrus flavanones in bovine milk following citrus pulp incorporation into the diet of dairy cows. EC Nutrition, 7(4): 143-154.

Martin, C., Copani, G., Niderkorn, V. 2016. Impacts of forage legumes on intake, digestion and methane emissions in ruminants. The journal of the International Legume Society, 12: 24-25.

Miller R.H. 1958. Morphology of *Humulus lupulus*. L. developmental anatomy of the primary root. American Journal of Botany, 45: 418-431.

Narvaez, N., Wang, Y., Zhonjou, X., Alexander, T., Garden, S., McAllister, T. 2013. Effects of hop varieties on ruminal fermentation and bacterial community in an artificial rumen (rusitec). Journal of the Science of Food and Agriculture, 93: 45–52.

Öztürk, Y.E., Gülümser, E., Mut, H., Başaran, U., Çopur Doğrusöz, M. 2020. Determination of silage quality of mixtures in hops with corn and forage soybean. Harran Journal of Agricultural and Food Science, 24(4): 440-446.

Öztürk, Y.E., Gülümser, E. 2023. Forage Yield, Nutritional Value and Phytotrepic Traits of Hops (*Humulus lupulus* L.). ISPEC Journal of Agricultural Sciences, 7(2): 350-358.

Patra, A. K., Kamra, D. N., Agarwal, N. 2006. Effect of plant extracts on in vitro methanogenesis, enzyme activities and fermentation of feed in rumen liquor of buffalo. Animal Feed Science and Technology, 128(3-4): 276–291.

Paula, E.M., Samensari, R.B., Machado, E., Pereira, L.M., Maia, F.J. 2016. Effects of phenolic compounds on ruminal protozoa population, ruminal fermentation, and digestion in water buffaloes. Livestock Science, 185: 136-41.

Robbins, R.J. 2003. Phenolic acids in foods. Journal of Agricultural and Food Chemistry, 51: 2866-2887.

Rochfort, S., Parker, A. J., Dunshea, F. R. 2008. Plant bioactives for ruminant health and productivity. Phytochemistry, 69(2): 299-322.

Santos Neto, T.M., Mota, R.A., Silva, L.B.G., Viana, D.A., Lima-Filho, J. L., Sarubbo, L.A., Converti, A., Porto, A.L.F. 2009. Susceptibility of Staphylococcus spp. isolated from milk of goats with mastitis to antibiotics and green propolis extracts. Letters in Drug Design & Discovery, 6, 63-68.

Seradj, A.R., Abecia, L., Crespo, J., Villalba, D., Fondevila, M., Balcells, J. 2014. The effect of bioflavex and its pure flavonoid components on in vitro fermentation parameters and methane production in rumen fluid from steers given high concentrate diets. Animal Feed Science and Technology, 197: 85-91.

Vitalini, S., Di Martile, M., Cicaloni, V., Iannone, M., Salvini, L., Del Bufalo, D., Iriti, M., Garzoli, S. 2023. Volatile and non-volatile content determination and biological activity evaluation of fresh *Humulus lupulus* L. (Cv. Chinook) Leaves And Inflorescences. Separations, 10: 91. Wheeler, T., Reynolds, C. 2013. Predicting the risks from climate change to forage and crop production for animal feed, Animal Frontiers, (1): 36-41.

Zanoli, P., Zavatti, M. 2008. Pharmacognostic and pharmacological profile of *Humulus lupulus* L. Journal of Ethnopharmacology, 116(3): 283-396.

CHAPTER 5

SPINY ATRAPHAXIS (*Atraphaxis spinosa* L.)

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1- INTRODUCTION

Atraphaxis spinosa L. is one of the 48 species in the Atraphaxis genus in the Polygonaceae family. This species is a perennial shrub-shaped plant that has a strong root system, is resistant to salty and arid soils, and can grow in nutrient-poor soils (Bentham and Hooker, 1880; Pavlov, 1970; Lovelius, 1979; Tavakkoli et al., 2013; Yurtseva et al., 2016; Temel et al., 2017; RBG, 2023). The plant sheds its leaves in winter and forms shoots and leaves again in spring (Karakuş and Keskin, 2018). Shoots and leaves of *Atraphaxis spinosa* are grazed by camels, sheep and goats (Shahriary et al., 2012; Rakhimova and Rakhimova, 2022). It also serves as a shelter for wild animals (Zadeh and Kharasmi, 2013).

In geographies where extreme ecological conditions are experienced, there is an intense forage deficit, especially in the summer and autumn seasons. However, halophyte and xerophyte species, especially shrubs, that can adapt to these conditions and maintain their greenness and productivity for a long time, have an important alternative feed potential. One of these shrub species is *Atraphaxis spinosa*. The nutritional content of *Atraphaxis spinosa* significantly meets the needs of animals. Crude protein ratio varies between 5.9% and 12.7% depending on the development periods throughout the year. Neutral detergent fiber varies between 44.4% and 68.2%, and acid detergent fiber varies between 27.1% and 47.1% (Karakuş and Keskin, 2018). Although the macro and micro (nitrogen, potassium, calcium, phosphorus, sodium, copper, magnesium, manganese, iron, zinc) nutritional contents of *Atraphaxis spinosa* vary significantly according to the development periods of the plant, it significantly meets the needs of animals (Keskin, 2018). However, *Atraphaxis spinosa* can accumulate high amounts of Cr and Pb (Sakizadeh et al., 2018). *Atraphaxis spinosa* lowers the pH of the soil where it grows and causes more calcium, potassium and magnesium accumulation (Karakuş and Keskin, 2018). Since *Atraphaxis spinosa* seeds collected in natural environments have a high rate of dormancy, when the plant is grown with seeds, dormancy breaking (Giberallic acid or cold and warm stratification) processes must be done on the seeds and sown (Temel et al., 2023).

The roots of *Atraphaxis* contain flavonoids, above soil parts of plant contain alkaloids, and the leaves contain tannins. Compounds found in the *Atraphaxis spinosa* plant are afzelin, N-trans-p-coumaroyldopamine, N-trans-

p-coumaroyl-3',4'-dihydroxyphenylethylamine, N-trans-feruloyldopamine, N-trans-feruloyl-3',4'-dihydroxyphenylethylamine, (-)-catechin, quercetin, quercetin-3-methyl ether, (-)-fisetinidol, 5-deoxykaempferol, butine, β-sitosterol glucoside,3-O-b-D-glucuronide-600-methyl ester, myricitrin, quercetin-3- O-b-D-glucuronide, 2-(b-D-glucopyranosyloxy, 200-galloyl-quercetin-3-O-b-D-glucuronide, methyl gallate, -4-hydroxy-6-methoxyacetophenone, a-linolenic acid, lucidulactone A, gallic acid, loliolide, luteolin 7-methyl ester, 4' -α-D-glucofuranoside 7-luteolin 7-methyl ester, 4'-β-D-glucofuranosyl-6-β-D-glucopyranoside 7-O-luteolin methyl ester, 3-β-L-rhamnopyranoside 3,8,3', 3,8,3', 4'-tetrahydroxyflavone and 4'-tetrahydroxyflavone (El-Gamal et al., 1994; Wang et al., 2018; Umbetova et al., 2020). With these determined features, it seems that the plant is suitable for use as medicinal raw material.

It is an important plant in preventing erosion and protecting natural resources (soil and water) because it covers a large area on the soil surface and has a strong root system (Karakuş and Keskin, 2017).

2. SYSTEMATIC AND MORPHOLOGY

Atraphaxis is a genus of flowering plants (Angiosperms) in the family Polygonaceae, containing approximately 48 species (Table 1).

The genus Atraphaxis is widespread in parts of Southwest Asia, Southern Siberia, Southeastern Europe, North Africa, Mongolia, and China. *Atraphaxis spinosa* species are found in countries such as Afghanistan, Russia, China, Egypt, Greece, Mongolia, Iran, Iraq, Kazakhstan, Turkmenistan, Kyrgyzstan, Lebanon, Syria, Saudi Arabia, Manchuria, Mongolia, Pakistan, Palestine, Turkey, Tajikistan, Ukraine and Uzbekistan (Bentham and Hooker, 1880; Pavlov, 1970; Lovelius, 1979; Cullen, 1967; Brandbyge, 1993; Webb, 1993; Rechinger and Schiman-Czeika, 1968; Bao and Grabovskaya-Borodina, 2003; Schuster et al., 2011; Yurtseva ve ark., 2016; Temel et al., 2017; Baasanmunkh et al. 2022; RBG, 2023). *Atraphaxis spinosa* has 3 synonyms (*Atraphaxis afghanica* Meisn., *Atraphaxis calvertii* Boiss. and *Tragopyrum spinosum* (L.) C.Presl).

The *Atraphaxis spinosa* plant, which is found in the form of a dwarf shrub, sheds its leaves in winter and its branches are usually thorny. *Atraphaxis*

spinosa has a plant height between 1.05 and 1.45 m and covers an area of 2.95 to 5.55 m in length and 2.80 to 4.46 m in width (Figure 1). Wood branches are hairless and whitish. The leaves are oval or rounded and have a length of 0.6 to 1.3 cm. The flowers are white and pink, 0.8 mm in diameter. Its fruit is triangular or flat. It is a hermaphrodite plant with female and male organs in the same flower (Güven, 1997; Tavakkoli et al., 2015; Karakuş, 2016; Wang et al., 2018; Erşen Bak and Cesur, 2021; IDS, 2023). The fruit is in the form of achene and there is one seed in each fruit (Dammer, 1893; Roth 1977; Ronse De Craene et al., 2000). *Atraphaxis spinosa* is annual shoots diameter 1.5-3.0 mm, annual shoots lignified and spiny, surface of annual shoot glabrous, petiole length 1-2 mm, perianth surface glabrous, achene surface smooth or smooth-pitted (Yurtseva et al., 2017).

Table 1: Species in the genus *Atraphaxis* (Tavakkoli et al., 2015; Yurtseva et al., 2017; Anonymous, 2023)

A. angustifolia	*A. ariana*	*A. spinosa*
A. intricata	*A. avenia*	*A. decipiens*
A. arida	*A. atraphaxiformis*	*A. teretifolia*
A. irtyschensis	*A. billardierei*	*A. selengensis*
A. aucheri	*A. salicornioides*	*A. pyrifolia*
A. kamelinii	*A. kermanica*	*A. manshurica*
A. badghysi	*A. bracteata*	*A. rodinii*
A. karataviensis	*A. caucasica*	*A. grandiflora*
A. binaludensis	*A. ledebourii*	*A. popovii*
A. botuliformis	*A. khajeh-jamali*	*A. frutescens*
A. radkanensis	*A. daghestanica*	*A. dumosa*
A. canescens	*A. kuvaevii*	*A. pungens*
A. kopetdagensis	*A. laetevirens*	*A. suaedifolia*
A. compacta	*A. laetevirens*	*A. seravschanica*
A. schischkinii	*A. muschketowii*	*A. toktogulica*
A. davurica	*A. macrocarpa*	*A. virgata*

Atraphaxis spinosa remains dormant for 120 days from mid-November to mid-March in regions with cold winters. It begins to develop shoots in mid-

March and completes all phenological observations by mid-November. The plant's leaf formation continues for 240 days between mid-March and early November (Table 2) (Temel and Keskin, 2019). *Atraphaxis spinosa* can produce flowers and fruits twice a year during its development period. The first flowering occurs in April-May and the second flowering occurs in August. Parallel to the flowering state, the fruit period also occurs twice a year (Li et al. 2010, 2011; Temel and Keskin, 2019; Kostina and Yurtseva, 2021). Figures of the *Atraphaxis spinosa* plant showing the dormant, shoot and leaf periods, flowering period and fruit periods are given in Figures 1, 2, 3 and 4, respectively (Temel and Keskin, 2019).

Figure 1. Plant height, length and width measurements of *Atraphaxis spinosa* (Karakuş, 2016)

Table 2. Phenological observations of *Atraphaxis spinosa* (Temel and Keskin, 2019)

	Phenological Observations Examined										
Months	**Dp**	**Sb**	**Sp**	**Lb**	**Lp**	**Bb**	**Bp**	**Pb**	**Pp**	**Pm**	**Dp**
Early March	+										
Mid March		+	+	+	+						
End of March			+		+						
Early April			+		+						
Mid April			+		+						
End of April			+		+	+	+				
Early May			+		+		+				
Mid May			+		+		+				
End of May			+		+		+				
Early June			+		+		+				
Mid June			+		+		+	+	+	+	
End of June			+		+				+	+	
Early July			+		+				+	+	
Mid July			+		+				+	+	
End of July			+		+				+	+	
Early August			+		+						
Mid August			+		+						
End of August			+		+	+	+				
Early September			+		+		+				
Mid September			+		+		+				
End of September			+		+		+	+	+	+	
Early October			+		+		+		+	+	
Mid October					+		+		+	+	
End of October					+		+		+	+	
Early November					+				+	+	
Mid November											+

Fenolojik Dönem Kısaltmaları		
Dp: Dormant period	**Dp:** Dormant period	**Dp:** Dormant period
Sb: Shoot beginning	**Sb:** Shoot beginning	**Sb:** Shoot beginning
Sp: Shoot perion	**Sp:** Shoot perion	**Sp:** Shoot perion
Lb: leaf beginning	**Lb:** leaf beginning	**Lb:** leaf beginning

Figure 1. Dormant period ((Temel and Keskin, 2019)

Figure 2. Shoot and leaf period ((Temel and Keskin, 2019)

Figure 3. Flowering period (Temel and Keskin, 2019)

Figure 4. Fruit period (Temel and Keskin, 2019)

3. ADAPTATION

Many shrub and woody species growing under natural conditions have high tolerance to drought, thanks to their deep and strong root systems, and can grow in areas where cultivated plants cannot grow. *Atraphaxis spinosa* is a xeromorphic shrub that grows in desert steppes, mountain shrub communities, salty, gravelly and stony surfaces, sand dunes, calcareous soils, nutrient-poor

soils, at altitudes up to 1600 m (Lovelius, 1978; Perevolotsky et al., 1989; Kapustina, 2001; Bondarenko et al., 2009; Wang et al., 2018).

Species with thick exocarps are common mainly in the mountainous regions of Central Asia, and species with thin exocarps are common in semi-deserts and steppes of Eurasia. Fruit color associated with amount of phenolics in exocarp cells may be related to differences in the timing of seed germination. Species with light brown fruits are common, while those with dark or black fruits are mostly local endemics (Yurtseva et al., 2022).

Vein elements and number of veins are important features in resistance to arid areas (Baas et al., 1983; Carlquist 1988). *Atraphaxis spinosa*'s short wood branches, narrow fibers, and high number of veins increase its resistance to arid areas compared to other Atraphaxis species and many plants (Erşen Bak and Cesur, 2021). In places where the annual rainfall is low, the *Atraphaxis spinosa* plant continues to develop (Rakhimova and Rakhimova, 2022). The layer on the outer surface of atraphaxis seeds protects the seeds against mechanical damage, accelerates the germination of seeds by retaining water, and protects the seeds against pathogens (Lattanzio et al., 2006, 2008).

There is a significant amount of dormancy in *Atraphaxis spinosa* seeds collected in natural environments. Germination rates of *Atraphaxis spinosa* seeds subjected to different temperatures (10, 15, 20, 25, 20/10, 20/15, 25/10, 25/15 °C) vary between 0.0-22.6%. While the seeds do not germinate at 10 °C, 22.6% of the seeds germinate when the germination test is performed at a variable temperature of 25/15 °C. *Atraphaxis spinosa* seeds have 77.4% dormancy. If the *Atraphaxis spinosa* seeds collected in the natural environment are sown and used to create new areas, the seeds should be sown considering that only one out of 5 seeds will germinate. Dormancy breaking studies were also carried out on *Atraphaxis spinosa* seeds, where dormancy is very high. In order to eliminate dormancy in *Atraphaxis spinosa* seeds, 12 dormancy breaking applications (Hydro-priming, matrix priming, potassium nitrate, gibberellic acid, mechanical scarification, Chemical (sulphuric acid) scarification, cold stratification, warm stratification, cold + warm stratification, warm + cold stratification, soaking in hot water and soaking in cold water) were made. When 250 ppm gibberallic acid was applied to the seeds, 77% of the seeds germinated. When *Atraphaxis spinosa* seeds were cold stratified at +5 °C for only 4 weeks or cold stratified at +5 °C for 4 weeks followed by warm

stratified at 20 °C for 2 weeks, it was observed that the dormancy in the seeds was completely removed and 100% of the seeds germinated (Temel et al., 2023). If the seeds obtained in the early stages are kept in high temperature and dry conditions for a while, it is seen that the seeds germinate immediately (Li et al., 2010, 2011).

Atraphaxis spinosa affects many properties of the soil in which it grows. Examining the soil samples taken from the inner and outer crown parts of the plant, it was seen that the soil inside the crown was more acidic. At the same time, the calcium, potassium and magnesium content of the soil inside the crown is high. It also has an effect on the mineral contents of the different depths of the soil where the plant grows. For example, calcium and potassium accumulate in abundance at a soil depth of 20-40 cm, while phosphorus and sodium accumulate in excess at a depth of 40-60 cm (Karakuş and Keskin, 2017). This species contributes significantly to the development of other species in the environment due to its positive contribution to the structure of the soil.

4. YIELD AND QUALITY

In regions with dry summers, plants in meadows areas cannot continue to grow in summer and autumn and dry out, and the roughage available per unit meadows area decreases significantly. Drought-resistant shrub species are a source of fodder for animals in the summer and autumn periods when herbaceous species dry out and their nutritional value decreases (Temel and Tan, 2011; Tan and Temel, 2012). Shrub plants can produce forage rich in energy, minerals, vitamins and nutrients for animals (Ghazanfar et al., 2011; Tan and Temel, 2012). In cases where there are no palatable species in the environment, *Atraphaxis spinosa*, a thorny species, is grazed by animals (Shahriary et al., 2012). Young shoots of *Atraphaxis spinosa* are consumed by camels in spring and partly in summer. Sheep and goats eat the leaves (Rakhimova and Rakhimova, 2022). Since the growth rate of the plant is low, feed efficiency is low, especially in the spring season (Rakhimova and Rakhimova, 2022).

Atraphaxis spinosa is a perennial shrub plant that grows up to 1.45 m tall, covers a large area up to 5.55 m length and up to 4.46 m wide (Karakuş, 2016). In regions with cold winters, it continues to develop leaves and shoots

for 240 days, from mid-March to early November (Temel and Keskin, 2019). Due to this feature of the *Atraphaxis spinosa* species, grazing animals in areas where this plant is commonly found can provide feed for a long time.

In a study in which the changes in the monthly nutritional content of the *Atraphaxis spinosa* shrub were determined according to its development periods throughout the year; acid detergent fiber, crude protein, neutral detergent fiber, dry matter digestibility, acid detergent lignin, digestible energy, dry matter intake, dry matter rate and relative feed value values were determined in the range 27.13-47.13%, 5.93-12.79%, 44.41-68.28%, 52.18-67.75%, 3.62-14.46%, 2.50-3.17 Mcal kg^{-1}, 1.75-2.71%, 27.33-70.66% and 71.46-142.32, respectively. Although the feed quality of the plant decreased significantly due to increased maturation, the lowest crude protein content was observed to be 5.93%. While feed values are high between mid-March and July, when the plant begins to develop, there are decreases in feed values from July until mid-November, when the plant enters the dormant period (Karakuş and Keskin, 2018). There are significant decreases in feed value with the advancement of development in many other shrub plants (Parissi et al., 2005; Gonzalez-Andres and Ceresuela, 1998; Papachristou et al., 2005; Kamalak, 2006; Ataşoğlu et al., 2010; Oktay and Temel, 2015; Temel, 2019; Dökülgen and Temel, 2019).

The shoot + leaf parts of the *Atraphaxis spinosa* plant are consumed by animals. Although the macro and micro mineral contents of shoots + leaves vary significantly according to their development periods, they significantly meet the mineral needs of animals. According to the development periods during the year, phosphorus, nitrogen, potassium, magnesium, calcium, sodium, copper, iron, zinc and manganese contents of *Atraphaxis spinosa* vary between 0.43-0.98%, 0.98-1.27%, 1.08-1.46%, 0.27-0.46%, 0.86-1.17%, 0.12-0.99%, 0.86-2.66 ppm, 112.0-344.7 ppm, 25.3-42,4 ppm and 44.1-64.9 ppm. The nitrogen content of the plant is high in May and October. As maturity progresses, phosphorus, potassium, sodium and zinc contents decrease, while manganese and iron contents increase. There is no significant change in the calcium and magnesium contents of the shoots and leaves of the plant depending on the development periods (Keskin, 2018). *Atraphaxis spinosa* plant is a species with a high potential to accumulate Cr and Pb (Sakizadeh et al., 2018).

REFERENCES

Anonymous, 2023. Wikipedia. https://en.wikipedia.org/wiki/Atraphaxis, Date of Access: 04.12.2023.

Ataşoğlu, C., Şahin, S., Canbolat, Ö., Baytekin, H. 2010. The effect of harvest stage on the potential nutritive value of kermes oak (*Quercus coccifera*) leaves. Livestock Research for Rural Development, 22(2): 182-185.

Baasanmunkh, S., Urgamal, M., Oyuntsetseg, B., Sukhorukov, A.P., Tsegmed, Z., Son, D.C., Erst, A., Oyundelger, K., Kechaykin, A.A., Norris, J., Kosachev, P., Ma, J.S., Chang, K.S., Choi, H.J. 2022. Flora of Mongolia: annotated checklist of native vascular plants. PhytoKeys, 192: 63-169. doi: 10.3897/phytokeys.192.79702.

Baas, P., Werker, E., Fahn, A. 1983. Some ecological trends in vessel characters. IAWA Bulletin 4(2-3): 141-159.

Bao, B., Grabovskaya-Borodina, A.E. 2003. *Atraphaxis* L. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China. Beijing, Science Press, 5: 328–332.

Bentham, G., Hooker, J.D. 1880. Polygonaceae. In: Bentham G, Hooker JD (eds) Genera plantarum ad exemplaria imprimis in herbariis Kewensibus servata definita 3(1). Reeve & Co, London, pp 88–105

Bondarenko, D.A., Peregontsev, E.A. 2009. Peculiarities of landscape distribution of the Central Asian Tortoise, *Agrionemys horsfieldii*, in Iran. Zoology in the Middle East, 48(1): 49-62. doi: 10.1080/09397140.2009.10638366.

Brandbyge, J. 1993. Polygonaceae. In: Kubitzki K, Rohwer JG, Bittrich V (eds) Flowering Plants · Dicotyledons. The families and genera of vascular plants, vol 2. Springer, Berlin, Heidelberg. pp 531–544. doi: 10.1007/978-3-662-02899-5_63

Carlquist, S. 1988. Methods for Comparative Wood Anatomy Studies, In: Comparative Wood Anatomy. Systematic, Ecological, and Evolutionary Aspects of Dicotyledon Wood (1st Ed.), Springer, Berlin, Heidelberg. doi: 10.1007/978-3-662-21714-6_1.

Cullen, J. 1967. *Atraphaxis* L. In: Davis PH (ed) Flora of Turkey and the East Aegean islands 2. Edinburgh University Press, Edinburgh, pp 266–267.

Dammer, U. 1893. Polygonaceae. In: Engler A, Prantl K (eds) Die natürlichen Pflanzenfamilien, T. 3, Abt. 1a. Engelmann, Leipzig, pp 1–36

Dökülgen, H., Temel, S., 2019. Determination of nutritional value of terebinth and styrax tree according to the grazed plant parts and seasons. Harran Journal of Agricultural and Food Science, 23(2): 178-188, doi: 10.29050/harranziraat.425602.

El-Gamal, A., Takeya, K., Itokawa, H., Halim, A.F., Amer, M.M., Saad H.E.A., Awad, S.A. 1994. Studies on the chemical constituents of *Atraphaxis spinosa* L. var. Sinaica BOISS. Nature Medicine, 48(4): 304–306.

Erşen Bak, F., Cesur, D. 2021. Comparative wood anatomy of *Atraphaxis* taxa in Turkey. BioResources 16(1): 835–845, doi:10.15376/biores.16.1.835-845.

Ghazanfar, S., Latif, A., Mirza, I.H., Nadeem, M.A. 2011. Maro-Minerals Concentrations of Major Fodder Tree Leaves and Shrubs of District Chakwal, Pakistan. Pakistan Journal of Nutrition, 10(5): 480-484.

Gonzalez-Andres, F., Ceresuela, J.L. 1998. Chemical composition of some Iberian Mediterranean leguminous shrubs potentially useful for forage in seasonally dry areas. New Zealand Journal of Agricultural Research, 41(2): 139-147, doi:10.1080/00288233.1998.9513297.

Güven, M. 1997. Some Important Tree and Shrub Forms in Use of Wastershed Improvement in Eastern Anatolis Region. Journal of Eastern Anatolia Forestry Research Institute Erzurum-Türkiye, 27-40.

IDS (International Dendrology Society). 2023. Trees and Shrubs Online *Atraphaxis spinosa* L. https://www.treesandshrubsonline.org/articles/atraphaxis/atraphaxis-spinosa/, Date: 30.09.2023).

Kamalak, A. 2006. Determination of nutritive value of a native grown shrub, Glycyrrhiza glabra L. Using in vitro and in situ measurements. Small Ruminant Research, 64(3): 268-278, doi:10.1016/j.smallrumres.2005.04.027.

Kapustina, L.A. 2001. Biodiversity, Ecology, and Microelement Composition of Kyzylkum Desert Shrubs (Uzbekistan). In: McArthur, E. Durant; Fairbanks, Daniel J., comps. 2001. Shrubland ecosystem genetics and biodiversity: proceedings; 2000 June 13–15; Provo, UT. Proc. RMRS-P-21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, pp: 98-103.

Karakuş, B. 2016. The effects on the soil and changes on nutrient content of shrub (*Atraphaxis spinosa* l.) grown in marginal areas. Master's Thesis, Iğdır University Graduate Education Institute, Iğdır.

Karakuş, B., Keskin, B.. 2018. Changes in Nutrient Content during the Growth Process of Goat's Wheat Manna (*Atraphaxis spinosa* l.). International Journal of Agriculture and Wildlife Science, 4(1): 39-44, doi:10.24180/ijaws.365936.

Karakuş, B., Keskin, B. 2017. Effects on Some Soil Properties of Soils in Different Deeps With Internal and External Canopy of Goat's Wheat (*Atraphaxis spinosa* L.) Growing on Erosion Fields. Journal of Adnan Menderes University Agricultural Faculty, 14(2): 13-17, doi:10.25308/aduziraat.305738.

Keskin, B. 2018. Determination of monthly changes in mineral content of Spiny *Atraphaxis* (*Atraphaxis spinosa* L.) as an alternative fodder crop. Progress in Nutrition 20(3): 318-322, doi:10.23751/pn.v20i3.6817.

Kostina, M.V., Yurtseva, O.V. 2021. Structure and developmental rhythm of shoot systems of *A. frutescens* (L.) K. Koch., *A. replicata* Lam., and *A. pyrifolia* Bunge (*Atraphaxis* L., Polygonaceae). Contemporary Problems of Ecology, 14(3):241–254, doi:10.1134/S1995425521030070.

Lattanzio, V., Lattanzio, V.M.T., Cardinali, A. 2006. Role of phenolics in the resistance mechanisms of plants against fungal pathogens and insects. Phytochemistry: Advances in Research, pp: 23-67, ISBN: 81-308-0034-9.

Lattanzio, V., Kroon, P.A., Quideau, S., Treutter, D. 2008. Plant phenolics—secondary metabolites with diverse functions. In: Daayf, F., Lattanzio, V. (eds) Recent advances in polyphenol research, vol: 1, Blackwell Publishing, pp 1–35.

Li, X., Zhao, X., Wang, Z., Dong, Z. 2010. Seed dormancy-breaking and germination requirements of two *Atraphaxis* species. Bulletin of Botanical Research, 30(5): 600–603.

Li, X., Zhao, X., Yu, R. 2011. Effects of seed maturation time and dry storage on germination of two *Atraphaxis* species. Ac-ta Ecologica Sinica, 30(14): 3727-3732.

Lovelius, O.L. 1978. Compositio specierum, Distributio geographica et cohaerentia oecologica generis *Atraphaxis* L. (Polygonaceae). In:

Klokov MV (ed) Novosti sistematiki vysshikh i nizshikh rasteniy (Novitates systematicae plantarum vascularium et non vascularium 1977). Naukova dumka, Kiev, pp 85–108.

Lovelius, O.L. 1979. Synopsis generis *Atraphaxis* L. (Polygonaceae) (A systematic review of the genus Atraphaxis L.). Novitates systematicae plantarum vascularium, 15: 114-128.

Oktay, G., Temel, S., 2015. Determination of Annual Fodder Value of Ebu Cehil (*Calligonum polygonoides* L. Ssp. Comosum (L'Hér.)) Shrub. Journal of Agricultural Faculty of Gaziosmanpasa University, 32(1): 30-36, doi:10.13002/jafag770.

Papachristou, T.G., Platis, P.D., Nastis, A.S. 2005. Foraging behaviour of cattle and goats in oak forest stands of varying coppicing age in Northern Greece. Small Ruminant Research, 59(2-3): 181-189, doi:10.1016/j.smallrumres.2005.05.006.

Parissi, Z.M., Papachristou, T.G., Nastis, A.S. 2005. Effect of drying method on estimated nutritive value of browse species using an in vitro gas production technique. Animal Feed Science and Technology, 123-124(1): 119-128, doi:10.1016/j.anifeedsci.2005.04.046.

Pavlov, V.N. 1970. *Atraphaxis* L. In: Komarov VL (ed) Flora of the USSR (Flora SSSR) 5. Izdatel'stvo Akademii Nauk SSSR, Moskva & Leningrad, 1936, pp 392–411. [Translated from Russian by Dr Landau N, Israel Program for Scientific Translations, Jerusalem 1970]

Perevolotsky, A., Perevolotsky, A., Noy-Meir, I. 1989. Environmental Adaptation and Economic Change in a Pastoral Mountain Society: The Case of the Jabaliyah Bedouin of the Mt. Sinai Region. Mountain Research and Development, 9(2); 153-164, doi:10.2307/3673478.

Rakhimova, N.K., Rakhimova, T. 2022. The Status of Salsola arbusculiformis and Anabasis salsa Shrub Grasslands on the Ustyurt Plateau in Karakalpakstan (Uzbekistan). Arid Ecosystems, 12(3): 286-295, doi:10.1134/S2079096122030106.

Rechinger, K.H., Schiman-Czeika, M. 1968. Polygonaceae. In: Rechinger KH (ed) Flora Iranica 56/28. Academishe Druck-u.Verlagsanstalt, Graz, pp 1–88.

RBG (Royal Botanic Garden), 2023. *Atraphaxis* L. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:32426-1.(Acces Date: 30.09.2023).

Ronse, De Craene, L.P., Hong, S.P., Smets, E. 2000. Systematic significance of fruit morphology and anatomy in tribes Persicarieae and Polygoneae (Polygonaceae). Botanical Journal of the Linnean Society, 134(1-2): 301-337. doi:10.1111/j.1095-8339.2000.tb02356.x.

Roth, I. 1977. Fruits of angiosperms. Handbuch der Pflanzenanatomie. Encyclopedia of plants anatomy. Part, 10. 2nd edn. Borntraeger, Berlin

Sakizadeh, M., Martín, J.A.R., Zhang, C., Sharafabadi, F.M., Ghorbani, H. 2018. Trace elements concentrations in soil, desert-adapted and non-desert plants in central Iran: Spatial patterns and uncertainty analysis. Environmental Pollution, 243: 270-281. doi: 10.1016/j.envpol.2018.08.071.

Schuster, T.M., Reveal, J.L., Kron, K.A. 2011. Phylogeny of Polygoneae (Polygonaceae: Polygonoideae). Taxon, 60(6): 1653-1666, doi:10.1002/tax.606010.

Shahriary, E., Palmer, M.W., Tongway, D.J., Azarnivand, H., Jafari, M., Mohseni Saravi, M. 2012. Plant species composition and soil characteristics around Iranian piospheres. Journal of Arid Environments, 82: 106-114. doi: 10.1016/j.jaridenv.2012.02.004.

Tan, M., Temel, S. 2012. Alternative Forage Crops. Ataturk Univ. Faculty of Agriculture Publications No: 246, 195-207, Erzurum/Türkiye.

Tavakkoli, S., Kazempour Osaloo, S., Mozaffarian, V., Maassoumi, A.A. 2013. *Atraphaxis* radkanensis (Polygonaceae), a New Species from Iran. Annales Botanici Fennic, 50(6):372-374, doi:10.5735/085.050.0612.

Tavakkoli, S., Osaloo, S.K., Mozaffarian, V., Maassoumi, A.A. 2015. Molecular phylogeny of *Atraphaxis* and the woody Polygonum species (Polygonaceae): taxonomic implications based on molecular and morphological evidence. Plant Systematics and Evolution, 301:1157-1170, doi:10.1007/s00606-014-1140-7.

Temel, S., 2019. Variations in Nutrient Composition During Noaea mucronata's Active Growth As a Source of Roughage. International Journal of Agriculture and Wildlife Science, 5(1): 117-123, doi:10.241180/ijaws.487284.

Temel, S., Tan, M. 2011. Fodder Values of Shrub Species in Maquis in Different Altitudes and Slope Aspects. Journal of Animal and Plant Sciences, 21(3): 508-512.

Temel, S., Keskin, B., Akbay Tohumcu, S., Tan, M., Unal, M., Yılmaz, I.H. 2017. Iğdır Province Meadow and Pasture Plants Guide. Öncü Printing Publication Promotion limited company, I. Edition, p:180, ISBN: 978-605-9028-57-8.

Temel, S., Keskin, B. 2019. Determination of Some Phenological Properties of Goat's Wheat Shrub Growing in Igdir Erosion Areas in Terms of Grazing Management. Umteb 6. International Vocational and Technical Sciences Congress. 11-12 April 2019. Iğdır University, Iğdır-Türkiye.

Temel, S., Keskin, B., Çakmakçı, S. 2023. Effect of different dormancy-breaking methodson seed germination and vigour of *Atraphaxis spinosa*. Zemdirbyste-Agriculture, 110(1): 39-46, doi:10.13080/z-a.2023.110.006.

Umbetova, A.K., Burasheva, G.Sh., Ikhsanov, Y.S., Abidkulova, K.T., Beyatli, A., Sagatova, S.N., Askanova, D.K. 2020. Chemical Research and Biological Activity of Plants of The Genus *Atraphaxis* (*A. spinosa*). News of The National Academy of Sciences of The Republic of Kazakhstan Series Chemistry and Technology, 6(444): 127-133, doi:10.32014/2020.2518-1491.107.

Yurtseva, O.V., Kuznetsova, O.I., Mavrodieva, M.E., Mavrodiev, E.V. 2016. What is *Atraphaxis* L. (Polygonaceae, Polygoneae): cryptic *taxa* and resolved taxonomic complexity instead of the formal lumping and the lack of morphological synapomorhies. PeerJ 4:1–52. doi:10.7717/peerj.1977.

Yurtseva, O.V., Severova, E.E., Mavrodiev, E.V. 2017. Persepolium (Polygoneae): A new genus in Polygonaceae based on conventional Maximum Parsimony and Three-taxon statement analyses of a comprehensive morphological dataset. Phytotaxa, 314(2):151-194. doi:10.11646/phytotaxa.314.2.1.

Yurtseva, O.V., Devlatov, A.G., Sokoloff, D.D. 2022. Exocarp structure in the genus *Atraphaxis* (Polygonaceae, Polygoneae). Plant Systematics and Evolution, 308(32): 1-25, doi:10.1007/s00606-022-01824-0.

Wang, X., Khutsishvili, M., Fayvush, G., Tamanyan, K., Atha, D., Borris, R.P. 2018. Phytochemical investigations of *Atraphaxis spinosa* L (Polygonaceae). Biochemical Systematics and Ecology, 77: 44-47. doi:10.1016/j.bse.2018.02.001.

Webb, D.A. 1993. *Atraphaxis* L. In: Tutin TG, Burges NA, Chater AO, Edmonson JR, Heywood VH, Moore DM, Valentine DH, Walters SM, Webb DA (eds) Flora Europaea 1, 2nd edn. Cambridge University Press, Cambridge, p 108.

Zadeh, S.A., Kharasmi, F. 2013. Summer Habitat Selection by Gebeer (*Gazella bennetii*) in Khabr National Park, Iran. International Journal of Environmental Science and Engineering, 7(8): 859-860.

CHAPTER 6

FODDER BEET

(*Beta vulgaris var. rapacea* Koch.)

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1. INTRODUCTION

Fodder beet (*Beta vulgaris var. rapacea* Koch.) is widely cultivated in many countries around the world. The roots have been used for animal feed for many years. Fodder beet originated in the Middle East. It was used to feed cattle in Greece around 500 BC. It has been cultivated in northern European countries since the Middle Ages (Açıkgöz, 2021).

Although fodder beet is poor in protein, vitamins and minerals, it is a delicious plant with high water content preferred by animals. It strengthens the digestive system of animals and ensures its regular functioning. It is especially used in cattle feeding. Fodder beet has abundant and high quality herbage and root yield in periods when the yield of pastures is reduced or insufficient. It is very high yielding especially in irrigated conditions (Özaslan Parlak and Ekiz, 2008).

Since it has a high water content and is soft, it can be used in animal feeding as a whole or chopped and mixed with other feeds. It is one of the forages that can be used in the fall, winter and early spring, especially in enterprises that are not large enough to make silage (Martin et al., 1975). Since it has a positive effect on the amount of milk and milk fat, it provides an increase in milk protein in animal feeding with fodder beet. Its rich carbohydrate content increases its importance in horse nutrition (Ergül, 1997). Low dry matter content is balanced by high yield. Its leaves are rich in Ca, Mg, Na, K, Cl, Fe and Mn (Akyıldız, 1969). Compared to other fodder crops, fodder beet provides the most nutrients and energy per unit area. Due to its high sugar content, it is delicious and has high energy value. It has a high digestibility rate of 80-90%. It is easy to harvest since its "thickened root" (rapum) develops mostly on the soil surface (Soya et al., 2009). Fodder beet is a suitable fodder plant for dairy cattle (Akyıldız, 1969). Birkenmaier et al. (1996) reported that increasing the amount of beetroot in dairy cattle feed decreased milk yield, but increased milk fat content. Özen et al. (1981) stated that fodder beet can be harvested when needed and fed fresh as long as the weather conditions are favorable. In addition, it has the effect of increasing milk yield due to its high water level (87%) and the fact that nearly 70% of its dry matter is composed of sugars as in sugar beet. They also stated that it is a

very suitable feed especially for dairy cows and that in European countries it can be chopped and fed to cattle as well as mixed with hay.
The roots can be used for feeding cows immediately after harvest or stored and used as fresh feed during the winter. In recent years, it has been used in biofuel production. It is a plant suitable for use in biogas plants and biofuel production with its high yield and digestion rate (Açıkgöz, 2021).

2. SYSTEMATIC AND MORPHOLOGY

The genus *Beta* L. is nested in the tribe Beteae, subfamily Betoideae, and family Chenopodiaceae Vent. (Wiersema, 2019). Chromosome numbers for fodder beet are 2n =2x= 18. Varieties can be diploid, triploid and tetraploid. Triploid and tetraploid varieties are generally more productive. Feed beet, which is included in the *Beta* L. genus, is called *Beta vulgaris subsp. vulgaris var. crassa* Mansf. or *Beta vulgaris var. rapacea* (Koch) Döll. in different sources (Soya et. al., 2009, Açıkgöz, 2021).

Fodder beet is a biennial plant. The vegetative part develops mainly during the first year of growth (Figure 1). If the roots of the plants are not harvested, in the second year generative organs develop after exposure to cold. Flower stalks develop from the head of the roots. The flower stalk carrying bisexual flowers is 50-80 cm tall (Al-Jbawi, 2020, Açıkgöz, 2021).

Figure 1: Fodder Beet Plants (Anonymous, 2023a)

Root is fleshy and swollen. The size, shape and colour of the root are extremely variable and depend on the variety. The dark green, heart-shaped leaves are borne in a rosette (Figure 1) (Al-Jbawi, 2020, Soya et. al., 2009). All of the roots of some varieties grow in the soil, while most of the roots of some varieties grow above the soil (up to 2/3 above ground) (Figure 2a, 2b, and 2c).

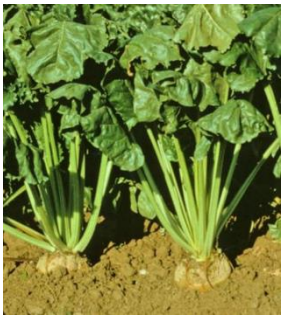

Figure 2a

Figure 2b

Figure 2c

Figure 2 a, b, c: Root Forms at Different Levels Above Ground
(2a: Anonymous, 2023b; 2b: , 2023c; 2c: Anonymous, 2023d)

Fodder beet occur in four different shapes (flat globe, globe, spindle, or cylinder) (Al-Jbawi, 2020) . Root color varies from light yellow to red purple (Figure 3 a and 3b). Often irregularly shaped, conical, cylindrical roots can be seen (Açıkgöz, 2021).

Figure 3a

Figure 3b

Figure 3 a and **b**: Different Color Fodder Beet Root
(3a: Anonymous, 2023e; 3b: Anonymous, 2023f)

Flowers are 3 to 5 together. Each flower has 5 male organs and 3-5 female organs. There is cross pollination in fodder beet. It has dirty yellow seeds (Figure 4a and 4b). The thousand seed weight is 35-40 grams (Soya et al., 2009). Traditional fodder beet had multigerm seeds resulting in clusters of 2 or 3 plants, which required manual separation (thinning) of the young plants. The development of monogerm varieties allowed higher yields in fodder beet (Al-Jbawi, 2020).

Figure 4a

Figure 4b

Figure 4 a and **b**: Fodder Beet Seeds (Original)

3. ADAPTATION

Fodder beet likes mild climate and has high moisture demand. It prefers less hot but humid climate than sugar beet (Gençkan, 1983, Soya et. al., 2009).

It likes sandy, loamy and deep soils with enough lime. It does not grow well in heavy clay or gravelly soils. Heavy soils can be made suitable by applying farm manure. High yields are achieved when fodder beet is grown in loose and light structured alluvial soils. It cannot tolerate too much salt. Any pH below 5.7 will require liming. The ground water should not be higher than 1.20 m (Gençkan, 1983, Geren and Avcıoğlu, 1997, Soya et. al., 2009, Al-Jbawi, 2020, Açıkgöz, 2021).

4. YIELD AND QUALITY

Planting

Crop rotation should be applied in the field where fodder beet will be planted, and fodder beet should not be planted in the same field for several years. Legumes or cereals should be planted before fodder beet. While it is planted in the fall in places with a Mediterranean climate, it is preferred to be planted in the spring where the climate is cold. The sowing time of fodder beet is best in the Aegean, Mediterranean and Southeastern Anatolia regions of Türkiye in October-November and in the other regions in April-May. Geren et al. (1997) reported that in the Aegean region of Türkiye, sowing of fodder beet between September 1 and 15 is suitable. In a study conducted under the same ecological conditions, a tendency to decrease in yield was observed as the sowing time was delayed and plant density decreased (Avcıoğlu et al. 1999). Manga et al. (1997) reported that sowing should be done in March under Samsun conditions in Türkiye.

Figure 5: Fodder beet field (Anonymous, 2023g)

When preparing the soil for planting, good and deep tillage is required. It should be plowed several times in the fall at a depth of 30 cm. It is useful to apply animal manure with this plowing (Gençkan, 1983).

It is sufficient to use 1-3 kg/da seed in fodder beet planting. It is planted 45-50 cm between rows and 5-20 cm above rows. Sowing depth should be 2-

4 cm (Açıkgöz, 2021; Soya et. al., 2009). Row spacing of 30 cm under wet conditions and 60 cm under dry conditions gives good results. In different studies, it is stated that the most suitable row spacing is 40-60 cm (Manga et al., 1997). Avcıoğlu et al. (1999) determined the highest leaf (2675 kg/ha) and root yields (3183 kg/ha) of Rota variety at 40x40 cm spacing.

Seeds emerge on the soil in 10-12 days under optimum conditions. However, in heavy soils, there may be a problem of soil crusting after irrigation. This problem is solved by hoeing or irrigation (Soya et al., 2009).

Krousky (1991) reported a 55.6% yield loss in non-irrigated areas and a 36% yield loss in irrigated areas with 14 days delay in sowing time of fodder beet. In a study conducted in İzmir ecological conditions, a tendency to decrease in yield was observed as the sowing time was delayed and plant density decreased (Avcıoğlu et al. 1999). Acar (2000) determined the highest root yield when 8500 plants per decare were planted on April 5 in Konya conditions.

Fertilizer

In fodder beet cultivation, it is possible to obtain high yields if water and nutrients are sufficient. Fertilizer requirement of fodder beet is quite high. Nitrogen and potassium requirements are quite high. Fodder beet needs 13-15 kg/da nitrogen (N), 6 k/da phosphorus (P_2O_5) and 28-36 kg/da potassium (K_2O) (Gençkan, 1983). Fertilizer applications significantly affect the yield and quality of fodder beet. Before planting, soil analyzes should be made and the amounts of plant nutrients in the soil should be determined. For fodder beet, 15-16 kg/da of nitrogen and 9-10 kg/da of phosphorus fertilizer should be applied. All phosphorus fertilizer should be applied with planting (Soya et al., 2009).

Especially, in soils with low organic matter, nitrogen application to fodder beet is important. Albayrak and Yüksel (2010) determined that nitrogen applications increased root yield, dry matter yield, crude protein content, crude protein yield, root diameter and root length but decreased ADF and NDF contents of roots. The researchers recommend applying 15 kg of nitrogen per decare due to the high crude protein yield in fodder beet. In Tekirdağ conditions, 20 kg/da N application is recommended due to high yield

and protein content in leaves and roots (Altın et al., 2005). Half of the nitrogen fertilizer should be applied at planting, and the remaining half of the nitrogen should be applied when the plants have 3-4 leaves (Soya et al., 2009).

Farm manure and mineral fertilizers significantly increase root, leaf and crude protein yields in fodder beet. If farm manure was not applied in the autumn, additional mineral fertilizer should be applied even if it is applied in the spring. (Manga et al., 1997).

Weed Control

The most important maintenance process after emergence is weed control. For weed control, the first hoeing should be done when the plants are fully emerged and the second hoeing should be done when they have 2-3 leaves. Hoeing should be continued according to the density of weeds (Soya et. al., 2009). Producers should avoid planting fodder beet in poor fields with insufficient nutrients and high weed load. Also, as the seedling stage may be sensitive to residual chemicals, attention should be paid to field history of herbicide use (Al-Jbawi, 2020).

Irrigation

Irrigation is very important in arid regions. It may be necessary to irrigate 4-5 times during fodder beet cultivation (Gençkan, 1983). The first irrigation is important in fodder beet. Manga et al. (1997) reported that irrigation increased root, leaf and protein yield. In dry conditions with insufficient rainfall, especially root development is negatively affected. In order to achieve high efficiency, adequate irrigation must be provided. If there is no rain after planting, it must be irrigation. Other irrigations are adjusted according to the development status of the beet, soil structure and the number of hoeing (Soya et al., 2009).

Yield

Harvesting should be done when the root growth stops, the leaves dry up and curl down, and the middle leaves start to turn yellow (Figure 6). Harvesting is carried out between September and November in spring sowings before the onset of cold weather in the fall. If the weather is sunny in late fall, high yields are obtained. Since it is sensitive to cold, harvesting should be

completed before the onset of severe cold. In autumn sowing, it should be harvested in March-April (Gençkan, 1983, Soya et al.2009, Al-Jbawi, 2020). Altın et al. (2005) stated that the harvest time should be at the end of October in Tekirdağ conditions. Harvesting is done manually or with uprooting tools.

Figure 6: Harvesting Fodder Feed (Anonymous, 2023h)

Root yield is 10-15 tons/da from fodder beets whose roots grow above the soil and 7-10 tons/da from those growing in the soil (Soya et al., 2009). Root yield was reported as 1866.25 kg/da under Adana conditions (Sağlamtimur and Tansı, 1989), 4490 kg/da under İzmir conditions (Geren et al., 1997), 5886.67 kg/da under Ankara conditions (Özaslan Parlak and Ekiz, 2008) and 14515.8 kg/da under Konya conditions (Acar, 2000). Acar and Mülayim (2001) reported root yield of fodder beet as 11407.3 kg/da.

Leaf yield is lower than sugar beet and is 1/8 - 1/10 of the root weight (Soya et al., 2009). Green leaves can be fed directly to animals or silage can be made with pure or different plants (Kılıç, 2010). Leaf yield varies between 1000 - 2000 kg/da. Sometimes leaf yield can be as high as 3000 kg/da (Açıkgöz, 2021). Leaf yield was 1559.83 kg/da under Adana conditions (Sağlamtimur and Tansı, 1989) and 3941 kg/da under İzmir conditions (Geren et al., 1997). Acar and Mülayim (2001) reported leaf yield of fodder beet as 2552.7 kg/da.

The roots or leaves of fodder beet are fed to animals immediately after harvest and can be easily stored. The storage should not be exposed to light and should have a temperature between 1-5 ^{o}C. Stack height should not exceed 1.5 m. The longer the storage period, the higher the wet weight loss (Soya et al., 2009).

Quality

Fodder beet has a lower sugar content than sugar beet. Most of the sugar it contains is in the form of sucrose. In the roots, sugar content varied between 3-9 %, crude protein between 13-14 %, digestibility rate was found to be 68 %, ADF 26 %, NDF 43 % depending on the region, growing conditions and varieties (Kılıç, 2010). In fodder beet, digestible protein is 8.6 % and total digestible nutrients are 63.7 % (Gökkuş, 1994, Özen et al., 1993). Özdemir and Kökten (2020) reported that crude ash rate varied between 1.48-1.95 %, crude protein rate 4.87-6.03 %, crude protein yield 50.35-65.29 kg/da, ADF 8.85-9.95 %, NDF 13.88-15.80 % under Bingöl conditions. In a study conducted under Tokat conditions, crude protein rate in leaves and roots varied between 13.05-13.13.62 % and 8.90-10.32 %, respectively (Karadağ et. al., 2014).

Due to the high water content, the use of additives that increase the dry matter content provides ease of storage (Kılıç, 2010).

REFERENCES

Acar, R. 2000. Effects of different sowing dates and plant densities on the yield, yield components and quality of some fodder beet (*Beta vulgaris* L. *rapacae* Koch.) varieties. Selçuk University Graduate School of Natural and Applied Sciences, Department of Field Crops, Ph.D. Thesis, 173 pages, Konya.

Acar, R., Mülayim, M. 2001. Effects of Different Sowing Dates and Plant Densities on Dry Matter Yield and Some Yield Compenents of Fodder Beet (*Beta vulgaris* L. *rapacea* Koch.) Varieties. Türkiye 4. Field Crops Congress, 17-21 September, p:85-89, Tekirdağ.

Açıkgöz, E. 2021. Forage Crops, Vol. I. Republic of Turkey Ministry of Agriculture and Forestry Department of Training and Publication Press, Yenimahalle/Ankara. ISBN: 978-625-8451-02-3 (1.c) (In Turkish).

Akyıldız, A.R. 1969. Forages Information. Ankara University Faculty of Agriculture Publications. No:182, 136 pages. (In Turkish).

Al-Jbawi, E. 2020. All about fodder beet (*Beta vulgaris subsp. crassa* L.) as a source of forage in the World and Syria. Research Journal of Science, 1(2): 24-44.

Albayrak, S., Yüksel, O. 2010. Effects of nitrogen fertilization and harvest time on root yield and quality of fodder beet (*Beta vulgaris* var. *crassa* Mansf.). Turkish Journal of Field Crops, 15(1): 59-64.

Altın, M., Yaver, S., Tuna, C., Arslanoglu, F., Nizam, I., Satana, A. 2005. The Effect of Different Nitrogen Fertilizer and Harvest Dates on The Yield and Quality of Fodder Beet (*Beta vulgaris* L. *rapa*) İn Tekirdağ conditions. Türkiye VI. Field Crops Congress, Book II, p: 923-928, 5-9 September, Antalya.

Anonymous,2023a.https://ruralnewsgroup.co.nz/media/k2/items/cache/2f0400e40a0b43e607f5a83d49a9bb9a_XL.jpg (Acces Date: 02.12.2023)

Anonymous, 2023b. https://www.feedipedia.org/node/534 (Acces Date: 02.12.2023)

Anonymous, 2023c. https://www.fwi.co.uk/livestock/benefits-fodder-beet-get-best

Anonymous,2023d.https://www.online.unimarburg.de/botanik/php/bild.php?bild=beta_vulgaris_runkelruebe_ruebe1.jpg&name=Beta+vulgaris+L.+ssp.+vulgaris+var.+rapacea+K.+Koch&nr=1&gesamt=3&unterschrift= (Acces Date: 02.12.2023)

Anonymous,2023e.https://www.swseeds.co.uk/agricultural-grass-forage-seeds/magnum/ (Acces Date: 02.12.2023)

Anonymous,2023f.https://www.farmseeds.co.uk/products/forage-crops/roots/fodder-beet/tarine-fodder-beet.html (Acces Date: 02.12.2023)

Anonymous, 2023g. https://www.yara.co.uk/crop-nutrition/forage-crops/fodder-beet-programme/ (Acces Date: 02.12.2023)

Anonymous, 2023h. https://www.feedipedia.org/node/534 (Acces Date: 02.12.2023)

Avcıoğlu, R., Geren, H., Elmalı, Y., Erkul, O. 1999. Research on The Effects of Different Planting Times and Density on Yield and Some Other Characteristics of Fodder Beet (*Beta vulgaris var. rapacea* Koch). Türkiye 3. Field Crops Congress, p:113–118. 15–18 Kasım 1999, Adana.

Birkenmaier, F., Schwarz, F.J., Muller H.L., Kirchgessner, M. 1996. Feed intake and milk performance of dairy cows fed fodder beets together with grass silage. Archives of Animal Nutrition-Archiv Fur Tierernahrung, 49 (4): 335–347.

Ergül, M., 1997. Forages Information and Technology. Ege University Faculty of Agriculture Publications. No: 487 (In Turkish).

Gençkan, S. 1983. Forage Crops Cultivation, E.U. Press, No: 467, Bornova-İzmir (In Turkish).

Geren, H., Avcıoğlu, R. 1997. Effect of Different Sowing Dates on The Yield and Some Other Characteristics of Various Fodder Beet Cultivars. Türkiye II. Field Crops Congress, p:699-704, 22-25 September, Samsun.

Gökkuş, A. 1994. The importance of meadow pasture and forage crops in forage production in Turkey. Atatürk University Journal of Agricultural Facuty, 25(2): 250-261.

Karadağ, Y., Dündar, Z., Özkurt, M. 2014. Yield and yield characteristics of some fodder beet (*Beta vulgaris* L. *var. rapacea* Koch.) cultivars under Tokat-Kazova ecological conditions. Journal of Agricultural Faculty of Gaziosmanpasa University, 31 (2), 1-6.

Kılıç, A., 2010. Silage. Hasad Publishing Ltd. Şti., İstanbul. ISBN: 978-975-8377-73-2. (In Turkish).

Krousky, J. 1991. Sugar and fodder beet seed from the precultivated sugar-root seedling. Rostlinna Vyroba. 37 (3): 231–242.

Manga, İ., Acar, Z., Ayan, İ., Tiryaki, İ.,. Özyazıcı, M. A. 1997. The Effect of Manure and Mineral Fertilizers, Sowing Dates, and Plant Density On The Yield and Some Quality Characteristics of Fodder Beet (*Beta vulgaris* L. *var rapa*) Under İrrigated and Nonirrigated Conditions of Samsun. Türkiye II. Field Crops Congress, p:482-486, 22-25 September, Samsun.

Martin, S.H., Leonard, W.H., Stamp, D.L. 1975. Principles of Field Crop Production (Third Edition) Macmillen Publishg Co., inc. New York, USA.

Özdemir, A.M., Kökten, K. 2020. Tuber yield and quality properties of some fodder beet (*Beta vulgaris var. rapacea*) varieties. Journal of the Institute of Science and Technology, 10(3): 2191-2198.

Özen. N., Çakır, A., Haşimoğlu, S., Aksoy, A. 1981. Feeds. Atatürk University Faculty of Agriculture Animal Science Lecturer Notes, Erzurum, 286 pages.

Özen, N., Çakır, A., Haşimoğlu, S., Aksoy, A. 1993. Forages Information and Technology. Atatürk University Faculty of Agriculture Lecturer Notes: 50, Erzurum.

Özaslan Parlak, A., Ekiz, H. 2008. The comparison of yield and yield components in some fodder beet (*Beta vulgaris* L. *ssp. crassa* Mansf.) varieties under Ankara conditions. Journal of Agricultural Sicences, 14 (2): 95-100.

Sağlamtimur, T., Tansı, V. 1989. A research on the determination of the most suitable planting time of fodder beet in Çukurova. Çukurova University Journal of the Faculty of Agriculture, 1 (4): 62-75.

Soya, H., R. Avcıoğlu, H. Geren, G. Demiroğlu, 2009. Fodder Beet (*Beta vulgaris* L. *var. rapacea* Koch). Forage Crops III. T.R. Ministry of Agriculture and Rural Affairs Publications, İzmir.

Wiersema J.H., 2019. GRIN Taxonomy. US National Plant Germplasm System. Checklist dataset https://doi.org/10.15468/ao14pp accessed via GBIF.org on 2023-11-26. https://www.gbif.org/species/101343861

CHAPTER 7

PHACELIA (*Phacelia tanacetifolia* Bentham)

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1. INTRODUCTION

In order to survive in our globalising world and to take our place as a country in all sectors, rapid developments in world agriculture have started to make the use of intensive agricultural techniques compulsory. Recently, especially chemical-containing agricultural pesticides such as pesticides, insecticides and herbicides have brought negative effects on honey bees (Kumova et al., 2003). Honey bees and other insects are needed as pollinators in the production of many plants in nature (Free, 1970). Insects and bees are directly or indirectly involved in the production of about 1/3 of the food consumed by humans worldwide (McGregor, 1971). Bee-plant relationship is the most effective way to increase the quality and quantity in agricultural production.

Beekeeping is widely practised in the world for both mass production and hobby purposes without the need for land. Beekeeping is an important farming activity and bee products are a valuable food item for balanced and healthy human care. In addition, bees are of vital importance in the production, pollination and maintenance of ecological balance and management of their products. Beekeeping development provides jobs, income and healthy nutrition services to the rural population. With all these features, it has a privileged place in beekeeping management (Burucu and Gülse Bal, 2017). Honey production has started to be done more scientifically in our country. Thanks to the geographical location of our country, there are flowering plants in almost every period of the year (Demiroğlu Topçu and Özkan, 2020). However, due to the extreme temperatures in the summer period, nomadic beekeeping comes to the fore and hives are moved to places with higher altitude in the summer months.

When the number of hives in the world is analysed, it is seen that Asia is the leading continent. In parallel with this, approximately half of the world honey production is provided from Asia.

Beekeeping, which is important for both developed and developing countries, is one of the agricultural activities that are widely carried out today. The number of hives in the world was 102 million in 2021. Türkiye ranks 3rd after India and China in terms of the number of hives (Table1.)

Table 1. World Hive Existence housand Units)

Countries	2017	2018	2019	2020	2021
India	12.166	12.124	12.348	12.589	12.848
China	9.096	9.158	9.165	9.192	9.217
Türkiye	7.991	8.108	8.128	8.179	8.733
Iran	6.951	7.466	7.247	7.333	7.527
Ethiopia	6.524	7.075	6.958	6.986	7.106
Tanzania	2.968	3.005	3.012	3.031	3.051
Argentina	2.923	2.966	2.959	2.962	2.965
Spain	2.905	2.966	3.034	2.967	2.953
Russian Fed.	3.317	3.182	3.094	2.982	2.890
USA	2.684	2.828	2.812	2.706	2.696
Other	35.529	38.375	39.290	40.542	41.638
World	93.054	97.253	98.047	99.469	101.624

Source: TEPGE, 2023

In 2021, while 1,771,944 tonnes of honey will be produced in the world, Türkiye ranks 2nd after China with 96,334 tonnes. According to FAO data, while the average honey yield per hive is 17.4 kg, it is 11.3 kg in Türkiye (Table 2).

Table 2. World Honey Production (Tons)

Countries	2017	2018	2019	2020	2021
China	542.544	446.879	444.054	458.100	472.700
Türkiye	114.471	107.920	109.330	104.077	96.344
Iran	72.206	72.796	72.851	74.293	77.152
Argentina	76.379	79.468	78.909	72.441	71.318
Ukraine	66.231	71.279	69.937	68.028	68.558
India	62.810	63.826	64.514	65.250	66.278
Russia	65.167	65.006	63.526	66.368	64.533
Mexico	51.066	64.253	61.986	54.165	62.080
USA	67.596	69.857	71.179	66.948	57.364
Brazil	41.696	42.268	45.801	51.508	55.828
Other	718.142	754.957	675.037	693.299	679.789
World	1.878.308	1.838.509	1.757.124	1.774.477	1.771.944

Source: TEPGE, 2023

In 2022, as in world honey production, China ranked first in terms of export amount, while Türkiye, which ranked second in terms of production amount, ranked 7th (Table 3).

Table 3. World Honey Export (Tons)

Countries	2018	2019	2020	2021	2022
Çin	123.477	120.845	132.469	145.886	156.002
Arjantin	68.787	63.522	68.985	63.934	67.380
Brezilya	28.524	29.812	45.728	47.190	36.886
Belçika	19.835	17.654	22.353	25.740	31.975
Almanya	22.789	25.350	29.740	29.758	30.350
İspanya	23.090	22.471	28.263	28.442	28.370
Türkiye	6.413	5.548	6.038	9.994	17.248
Polonya	14.646	17.014	24.815	19.277	15.036
Macaristan	22.018	21.003	23.063	18.329	14.483
Bulgaristan	10.719	12.950	12.834	12.137	12.738
Other	308.308	290.119	326.489	329.645	122.213
World	648.606	626.288	720.777	730.332	532.681

Source: TEPGE, 2023

Although Türkiye consumes most of its honey production within the country, it exported 17.248 tons of honey in 2022, generating an income approximately 50 million USD.

In addition to the richness of natural plant resources, the diversity of cultivated plants is also important for the development of honey bee colonies at the desired level and the increase in honey yield. Among the most important food sources of bees are citrus gardens, fruit orchards, forage crops and pastures (Doyduk, 2014). If bee colonies are not provided with sufficient nectar and pollen sources, it becomes difficult for bees to survive. For this reason, arranging the plant pattern suitable for regional conditions or transporting bee colonies to natural or cultivated plant resources throughout the year reveals the dimensions of ecological agriculture in obtaining bee products for human health and food (Kumova et al., 2003).

Intercalarily, the agricultural structure of the our country is changing every year and unsustainable agricultural practices are becoming widespread. Incorrect practices such as widespread monocultural agriculture, soil cultivation and stubble burning restrict the habitats of honey bee and other

fertilising insects and significantly reduce their efficiency in plant production. In terms of beekeeping, especially in the early spring period, it is important to spread new and different plants that can be a source of nectar and pollen, and to establish bee pastures with plant mixtures including these plants (Kumova and Korkmaz, 2003).

In addition to all these developments, the use of new production techniques in beekeeping in our country and the cultivation of plants that have economic value and are successfully produced in countries with similar climates in our country are on the agenda (Kumova and Korkmaz, 2000).

Figure 1. Phacelia bud and flowers (Original)

Phacelia, which is not only used in honey production, can increase fruit set thanks to pollinating insects, especially when planted between trees in orchards. When it is evaluated as a cover plant; it protects these areas against water and wind erosion by covering the soil surface to the desired extent. In addition, Phacelia can also be used as a green fertiliser by mixing with the soil towards the end of the flowering period in the region where it is grown. Thus, it is important in terms of returning the plant nutrients removed from the soil back to the soil and strengthening the soil structure. Due to the fact that its flowers attract many insect species, it also allows harmful insects to be caught and removed from the environment en masse by biological warfare method (Kahl, 1996).

2. SYSTEMATIC AND MORPHOLOGY

Systematic

Kingdom: Plantae,
Phylum: Tracheophyta,
Class: Magnoliopsida
Order: Boraginales,
Family: Hydrophyllaceae,
Genus: *Phacelia*,
Species: *Phacelia tanacetifolia* Benth. (GBIF, 2023).

Phacelia is an annual plant that does not belong to the wheatgrass and legume families. It originates from North America. There are 13 species in the world but 4 species (*Phacelia distani*, *P. ramosissima, P. hispida, P. tanacetifolia*) are valuable for beekeeping (Everet, 1963).

Phacelia is a plant that grows up to 100-120 cm tall and grows upright, depending on the region, planting date and climatic conditions. The leaves of the Phacelia plant are alternate and covered with thorn- like hairs. When there is cold damage in the first seedling period, red colour can be seen on the plant.

Depending on the vegetation period, it branches from the stem parts close to the soil and completes the plant development horizontally (Korkmaz, 2009). Inflorescences are mostly located on the upper parts of the plant stem (Ozkan, 2014). At least one inflorescence is formed on almost every branch. Lilac, light purple-blue, pink or white flowers (Kumova and Korkmaz, 2002) are an important source of pollen and nectar (Howes, 1979; Bilgen and Özyiğit, 2005).

Flowering in an inflorescence starts from the lower part of the panicle and lasts about a week. It has diploid 2n=22 chromosomes. Phacelia plant has 5 petalled flowers, 5 anthers and 2 female organs. Depending on the climatic characteristics of the region where it is grown, the flowering period for a plant is 1 month (Geren and Kaymakkavak, 2007), while this period can be 1.5 to 2.5 months on a field basis (Kumova and Korkmaz, 2002). In fact, this length of flowering period is not common in many cultivated plants (Karadağ and Büyükburç, 1999).


Figure 2 and 3. Phacelia Flowers Structure (Original)


Figure 4 and 5. Phacelia seedling and leaves (Original)

In a field of Phacelia that has completed its normal development, there are 4733-9250 pcs/m^2 flowers depending on different sowing times in winter sowing (Tansı et al., 1996). Phacelia plant, which can produce both pollen and nectar in its flowers, is recognised as one of the world's leading honey plants. With a dry matter content of 15.90-18.43%, Phacelia can produce 0.30-0.66 mg/flower/day nectar and 0.45-0.56 mg/flower/day pollen. At the end of the flowering period in the same area, it was found to have a nectar production potential of 7.81-14.45 kg/da and pollen production potential of 11.72-12.26 kg/da (Kumova et al., 2003).

Figure 6,7, and 8. Before flowering, at the beginning of flowering and after flowering of Phacelia inflorescences (Original)

3. ADAPTATION

Phacelia can be grown in almost all soil types (Doyduk, 2014). It attracts attention in regions up to 500 m above sea level and mostly in rocky and stony lands. It was first cultivated in the European continent in Germany in 1832. Afterwards, it spread all over Europe from England to Russia. At first, it was used as erosion control, dry and green grass, but later it started to be used effectively as bee pasture. Phacelia is recognised as one of the top 20 nectar plants in the world in terms of providing pollen and nectar to honey bees (Craine, 1975). In our country, studies were started for the first time in 1978 at Çukurova University, Faculty of Agriculture, Department of Field Crops. It has been determined that it can be successfully cultivated as a winter intermediate crop for bee pasture formation after its adaptation in Çukurova Region.

Phacelia is a plant that can be grown as a winter intercrop in the Mediterranean, Aegean and other coastal regions except Çukurova region. In the Aegean and Mediterranean regions, it can be grown as a winter intercrop before planting summer main crops such as tobacco, corn, cotton, sunflower and soya. It develops well during the winter months and reaches harvest maturity in early spring. However, Phacelia should be used as bee pasture rather than forage production. It is intensively visited by many beneficial insects, especially honey bees, because it has abundant flowers, stays flowering for a long time, and its flowers contain abundant pollen and honeydew. In

honey bee colonies that are wounded in the bee pasture, offspring productivity increases considerably, so honey yield can increase 3-6 times in each colony. Honey obtained from Phacelia is extremely high quality.

Figure 9. Phacelia Flowers (Original)

The cultivation of Phacelia is similar to the cultivation of other winter intermediate crops. However, as the seeds are slightly smaller, a more careful seedbed preparation is required. Sowing can be done in rows 20-70 cm apart. Seed amount should be kept between 1.0-2.0 kg/da and sowing depth between 1.0-2.0 cm in machine sowing. In sprinkle sowing, the amount of seed should be slightly increased. Another point to be considered is to cover the seeds with soil. Because the seeds that are outside and exposed to sunlight cannot germinate. In sowing too deep, new seedlings that cannot reach the soil surface cannot survive. It is recommended to apply 7.5-12 kg of pure nitrogen and phosphorus fertiliser per decare and to spray the seed before sowing, especially against ants. Since Phacelia is a highly tolerant plant against diseases and pests, it does not need to be sprayed in any way during the growing season. Therefore, the honey obtained due to its suitability for biological honey production can be sold at high prices in the markets.

Sowing is done in October-December in the coastal belt and in the transition regions where winters are not harsh. At altitudes above 500 m or in regions where snow falls in winter, it is considered appropriate to sow in early spring. It is possible to benefit from Phacelia planted at different altitudes throughout the year. In the coastal and Çukurova regions, it develops throughout the winter months and starts flowering at the end of March and beginning of April. However, in coastal regions, red colour can be seen in the plant during short-term frosts. Exposure to frost for periods that do not prevent the development of the plant is not very effective.

Figure 10. Phacelia cold damage (Original)

4. YIELD AND QUALITY

At the beginning of flowering, it can be harvested for silage production. However, it is recommended to leave it and utilize it as bee pasture for 1.5-2 months and harvest it when the flowers are well reduced. Dry fodder can be easily consumed especially by small ruminants. Green herbage is suitable for silage production provided that additives such as barley crush, corn extract and molasses are added. Green herbage of 25400-60470 kg^{-1} and dry fodder of 5340-9870 kg^{-1} can be obtained from Phacelia harvested at different growth

periods and after fertilisation at different doses (İnal, 1997, Geren and Kaymakkavak, 2007, Ateş et al., 2010, Yılmaz, 2014, Ateş et al., 2014). When the feed quality values of Phacelia are examined, it has been revealed that ADF ranges between 37-42%, NDF between 45-46.5% and crude protein ratio between 10-13% (Ateş et al., 2010, Amet, 2017).

The ripening of the seeds in the Phacelia plant occurs from the bottom of the inflorescences upwards. Therefore, it is very important to determine the harvest time. When the seeds in the lower part of the panicle ripen and turn brown, the flowers can still be seen in the upper part. If these flowers are expected to turn into seeds, the first seeds are shed. In order not to lose the first ripened seeds, harvest when almost half of the seeds in the cluster turn brown, while the plant stem is still wet. It is dried by heaping on a flat and hard ground. In practice, it is separated from the stalk and straw by beating or travelling on it with a tractor. It is cleaned by blowing in light wind. If harvesting with a combine harvester, harvesting before dew will minimise seed loss. Seed should be kept in clean and cool places. The seeds obtained after harvesting do not lose their germination power for several years and can be used as seed. Seed yields vary between 38-86 kg/ha depending on the region and sowing dates (Uçar and Tansı, 1996, Kızılşimşek and Ateş, 2004).

Figure 11. Phacelia seeds (Original)

REFERENCES

Amet, T. 2017. Ensiling Possibilities of Phacelia (*Phacelia tanacetifolia* Bentham.) Harvested After Flowering, Ege Uni. Science and Technology Inst. Department of Zootechnics, Master's Thesis, Izmir.

Ateş, E., Coskuntuna, L., Tekeli, A.S., 2010. Plant Growth Stage Effects On The Yield, Feeding Value and Some Morphological Characters of The Phacelia (*Phacelia tanacetifolia* Benth.), Cuban Journal of Agricultural Science, Volume 44, Number 4.

Ates, E. Tekeli, AS. Boynukara, B. 2014. Performance Of Fodder Pea (*Pisum arvense* L.) - Fiddleneck (*Phacelia tanacetifolia* Bentham) Mixture Under Different Nitrogen Doses. Romanian Agricultural Research, No. 31: 1-6. Yilmaz, 2014,

Bilgen, M. Özyiğit, Y. 2005. The Effect of Vegetative Growth on Flowering Characteristics in Bee Grass (*Phacelia tanacetifolia*), Akdeniz Univ. Agricultural Faculty. Journal, 18(2): 235-240.

Burucu, V. and Gülse Bal, H.S., 2017. Current Status of Beekeeping in Turkey and Honey Production Forecast. Journal of Agricultural Economics Research (2017) 3(1): 28-37, Ankara Access: 10.04.2023.

Crane, E. 1975. Honey, a Comprehensive Survey. Heinemann in Co-operation with International Bee Research Association. London, UK.

Demiroğlu Topçu, G., Özkan, Ş.S. 2020. The Importance Of Bees In Rangelands, Innovative Approaches In Meadow-Rangeland And Forage Crops, Chapter 14, p:315, Editor: Assoc. Prof. Dr. Seyithan Seydoşoğlu, Ankara

Doyduk, I. 2014. The Effects of Different Sowing Times on Yield and Some Agricultural Characters of Different Arıotu (*Phacelia tanacetifolia* Bentham) Varieties under Çukurova Conditions, Ç.Ü. Institute of Science and Technology. Department of Field Crops, Master's Thesis.

Everett, T. H., 1963. New Illustrated Encyclopedia of Gardening. The Greystone Press. New York. USA.

Free, J. B. 1 9 7 0 The Behaviour of Honeybees Visiting the Flowers of Fruit Trees.J. Anim. Ecol. 29. 385-395.

Geren, H, Kaymakkavak, D. 2007. Effects of Different Row Spacing on

Herbage Yield and Yield and Quality Characteristics of Some Phacelia *(Phacelia tanacetifolia* Bentham*)* Varieties, Ege Univ. Agric. Derg., 44 (1):71-85, ISSN 1018-8851, Izmir.

Global Biodiversity Information Facility (GBIF), 2023. https://www.gbif.org/species/152545481/verbatim. Access Date:27.11.2023

Howes, FN, 1979. Plants and beekeeping. Faber and Faber, London and Boston, p:236.

Inal, I. 1997. Investigations on the Determination of the Possibilities of Using Different Intermediate Crops as Green Fertiliser in Maize Cultivation under Çukurova Conditions, Ç.Ü. Institute of Science and Technology. Department of Field Crops, Master Thesis.

Kahl, H. 1996. Border Strip Planting to Enhance Biological Control of the Cabbage Aphid Brevicoryne brassicae L. by Hoverflies (Diptera:Syrphidae). Christchurch Polytechnic. Institute of Technology, New Zealand.

Karadağ Y, Büyükburç, U. 1999. A Research on the Yield and Adaptation of Phacelia (*Phacelia tanacetifolia* Bentham) Grown in Tokat Conditions, GOU Agriculture Faculty. Journal, 16(1): 155-169, Tokat.

Kızılşimşek, M., Ateş, F. 2004. Flowering course of bee grass (*Phacelia tanacetifolia* Bentham) at different sowing times and its evaluation as bee pasture under Kahramanmaraş conditions. KSU Science and Engineering Journal 7(1):96-103.

Korkmaz, A. 2009. PhaceliaCultivation. Samsun Provincial Directorate of Agriculture, Farmer Training and Extension Branch Publication, Samsun, 28s.

Kumova, U., Korkmaz, A., 2000. The Place and Importance of Çukurova Region in Bee Breeding in Turkey. Animal Production. 41:48-54.

Kumova, U., Korkmaz, A. 2002. The Importance of Phacelia (*Phacelia tanacetifolia* Benth.) Plant in Terms of Beekeeping and the Studies Carried Out in Our Country on This Subject, Uludağ Journal of Beekeeping, 2(1): 11-16, Bursa.

Kumova, U., Sağlamtimur, T., Korkmaz, A., İnal, İ. 2003. Investigation of Utilisation and Mutual Interaction Relationships of Honey Bee with Phacelia and Rapeseed Plants. TUBITAK TOGTAG-2629 Project Final

Report. January-2003 Adana, 276 Page.

Özkan, U. 2014. Importance of Bee Grass (*Phacelia tanacetifolia* Benth.), Cultivation, Studies in Turkey and the World, Agricultural Engineering, January-June, 2014. Issue: 361.

McGregor, S. E., 1971. Insect Pollination of Cultivated Crop Plants. Agricultural Handbook No: 496. USDA. 411 p..

Tansı, V., Kızılşimşek, M., Kumova, U., Sağlamtimur, T. 1996. Investigation of the Possibilities of Utilisation of *Phacelia tanacetifolia* Bentham, a New Forage Plant in Çukurova Region, for Honey Bees. Technical Journal of Beekeeping, Issue: 52: pp: 2-6.

TEPGE, 2023. Product Report, Beekeeping. Institute of Agricultural Economics and Policy Development, Publication. No: 370, ISBN: 978-625-8451-83-2. July-2023, Ankara, Türkiye

Uçar, H, Tansı, V. 1996. The Effects of Different Sowing Time and Row Spacing on Grain Yield of Phacelia (*Phacelia tanacetifolia* Bentham) and Its Utilisation as Bee Pasture under Çukurova Conditions, Turkey 3rd Meadow and Forage Crops Congress (17-19 June), pp: 415-421, Erzurum.

CHAPTER 8

FENUGREEK (*Trigonella foenum-graecum* L.)

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1.INTRODUCTION

Fenugreek is a plant species that is generally native to the Mediterranean climate and has played an important role in cuisine and traditional medicine throughout history. This plant, whose Latin name is *Trigonella foenum-graecum*, is utilized for a variety of cultural and health purposes, using both its leaves and seeds. Fenugreek has a distinctive odor and flavor profile, which is why it is frequently used as a spice in many culinary cultures. In addition, fenugreek is attributed to a variety of health benefits in traditional medicine, and is particularly important for digestive health, blood sugar regulation and increased energy. The herb's rich cultural and health history are just some of the factors that make fenugreek popular around the world.

Fenugreek is a member of the *Fabaceae* family. Because of its yellowish-white, triangular blossoms, it was given the Latin name *Trigonella*, which translates to "little triangle" (Flammang et al, 2004). It is called Hulba (Arabic), Uluva (Malayalam), Moshoseitaro (Greek), Methi (Hindi, Urdu, Punjabi, and Marathi), Shoot (Hebrew), Dari (Persian), heyseed (English) and çemen (Turkish). One of the first *Fabaceae* family medicinal herbs, fenugreek (*Trigonella foenum-graecum* L.) evolved in central Asia at approximately 4000 BC (Ahmad et al, 2016).

A common annual forage legume grown primarily in the ancient world, fenugreek is both a significant spice crop and a therapeutic herb. Related sectors are currently screening and investigating it extensively for its many medical, pharmacological, and nutraceutical characteristics. Numerous significant phytochemicals, including complex carbohydrates (galactomannan), steroidal sapogenins (diosgenin), and amino acids (hydroxyisoleucine) are abundant in fenugreek seed. It also possesses a good number of physico-chemical properties that have therapeutic value for both humans and animals (Zandi et al, 2015).

Many functional elements are present in fenugreek seeds, including choline, vitamin A, B1, B2, C, nicotinic acid, niacin (Leela and Shafeekh, 2008), phospholipids, glycolipids, oleic acid, linolenic acid, linoleic acid (Sulieman et al, 2000), and a significant amount of fiber (Montgomery, 2009; Meghwal and Goswami, 2012). Rarely any research has been conducted on its genetic modifications and the creation of production agronomy, despite its remarkable nutritional and therapeutic qualities. Throughout this review, we have covered the morphology, adaptability, nutritional components, connected

functionality, and therapeutic relevance of fenugreek; we have also covered its ethnohistorical usage and pharmacological presumptions. Improved output and flexibility can be achieved by researching these areas.

Recent studies on fenugreek have revealed a host of health benefits, including anti-inflammatory, antibacterial, antifungal, anti-carcinogenic, anti-thiurigenic, anti-cholesterolemic, antioxidant, hepatoprotective, neuroprotective, and antidiabetic effects in both experimental animals and human clinical trials (Yadav and Baquer, 2014; Nathiya et al., 2014; Adedapo et al., 2014). For ruminant animals, fenugreek has the capacity to yield high-quality feed. *Foenum graecum*, the species name for fenugreek, literally translates to "greek hay," and it was historically grown as a forage crop in the Mediterranean region (Acharya et al, 2006; Petropoulos, 2002).

In international trade, the seeds, fresh and dried leaves are used to flavor and flavor curries. In the food industry, it is also used as a flavor enhancer, to prevent bacterial contamination and to extend shelf life. The primary use of fenugreek seeds is in processed meat products. Fresh fenugreek leaves are also consumed as vegetables and spices in India, Italy and some other countries. Fenugreek seeds are also present in the composition of some local hot sauces prepared in southeastern Türkiye and are also used medicinally and in pickling in rural areas in India (Gupta, 1996).

Figure 1. Fenugreek leaves (Britannica, 2023; Flora Encounters; 2023).

2. SYSTEMATIC AND MORPHOLOGY

Family: *Fabaceae*

Genus: *Trigonella*

Species: *T. foenum graecum* L.

Fenugreek is in the genus *Trigonella* of the *Fabaceae* (Legumes) family of the *Fabales* order. This plant, popularly known as "buy grass", has a wide distribution in the world. The genus Trigonella includes about 50 species mostly distributed around the Mediterranean and 45 of these species are cultivated naturally in Türkiye. *Trigonella foenum graecum* L. is cultivated in Türkiye (Arslan et al, 1989; Davis 1970). Fenugreek is an annual species and self-fertilizing. It has a diploid chromosome number of 2n=16 (Martin et al, 2011; Açıkgöz, 2021).

Fenugreek is an annual leguminous forage crop growing 30-60 cm tall. The round stems grow upright and are hollow inside. Leaves have three leaflets. the stalk of the middle leaflet is long. The leaflets on the side are sessile. Flowers arise singly or in pairs from the leaf axils. The petals are yellowish-white in the sessile flowers. Pods are 5-15 cm long, slightly curved and pointed. Each pod contains between 5-20 seeds. Seeds are 3-5 mm long, hard, angular, bright yellow in color. Sometimes dull yellow or brown seeds are also seen. Thousand grain weight varies between 20-30 gr. Seeds have a typical odor caused by the chemical substance sotolone. This odor is stronger in ground seeds (Açıkgöz, 2021).

In all three leaflets, the base is straight-edged and the upper parts are toothed. However, unlike clover, the mid-vein extension is not prominent. The auricle is quite large and triangular, ranging from lanceolate to egg-shaped. Flowers are 10-18 mm long, single or in pairs, arising from the leaf axils and sessile. Petals are yellowish white, sometimes slightly pink. The petals are twice as long as the sepals and consist of a flag on the outside and two winglets and boatlets on the inside. The winglets are half the length of the flagella. The globule is blunt or rounded and only as long as the sepal. The sepal tube is leathery. The petals are surrounded at the base by a six-part sepal. The sepals are conspicuously hairy. Fruit setting was observed within 10 days after flowering (Beyza et al, 2010).

Fenugreek seeds contain 27% protein, 7-10% fixed oil, nitrogenous compounds, alkaloids (trigonelline) 1%, flavonoids (Akgül 1993; Gruenwald

et al, 2004). Fenugreek seeds also contain phosphorus compounds, phytin, choline, essential oil and nicotine amide (Kızıl and Arslan 2003).

Figure 2. Fenugreek seeds (Feedipedia, 2023; WeberSeeds, 2023).

3. ADAPTATION

Fenugreek is a cultivated plant originating from Anatolia. It has a wide adaptation ability. The fact that it is especially abstemious in terms of soil requirements and has a wide range of uses has made fenugreek an important cultural plant in this ecology for centuries. In recent years, as in other semi-arid region crops, fenugreek cultivation areas have been shrinking. The lack of full utilization of the genetic richness existing in Anatolia also plays a role in this decline. The breeding of productive and high-quality varieties by utilizing this wealth of genetic material has not been worked on (Sade et al, 1996).

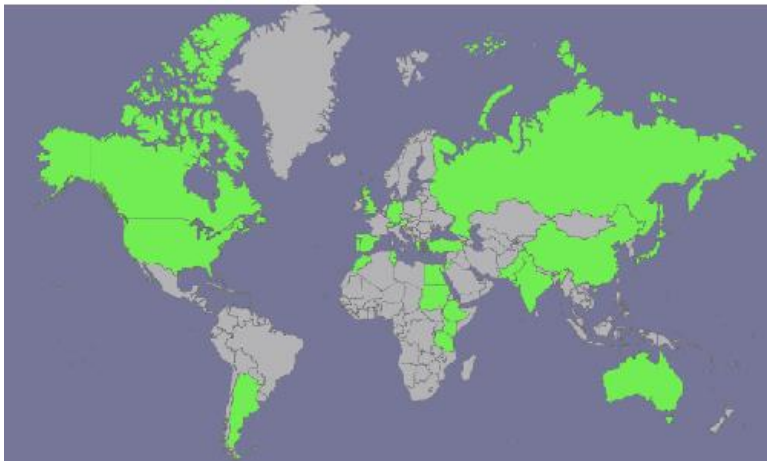

Figure 3. Cultivation of *Trigonella foenum-graecum* L. in the world; in green, countries where fenugreek is cultivated (Chaudhary et al, 2018).

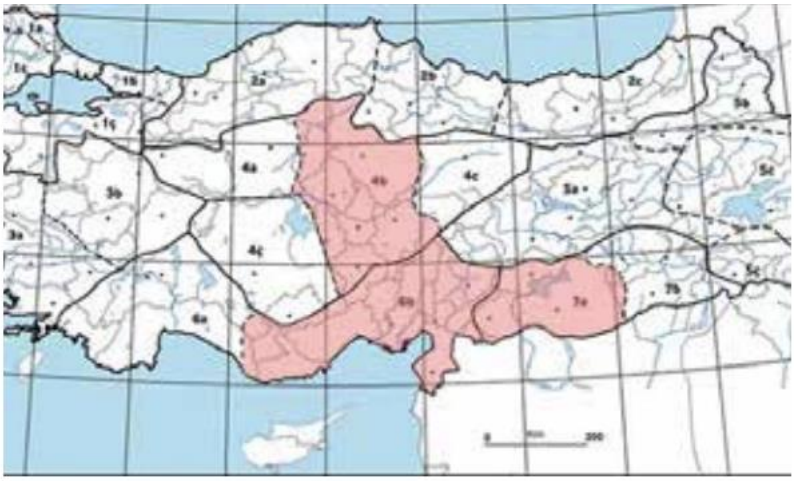

Figure 4. Distribution of fenugreek in Türkiye (Anonymous, 2023).

Fenugreek is a plant that grows well in temperate climates and can be cultivated as a winter crop, resistant to drought and high temperatures. In Türkiye, it is cultivated in winter or early spring in warm regions and in summer in cold regions (Kevseroğlu and Özyazıcı, 1997).

Apart from Türkiye, fenugreek is cultivated in countries such as India, Egypt, Morocco, Algeria, Italy, Spain, France and Greece. In Türkiye, it is cultivated in provinces such as Konya, Kayseri, Çankırı, Ankara, Gaziantep, Kahramanmaraş (Figure 4.). Afyon, Urfa, Hatay and Tokat. Although it varies from year to year in our country, it has an annual average production of 2,000 tons in an area of 2,000 ha. Fenugreek cultivation is carried out at a higher rate in Konya province compared to other provinces. Almost half of country's production belongs to Konya province. In recent years (1998-2005), the cultivation area of Konya province has averaged 8200 ha per year and the yield has averaged 110 kg/ha. Fenugreek seeds are also one of our pharmaceutical and spice plants that are exported, albeit in small amounts (Kan et al, 2007).

Fenugreek accessions are found in the genebanks and research facilities of numerous nations in Europe, East and Southern Africa, West Asia, South East Asia, North Africa, and Australia (Figure 3.). Globally, there are 1074 registered varieties, far fewer than what genebank currently has because the majority of accessions are not registered. Zandi et al, (2017) reported that there are three registered varieties in the United States, but the USDA repository contains 192 accessions. India, Ethiopia, Canada, and Oman have the next-

largest germplasm collections. The highest-yielding fenugreek accessions are from West Asia, North Africa, and India, indicating the availability of the diversity needed to develop cultivars suitable for various agroecologies. Studies on 207 fenugreek accessions from 13 countries showed high variability to days to flowering (98–147 days) and yield (0.6–2.5 t/ha) (Malhotra, 2011).

4. YIELD AND QUALITY

Since fenugreek is a legume plant, its seed contains significant amounts of protein, mineral substances and vitamins. *Rhizobium meliloti* inoculation in fenugreek causes significant increases in the protein, oil and fiber content of the seed and improves the composition and quality of the seed (Abdelgani et al, 1999; Elsheikh, 2001). In many studies on *Rh. meliloti* inoculation in fenugreek (Chaudhary, 1999; Parakhia et al. 2000; Kumawat et al, 2003; Bhunia et al, 2006; Mathur et al, 2006; Purbey and Sen 2007; Tunçtürk et al, 2016) inoculation has been shown to increase increases in the yield of fenugreek. Number of branches, number of pods, directly affect the yield of fenugreek, yield traits such as number of grains in pods and pod length were also improved by bacterial inoculation practices. (Chaudhary, 1999; Kumawat et al, 2003).

Fenugreek is mainly grown for seed production. After the pods are formed in the self-fertilized plant and the plant turns yellow, it is separated from the seeds directly with a combine harvester or with harvesting machines after being mowed with a scythe. Seed yield is generally not very high. In the USA and Canada, the maximum seed yield reached 125-150 kg/ha. Irrigation does not affect seed yield (Acharya et al, 2007; Basu et al, 2009)

Özyazıcı et al (2022), in their study, examined the quality characteristics of the mixtures of straw with oat and rye. It is stated that better silage was obtained in the mixtures compared to plain species silages. In the study stating that fenugreek, which is a legume, can form a good silage with grasses, silage quality was superior to the mixture of 25% oats + 75% fenugreek

Çakmakçı and Çeçen (1999) compared different annual forage crops in terms of dry matter yield. They found the dry matter yield of forage to be 317.5 kg/da.

Uğur and Kan (2016) found the average seed yield to be 86.67 kg/ha and crude oil yield to be 6.24% under Ankara (Türkiye) conditions. Some of the average values of fenugreek, which is quite remarkable in terms of the

components in the seed and leaf, are given in Table 1. According to the results of the study conducted by Srinivasan (2006), it was observed that the amount of calcium in the leaves was higher than in the seed, while a high protein content was detected in the seed.

Table 1. Composition of fresh fenugreek leaves and mature fenugreek seeds (derived from Srinivasan (2006)).

Component	Fresh fenugreek leaves	Fenugreek seeds
Moisture	86.0 g	
Protein	4.4 g	30 g
Fat	1.0 g	7.5 g
Fiber	1.0 g	50 g
Sapogenins		2 g
Trigonelline		380 mg
Ca	395 mg	160 mg
Mg	67 mg	160 mg
P	51 mg	370 mg
Fe	16.5 mg	14 mg
Na	76 mg	19 mg
K	31 mg	530 mg
Cu	0.26 mg	33 mg
S	167 mg	16 mg
Cl	165 mg	165 mg
Mn		1.5 g
Zn		7.0 mg
Cr		0.1 mg
Choline	1.35 g	50 mg
Vitamin C	52 mg	43 mg
β-Carotene	2.3 mg	96 µg
Thiamine	40 µg	340 µg
Riboflavin	310 µg	290 µg
Nicotinic acid	800 µg	1.1 mg
Folic acid		84 µg

Values expressed per 100g.

The most valuable portion of the plant is its seeds, or biological endosperm. The raw seeds taste bitter, yet they have a golden tint and a maple

flavor. Roasting, though, might lessen this bitterness. According to Jani et al. (2009), the seeds are naturally fibrous, sticky, and gummy. Seeds that contain alkaloids and saponins are thought to be anti-nutritional. But defatted seeds don't contain these substances, thus those who struggle with their weight may consume them (Altuntaş et al, 2005).

Fiber content in fenugreek seeds is high (50–65g/100g), mostly in the form of non-starch polysaccharides. Fenugreek fiber has the potential to moderate human glucose metabolism when used medicinally. Additionally, bile salt absorption in the colon is inhibited by mucilage, tannins, pectin, and hemicellulose, which helps lower blood levels of low-density lipoprotein cholesterol (LDL). It binds food pollutants and indiscriminately shields the gut epithelial membrane from the development of cancer. Additionally, it aids in regulating blood sugar levels and lowering blood glucose absorption, which promotes the action of insulin. The primary component of seeds' soluble fiber, galactomannans, reduces the body's absorption of glucose (Meghwal and Goswami, 2012).

Proteins such as globulin, lecithin, and albumin are abundant in fenugreek endosperm (43.8 g/100 g) (Mathur and Choudhry, 2009; Naidu et al, 2011). It contains a high percentage (20–30%) of free amino acids, especially histidine and 4-hydroxyisoleucine, which may increase insulin activity (Işıklı and Karababa, 2005). The proteins found in fenugreek are sufficiently stable and unaffected by booking (Srinivasan, 2006). Furthermore, the contents of debitterized fenugreek seeds are high in lysine and protein.

Because of its natural ability to fix nitrogen, fenugreek is environmentally friendly and can reduce the need for synthetic fertilizers. It can also be used to enrich soil nitrogen in organic farming (Acharya et al, 2006; Basu et al, 2008a,b; 2009; Basu & Prasad, 2011; Zandi et al, 2011a,b). It reduces irrigation costs because it is appropriate for short-term rotations (Acharya et al, 2008; Basu et al, 2008a, b; 2009; Zandi et al, 2013). It is also suitable for dry land and rainfed conditions that are appropriate for semi-arid regions (Acharya et al, 2006; Basu et al, 2007a,b; Zandi et al, 2010). Fenugreek has been discovered to have higher crude protein levels and in vitro dry matter disappearance than alfalfa; on the other hand, in vitro gas generation and volatile fatty acid content are nearly the same. Mature fenugreek has forage quality (protein and fiber content) that is similar to prime-cut alfalfa, making it

easy to use at any stage of growth (Acharya et al, 2006; Zandi et al, 2010; Basu & Prasad, 2011). Semi-arid locations are known to generate a fairly high yield of fenugreek for forage (Acharya et al, 2008). In contrast to alfalfa, the crop is reported to be bloat-free (Zandi et al, 2010; Acharya et al, 2011; Basu and Prasad, 2011).

Flavonoids, alkaloids, amino acids, coumarins, vitamins, saponins, and other antioxidants can be found in fenugreek. With two major steroidal sapogenin compounds, diosgenin and yamogenin, accounting for 4.8% of seeds, saponins are a class of glycosylated triterpenes that have been shown to exhibit antifertility activity and trigger teratogenicity through their androgenic and estrogenic properties (Dande and Patil, 2012; Al-Yahya, 2013). As stated by Zhou et al (2012), fenugreek comprises 35% alkaloids, essentially trigonelline, which has low toxicity and beneficial therapeutic potential. The flavor of the seed is caused by triphenylline, which is converted during roasting into nicotinic acid and related pyridines (Naidu et al, 2011). Additionally, fenugreek seed's volatiles and alkaloids produce an unpleasant taste and odor, which makes people try to avoid consuming fenugreek seed and its products.

REFERENCES

Abdelgani, M. E., Elsheikh, E. A. E., & Mukhtar, N. O. 1999. The effect of *Rhizobium* inoculation and chemical fertilization on seed quality of fenugreek. Food Chemistry, 64(3), 289-293.

Acharya, S.N., Blade, S., Mir, Z. and Moyer, J.S.2007. Tristar fenugreek. Can. J. Plant Sci. 87: 901–903.

Acharya, S.N., Thomas, J.E. & Basu, S.K. 2008. Fenugreek (*Trigonella foenum-graecum* L.) an alternative crop for semiarid regions of North America. Crop Sci. 48: 841–853.

Acharya, S. N., Thomas, J. E., & Basu, S. K. 2006. Fenugreek: an "old world" crop for the "new world". Biodiversity, 7(3-4), 27-30.

Acharya, S.N., Acharya, K., Paul, S. & Basu, S.K. 2011. Variation in the antioxidant and anti- leukemic properties among different Western Canada grown fenugreek (*Trigonella foenum-graecum* L.) genotypes. Can. J. Plant Sci. 91 (1): 99–105.

Açıkgöz, E. 2021. Ministry of Agriculture and Forestry, General Directorate of Crop Production, Ankara. (In Turkish).

Adedapo, A. A., Ofuegbe, S. O., & Soetan, K. O. 2014. Pharmacologic and medicinal properties of fenugreek (*Trigonella foenum-graecum* L). American Journal of Social Issues and Humanities (Special Issue), 13-20.

Ahmad, A., Alghamdi, S. S., Mahmood, K., & Afzal, M. 2016. Fenugreek a multipurpose crop: Potentialities and improvements. Saudi Journal of Biological Sciences, 23(2), 300-310.

Al-Yahya, A. A. 2013. Reproductive, cytological and biochemical toxicity of fenugreek in male Swiss albino mice. African Journal of Pharmacy and Pharmacology, 7(29), 2072-2080.

Altuntaş, E., Özgöz, E., & Taşer, Ö. F. 2005. Some physical properties of fenugreek (*Trigonella foenum-graceum* L.) seeds. Journal of Food Engineering, 71(1), 37-43.

Arslan, N., Tekeli, S., & Gençtan, T. 1989. Seed yield of fenugreek (*Trigonella foenum-graecum* L.) populations from different regions. VIII. Herbal Medicine Raw Materials Meeting, 19(21), 93-97.

Anonymous, 2023. Fenugreek feasibility report and investor guide, Ministry of Agriculture and Forestry Publications (https://www.tarimorman.gov.tr/TRGM/TARYAT/Belgeler/Projeler/cemen_FIZIBILITE_RAPORU_VE_YATIRIMCI_REHBERI.pdf accesed: 29.11.2023).

Basu, S.K., & Prasad, R. 2011. Trends in new technological approaches for forage improvement.AustJ Agric Eng. 2(6): 176–185.

Basu, S.K., Acharya, S.N., Bandara, M.S., Friebel, D., & Thomas, J.E. 2009. Effects of genotype and environment on seed and forage yield in fenugreek (*Trigonella foenum-graecum* L.) grown in western Canada. Aust. J. Crop Sci. 3(6): 305–314.

Basu, S.K., Acharya, S.N., Thomas, J.E.2007a. Colchicine treatment produces genetic improvement in fenugreek seed size and yield. Proc.Multi. Grad. Res.Conf., 1(1): 37–43.

Basu, S.K., Acharya, S.N., &Thomas, J.E.2007b. Foliar spray to improve fenugreek seed yield and reduce maturity duration. Proc.Multi. Grad. Res. Conf. 1(1):44–50.

Basu, S.K., Acharya, S.N., Thomas, J.E.2008a. Application of phosphate fertilizer and harvest management for improving fenugreek (*Trigonella foenum-graecum* L.) seed and forage yield in a dark brown soil zone of Canada. KMITL Sci. &Tech. J. 8(1):1–7.

Basu, S.K., Acharya, S.N.,Thomas, J.E.2008b. Genetic improvement of fenugreek (*Trigonella foenum-graecum* L.) through EMS induced mutation breeding for higher seed yield under prairie conditions of western Canada. Euphytica, 160:249–258.

Basu, S.K., Acharya, S.N., Bandara, M.S., Friebel, D., Thomas, J.E. 2009. Effects of genotype and environment on seed and forage yield in fenugreek (*Trigonella foenum-graecum* L.) grown in western Canada. Aust. J. Crop Sci. 3(6): 305–314.

Beyzi, E., İlbaş, A. İ., Gürbüz, B. 2010. Fenugreek (*Trigonella foenum graecum* L.) and its general characteristics. Erciyes University Graduate School of Science Journal of Science, 26(4), 316-322.

Bhunia, S. R., Chauhan, R. P. S., Yadav, B. S., & Bhati, A. S. 2006. Effect of phosphorus, irrigation and Rhizobium on productivity, water use and

nutrient uptake in fenugreek (*Trigonella foenum-graecum*). Indian journal of Agronomy, 51(3), 239-241.

Britannica.(2023. Fenugreek (https://www.britannica.com/plant/fenugreek accessed 29.11.2023).

Chaudhary, G. R. 1999. Response of fenugreek (*Trigonella foenum-graecum*) to N, P and Rhizobium inoculation. Indian Journal of Agronomy (India), 44(2).

Chaudhary, S., Chaudhary, P. S., Chikara, S. K., Sharma, M. C., & Iriti, M. 2018. Review on fenugreek (*Trigonella foenum-graecum* L.) and its important secondary metabolite diosgenin. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 46(1), 22-31.

Çakmaçı, S., & Çeçen, S. 1999. The possibilities at entering crop rotation system of certain annual legume plants in Antalya. Turkish Journal of Agriculture and Forestry, 23(1), 119-124.

Dande, P., & Patil, S. 2012. Evaluation of Saponins from *Trigonella foenum graecum* Seeds for its Antifertility Activity. Asian J Pharm Clin Res, 5(3), 154-157.

Davis, P. H. 1970. Flora of Turkey and the East Aegean Islands. Vol. 3. Flora of Turkey and the East Aegean Islands. Vol. 3.

Elsheikh, E. A. 2001. Effect of inoculation with Rhizobium on the seed chemical and physical properties of legumes. Aspects of Applied Biology. 63: 151-163.

Feedipedia,2023.Fenugreekseeds. https://www.feedipedia.org/content/fenugreek-trigonella-foenum-graecum-seeds accessed: 30.11.2023).

Flammang, A. M., Cifone, M. A., Erexson, G. L., & Stankowski Jr, L. F. 2004. Genotoxicity testing of a fenugreek extract. Food and chemical toxicology, 42(11), 1769-1775.

Floral Encounters. 2023. Fenugreek. (https://www.floralencounters.com/Seeds/seed_detail.jsp?grow=plants &productid=92652 accessed: 30.11.2023).

Gupta, K., Thakral, S., Arora, S. K., & Chowdhary, M. I. 1996. Structural carbohydrate and mineral seeds. Ind. Cocoa Arecen. Spec. J, 20, 120.

Işıklı, N. D., & Karababa, E. 2005. Rheological characterization of fenugreek paste (çemen). Journal of food engineering, 69(2), 185-190. Zhou, J.,

Chan, L., & Zhou, S. (2012). Trigonelline: a plant alkaloid with therapeutic potential for diabetes and central nervous system disease. Current medicinal chemistry, 19(21), 3523-3531.

Jani, R., Udipi, S. A., & Ghugre, P. S. 2009. Mineral content of complementary foods. The Indian Journal of Pediatrics, 76, 37-44.

Kan, Y., Kartal, M., & Aboutakers, M. 2007. The effect of organıc and ınorganıc fertılızer on some quality characters of fenugreek seeds (*Trigonella foenum graecum* L.). Selcuk Journal of Agriculture and Food Sciences, 21(41), 118-122.

Kevseroğlu, K., & Özyazıcı, G. 1997. Effects of nitrogen fertilizer doses on some agronomic characteristics of fenugreek (*Trigonella foenum-graecum* L.). Proceedings of the Second Field Crops Congress of Turkey, Samsun, 367-371.

Kızıl, S., & Arslan, N. 2003. Investigation of the effects on yield and yield components of different sowing rates in some fenugreek (*Trigonella foenum-graecum* L.) Lines, Journal of Agricultural Sciences, 9(4); 395-401.

Kumawat, P. D., Choudhary, G. R., & Pareek, R. G. 2003. Response of fenugreek (*Trigonella foenum-graecum* L.,) to iron, molybdenum and rhizobium ınoculation. advances in plant sciences, 16(1), 83-86.

Leela, N., & Shafeekh, K., 2008. Fenugreek, Chemistry of Spices. CAB International, Pondicherry, India.

Malhotra, S. K. 2011. Fenugreek (*Trigonella foenum-graecum* L.). book: Genetic Resources, Chromosome Engineering, and Crop Improvement Edition: First.

Martin, E., Akan, H., Ekici, M., & Aytac, Z. 2011. Karyotype analyses of ten sections of Trigonella (Fabaceae). Comparative Cytogenetics, 5(2), 105.

Mathur, K., Bansal, R. K., & Gurjar, R. B. S. 2006. Organic management of Fusarium wilt of fenugreek (*Trigonella foenum graecum* L.)–a seed spice. Journal of Mycology and Plant Pathology, 36(1), 94-95.

Mathur, P., & Choudhry, M. 2009. Consumption pattern of fenugreek seeds in Rajasthani families. Journal of human ecology, 25(1), 9-12.

Meghwal, M., & Goswami, T.K., 2012. A review on the functional properties, nutritional content, medicinal utilization and potential application of fenugreek. J. Food Process Technol. 3.

Montgomery, J. 2009. The potential of fenugreek (*Trigonella foenum-graecum*) as a forage for dairy herds in central Alberta. University of Alberta, USA, pp. 4–15.

Naidu, M. M., Shyamala, B. N., Naik, J. P., Sulochanamma, G., & Srinivas, P. 2011. Chemical composition and antioxidant activity of the husk and endosperm of fenugreek seeds. LWT-Food Science and technology, 44(2), 451-456.

Nathiya, S., Durga, M., & Devasena, T. 2014. Therapeutic role of *Trigonella foenum-graecum* [fenugreek]–a review. Int. J. Pharm. Sci. Rev. Res, 27(2), 74-80.

Özyazıcı M. A., Seydoşoğlu, S., & Açıkbaş, S. 2022. Determination of silage quality of fenugreek (*Trigonella foenum-graecum* L.) with oat (*Avena sativa* L.) and rye (*Secale cereale* L.) mixtures. Turkish Journal of Nature and Science, 11(3), 102-109.

Parakhia, A. M., Akbari, L. F., & Andharia, J. H. 2000. Seed bacterization for better quality and more yield of fenugreek. Gujarat Agricultural University Research Journal, 25(2), 34-38.

Purbey, S. K., & Sen, N. L. 2007. Effect of bioinoculants and bioregulators on yield and nutrient uptake by fenugreek (*Trigonella foenum-graecum* L.). Indian Journal of Agricultural Research, 41(2), 154-156.

Sade, B., Akınerdem, F., Tamkoç, A., Topal, A., Acar, R., & Soylu, S. 1996. The correlation and path analysis of yield and yield components on fenugreek lines (*Trigonella foenum graecum* L.). Turkish Journal of Agriculture and Forestry, 20(2), 153-156.

Srinivasan, K. 2006. Fenugreek (*Trigonella foenum-graecum*): A review of health beneficial physiological effects. Food reviews international, 22(2), 203-224.

Sulieman, A. M. E., Ali, A. O., & Hemavathy, J. 2008. Lipid content and fatty acid composition of fenugreek (*Trigonella foenum-graecum* L.) seeds grown in Sudan. International journal of food science & technology, 43(2), 380-382.

Tunçtürk, R., Kulaz, H., & Çiftçi, V. 2016. Effect of Different Organic Fertilizers and *Rhizobium* Strains Applications on Some Agronomical Traits in Fenugreek (*Trigonella foenum-graecum* L.) Yuzuncu Yil University Journal of Agricultural Sciences 26(4): 475-483 (In Turkish)

Uğur, Ş., & Kan, Y. 2016. Determination of yield and quality characteristics of cumin (Cuminum cyminum L.) and fenugreek (*Trigonella foenum-graecum* L.) cultivated different sowing date in conditions (Golbasi) Ankara. Selcuk Journal of Agriculture and Food Sciences 3(2), 210-214. (In Turkish)

WeberSeeds. 2023. Fenugreek. (https://www.weberseeds.de/trigonella-foenum-graecum.html accessed: 30.11.2023).

Yadav, U. C., & Baquer, N. Z. 2014. Pharmacological effects of *Trigonella foenum-graecum* L. in health and disease. Pharmaceutical biology, 52(2), 243-254.

Zandi, P., Shirani Rad, A.M., & Bazrkar Khatibani L. 2011a. Agronomic study of fenugreek grown under different in-row spacing and nitrogen levels in a paddy field of Iran, Amer- Eurasian J Agri & Environ Sci. 10 (4): 544–550.

Zandi, P., Shirani Rad, A.H., Daneshian, J., & Bazrkar Khatibani, L. 2011b. Agronomic and morphologic analysis of Fenugreek (*Trigonella foenum-graecum* L.) under nitrogen fertilizer and plant density via factor analysis. African Journal of Agricultural Research, 6(5): 1134–1140.

Zandi, P., Daneshian, J., & Shirani Rad, A.H. 2010. Determination of Ideal Nitrogen Fertilizer Rate and Plant Density in Fenugreek under Dry Farming Conditions: The Regional Congress on Modern Results in Agronomy and Nanotechnology, Quds Azad University, Quds city, Iran.

Zandi, P., Shirani Rad, A.H., Daneshian, J., & Bazrkar Khatibani, L. 2013. Evaluation of nitrogen fertilizer and plant density effects on yield and yield components of Fenugreek in double cropping. Journal of Plant Production (Chamran University, Ahvaz), 35 (4): 81–91.

Zandi, P., Basu, S. K., Khatibani, L. B., Balogun, M. O., Aremu, M. O., Sharma, M., ... & Cetzal-Ix, W. 2015. Fenugreek (*Trigonella foenum-graecum* L.) seed: a review of physiological and biochemical properties and their genetic improvement. Acta Physiologiae Plantarum, 37, 1-14.

Zandi, P., Basu, S. K., Cetzal-Ix, W., Kordrostami, M., Chalaras, S. K., & Khatibai, L. B. 2017. Fenugreek (*Trigonella foenum-graecum* L.): an important medicinal and aromatic crop. Active Ingredients from aromatic and medicinal plants, 207-224.

CHAPTER 9

MARALFALFA (*Pennisetum sp*.)

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1. INTRODUCTION

One of a forage plant receiving interest recently in the agricultural and animal sectors is maralfalfa (*Penissetum sp.*). Limited cultivation lands and the impact of global warming have both contributed to the increasing attention on alternative feeds. The amount and quality of roughage, particularly in ruminant animal diet, are critical for the rumen microbiota. Good and inexpensive forages allow for more cost-effective ration preparation by lowering the requirement for concentrated feed. Maralfalfa is a simple to maintain perennial hybrid plant with a high biomass production. Furthermore, according to Boğa et al. (2023), it has a nutritional value that is comparable to corn silage and have a high yield of silage, making it suitable for use as a roughage source in animal nutrition.

Türkiye is home to 73 million farm animals in total, of which about 17 million are cattle and 56 million are sheep (TUIK, 2022). To feed these animals, the country needs 86 million tonnes of high-quality fodder. Natural meadow-pasture regions and the production of forage plants in field agriculture are two ways that the roughage demands of the animals are attempted to be satisfied. But there is still a 56 million tonne quality roughage shortfall in the country, given that pasture and forage crop cultivation regions produce about 30 million tonnes of quality roughage annually (Turan and Altuner, 2014; Turan et al., 2015). Plants like elephant grass (*Miscanthus giganteus*), giant king grass (*Pennisetum hybridum), maralfalfa (Pennisetum sp.*), and sweet sorghum (*Sorghum bicolor* (L.) Moench) are vital for minimising or eliminating the fodder shortages, which is a significant issue in Türkiye.

Feed costs account for about half of all operational costs in an agricultural firm that breeds animals. As a result, lower feed prices have a direct and favourable impact on company profitability. Perennial forage crops have a significant influence in lowering feed costs as well (Budaklı Carpici et al., 2010; Demiroğlu Topçu and Özkan, 2017; Hazar and Velibeyoğlu, 2018). According to Atis et al. (2019), perennial fodder crops are planted only once and have the potential to remain productive for five to six years, provided that the required maintenance operations like fertilisation, watering, shape, and so forth, are performed.

Roughage is the feed raw material that ruminant animals must consume in order for their rumens to be healthy and productive. Because it provides the fibre required to maximise rumen function, roughage is an essential part of

ruminant diets. Efforts are being undertaken to replace the shortage of roughage in the world and in Türkiye with alternative roughage. As a substitute forage, maralfalfa (*Pennisetum sp.*), is favoured because of its perennial nature and high output (300-600 tonnes per hectare). It is thought that with the use of this plant in animal feeding, the roughage deficit in the sector can be closed, the cost of feed will be reduced, and land will be saved by obtaining high efficiency from the unit area (Cerdas Ramírez, 2015, Turan, 2020). In recent years, Maralfalfa grass has attracted attention in ruminant animal breeding due to its high biomass yield, lower structural carbohydrate concentration and higher non-structural carbohydrate concentration compared to other species of the same genus (Villegas González, 2020).

2. SYSTEMATIC AND MORPHOLOGY

2.1. Plant characteristics of maralfalfa (*Pennisetum sp*.)

Maralfalfa, "*Pennisetum sp*." It is a species of hybrid (sterile) plant known as. Since maralfalfa grows only vegetatively, it can grow, leaf, and tiller in a relatively short amount of time. It also generally has the traits of the plants with which it is hybridised.

No plant known as maralfalfa grows naturally on its own. The plant variety that is commonly referred to as Maralfalfa, Napier, Capiaçu, Giant King Grass, or Elephant Grass is the result of crossing two distinct species. It is impossible to generate *Mischantus x giganteus*, also referred to as "elephant grass," by seed. *Miscanthus sacchariflorus* and *Miscanthus sinensis*, a sterile (sterile) hybrid plant, emerged via natural fertilisation of the Maralfalfa plant. Alternatively, the root region which we refer to as the shoot or rhizome may be used to propagate it (Greef and Deuter, 1993).

Figure 1. Production from Maralfalfa cuttings **(**Anonymous, 2023-a**)**

Figure 2. Height of Maralfalfa plant (Anonymous, 2023-b.)

Animal feed, decorative plants, and bedding have historically been made from the low-cost, perennial hybrid maralfalfa plant, which may reach heights of up to six metres. Despite being distinct species that proliferate by seed, napier grass (*Pennisetum purpureum)*, gigantic reed (*Arundo donax*), and tall bunch grass (*Saccharum ravenae*) are also referred to as "elephant grass." Perennial maralfalfa is a plant that can be economically left in the field for 15 to 30 years. It can produce grass for as long as it is left there if it is properly maintained.

2.2. Utilisation in animal nutrition

The incapacity of our nation's animal husbandry to produce enough high-quality fodder is one of the biggest issues. Two major sources of high-quality roughage are forage crop agriculture and natural meadow and pasture habitats. It is a known fact that the best livestock farming method is based on natural pasture. However, our pasture areas have become unable to produce sufficient grass because they are overgrazed beyond their capacity. For this reason, there is a need for quality forage plants that can provide high yield per unit area and have nutritious properties (Turan et al., 2015; Turan, 2019; Eliş and Özyazı, 2019; Özyazıcı and Açıkbaş, 2023).

Because it contains minerals like calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), and other elements, maralfalfa is a good option for maintaining an animal's bones, muscles, and overall health. Maralfalfa herb, which contains vitamins such as A, C, E and K, is important in that it significantly supports animals in meeting their vitamin needs. Although it varies depending on climate, soil properties and planting conditions, when the Maralfalfa plant reaches maturity, it has approximately 35% dry matter, 16% digestible crude protein, 12% carbohydrate and approximately 3% crude fat content in terms of nutritional values.

The perennial maralfalfa plant has a maximum height of 4 to 6 metres. Maralfalfa plant, whose leaves and stems have high nutritional value for cattle and sheep, can be used as green grass, hay and silage in animal feeding, and can also be used by grazing animals when it is short. Maralfalfa grass, which contains sufficient sugar, completes fermentation 2 weeks after it is harvested and ensiled, and the pH is approximately 4.2 and the silage dry matter is around 40%.

Figure 3. Utilisation for green grass (Anonymous, 2023-c)

Figure 4. Making silage from Maralfalfa (Anonymous, 2023-d**)**

In times when the season is unsuitable (green fodder is unavailable), silage is produced to make up for the roughage shortfall and to guarantee feed preservation. It is possible to produce dairy and livestock farming using only the silage of Maralfalfa (*Pennisetum sp.*), which is known as an alternative plant to silage corn. Maza et al. (2011) reported that adding fresh cassava root to Maralfalfa silage had a positive effect on the nutritional quality and sensory (taste, odor, color and appearance) properties of the silage. Vargas Naranjo et al. (2015) added sugar cane syrup to Maralfalfa silage and reported that this addition increased the soluble fraction, potentially degradable fraction degradability and DM degradability by approximately 9.4%.

Figure 5. Cattle feeding **(**Anonymous, 2023-e)

Figure 6. Sheep feeding **(**Anonymous, 2023-f)

3. ADAPTATION

3.1. Climatic requirements

The maralfalfa plant is a versatile plant that can grow in a variety of climates. Turkey's several locations, particularly Ankara, Aksaray, Sivas, and Muş, are where it is farmed. Maralfalfa belongs to the same family as plants like corn, sugar sorghum, and sudan grass, and it can be produced with ease in any climate where these plants are grown, according to Fradj et al. (2020). It is known that the Maralfalfa plant, which spends the winter dormant like a reed, can grow up to 2,700 altitudes in high places such as Peru, Bolivia and Paraguay in South America, reaches its highest yield in the climates of Thailand and Brazil, yielding 70-80 tons of dry grass per hectare per year. This corresponds to a green grass yield of approximately 150-200 tons/ha. Although it is resistant to adverse weather conditions, the fastest growing period is spring and summer. Maralfalfa plant loves hot and humid regions and its cold tolerance level varies between -3 and -8. Some researchers, Jones and Walsh (2007), state that the Maralfalfa plant, which originates from Japan, likes temperate climates, and its underground rhizomes maintain its vitality in cold climates, and that it develops by sprouting shoots from the rhizomes in the spring. Calsin et al. (2011) stated that cold resistance is low at first planting and that plants may die in cold temperatures below -3°C, especially if spring frosts occur early. Friesen et al. (2015) state that if the underground rhizomes develop well when root development is achieved in the following years, more resistance to subzero temperatures in winter will be provided, but 90% of the rhizomes die at temperatures below -8 °C. Thus, based on the researchers' statements, it is believed that temperatures below zero are dangerous for maralfalfa plants, which is why areas near the sea and with warm winters are more suited for their climate.

Figure 7. Maralfalfa flood irrigation (Anonymous, 2023-g)

Figure 8. Drip irrigation (Anonymous, 2023-h)

The water requirement of maralfalfa, a plant good for irrigated agriculture, is half that of maize. But while its height persists, it has been seen that in soils with an abundance of water, ponding, and accumulation, its development slows down and its tillering performance declines. According to studies done by several researchers in European circumstances, the dry matter yield drops to 4000-5000 kg/ha in dry conditions from 34000–44000 kg/ha in irrigated conditions (Arundale et al. 2014). If watering is necessary, water conservation can be achieved by using a drip irrigation system.

3.2. Soil requirements

The maralfalfa plant can survive in any soil where plants of the same family, including sorghum and corn, are grown since it can adapt to nearly any kind of soil condition. Nonetheless, fertile soils that are loose and damp are ideal for maralfalfa plant growth. The maralfalfa plant, which grows in nutrient-poor soils and needs little water, makes effective use of arid areas.

As a hybrid plant, maralfalfa reaches its peak yield three years after planting, yields more dry matter (DM) than conventional crops, has rhizome roots, produces a large amount of biomass, and adapts to a variety of soil types and weather patterns with less tillage (Heaton et al., 2008; Geren et al., 2016).

Figure 9. The soil in which Maralfalfa plant is grown (Anonymous, 2023–i)

Animals love the fodder plant maralfalfa because it is high in nutrients including magnesium (Mg), calcium (Ca), cobalt (Co), selenium (Se), and potassium (K), and it has a high rate of digestion. Water and animal fertiliser are the two things that the maralfalfa plant most needs because it takes a lot of minerals out of the soil each year in order to grow and flourish. It is not necessary to apply additional chemical fertiliser if an adequate amount of animal fertiliser is provided. An additional application of chemical fertiliser (NPK) is advised for any deficiencies in nutrients identified by soil analysis.

3.3. Production of marafalfa plant

The maralfafa plant is a perennial fodder that is hybrid. Its economic life can extend to about 25-30 years with proper maintenance. It is grown extensively in South American countries, Southern Europe and different regions. Nakajima et al. (2018) states that the maralfalfa plant, which is a sterile hybrid plant, cannot be propagated by seeds and can instead be propagated by using the root area, which we call shoots or rhizomes.

Cuttings of maralfalfa can be planted in virtually any season, with the exception of areas that have extremely harsh winters. Nonetheless, it is advised to sow in the autumn to guarantee the first crop in the early spring. In the milder-climated regions of the Southeast, the Mediterranean, and the Aegean, planting can be done until the end of November; in the colder regions, it can be done until the end of October.

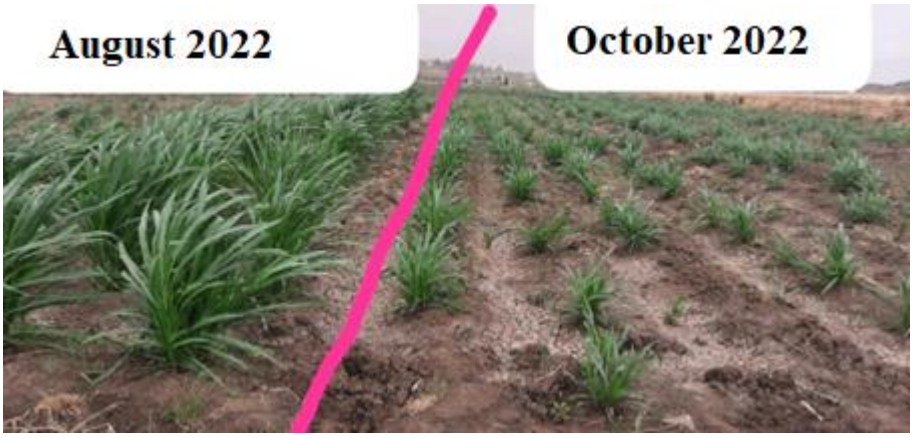

Figure 10. The growth of maralfalfa based on the timing of sowing (Anonymous, 2023-j)

An average of 4000 to 6000 kg cuttings of the maralfalfa plant generated from cuttings can be planted every decare. However, if planting is done with 70 cm between rows and 50 cm between rows, 2,700 cuttings are sufficient. The number of plants per square meter should be between 1 and 5. Each cutting should be cut into four eyes and planted. Even if planting more cuttings per unit area provides an increase in yield in the first place, it may cause problems and lead to loss of yield from the second year onwards due to high tillering capacity. The plant has an intense tillering feature; approximately 25-30 siblings can be produced from each root. For this reason, planting in accordance with certain row spacing and row distances is important to ensure long-lasting and uninterrupted yield (Anonymous, 2).

Figure 11. Maralfalfa stick (Anonymous, 2023-l)

Figure 12. Maralfalfa stick planting (Anonymous, 2023-m)

Maralfalfa is a plant that can withstand a variety of environmental conditions, once planted with cuttings. It should not be ignored that maralfalfa, which is a perennial plant, has an economic life of up to 20-30 years, and since it is produced only from roots and shoots, not seeds, there may be serious problems in steel supply. The plant is easy to care for after planting and grows and develops very quickly due to its invasive character. For this reason, it does not harbour weeds easily. The plant has no known diseases or pests. Therefore, there is no need for any chemical control in maralfalfa cultivation (Anonymous, 2).

4. YIELD AND QUALITY

4.1. Harvest

Every 45-60 days, or three cuttings a year, are possible under Turkish conditions, yielding 15-20 tonnes of fresh grass output each time. Some researchers have suggested that the cutting time should not be postponed beyond the 50th day (Márquez et al., 2007; Palacios-Díaz et al., 2013). As the cutting time is delayed, the protein ratio decreases and the sap ratio increases, thus the cellulose ratio increases. The digestibility of feed with high cellulose content decreases. Indeed, Ventura Ríos et al. (2019) reported that the maralfalfa plant, which has a high tillering number, had the highest HP content on the 30th day (9.3%), and that the HP content decreased as the harvest time was delayed, while some other researchers (Ventura Ríos et al., 2019; Álvarez-Vázquez et al., 2021) states that by delaying the harvest time of maralfalfa grass, there is a decrease in protein content and therefore in nutritional quality (Table 1).

The maximum in vitro dry matter digestibility values of 62.45% were recorded after three weeks of growth in certain research examining the impact of harvest time on maralfalfa quality, and subsequently this value declined. Dead material accumulated in the plant profile and cell walls, and structural carbohydrate concentrations rose as the harvest period grew longer. Maralfalfa grass should be collected after around six weeks of growth to maximise its nutritional content because it has been documented that lignification develops and that the quality of the grass deteriorates when the cutting time is postponed (Ramos Santana et al., 2014).

Figure 13. Maralfalfa harvest for silage (Anonymous, 2023-n)

Figure 14. Maralfalfa fresh grass production (Anonymous, 2023-ö)

The maralfalfa plant cuttings can be harvested for ten years or more after they are planted. The maralfalfa plant grows to a height of around 3 m in 60 days and 5 m in 90 days. When maralfalfa reaches this maturity, its nutritional contents are estimated to be 35% dry matter, 16% digestible crude protein, 12% carbs, and around 3% crude fat. Although maralfalfa has a higher nutritional value than other forage crops overall, Sosa (2006) claimed that it is only superior to alfalfa in terms of energy content. Cerdas Ramírez (2015), on the other hand, stated that the plant's crude protein content ranges from 8-16% and its digestibility from 55-70%.

Table 1. Chemical composition of Maralfalfa plant harvested at different times (Ventura et al., 2019)

	Harvest Time (Day)			
	30	60	90	120
HP %	9.3	6.1	5.4	4.0
NDF %	59.7	64.6	62.4	66.7
ADF %	42.1	50.0	46.2	49.9
ADL %	4.7	4.6	4.0	4.4
Cellulose %	37.4	45.4	42.2	45.4
HS %	17.6	14.6	16.2	16.7
Ash %	11.7	10.2	8.5	7.4
Humidity %	8.48	7.57	729	6.94
Energy (M) kg^{-1}MS	15.7	16.1	16.1	16.3
EE %	0.91 1	.35	1.87	1.24

Correa (2006) determined the effect of harvest time on the nutritional value of maralfalfa grass (*Pennisetum sp*.), three samples of this grass were

randomly collected on the 56th and 105th days of regrowth. In each of these samples, crude protein (HP), neutral detergent fiber (NDF), lignin (Lig), ash content and oil rates were examined. The content of non-structural carbohydrates and total digestible nutrients and net lactation energy were calculated (Table 2). Likewise, calcium (Ca), phosphorus (P), magnesium (Mg) and potassium (K) contents in the collected samples were examined. It has been reported that by delaying the harvest time, the concentration of HP, fat and non-structural carbohydrates decreases, while there is no change in the content of lignin, ash, Ca, P, Mg and K, and the content of total digestible nutrients and net lactation energy decreases with the advancement of harvest time.

Table 2. Nutrient content of Maralfalfa (g/kg KM) (Criscioni et al., 2016)

g/kg KM	***Maralfalfa*** (*Pennisetum sp*.)
DM	934
OM	908
HP	144
EE	9
NDF	610
ADF	365
ADL	36
NFC	144
Nitrogen	23
Carbon	444
C:N Ratio	19

In a two year study, the yield of green grass ranged from 9 tonnes in the first year to 14 tonnes in the second year, the yield of hay was between 1.5 and 2.5 tonnes, the pH of the silage was between 3.79 and 3.66, and the yield of raw grass was between 9 tonnes in the first year and 14 tonnes in the second year in Izmir, Turkey's Aegean area. According to reports, the protein ratio ranges from 5.71 to 5.53 (Yuksel, 2019).

Table 3. Degradability and fatty acids of Maralfalfa plant harvested at different times by in vitro gas production technique (Ventura et al., 2019)

	Harvest time (day)			
	30	**60**	**90**	**120**
Digestibility (%)	55.69	50.57	46.96	42.49
CH_4(%)	11.90	11.65	10.75	10.28
CO_2(%)	88.1	88.3	89.2	89.7
Acetic acid (mmol)	77.85	76.01	70.40	68.73
Propionic acid (mmol)	29.41	28.71	26.44	25.84
Butyric acid (mmol)	12.65	116.10	9.78	9.54
Total VFA (mmol)	119.16		106.63	104.12

Although feed expenses constitute the most important share in the total cost of ruminant breeding, roughage has a greater impact on this ratio. Therefore, the importance of quality forage is increasing day by day. When it comes to quality forage sources, meadows and pastures, forage crops and silage feed come to mind first. The most basic problems in animal nutrition in Turkey are; Rather than the inability to supply feed raw materials, it is the inability to feed the animals in a way that they can get the maximum efficiency allowed by their genetic capacity. The role of cellulose in animal nutrition, provided by the roughage required for rumen function in the diet, is not fully understood. High quality forage is about being able to harvest it at the right time when it contains the most protein and the lowest NDF and ADF levels. The amount of NDF (neutral detergent cellulose) is an indicator of how much feed an animal will consume in 24 hours. 75% of NDF is provided by roughage. To target high performance in dairy cattle, the NDF rate in the ration should be below 30%. It is desirable that the ADF needed in the ration be obtained from roughage. ADF (acid detergent cellulose) is the least digestible fiber component and its rate is not desired to be more than 19% in the ration. Animals consume more roughage when its quality rises, which has a good impact on the animals' production and performance (Budak and Budak, 2014).

Since the use of Maralfalfa grass is ineffective on the milk composition and reduces the release of methane CH4, it can be used in feeding ruminant animals as a roughage source, and the feed consumption in the ration prepared in two different ways, consisting of alfalfa (*Medicago sativa*) and Maralfalfa (*Pennisetum sp*.) grass, as roughage for lactating goats, is reduced by dry milk. substance intake and live weight gain were found to be higher in the alfalfa fed

group, and this was due to the high fiber (NDF and ADF) and low NFC (fiber free carbohydrate content) and ADL (acid detergent lignin) content of maralfalfa, but the DM, OM, It was reported that the digestibility of HP, EE, NDF and ADF was higher, as well as acetic acid (62.19-62.94) and propionic acid (15.59-17.52) in the maralfalfa group (Criscioni et al., 2016). Some other researchers state that when the maralfalfa plant is used as the sole raw material of the ration, the first factor limiting milk yield is metabolic energy (ME), so it should be used in animal feeding with different feeds in most studies (Turano et al., 2016; Criscioni et al., 2016; Guerra Medina et al., 2015; Özyazıcı and Açıkbaş, 2020).

Silage plus 16% crude protein (HP) supplement was utilised after weaning in the study to assess the responsiveness of calves fed corn silage *(Zea mays* L.) and without corn to Maralfalfa (*Pennisetum sp.*), as grasses typically have higher HP content than legumes. According to their report (Guerra Medina et al., 2015), calves should be fed without maize in the future.

While milk production was higher in the group fed alfalfa, dry matter intake was found to be equivalent in the study where two different rations consisting of alfalfa (*Medicago sativa*) and alfalfa + maralfalfa (*Pennisetum sp.*) grass were provided as roughage for nursing goats. However, milk fat and lactose content are unaffected by ration variations; instead, animals fed a lucerne + maralfalfa group exhibit higher levels of long chain and monounsaturated fatty acids, which in turn improves the quality of fatty acids like conjugated linoleic acid. Research has demonstrated that using maralfalfa has positive effects on human health and nutrition. A beneficial impact on the profile has been documented (Castillo Mitre et al., 2016).

4.2. Maralfalfa as an energy plant

The maralfalfa plant has gained attention recently as a possible energy source because of its large yield of biomass, or the portion of the plant above ground (Nakajima et al., 2018; Ussiri et al., 2019).

4.3. Conclusions

Maralfalfa belongs to the same taxonomic class as corn and sorghum, so it can be said to be one of the important and promising feed plants. Its high starch content, low acid detergent lignin, and high fibre content make it suitable

for use in ruminant animal nutrition. However, since the use of only maralfalfa grass cannot meet the needs of the animal in terms of vegetative propagation and nutritional value of maralfalfa, it is recommended to use it in the ration with different raw materials such as cassava root, alfalfa and corn. The high yield of this plant, which is an important factor as well as its high nutritional value, has enabled it to be used as silage. However, to enhance their nutritional and fermentation qualities, grass silages like maralfalfa must be ensiled with various raw ingredients (Boğa et al., 2023).

Because of this, maralfalfa is a useful feed and energy plant that produces large yields per unit of land. Years of experience in the field might pay off in terms of annual sowing costs and soil tillage. It may, however, be challenging for the producer in the early years due to its susceptibility to low temperatures, the high initial investment costs, the difficulties of competing with other fodder crops in terms of grass and silage content value, and issues in the market as a forage crop. To help our farmers make better use of their resources, it will be crucial to do a productivity analysis with a minimum of a 10- to 15-year programme and take climate and regional aspects into account before beginning maralfalfa production (Boğa et al., 2023).

REFERENCES

Álvarez Vázquez, P., Mendoza Pedroza, S.I., Cadena Villegas, S., Calzada Marín, J.M., Ortega Jiménez, E., Vaquera Huerta, H., Rivas Jacobo, M.A. 2021. Cambios en el rendimiento y composición química del pasto maralfalfa (*Cenchrus sp.*) a diferente edad. Revista Fitotecnia Mexicana, 44(4-A): 719-729.

Anonymous 1, 2023. https://www.maralfalfaturkey.net/blog/maralfalfa-yembitkisi/maralfalfa-yem-bitkisi-19.06.2023

Anonymous 2, 2023. https://tarbigem.com.tr/ciftcilerimizin-dertlerine-deva-olacak-birbitki-seker-sorgumu 19.06.2023

Anonymous, 3. 2023 https://www.facebook.com/photo/?fbid=5192010330843552&set=pcb.5192010560843529 (Agriculture and Life_)

Anonymous, 4. 2023 https://www.mansetaydin.com/haber/15737660/cineye-maralfalfa-ekildi_

Anonymous, 5**.** 2023 https://www.ekopara.com/haber/10-yasindaki-cocuk-internette-izledigi-video-ile-ailesinin-hayatini-degistirdi_

Anonymous, 6. 2023https://www.maralfalfa.com.tr/maralfalfa-yem-bitkisi_

Anonymous, 7. 2023https://www.maralfalfa.com.tr/maralfalfa-yem-bitkisi_

Anonymous, 8. 2023https://m.facebook.com/100054621031937/videos/maralfalfa-yem-bitkisi/578264373547388/_

Anonymous, 9. 2023http://ziraatkent.com/maralfalfa-yem-bitkisi-hayvanciliga-care-olur-mu/774_

Anonymous, 10. 2023https://tr.linkedin.com/in/furkan-tokmak-7687a7202?original_referer=https%3A%2F%2Fwww.google.com%2F (Furkan Tokmak_)

Anonymous, 11. 2023https://tr.linkedin.com/in/furkan-tokmak-7687a7202?original_referer=https%3A%2F%2Fwww.google.com%2F (Furkan Tokmak_)

Anonymous, 12. 2023 https://tr.linkedin.com/posts/furkan-tokmak-7687a7202_maralfalfa-dikim-tarihine-g%C3%B6re-2023-y%C4%B1l%C4%B1-activity-7070882659043819520-imJC?trk=public_profile (Furkan Tokmak_)

Anonymous, 13. 2023 https://www.facebook.com/100274548783468/photos/a.100274582116798/124454416365481/?type=3_

Anonymous, 14. 2023)https://www.maralfalfa.com.tr/maralfalfa-yem-bitkisi (Turan Kendirli_

Anonymous, 15. 2023 https://www.teffgrass.biz/blog/yem-bitkileri/maralfalfa-otu-cocuk-ailesinin-hayatini-degistirdi-aldiklari-sonuca-inanamadilar/448865_

Anonymous, 16. 2023 https://www.torunoglutohum.net/blog/yem-bitkileri/silajlik-maralfalfa_Arundale, R.A., Dohleman, F.G., Heaton, E.A., Mcgrath, J.M., Voigt, T.B., Long, S.P. 2014. Yields of *Miscanthus* x *giganteus* and *Panicum virgatum* decline with stand age in the Midwestern USA. Gcb Bioenergy, 6(1): 1-13.

Atis, I., Celiktas, N., Can, E., Yilmaz, S. 2019. The effects of cutting intervals and seeding rates on forage yield and quality of alfalfa. Turk. J Field Crops, 24 (1): 12-20.

Boğa, M., Kılıç, H.N., Boğa, D.Ç., Varış, C.G. 2023. Use of Maralfalfa (*Pennisetum sp.)* in ruminant animal nutrition. Pioneering and Contemporary Studies in Agriculture, Forestry and Aquatic Sciences, 2023. ISBN: 978-625-6945-77-7.

Budak, F., Budak, F. 2014. Quality on Forage Plants and Factors Effecting Forage Quality. Turkish Journal of Scientific Reviews, (1): 1-6.

Budaklı Carpici, E.., Celik, N., Bayram, G. 2010. Yield and quality of forage maize as influenced by plant density and nitrogen rate. Turk. J Field Crops, 15(2): 128-132

Calsin, B., Finnan, J., McCracken, A. 2011. Miscanthus best practice guidelines. Teagasc: The Agriculture and Food Development Authority in Ireland.

Castillo Mitre, G.F., Rojo Rubio, R., Avendaño Reyes, L., Vázquez Armijo, J.F., Lee Rangel, H.A., Albarrán Portillo, B., Salem, A.F. 2016. Productividad, calidad y perfil de ácidos grasos en leche de cabras alimentadas con dos forrajes. Ecosistemas y Recursos Agropecuarios, 3(8): 173-180.

Cerdas Ramírez, R. 2015. Comportamiento productivo del pasto maralfalfa (*Pennisetum sp*.) con varias dosis de fertilización nitrogenada. InterSedes, 16(33): 124-145.

Correa, H.J. 2006. Calidad nutricional del pasto maralfalfa (*Pennisetum sp*.) cosechado a dos edades de rebrote. Livestock Research for Rural Development, 18(6): 326-335.

Criscioni, P., Marti, J.V., Pérez Baena, I., Palomares, J.L., Larsen, T., Fernández, C. 2016. Replacement of alfalfa hay (*Medicago sativa*) with maralfalfa hay (*Pennisetum sp*.) in diets of lactating dairy goats. Animal Feed Science and Technology, 219: 1-12.

Demiroğlu Topçu, G., Özkan, Ş. S. 2017. General View to Meadow-Rangelands and Forage Crops Cultivation of Aegean Region and Turkey,. ÇOMÜ Journal of Agriculture Faculty, *5*(1), pp:21-28.

Eliş, S., Özyazıcı, M.A. 2019. Determination of the silage quality characteristics of different switchgrass (*Panicum virgatum* L.) cultivars. Applied Ecology and Environmental Research, 17(6): 15755-15773.

Fradj, N.B., Rozakis, S., Borzęcka, M., Matyka, M. 2020. Miscanthus in the European bio-economy: A network analysis. Industrial crops and products, 148 (2020): 112281.

Friesen, P.C., Peixoto, M.M., Lee, D.K., Sage, R.F. 2015. Sub-zero cold tolerance of *Spartina pectinata* (prairie cordgrass) and Miscanthus x giganteus: candidate bioenergy crops for cool temperate climates. J. Exp. Bot., 66: 4403-4413. doi:10.1093/jxb/erv085

Geren, H., Yaman, M. 2016. Effect of different N and P levels on the forage yield and some yield characteristics of *Pennisetum hybridum*. EGF 2016, 26th General Meeting, Norway, 21: 448-450.

Greef, J.M., Deuter, M. 1993. Syntaxonomy of Miscanthus x giganteus. Angewandte Botanik, 67: 87-90.

Guerra Medina, C., Partida González, O., Ley de Coss, A., Montañez Valdez, O., Silva Luna, M., Cárdenas Flores, J., García Castilla, C. 2015. Respuesta productiva de becerros posdestete alimentados con ensilado de maíz (*Zea mays* L.) y maralfalfa (*Pennisetum sp*. Schum). Agroproductividad, 8(6): 47-51.

Heaton, E.A., Dohleman, F.G., Long, S.P. 2008. Meeting US biofuel goals with less land: the potential of Miscanthus. Global change biology, 14(9): 2000-2014.

Jones, M.B., Walsh, M. 2007. Miscanthus, for energy and fibre. Earthscan UK, 192p.

Márquez, F., Sánchez, J., Urbano, D., Dávila, C. 2007. Evaluación de la frecuencia de corte y tipos de fertilización sobre tres genotipos de pasto elefante (*Pennisetum purpureum*).:1. Rendimiento y contenido de proteína. Zootecnia tropical, 25(4): 253-259.

Maza, L., Vergara, O., Paternina, E. 2011. Evaluación química y organoléptica del ensilaje de maralfalfa (*Pennisetum sp*.) más yuca fresca (*Manihot esculenta*). Revista MVZ Córdoba, 16(2): 2528-2537.

Nakajima, T., Yamada, T., Anzoua, K.G., Kokubo, R., Noborio, K. 2018. Carbon sequestration and yield performances of Miscanthus x giganteus and Miscanthus sinensis. Carbon Management, 9(4): 415-423.

Özyazıcı, M.A., Açıkbaş, S. 2020. The Effect of Harvest Time on Macro Nutrient Concentrations in Sorghum x Sudangrass Hybrid and Sudangrass Varieties. Turk J Agric. Res., 7(1): 47-58.

Özyazıcı, M.A., Açıkbaş, S. 2023. Forage quality and mineral composition of common grasspea (*Lathyrus sativus* L.) genotypes. Journal of Elementology, 28(2): 405-421.

Palacios Díaz, M.P., Mendoza Grimón, V., Fernández Vera, J. R., Hernández Moreno, J.M. 2013. Effects of defoliation and nitrogen uptake on forage nutritive values of Pennisetum sp. J. Anim. Plant Sci, 23(2): 566-574.

Ramos Santana, R., Quijano Cabrera, Y., Macchiavelli, R. 2014. Evaluación del rendimiento y la calidad del forraje Maralfalfa en tres vaquerías del norte de Puerto Rico en la época de días largos. *J. Agrie. Univ*. P.R. 98(l):49-56.

Sosa, D. 2006. Digestibilidad de maralfalfa (*Pennisetum sp.*) en cabras. Boletín Técnico, Serie Zoológica, 6(2).

Turan, N., Altuner, F. 2014. The Roughage Production Potential, Problems and Suggestions in Van Province Turk. J. Agric. Res., (2014) 1: 91-97.

Turan, N., Özyazıcı, M.A., Yalçın Tantekin, G. 2015. Production potential of fodder obtained from the meadow-rangelands and forage crops fields in Siirt Province. Turk. J. Agric. Res., (2015) 2: 69-75.

Turan, N. 2019. Determination of Chemical Composition and Quality properties of Silage produced by Mixing Green Hungarian Vetch and Barley in varıous Proportions. *European Journal of Science and Technology,* (17):787-793.

Turan, N. 2020. Determining the chemical composition and nutrition quality of Hungarian vetch silage (*Vicia pannonica* Crantz) mixed with wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) at different rates. *Applied Ecology and Environmental Research,* 18(2):2795-2806.

Turano, B., Tiwari, U. P., Jha, R. 2016. Growth and nutritional evaluation of napier grass hybrids as forage for ruminants. Tropical Grasslands-Forrajes Tropicales, 4(3):168-178.

TUİK, 2022. Turkish Statistical Institute. Livestock Data, 2022.

Ussiri, D.A.N., Guzman, J.G., Lal, R., Somireddy, U. 2019. Bioenergy crop production on reclaimed mine land in the North Appalachian region, USA. Biomass and Bioenergy, 125:188-195.

Vargas Naranjo, S.A., Rosero Noguera, R., Barahona Rosales, R. 2015. Cinética de la degradabilidad in vitro de ensilajes de Maralfalfa (*Pennisetum sp.*) con diferentes niveles de inclusión y concentración de vinaza de caña (*Saccharum officinarum*). *CES Medicina Veterinaria Zootecnia*, 10(2): 82-94.

Ventura Ríos, J., Reyes Vazquez, I., García Salas, A., Muñoz García, C., Muro Reyes, A., Maldonado Peralta, M.D.L.Á., Cruz Hernández, A. 2019. Rendimiento, perfiles nutrimental y de fermentación ruminal in vitro de pasto maralfalfa (*Cenchrus purpureus* Schumach.) Morrone a diferentes frecuencias de corte en clima cálido. Acta Universitaria, v:29, pp:1-11. http://doi.org/10.15174/au.2019.2204

Villegas González, M. 2020. Efecto de la alimentación con pasto Maralfalfa comparado a pasto Buffel y sorgo forrajero sobre la producción láctea en vacas Holstein regulares y pelonas (Doctoral dissertation), (pp: 4). General Library © - University of Puerto Rico.

Yuksel, O. 2019. Determination of some physical and chemical characteristics of giant miscanthus (*Miscanthus x giganteus*) silages harvested at different development stages. Fresenius Environmental Bulletin, 28(5): 4226-4231.

CHAPTER 10

SMALL BURNET (*Sanguisorba minor* Scop.)

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1. INTRODUCTION

Sanguisorba minor Scop., a perennial forage plant, is a native species of Turkiye's rangelands. The vegetation period of the plant begins in early spring and may sustain its greenery through the initial few days of winter. It is of great value since it grows in the early seasons when animals have a feeding shortage after the winter, especially when they require green fodder. Its crude protein content is almost the same in alfalfa and sainfoin (Ipek and Sevimay, 2002). The plant took its nomenclature as ' *Sanguisorba minor* Scop.' after Johannes Antonius Scopoli (Giovanni Antonio) (1723-1788), who discovered this species (Tocai (Motoc) et al., 2023). The plant is also referred to in English as sheep's burnet, salad burnet, small burnet, and lesser burnet (Nelson, 2013). However, it is referred to by various other names in some provinces of Turkiye. For instance, it is typically called 'Amelotu' in Isparta-Gelendost, 'kelekotu' in Antalya-Elmalı, and 'Kara Gündürme' in the vicinity of Silifke (Gullap et al., 2021). *Sanguisorba minor* Scop. species is resistant to drought, winter, and fire (Fryer, 2008; Ogle et al., 2012; Nelson, 2013). In pasture improvement studies in Turkey, this species is typically found in bottom rangelands (Bayraktar, 2012).

'*Sanguisorba minor* Scop.' is a plant species with versatile applications. It is possible to use this plant as a source of high-quality roughage. Its vegetation begins in early spring, and its florescence usually emerges between May-June period. The plant grows slowly; hence, it should at least remain ungrazed until the second growing season. The plant species persist in western rangelands for over 20 years (Ogle et al., 2012). The beginning and ending period for grazing is when the plants are 30 cm tall and 15 cm tall, respectively. The ideal duration between two grazing should be approximately 35 days (Ogle et al., 2012). Farm animals, cattle and sheep, enjoy this plant species since it retains similar crude protein content with clover and sainfoin. Its digestion rate also varies around 60-65% due to its fiber content (Gullap et al., 2021). In addition, the leaf ratio of the plant is substantially higher and varies between 44-55% depending on ecotypes and varieties (Kendir, 1999). Cattle and sheep enjoy this plant species since it induces no swelling problem, such as alfalfa (Sevimay 1997). It is viable to add this plant into silage mixtures with sufficient carbohydrates but low protein content to compensate for its protein deficiency (Arslan et al., 2016). Apart from farm animals, it is considered a highly

desirable forage as grass or seed for deer, antelope, and birds (Ogle et al., 2012). This plant may also be grown for weed control. For instance, *Trifolium alexandrinum* var. Carmen, *T. alexandrinum* var. Tabur, *Vicia sativa*, and *Poterium sanguisorba* L. species yielded the lowest weed propagation area, respectively, according to Koloren and Uygur (2003), which studies the most effective species controlling weeds in citrus orchards. Hancerli (2017) identified that small burnet is among the species that most reduce the weed coverage area in corn cultivation in Cukurova conditions. This plant species is also considered a moderate feeding source for honey bees in New Zealand (Ogle et al., 2012). Furthermore, small burnet is a household remedy in Europe and the Middle East. Its roots and leaves are astringent and are used to stop bleeding. It is also possible to utilize this plant to treat gout and rheumatism (Fryer, 2008). The medical studies conducted on subspecies of '*Sanguisorba minor* Scop.' in Europe, Türkiye, and Iran revealed that these plants potentially retain anti-HIV activity, reduce blood sugar levels, provide protection against ulcers (in mice), and have fungicidal activity (Fryer, 2008). For instance, extracts isolated from samples collected during the florescence period of *Sanguisorba minor magnolii* in Spain indicated anti-HIV activity (Bedoya et al., 2001). In addition to being used as a hedge plant, ornamental plant, and medicinal plant, this plant species also serves several opportunities as a forage plant, including soil formation, reclamation, conservation, and as a protective plant against fire in cover crop and rangeland areas (Mulayim et al., 2009). Additionally, this plant is ideal for salads and can be consumed raw or cooked (Tocai (Motoc) et al., 2023).

2. SYSTEMATIC and MORPHOLOGY

2.1. Systematic

Sanguisorba is a member of the genus *Sanguisorba*, tribe Sanguisorbae, subfamily Rosideae, and family Rosaceae. Tetramerous or trimerous, small flowers without petals, and elongated, imparipinnate leaves set this genus apart from others (Tocai (Motoc) et al., 2023). Accordingly, this genus includes over 148 species and subspecies spread throughout East Asia and Southern Europe (Zhou et al., 2021). The Latin term "sanguis" refers to 'blood,' and "sorbet" denotes 'to soak up' and was typically used to stop bleeding. The most commonly known species within this genus are *Sanguisorba officinalis* L. and

'*Sanguisorba minor* Scop.,' and several recent studies focused, in particular, on '*Sanguisorba minor* Scop.' since it retains numerous active compounds beneficial to human health (Tocai (Motoc) et al., 2023). Sanguisorba species are rich in secondary metabolites with significant bioactive properties (Karkanis et al., 2019). Over 120 chemical compounds have been identified and isolated from these plants up until today, especially *S. officinalis* and *S. minor* (Zhao et al., 2017). Table 1 lists the systematics of the '*Sanguisorba minor* Scop.' species within the plant kingdom.

Table 1. Taxonomic classification of *Sanguisorba minor* Scop. (Mulayim et al., 2009).

Class	*: Magnoliopsida*
Order	*: Rosales*
Family	*: Rosaceae*
Subfamily	*: Rosoideae*
Tribe	*: Sanguisorbeae*
Subtribe	*: Sanguisorbinae*
Genus	*: Sanguisorba L.*
Species	: *Sanguisorba minor* Scop.

Considering other burnet species, '*Sanguisorba minor* Scop.' takes its name from its size (minor) as it is much smaller compared to others (Tocai (Motoc) et al., 2023). There are three common subspecies -*Sanguisorba minor* ssp. *magnolii* (Spach) Briq., *Sanguisorba minor* ssp. *Minor*, and *Sanguisorba minor* Scop. ssp. *muricata*- under '*Sanguisorba minor* Scop.' species (Fryer, 2008). On the other hand, six '*Sanguisorba minor* Scop. subspecies are listed by World Flora Online (Table 2, Tocai (Motoc) et al., 2023). Its chromosome number is x = 14 (Cronquist et al., 1997) and has synonyms such as *Poterium sanguisorba* L., *Poterium dictyocarpum* (Spach.), and *Poterium polygamum* (Mulayim et al., 2009).

Table 2. Subspecies of *Sanguisorba minor* Scop. (Tocai (Motoc) et al., 2023)

Sanguisorba minor subsp. *balearica*
Sanguisorba minor subsp. *lasiocarpa*
Sanguisorba minor subsp. *magnolii*
Sanguisorba minor subsp. *mauritanica*
Sanguisorba minor subsp. *muricata*
Sanguisorba minor subsp. *verrucosa*

2.2. Morphology

Root: The plant has strong roots that can reach great depths and survive for many years (Figure 1, Mulayim et al., 2009). While the plant root length in southern England is about 40 cm long, it extends up to 1 m deep in New Zealand. Small burnet occasionally retains short rhizomes (Fryer, 2008).

Stem: The plant stem grows vertically (Figure 2). Plant height varies based on regional conditions, whereas it typically ranges from 25 to 105 cm (Lackschewitz, 1991; Karadag and Iptas, 2007; Mulayim et al., 2009; Yavuz, 2011; Andrabi et al., 2012; Ogle et al., 2012). The stem is simple or has upward branches (Ogle et al., 2012), and branches protrude from the root crown. Its cross-section is angular and its interior is full of essence. (Mulayim et al., 2009).

Figure 1. Roots of the *Sanguisorba minor* Scop. (original)

Figure 2. General appearance of the *Sanguisorba minor* Scop. (original)

Leave: The plant has pinnate leaves, and petioles are short. The leaf rachis (axis) terminates with a leaflet. The number of leaflets in the leaf is between 9-25, and they are arranged opposite or alternatively and are 1-1.5 cm or 0.5-2.0 cm long (Figure 3). It is a plant species with myriad foliar, and the edges of the leaflets are deeply toothed. In the center of the plant is the crown, from which young leaves emerge. (Mulayim et al., 2009; Zhou et al., 2021). The stipules are attached to the petioles, are large and toothed (Mulayim et al., 2009; Ogle et al., 2012), and are 6-9 mm long (Andrabi et al., 2012). The leaves are green throughout the year. *Sanguisorba minor* Scop. has pores on both the abaxial and adaxial sides, and its guard cell and stomata rim are not entirely wax-covered. *Sanguisorba minor* Scop is amphistomatic due to its distribution on both sides of the stomata (Tocai (Motoc) et al., 2023).

Figure 3. Leaves of *Sanguisorba minor* Scop. (original)

Flower: Inflorescences are at the end of the stems (Figure 4, Fryer, 2008; Kew Botanical Garden, 2023). The flowers are small (Mulayim et al., 2009). The flower retains only four sepals and no petals (Zhou et al., 2021), and the inflorescences are a thick head or spike, 10 to 25 mm long, at the end of a long, bare stem. Each flower possesses a papery bracteal leaf with around 12 stamens at the bottom. The sepals are wide, 4-5 mm long, and greenish or white to red or purple colored (Ogle et al., 2012). Small burnet is pollinated by bees (Fryer, 2008) and has brown-colored, indented, and four-cornered fruits.


Figure 4. Flowers of *Sanguisorba minor* Scop. **(**Fryer, 2008; Kew Botanical Garden, 2023).

Fruit and seed: The fruit thickness is about 1.4-2.3 mm, and its length is approximately 4-5 mm (Figure 5). Each fruit contains 1-2 seeds (Mulayim et al., 2009). The weight of 1000 burnet seeds varies between 3.6 and 10.0 g (Kendir, 1999; Karkanis et al., 2014). It is also referred to as a 'permanent soil seed bank' since its seeds survive in the soil for at least 30 years, according to studies conducted in Northwest Europe (Fryer, 2008). Burnet is a plant species propagated from its fruit-similar to sainfoin (Ozaslan Parlak and Ekiz, 2006). While it yields 20-25 kg/da seed in dry conditions, this rate increases by 50-70% in irrigated soil conditions (Gullap et al., 2021).

Figure 5. Fruits and seeds of *Sanguisorba minor* Scop. (Gullap et al., 2021)

3. ADAPTATION

Small burnet is a perennial species resistant to cold, frost, and drought (Fryer, 2008; Mulayim et al., 2009; Ogle et al., 2012; Calone et al., 2021). It may also grow in mildly saline soils (Duf, 2006; Fryer, 2008). Calone et al. (2021) reported that fresh weight lessened by 81% compared to the control in saline soils, and relative water content was comparable to the control up to 300 mM NaCl level; however, it considerably declined at 600 mM NaCl level. For small burnet, calcareous soil conditions are ideal; however, it may also grow well in sandy, light clay, loamy, and well-drained soils. After six months of dry storage at four (4) °C, 'Sanguisorba spp.' seeds readily germinate at constant temperatures of 24-25 °C (Karkanis et al., 2014). Azimi et al. (2016) identified the highest and lowest seed germination rates of small burnet as 30-35 °C and 5-10 °C, respectively. Yet, the light and dark conditions were insignificant to the germination rate (Hollaway and Matheke, 2003; Karkanis et al., 2014; Hasanovi´c et al., 2022). The species is found naturally in all regions of Turkiye and spreads up to 2,000 m above sea level (Mulayim et al., 2008). However, it fails to survive in shady or poorly drained soils for a long time. Although the meadow button is normally distributed in the Mediterranean Basin, it is most concentrated in Central and Southern Europe. The subspecies of the plant have

shown a wide distribution area from Turkey to Afghanistan (Gullap et al., 2021). The distribution areas of the *Sanguisorba minor* Scop. in the world are given in Table 3.

Table 3. Distribution of *Sanguisorba minor* Scop. in the world (Kew Botanical Garden, 2023).

Doubtfully present in	Norway
Native to	Afghanistan, Albania, Algeria, Austria, Baleares, Belgium, Bulgaria, Central European Rus, Corse, Cyprus, Czechoslovakia, Denmark, East Aegean Is., Finland, France, Germany, Great Britain, Greece, Hungary, Iran, Iraq, Ireland, Italy, Kriti, Krym, Libya, Morocco, Netherlands, Northwest European R, Palestine, Poland, Portugal, Romania, Sardegna, Sicilia, Spain, Switzerland, Transcaucasus, Tunisia, Turkey, Turkey-in-Europe, Turkmenistan, Ukraine, Yugoslavia
Introduced into	Argentina Northeast, Argentina Northwest, Baltic States, Belarus, Bolivia, Chile Central, Colorado, Illinois, Korea, New South Wales, North European Russi, Queensland, South Australia, Sweden, Western Australia, Wisconsin

The planting process should not involve deep seed-sowing while cultivating. For instance, a planting depth of 0.6 to 1.9 cm is suitable. The plant showed the best planting results in late autumn and early spring on heavy and medium textured soils and in late autumn on medium and light textured soils. Planting at the end of summer (mid-August-September) in areas where irrigation is unfeasible is generally not recommended (Ogle et al., 21012). The quantity of seeds required per decare is 2-2.5 kg. Row spacing for planting should be 70 cm in dry conditions and 35-40 cm in irrigated conditions (Mulayim et al., 2008).

It is possible to apply numerous herbicides during plant cultivation, including clethodim, metribuzin, quinclorac, clopyralid, dimethenamid-P,

bromoxynil, and pendimethalin. Although these herbicides may initially harm the plant, their adverse effects are temporary, and the plant may recover quickly (Nelson, 2013). The most suitable mowing time for its fodder is the 50% inflorescence stage (Mulayim et al., 2009). *Sanguisorba minor* Scop., which has a higher yield than many forage plants in adverse environmental conditions, boosts its yield in irrigated and fertilized conditions. İpek and Sevimay (2002) reported that 8 kg/da of nitrogen application resulted in 1951-2394 kg/da of green fodder and 438-504 kg/da of dry fodder. According to Acar et al. (1999), it is possible to harvest fresh fodder twice a year under non-irrigated conditions, and the application of 12 kg of nitrogen per decare increased the green fodder yield approximately two times, albeit it varied between years. The plant's disease problems are minimal. It may be necessary to control damage caused by rats and wild animals (Ogle et al., 2012).

4. FORAGE YIELD and QUALITY

In a study analyzing the effects of alternative mowing stages (60% budding, 10% inflorescence, and 60% inflorescence) on forage grass yield and quality in three different burnet species under Ankara conditions, Erol (1998) reported the following data for the selected parameters: natural plant height was 58.20-78.98 cm, green forage grass yield was 904.9-1333.6 kg/da, dry matter yield was 257.1-368.5 kg/da, and crude protein rate and yield were 10.53-13.18% and 28.50-42.72 kg/da, respectively. Similarly, Kuluoglu (2004) indicated that under the conditions of the Harran Plain, the fourth mowing stage with 20 cm row spacing generated the highest dry matter yield (368.86 kg/da), whereas the fourth mowing stage with 50 cm row spacing resulted in the highest crude protein rate (15.62%). Ozaslan Parlak and Ekiz (2006) discovered that planting methods and the 'seed mixture x planting method' had a significant effect on the seedling emergence rate of burnet in the arid conditions of Central Anatolia; however, these methods were ineffective on the number of seedlings per m^2. Mulayim (2009) reported that *Sanguisorba minor* Scop. is a quality forage crop, it is richer in crude protein than grasses and has a ratio closer to legumes. In addition, the crude cellulose rate of the plant is lower than other forage plants (Table 4). Sahin Demirbag et al. (2014) harvested 3 different varieties of *Sanguisorba minor* Scop. (Altinova, Bunyan and Gozlu) in 6 different phenological periods under Ankara conditions in 2007 and 2008.

Researchers found that the highest crude protein rates (16.3 % and 16.2 %, respectively) were obtained from the 1. cutting in both years. In the research, the highest crude protein ratio was obtained from the Altinova variety. Additionally, researchers have reported that the crude cellulose rate varies significantly depending on the harvest period, with the lowest crude cellulose rate (24.9 %) being determined in the 1. cutting period and the highest (35.7 %) in the 6. cutting period. Yavuz and Karadag (2016) reported that, in general, the crude protein yields of pure sown legumes and all mixtures including *Sanguisorba minor* Scop. were higher than that of pure sown grasses. Muhammed Salih (2017) reported that dry matter was 23.32 %, crude ash was 7.98 %, crude protein was 17.78 %, NDF was 20.78 %, ADF was 14.72 % and eter extract was 3.82 % in Kahramanmaras conditons. In a study on 46 different burnet genotypes, Doron (2020) reported that green fodder yield was 403.68-1961.92 kg/da, dry fodder yield was 179.26-591.37 kg/da, ADF rates were 25.62-41.04%, NDF rates were 34.69-55.42%, and condensed tannin content was 1.1-4.19%. He also identified that crude oil, ash, and protein rates varied between 0.42-2.73%, 5.69-11.63%, and 9.48-15.44%, respectively. On the other hand, Ozdogan Cavdar et al. (2021) documented a 14% crude protein, 2.25% N, 0.26% P, 2.24% K, 1.68% Ca, and 0.66% Mg content among burnet plants irrigated at field condition. Ceccanti et al. (2023) reported that wild and cultivated '*Sanguisorba minor* Scop.' plants contained 18.80 g/100 g and 23.10 g/100 g proteins, respectively. Finally, the harvest period is one of the most critical factors affecting the plant fodder quality. Accordingly, Kaplan et al. (2014) discovered that burnet grass harvested during the inflorescence period retained 24.9% dry matter, 13.7% crude protein, 7.5% crude ash, 49.2% NDF, and 29.8% ADF.

Table 4. Crude protein and crude fiber values of some forage crops and *Sanguisorba minor* Scop. (Mulayim et al., 2009)

Crop	Crude protein (%)	Crude cellulose (%)
Sanguisorba minor Scop.	14.0	17.5
Medicago sativa L.	19.4	28.5
Onobrychis sativa L.	17.0	28.0
Trifolium	14.9	30.1
Dactylis glomerata L.	9.7	34.0
Avena sativa L.	9.2	31.0
Vicia sativa L.	20.0	28.5
Beta vulgaris (leaves)	10.0	20.9
Hordeum vulgare L.	8.9	26.4
Sorghum bicolor L.	6.9	27.5
Lotus corniculatus L.	15.6	29.6

Kapp-Bitter et al. (2023) reported in their study to examine the effects of dietary *Sanguisorba minor*, *Lolium perenne* and *Lotus corniculatus* on the urinary N excretion of dairy cows that the characteristics of the plants were as shown in Table 5. Researchers have reported that meadow button may have potential as a feed additive for dairy cows in terms of N use efficiency and lower emissions to the environment.

Table 5. Some characteristics of *Lolium perenne, Lotus corniculatus and Sanguisorba minor* (Kapp-Bitter et al., 2023).

Characteristics	*Lolium perenne*	*Lotus corniculatus*	*Sanguisorba minor*
Dry matter (gkg^{-1} wet weight)	940	901	848
Nitrogen (gkg^{-1} dry weight)	7.5	34.4	9.4
NDF (gkg^{-1} dry weight)	744	347	441
ADF (gkg^{-1} dry weight)	482	277	246
Crude fibre (gkg^{-1} dry weight)	375	242	256

It is possible to grow the small burnet directly in the field and use it successfully, particularly in dry rangelands. For instance, in a study to find artificial rangeland seed mixtures suitable for arid regions of the Transition Climate Zone within the Black Sea Region, Yavuz (2011) identified the highest

dry matter yield as 1166.0 kg/da by the mixture of *Medicago sativa* L. (30%) + *Sanguisorba minor* Scop. (10%) + *Bromus inermis* Leyss. (30%) + *Dactylis glomerata* L. (30%). The researcher further reported that, in addition to 15.43%, 34.16%, 10.05%, and 45.82% crude protein, ADF, ADL, and NDF rates, respectively, the '*Sanguisorba minor* Scop.' species' dry matter yield was 601.7 kg/da and crude protein yield 93.2 kg/da under these conditions. In the artificial rangeland facility in Van province, where six different mixtures generated by *Agropyron cristatum* L., *Festuca ovina* L., *Onobrychis sativa* L., and '*Sanguisorba minor Scop*.' species, there were the highest dry fodder and crude protein yield with 25% *Agropyron cristatum* L., 25% *Festuca ovina* L., 30% *Sanguisorba minor* Scop., and 20% *Onobrychis sativa* L. mixture. As a result, this mixture can be used in artificial rangelands to be established in arid areas (Terzioglu and Yildirim, 2008). Similarly, Geze (2013) reported 667.2 kg/da of dry matter yield, 18.3% crude protein, 122.4 kg/da crude protein yield, 26.8% ADF, and 49.3% NDF using the mixture of *Medicago sativa* L. + *Poterium sanguisorba* L. + *Bromus inermis* Leyss + *Agropyron cristatum* L. species under Yozgat conditions, further documenting that the relative feed value of this mixture's fodder was 128.5. Turk et al. (2014) reported that in the artificial pasture they made using 2 different mixtures (M1: *Medicago sativa* L. (20%) + *Bromus inermis* L. (40%) + *Agropyron cristatum* L. (30%) + *Poterium sanguisorba* (10%), M2: *Medicago sativa* L. (15%) + *Onobrychis sativa* Lam. (15%) + *Agropyron cristatum* L. (35%) + *Bromus inermis* L. (35%)) under Isparta conditions, the highest N , K and Mg content was obtained from the mixture of *Medicago sativa* L. (15%) + *Onobrychis sativa* Lam. (15%) + *Agropyron cristatum* L. (35%) + *Bromus inermis* L. (35%).

REFERENCES

Acar, Z., Sancak, C. and Ayan, I., 1999. Determination of Yield and Some Characteristics of Lesser Burnet (*Sanguis, minor* Scop.) Grown in Different Nitrogen Doses and Row Spacings. Journal of Agricultural Sciences, 5(2): 41-49.

Andrabi, S.M., Rehman, W., Reshi, Z.A., Naqshi, A.R. and Ganie, A.H., 2012. *Sanguisorba minor* Scop. (Rosaceae), A New Addition to the Indian Flora. Taiwania, 57(4): 410-412.

Arslan, M., Erdurmus, C., Oten, M., Aydınoglu, B., Cakmakci, S., 2016. The Crude Nutrient Contents and Quality Characteristics of Maize (*Zea mays* L.) Silages Mixed with Lesser Burnet (*Sanguisorba minor* Scop.) at Different Rate. Turkish Journal of Agricultural and

Azimi, R., Heshmati, G.A., Kianian, M.K. and Jafar, S.H., 2016. Investigating the Germination Characteristics of *Poterium sanguisorba* Seeds under the Influence of Thermal Treatments for Pasture Establishment. Journal of Rangeland Science, 6(1):53-62.

Bayraktar, E., 2012. On a Research Yield, Space Composition and Some Properties of Important Species of Vegetations In Floodplain and Forest Rangelands. Namık Kemal University Graduate School of Natural and Applied Sciences Main Science Division of Department of Field Crop. Ph.D. Thesis, 107 p., Tekirdag.

Bedoya, L. M.; Sanchez-Palomino, S.; Abad, M. J.; Barmejo, P.; Alcami, J. 2001. Anti-HIV Activity of Medicinal Plant Extracts. Journal of Ethnopharmacology, 77(1): 113-116.

Calone, R., Bregaglio, S., Sanoubar, R., Noli, E., Lambertini, C. and Barbanti, L., 2021. Physiological Adaptation to Water Salinity in Six Wild Halophytes Suitable for Mediterranean Agriculture. Plants, 10, 309. https://doi.org/ 10.3390/plants10020309.

Ceccanti, C.; Finimundy, T.C.; Barros, L., 2023. Nutritional Value of Wild and Domesticated Sanguisorba minor Scop. Plant. Horticulturae, 9:560. https://doi.org/10.3390/ horticulturae 9050560.

Cronquist, A., Holmgren, N., Holmgren, P. 1997. Intermountain Flora, Vascular Plants of the Intermountain West, U.S.A. Volume 3 part A

Subclass Rosidae (except Fabales). The New York Botanical Garden. 446 p.

Doron, T., 2020. Determination of Herbage Yield and Quality Characteristics of Different Sanguisorba minor Scop. Genotypes.Erciyes University Institute of Natural and Applied Sciences. Graduate Thesis, Kayseri.

Duf, J.F., 2006. Plant Fact Sheet: Small Burnet Scop, Sanguisorba Minor; USDA: Washington, DC, USA.

Erol, T., 1988. Effect of Different Harvesting Times on Forage Yield of Burned (*Sanguisorba minor* Scop.). Ankara University, Graduate School of Natural and Applied Sciences Department of Field Crops MSc Thesis, 42 p.

Fryer, Janet L. 2008. Sanguisorba minor. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.usda.gov/database/feis/plants/forb/ sanmin /all.html [2023, October 2].

Geze, M., 2013. Determination of Suitable Forage Mixture To Use For Artificial Pasture Establishment in The Yozgat Province. Bozok University Graduate School of Natural and Applied Sciences Department of Field Crops MSc Thesis, 61 p.

Gullap, M.K., Severoglu, S. and Yazici, A., 2021. The Place and Importance of Small Burnet (*Sanguisorba minor* Scop.) as an Alternative Forage Plant. Sustainability from Seed to Table Some Suggestions for Agricultural Resource Consumption, Section: 8: 175-192.

Hancerli, L., 2017. Determination of The Most Troublesome Weed Species Infesting Corn-Growing Areas in Cukurova Region and Possible Cover Crop Species That Can Be Used in Their Management. Cukurova Universıty Institute of Natural and Applied Sciences Department of Plant Protection. MSc Thesis, 102 p.

Hasanovi´c, M.; Cakar, J.; Ahatovi´c, A.; Murti´c, S.; Subaši´c, M.; Bajrovi´c, K.; Durmi´c-Paši´c, A., 2022. Physiological Parameters Indicate ˇ Remarkable Survival Mechanisms of Sanguisorba Minor Scop. on Metalliferous and Non-Metalliferous Sites. Biologia, 77:1915-1929.

Holloway, P.S. and Matheke, G.E., 2003. Seed Germination of Burnet, Sanguisorba Spp. Nativ. Plants J., 4: 95-99.

Ipek, A. and Sevimay, C.S. 2002. Effects of Nitrogenous Fertilization on Forage Yield and Yield Components of Garden Burnet (*Sanguisorba minor* Scop.). Journal of Agricultural Sciences, 8(4): 274-279.

Kaplan, M., Kamalak, A., Kasra, A.A. and Guven, I., 2014. Effect of Maturity Stages on Potential Nutritive Value, Methane Production and Condensed Tannin Content of *Sanguisorba minor* Hay. Journal of the Faculty of Veterinary Medicine, Kafkas University 20 (3): 445-449.

Kapp-Bitter, A.N., Berard , J., Amelchanka , S.L., Baki, C., Kunz, C., Steiner, A.K., Kreuzer, M. and Leiber, F., 2023. Effects of Dietary *Sanguisorba Minor*, *Plantago Lanceolata*, and *Lotus Corniculatus* on Urinary N Excretion of Dairy Cows. Animal Production Science, 63(15): 1494–1504.

Karadag, Y. ve Iptas, S., 2007. Some Characteristics of Small Burnet (*Sanguisorba minor* Scop.) Found in Pasture Vegetations in Tokat and Its Region. Turkey VII. Field Crops Congress, 25-27 June, Erzurum.

Karkanis, A., Vellios, E., Thomaidis, T., Bilalis, D., Efthimiadou, A. and Travlos, I., 2014. Phytochemistry and Biological Properties of Burnet Weed (*Sanguisorb*a spp.): A Review. Not Sci Biol, 6(4):395-398. DOI:10.1583/nsb649471

Karkanis, A.C., Fernandes, A., Vaz, J., Petropoulos, S., Georgiou, E., Ciric, A., Sokovic, M., Oludemi, T., Barros, L. and Ferreira, I.C.F.R., 2019. Chemical composition and bioactive properties of *Sanguisorba minor* Scop. under Mediterranean growing conditions. Food Funct., 10:1340–1351.

Kendir, H., 1999. Variation in Some Morphological and Agronomic Characters of Lesser Burnet (*Sanguisorba minor* Scop.). The Journal of Agricultural Sciences, 5 (1), 84-88.

Kew Botanical Garden 2023. Sanguisorba Minor Scop. Available at: http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:741394-1 (Accessed October 2, 2023).

Koloren, O. and Uygur, F.N., 2003. Research on Weed Control Using Some Cover Crops. 7th EWRS (European Weed Research Society) Mediterranean Symposium, 35-36.

Kutluoglu, E., 2004. A Study Effect of Different Planting Space on the Green Yield and Yield Components of Burnet (*Poterium sanguisorba* L.) under the Harran Plain Conditions. Harran University, Graduate School of Natural and Applied Sciences Department of Field Crops, MSc Thesis, 43 p.

Lackschewitz, Klaus. 1991. Vascular Plants of West-Central Montana--identification Guidebook. Gen. Tech. Rep. INT-227. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 648 p.

Mulayim, M., Acar, R. ve Demirbag, N. S., 2009. Small Burnet (*Sanguisorba minor* Scop.). Forage Plants, Grass and Other Families Forage Plants. III. Volume, Editors: Avcioglu, R., Hatipoglu, R. and Karadag, Y. Ministry of Agriculture and Rural Affairs Publications, Izmir, p. 757-764

Nelson, R.L., 2013. Small Burnet (*Sanguisorba minor* Scop.) Response to Herbicides Applied Postemergence. Utah State University Logan, Utah. https://digitalcommons.usu.edu/cgi/view content.cgi?article=2494&context=etd (Accessed October 1, 2023).

Ogle, D., St. John, L., Peterson J. Ed., 2012. Plant Guide for Small Burnet (*Sanguisorba minor*). USDA-Natural Resources Conservation Service, Aberdeen Plant Materials Center. Aberdeen, Idaho 83210.

Ozaslan Parlak, A., Ekiz, H., 2006. The Effect of Sowing Methods and Nitrogen Doses on the Seedling Growth in Artificial Range Mixtures. The Journal of Agricultural Sciences, *Ankara University Faculty of Agriculture, 12 (2):203*-209

Ozdogan Cavdar, T., Tepecik, M. and Geren, H., 2021. A Preliminary Study on the Effect of Deficit Irrigation Application on the Yield and Some Yield Characteristics of Burnet (*Poterium sanguisorba*) in Early Growth Stage. ISPEC Journal of Agr. Sciences 5(2):362-371.

Sahin Demirbag, N., Ozkan, U. and Sevimay, C.S., 2014. The Effects of Different Reaping Periods on Different Lesser Burnet Cultivars to the Feed Efficiency and Herbage Yield under Conditions of Central Anatolia. Journal of Applied Biological Sciences, 8 (3): 21-27

Sevimay, C. S. 1997. The Importance of Small Burnet (*Sanguisorba minor* Scop.) Plant in Forage Crop Agriculture. Ant Cooperative Post., 726, 18-20.

Terzioglu, O., Yildirim, B., Ethnobotanical and Pharmacological Uses of Some Plants in the Districts of Karpuzalan and Adıgüzel (Van-Turkey), AsianJournal of Animal and Veterinary Advances, 7 (7), 873-878, 2008.

Turk, M., Albayrak, S. and Bozkurt, Y., 2014. Seasonal Trends in Chemical Composition of Different Artificial Pastures. Turkish Journal of Field Crops, 19(1):53-58.

Tocai (Motoc), A.C., Kokeric, T., Tripon, S., Barbu-Tudoran, L., Barjaktarevic, A., Cupara, S. and Vicas, S.I., 2023. *Sanguisorba minor* Scop.: An Overview of Its Phytochemistry and Biological Effects. Plants, 12, 2128. https://doi.org/10.3390/ plants12112128.

Yavuz, T., 2011. Determination of Artificial Pasture Mixtures for Dryland Conditions of Transitional Climate Zone of Black Sea Region. GaziosmanpaȻa University Graduate School of Natural and Applied Sciences Department of Field Crops. Ph. D. Thesis

Zhao, Z., He, X., Zhang, Q., Wei, X. and Huang, L., 2017. Traditional Uses, Chemical Constituents and Biological Activities of Plants From The Genus *Sanguisorba* L, Am. J. Chin. Med., 45, 199–224.

Zhou, P., Li, J., Chen, Q., Wang, L., Yang, J., Wu, A., Jiang, N., Liu, Y., Chen, J., Zou, W., Zeng, J. and Wu, J., 2021. A Comprehensive Review of Genus Sanguisorba: Traditional Uses, Chemical Constituents and Medical Applications. Front. Pharmacol. 12:750165. doi: 10.3389/fphar.2021.750165.

CHAPTER 11

FORAGE CARROT (*Daucus carota* L. subsp. *sativus* (Hoffm.))

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1.INTRODUCTION

The world's carrot (*Daucus carota* L.) germplasm can be separated into two significant groups: Eastern and Western. The Eastern group includes the first domesticated carrots, which were purple or yellow and originated in the region spanning Asia Minor and Central Asia (Coe et al., 2023). Forage carrot [*Daucus carota* L. subsp. *sativus* (Hoffm.)], of which wild species are found in Türkiye, is thought to be native to Afghanistan and neighboring countries and is cultivated in some countries of Europe, Asia, and North Africa (Sağlamtimur et al., 1989; Sarı, 1999). In Konya province (Türkiye), edible carrots are cultivated in large areas, and cultivation techniques are developed. When this situation is considered, it should be investigated that there may be the possibility of feeding carrot varieties and cultivating them that can be used in animal feeding.

Carrots are fragile vegetables, and their production can be wasteful. For instance, more than half of the carrots produced for canning are discarded in France. Forage carrots are usually grade-out or surplus carrots obtained during periods of overproduction. Also, using grade-out and surplus carrots in animal feeding may reduce the environmental cost associated with their clearance. However, in temperate climates, they can be used as winter feed.

Carrots are palatable and readily consumed by cattle. It is typically fed fresh and is available whole or chopped, unwashed, or washed to livestock. Also forage carrots can also be ensiled. Dehydrated carrots are popular treats for horses and pets. Other carrot products occasionally fed to livestock include the tops from harvesting and various by-products of carrot processing, such as juice aromas (Tran, 2016).

2. SYSTEMATIC AND MORPHOLOGY

Carrot is a biennial plant from the *Apiaceae* (formerly *Umbelliferae*) family. It forms vegetative organs, leaves, and fleshy roots in the first year. In the second year, the plant passes into the generative phase, flowering and dying after forming seeds.

With the seed germination, a plant develops into two grass leaves, a root shoulder (stem), and a thin taproot. The shoulder, which is not visible on the soil at first, is then pulled into the soil with increased leaves. Carrot varieties with shoulders outside the soil are not preferred for eating in production. Because the upper part of the root is colored green or purple due to the accumulation of anthocyanin, it has been stated that the root color of carrots varies from white to yellow, orange, red, and purple; color is essential in determining the variety, and particular fodder carrot varieties are used in cultivation for feed production (Popov et al., 1957; Günay, 1984).

In carrots, the main root has a taproot structure. There are thin, white-colored capillary roots on it. When the leaves reach a specific size, the shoulder and taproot begin to develop transversely, and with the storage of nutrients, the fleshy root, the edible part of the carrot, begins to form. When looking at the transverse or longitudinal section of the taproot, two regions, namely, the xylem and phloem, are distinguished. The cambium tissues between the xylem and phloem develop into a circle and produce a secondary xylem towards the center of the root and a secondary phloem towards the outside. When looking at the longitudinal section of a mature carrot, the outer shell (periderm) can be seen at the outermost part. The outer shell contains suberin and wax-like substances and protects the root from external factors by performing cuticle functions on the leaves. Under the outer shell is a dark-colored shell (Phloem) and a light-colored pith (Xylem), which form the fleshy part of the carrot.

Flowering carrots require 6-8 weeks below 10°C (Figure 1). Long days after this requirement is completed, accelerate flowering. Carrot seedlings with cylindrical tips are less sensitive to low temperatures than those with blunt tips. Red-colored carrots flower on long days, regardless of temperature. Flowering plants develop a main shoot with a flower cluster at its tip. Secondary flower clusters are formed from the shoots of the leading flower

cluster, and tertiary flower clusters are formed from the shoots of the secondary flower clusters (Yanmaz, 1988).

Figure 1. Root, above-ground organs, and flower appearance in forage carrot (Acar et al., 2000)

3. ADAPTATION

A carrot is a plant that likes cool climates. For this reason, it shows the best development where the temperature is relatively warm and soil moisture is sufficient. The most important climatic factor affecting carrot cultivation is temperature. Temperature influences the color and shape of the root and plant growth. The optimum temperature limits for carrot cultivation are 15-20°C. When the air temperature rises above 28°C during cultivation, leaf growth decreases, root length shortens, and the root tip becomes blunt. When the temperature drops below optimum during the early developmental stages, early flowering occurs; the most undesirable situation in carrot cultivation is that plants at low temperatures cannot grow large roots as they enter the flowering phase. In addition to the variety and the age of the roots, the temperature of the growing environment is also effective in the formation of color substances that give color to carrots. The color darkens with the progression of ripening. Color lightening occurs at temperatures above and

below optimum temperatures. For this reason, the colors of carrots grown in spring are brighter and darker than those produced in winter and autumn.

Soil structure has a vital role in the quality of carrot roots. Light-textured, deep, sandy, loamy, and sandy soils should be preferred in carrot cultivation. Carrots grown in heavy textured soils have short and thick roots. Shrinkage and secondary root formation are observed on the roots. Bifurcations occur at the root tip in blunt-tipped varieties. The shape of the root also changes due to the variety's characteristics.

Carrots are grown by direct seed sowing. For this reason, the soil to grow carrots should have good drainage and be free of stones and plant parts. The soil for carrot cultivation should be deeply plowed before planting, and then the soil should be broken up using a disc harrow. In sandy and loamy soils, passing a rotavator after deep plowing is sufficient. After deep plowing and disking on heavy soils, the soil should be watered, and a second plowing and disking should be done. In soils that tend to clod, clods should be broken up immediately. Clayey soils prevent root development and cause malformed roots.

In carrot cultivation, seeds can be sown from February to the end of June and from September to November, depending on the ecological conditions of the region. Practically, it is possible to sow from spring, the earliest time the soil can be cultivated, until the end of the fall season. Where commercial cultivation is practiced, growers sow seeds at 2–3 week intervals to harvest continuously.

Seed sowing is done by sprinkling or in rows. Nowadays, 500-1000 g/ha of seed is used when sowing by hand or machine, considering the number of plants per square meter. Some producers sow the seeds by mixing them with sand to prevent frequent sowing of the seed and to eliminate the thinning process to be done in the future because the carrot seeds are small and thorny (Sarı, 1999). The sowing depth is 0.5-1 cm (Haase, 1964). Sowing spacing in carrot cultivation is adequate on the shape and size of carrot roots. Carrots cannot reach their average diameters in frequent spacing, and young roots fuse and cause the formation of misshapen roots. Spacing between and above the rows varies according to carrot size, variety, and growing conditions.

Carrots like high soil moisture. In addition, soil moisture should be uniform throughout the soil. Water stress during cultivation slows plant growth and causes the formation of woody tissues with thickened walls. This results in roots that are not friable, and carrots become bitter or do not taste like carrots grown under normal conditions. During prolonged droughts, root splitting is joint. The total water requirement is between 450-600 mm. This amount is higher in arid areas and light soils (Yanmaz, 1988).

The soil planted in carrot cultivation should also be rich in nutrients. Especially in winter and late varieties, it is necessary to pay more attention to fertilization as the vegetation period is extended. Carrots are like high organic matter. Organic matter given just before planting accelerates plant growth, but organic matter that is not thoroughly burned prevents the roots from being properly shaped and causes bifurcation. If barnyard manure is used as organic fertilizer, care should be taken to ensure that the manure is mature (decomposed), and immature manure should not be given. Immature fertilizers accelerate the development of the carrot fly and cause the quality of the roots to decrease. Considering the organic matter in the soil, 2-4 tons da^{-1} of well-matured organic fertilizer should be given.

Fertilizers should be applied as sprinkling before the disc harrow is passed or as a band if used with the planting; in soils to be irrigated with furrow irrigation, fertilizers to be given as sprinkling are given before the rollers are made. If the fertilizers are to be applied as a band, they should be used 2.5-7.5 cm away from the seed and in the gap between the irrigation channel and the seed.

Carrots prefer nitrogen (N) and phosphorus (P_2O_5) from commercial fertilizers. Nitrogen influences the color of carrots and accelerates the color change from red to yellow. Too much nitrogen fertilization causes root splitting, increases leaf area, and reduces root yield. It increases the water content in the roots and reduces the storage life. Phosphorus has a direct effect on yield. Conversely, potassium is more effective in carrots' quality characteristics and storage life (Sarı, 1999).

Since carrots are grown in different types of soil, fertilizer rates vary. In determining the amount of commercial fertilizer used in carrot cultivation, it is necessary to know the amount of nutrients consumed according to the

yield obtained from the unit area. Based on yield, for getting 5 tons/da of root yield, 11.5 kg N, 3.5 kg P_2O_5, 10.5 kg K_2O is used from the soil, while the plant and leaf parts remove 12.5 kg N, 1.3 kg P_2O_5, 25 kg K_2O from the soil. Accordingly, considering soil analysis, it is helpful to give 15-20 kg N, 10-12 kg P_2O_5, and 10-30 kg K_2O da^{-1}.

Carrots prefer N fertilizers in the form of ammonium. Nitrogen fertilizers should be given with irrigation water. Because they dissolve quickly, 50% of nitrogen fertilizers can be provided with planting, and 50% can be presented at the time of root development, when the roots reach the thickness of a pencil. Boron and rarely manganese deficiency can be found in some soils. Deficiencies should be checked by soil and leaf tests. In case of deficiency, it is sufficient to give 25-35 kg da^{-1} boron every three years (Sarı, 1999).

One of the most important problems encountered in carrot cultivation is poor emergence after planting. The soil clotting layer, temperature, and moisture affect the emergence rate. In addition, the vigor rate and size of the seed used are also effective. After sowing, 1.5 cm of the soil should not be dry. Also, water uptake by the seed should be slow. In this way, the distribution of germination-inhibiting substances given out of the seed during germination into the soil is prevented, and as a result, a proper emergence is ensured. Adequate soil moisture also reduces soil cracking and, in some cases, soil temperature. Coating carrot seeds with different suitable materials can increase the emergence rate.

Since carrot seeds are tiny and have a long germination time, they must compete with weeds after sowing. Weed seeds germinate earlier than carrot seeds, and if not controlled, they negatively affect the yield and quality of carrots. For this reason, pre-sowing and pre-emergence weed killers are effective. Successful results can be obtained from the use of trifluralin (2 L/ha) before sowing or prometryn (2 L/ha) and diflufenican (0.05 kg/ha) before emergence. Post-emergence pesticides should be used before the plants reach pencil thickness (7.5 cm length) (Sarı, 1999).

Carrot plant is more resistant to diseases and pests than other cultivated plants. Carrot cultivation does not have as many essential disease problems as other crops, but some diseases and pests are found in the field and during

storage. It can be examined periodically as diseases seen in carrots in the field and diseases seen both in the field and in storage. Diseases seen both in the field and in the warehouse are *Rhizoctonia* (in the roots), *Scelerotinia* (Soft Rot), *Rhizoctonia violeceae* (Purple Rot or Ink Disease). Diseases seen in the warehouse: *Botrytis* sp, *Rhizoctonia carotae* Carrot Pests; *Agrotis* sp. (Grizzlies), *Agroites* sp. (Wireworms), Dung beetle, Carrot fly *(Psibrasae* sp.) (Yerli, 1995).

Carrots can be harvested 75-85 days after planting. The average yield in Türkiye is between 2.5-3 tons (Yanmaz, 1995). Also, carrots should be topped before storage, but washing them is unnecessary to enhance storability. Topped carrots can be stored for 7-9 months at 0°C and 99% humidity (Benedict et al., 2012).

It was reported that the dry matter rate in the root of fodder carrot varies between 10% and 20% (Akyıldız, 1983); the xylem in the root of carrot has a woody and complex structure, especially in edible varieties. This issue was tried to be reduced, and breeding studies changed its properties, and successful results were obtained (Günay, 1984). It was also stated that water stress during cultivation slows down plant growth and causes the formation of woody tissues with thickened walls (Sarı, 1999). Yellow Austrian Lobbericher is an example of a fodder carrot variety (Benedict et al., 2012), and new varieties should be developed.

4. YIELD AND QUALITY

The root yield of forage carrots varies between 2-6 tons da^{-1} (Sağlamtimur et al., 1989; Popov et al., 1957). It is stated that it is possible to obtain root yield between 4-10 tons da^{-1} depending on the variety used, planting time, planting intervals, and maintenance conditions. However, it is stated that the biological power of the seed influences quality and yield (Günay, 1984). Studies conducted in our country reported that the inter-row and over-row spacing of Beypazarı carrot was 10-20 x 6-8 cm (Sarı, 1999). In the experiment shown in Konya in 1992-1996, four nitrogen dosages and four phosphorus fertilizer doses were tried in carrots planted in 12 cm fixed row spacing. The highest root yield was obtained as 12177.1 kg da^{-1} (18 kg N da^{-1}) and 12028.3 kg da^{-1} (12 kg P da^{-1}) with the same row (Işık, 1998).

Forage carrots as a root are essential in livestock nutrition; their leaves are protein-rich at 11.7% (Tran, 2016). It has been stated that forage carrot can be fed mixed with feeds such as corn, and its leaf yield is 20-40% of carrot yield (Haase, 1964; Sağlamtimur et al., 1989). In a study conducted in Konya, 8-10 tons of root yield was obtained from fodder carrots with light yellow root color originating from Turkmenistan (Acar et al., 2000). It was stated that the root length of the carrot is required to be between 10-20 cm (Günay, 1984), the root shape, size, and color of the carrot varying according to the varieties, the root length varies between 5-25 cm and can grow up to 30 cm, but long-rooted carrots are difficult to remove from the soil and are not suitable for machine harvesting because they will cause breakage, which increases labor costs, and the core part of the roots hardens and turns into a woody texture (Günay, 1984; Sarı, 1999).

Forage carrot is superior to fodder beetroot and turnip in terms of feed value and is especially rich in vitamins, carotene, phosphorus, nitrogen-free substances, and trace elements (Gençkan, 1983; Günay, 1984; Sağlamtimur et al., 1989). Forage carrot, which has a high digestibility of nutrients for ruminants at 87.5% OM digestibility, is very tasty and is eaten by animals (Akyıldız,.1983; Özgen, 1993; Venkataramanan et al., 2015; Tran, 2016).

It has been stated that it increases milk yield and quality and the quality of dairy products and improves the meat quality and flavor of the animals it is fed to. It is also recommended to be given to racehorses in small amounts but regularly (Haase, 1964; Coşkun et al., 1993).

It is recommended to add carrots to the rations of poultry for the egg yolk to have the desired color (Haase, 1964; Özen et al., 1981; Akyıldız, 1983; Coşkun et al., 1993; Siti and Bidura, 2021). It is also partially used in rabbit nutrition.

REFERENCES

Acar, R., Yıldırım, A.İ., Mülayim, M, Demiryürek, M., Uçar, İ. 2000. The Effect of Different Row Spacing on Yield and Some Yield Components in Forage Carrot [*Daucus carota* L. subsp. *sativus* (Hoffm)]. *Ekin ISSN-1301-515X*. p: 74-78 (In Türkish).

Akyıldız, A.R. 1983. Forages Information and Technology. *Ankara University Faculty of Agriculture Publication* No: 868. p: 72-73. Ankara (In Turkish).

Benedict, C., Miles, C, Johnson, S. 2012. Vegetable Fodder & Forage Crops for Livestock Production: Carrots. *Washington State University Extension Fact Sheet FSO 32E*. p: 1- 4.

Coe, K., Bostan, H., Rolling, W., Turner-Hissong, S., Macko-Podgórni, A., Senalik, D., Liu, S., Seth, R., Curaba, J., Mengist, M.F., Grzebelus, D., Van Devnze, A., Dawson, J., Ellison, S., Simon, P. & Iorizzo, M. 2023. Population genomics identifies genetic signatures of carrot domestication and improvement and uncovers the origin of high-carotenoid orange carrots. *Nature Plants*, 1-16.

Coşkun, B.,Şeker, E.,İnal, F. 1993. Animal Nutrition (Lecture notes I). S.Ü. Faculty of Veterinary Medicine. p.116. Konya (In Turkish).

Ekinci, A.S. 1976. Special Vegetables. (2nd edition) Ahmet Sait Printing House. p.31-36 Istanbul.

Gençkan, M.S. 1983. Forage crops Agriculture. Ege University Faculty of Agriculture. Publication No: 467. p.457-458. İzmir. (In Turkish).

Günay, A. 1984. Special Vegetable Cultivation, Vegetable Growing. Çağ Printing House Vol III. p. 180-197. Ankara (In Turkish).

Haase, H. 1964. Practical Farmer's Handbook. *Turkish Sugar Factories Publication* No: 88. Ankara (In Turkish).

Işık, Y. 1998. Nitrogen and Phosphorus Fertilizer Requirements of Carrot in Konya Region. Soil and Water Resources Research Yearbook. 1997.T.C. Prime Ministry General Directorate of Village Services Publication No: 106. Ankara (In Turkish).

Sağlamtimur, T., Tansı, V., Baytekin, H. 1989. Forage Crops Cultivation. *Çukurova University Faculty of Agriculture Publication* No: 74. P .221-222.Adana (In Turkish).

Sarı, T. 1999. Carrot Cultivation and Problems in Turkey. S.Ü. Institute of Science and Technology (Graduate Seminar, Unpublished). Konya (In Turkish).

Siti, N.W., Bidura, I.G.N.G. 2021. Effects of carrot leaves on digestibility of feed, and cholesterol and β-carotene content of egg yolks. *South African Journal of Animal Science*, *51*(6), 786-792.

Popov, A.T., Pavlov, K., Popov, T. 1957. Rasteniyevodstvo. Derjavno Izdatelstvo Zemizdat No:173, Sofia.

Tran, G. 2016. Carrot *(Daucus carota)*. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/539 Accessed on 30 Nov 2023.

Özen, N., Çakır, A., Haşimoğlu, S., Aksoy, A. 1981. Forages (Lecture Textbook). *Atatürk University Faculty of Agriculture Press*. p.111. Erzurum (In Turkish).

Özgen, H. 1993. Animal Nutrition (3rd Edition). *S.Ü. Faculty of Veterinary Medicine Publication* No:5. p.16. Konya (In Turkish).

Venkataramanan, R., Gunasekaran, S., Sreekumar, C., Anilkumar, R., Iyue, M. 2015. Nutritional value and suitability of carrot whole top as green fodder. *Ind J Vet Anim Sci Res*, *44*, 49-52.

Yanmaz, R. 1988. Carrot Cultivation. 1st Carrot symposium, Beypazarı, Ankara, p: 11 (In Turkish).

Yerli, E. 1995. Diseases and Pests of Carrots. Standard Economic and Technical Journal. Ankara. p: 43-48. (In Turkish).

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