
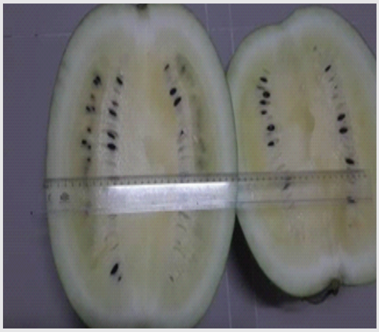






ALTERNATIVE FORAGE CROPS-I

EDITOR: Assoc. Prof. Dr. Gülcan DEMİROĞLU TOPÇU

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 Institution of Economic Development and Social Researches Publications®
(The Licence Number of Publicator: 2014/31220)
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USA: +1 631 685 0 853
E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com

ISBN: 978-625-6955-82-0
Cover Design: İbrahim KAYA
December / 2022
Ankara / Turkey
Size = 16x24 cm

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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

This book contains information such as climate and soil requirements, cultivation and usage areas of some alternative forage crops species, and it is thought that it can guide the studies to be done in both academic and private sectors. I would like to thank all the authors who contributed to the preparation of the book and contributed invaluable with their efforts. Also, my colleague, Assoc. Prof. Dr. I would like to thank Seyithan SEYDOŞOĞLU and IKSAD Publishing House.

Assoc. Prof. Dr. Gülcan DEMİROĞLU TOPÇU

Editor

CHAPTER 1

AMARANTHS (*Amaranthus* spp.)

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1. INTRODUCTION

Amaranthaceae family contains 178 genera and 2052 species. *Amaranthus* genus is in *Amaranthaceae* family and 298 species belonging to this genus have been identified. Species in the *Amaranthus* genus generally consist of annual and herbaceous plants. There are also *Amaranthus* species such as *Amaranthus deflexus*, *Amaranthus tricolor* and *Amaranthus spinosus*, which are short-lived perennial herbaceous, shrub and woody. Their stems usually grow erect, but there are also species that develop semi-erect and decumbent growth. The stems have light green, green, red, dark red and purple colors, the leaves are green, yellow, red, dark red, pink, purple, and the seeds are white, brown, blackish brown and black (Robertson, 1981; Eliasson, 1988; Standley, 1915). Although the species originated in Latin America, today they have spread throughout the world. The species is commonly found in continents such as Africa, America, Asia, Australia, in tropics, subtropics and temperate regions (Sauer, 1955; Bayón, 2015). They are adapted to many climatic and soil conditions, including dry, humid, salty and limy. Most of species can grow in extreme climate and soil conditions such as arid, salty, alkaline, degraded lands and roadsides (Assad et al., 2017).

Amarant species are used in human nutrition, animal feeding and as an ornamental plant. In human nutrition, both its leaves are used as a vegetable and its seeds are used as grain. Excavations showed that it was used as a grain in Mexico around 4000 BC. It is among the nutrients cultivated by the Aztecs. In regions such as South Asia and South America, *Amaranthus cruentus*, *Amaranthus caudatus* and

Amaranthus hypochondriacus are consumed as grains. *Amaranthus* genus contains important species with high energy, protein, fat, fiber, vitamins and minerals that are important in human and animal nutrition (Assad et al., 2017; Keskin et al., 2020; Temel and Keskin, 2022). In some studies, it has been determined that Amarant species are more nutritious than some plants used as cereals and forage crops (Molina et al., 2018). In addition to the protein and fat contents of Amarant species, it was determined that quality contents such as amino acids and fatty acids, which significantly affect the feed quality, are also high (Karamac et al., 2019; Nasirpour-Tabrizi et al., 2020). In addition, some species (*Amaranthus blitum*, *Amaranthus cruentus*, *Amaranthus viridis* and *Amaranthus tricolor*) are widely used as ornamental plants (Sauer, 1967; He et al., 2002; Jimoh et al., 2018; Waselkov et al., 2018).

Most of Amarant species are fed to animals as green, dried, silaged and their seeds added to concentrate feeds as an additive. Due to their high nutrient content and high yield per unit area, the use of these species in animal nutrition has become widespread (Karimi Rahjerdi et al., 2015; Abbasi et al., 2018; Oteri et al., 2021). Some species in chicken nutrition (Choct, 2006), in rabbit nutrition (Schamber and Misek, 1985; Bamikole et al., 2000; Molina et al., 2018), in the nutrition of cattle, sheep and goat by making silage with additives and silage without additives (Olorunnisomo, 2010; Rodriguez et al., 2011; Tan et al., 2012; Karimi Rahjerdi et al. 2015; Rezaei et al., 2015; Abbasi et al. 2018; Gresta et al., 2020; Filik and Filik, 2021). The species is also used for feeding sheep and goats (Hassan et al., 2020), feeding pigs

(Shilov and Zharkovskii, 2012; Jimoh et al., 2018), and feeding fish (Mulokozi et al., 2020). However, it has been observed that Amarant species are not generally preferred in pure nutrition due to their intense presence of saponin, oxalic acid, lectin, nitrate and phenolic compounds that can have a negative effect on animal nutrition. (Karimi Rahjerdi et al., 2015). While most of the negative effects are seen in cattle, it has been observed that these negative effects are not observed in animals such as chickens and rabbits (Schamber and Misek, 1985; Martens et al., 2012). On the other hand, it has been determined that some Amarant species used as feed additives reduce triglyceride, total cholesterol and HDL cholesterol in the blood of animals consuming the feed (Gamel et al., 2004; Kabiri et al., 2011). Some species have high antidiabetic and antihyperlipidemic potentials (Deepthi et al., 2021). On the other hand, it has been determined that they prevent the formation of many diseases thanks to the secondary compounds they contain (Pacifico et al., 2008; Karamac et al., 2019).

2. SYSTEMATIC AND MORPHOLOGY

There are 178 genera in the *Amaranthaceae* family, which is included in the Angiosperms (Flowering plants) team (Table 1) and 298 species have been identified worldwide to date (Table 2).

Table 1: Genus in the *Amaranthaceae* family

Achyranthes	*Centema*	*Fadenia*	*Iljinia*	*Nothosaerva*	*Sarcocornia*
Achyropsis	*Centemopsis*	*Froelichia*	*Irenella*	*Nucularia*	*Scleroblitum*
Acnida	*Centrostachys*	*Froelichiella*	*Iresine*	*Nyssanthes*	*Sclerochlamys*
Acroglochin	*Ceratocarpus*	*Gamanthus*	*Isgarum*	*Ofaiston*	*Sclerolaena*
Aerva	*Ceratoides*	*Girgensohnia*	*Kalidium*	*Oreobliton*	*Sclerostegia*
Agathophora	*Chamissoa*	*Gomphrena*	*Kochia*	*Osteocarpum*	*Seidlitzia*
Agriophyllum	*Charpentiera*	*Grayia*	*Krascheninnikovia*	*Pachycornia*	*Sericocoma*
Allenrolfea	*Chenolea*	*Guilleminea*	*Kyphocarpa*	*Panderia*	*Sericocomopsis*
Allmania	*Chenopodium*	*Gyroptera*	*Lagenantha*	*Pandiaka*	*Sericorema*
Allmaniopsis	*Chionothrix*	*Halanthium*	*Lagrezia*	*Patellifolia*	*Sericostachys*
Alternanthera	*Choriptera*	*Halarchon*	*Lecanocarpus*	*Pedersenia*	*Sevada*

Amaranthus	*Climacoptera*	*Halimocnemis*	*Lecosia*	*Petrosimonia*	*Spinacia*
Anabasis	*Cornulaca*	*Halocharis*	*Leucosphaera*	*Pfaffia*	*Stelligera*
Anthochlamys	*Cyathobasis*	*Halocnemum*	*Lithophila*	*Philoxerus*	*Stilbanthus*
Aphanisma	*Cyathula*	*Halogeton*	*Maireana*	*Physandra*	*Stutzia*
Archiatriplex	*Cycloloma*	*Halopeplis*	*Malacocera*	*Pleuropetalum*	*Suaeda*
Arthraerua	*Cyphocarpa*	*Halosarcia*	*Manochlamys*	*Pleuropterantha*	*Suckleya*
Arthrocnemum	*Dasysphaera*	*Halostachys*	*Marcelliopsis*	*Polycnemum*	*Sympegma*
Arthrophytum	*Deeringia*	*Halothamnus*	*Mechowia*	*Pseudoplantago*	*Tecticornia*
Atriplex	*Dicraurus*	*Halotis*	*Microcnemum*	*Pseudosericocoma*	*Telanthera*
Axyris	*Didymanthus*	*Haloxylon*	*Microgynoecium*	*Psilotrichopsis*	*Threlkeldia*
Baolia	*Digera*	*Hammada*	*Micromonolepis*	*Psilotrichum*	*Tidestromia*
Bassia	*Dissocarpus*	*Hebanthe*	*Monolepis*	*Ptilotus*	*Traganopsis*
Beta	*Dysphania*	*Hemichroa*	*Nanophyton*	*Pupalia*	*Traganum*
Bienertia	*Echinopsilon*	*Henonia*	*Nelsia*	*Quaternella*	*Trichuriella*
Blutaparon	*Einadia*	*Herbstia*	*Neobassia*	*Rhagodia*	*Volkensinia*
Bosea	*Enchylaena*	*Hermbstaedtia*	*Neocentema*	*Rosifax*	*Xerosiphon*
Calicorema	*Eremophea*	*Heterostachys*	*Neokochia*	*Roycea*	*Zuckia*
Camphorosma	*Eriostylos*	*Holmbergia*	*Nitrophila*	*Salicornia*	
Celosia	*Exomis*	*Horaninovia*	*Noaea*	*Salsola*	

Table 2: Species belonging to the genus *Amaranthus*.

A. acanthobracteatus	*A. cauliflorus*	*A. jonesii*	*A. probstii*
A. acanthocarpa	*A. celosioides*	*A. kloosianus*	*A. prostratus*
A. acanthochiton	*A. centralis*	*A. laetus*	*A. pseudogracilis*
A. acroglochin	*A. cernuus*	*A. lanatus*	*A. pubescens*
A. acutilobus	*A. chihuahensis*	*A. lancifolius*	*A. pumilus*
A. abyssinicus	*A. chipendalei*	*A. lanceolatus*	*A. purgans*
A. adulterinus.	*A. chlorostachys*	*A. laxiflorus*	*A. pycnostachys*
A. aeneus	*A. circinnatus*	*A. lecocarpus*	*A. pyramidalis*
A. affinis	*A. clementii*	*A. leptostachyus*	*A. quitensis*
A. albiformis	*A. coesius*	*A. lepturus*	*A. recurvatus*
A. albomarginatus	*A. communicates*	*A. lineatus*	*A. retroflexus*
A. albus	*A. cochleitepalus*	*A. littoralis*	*A. reverchonii*
A. alius	*A. commutatus*	*A. lividus*	*A. rhombeus*
A. alopecurus	*A. coracanus*	*A. lividus*	*A. rigidus*
A. altissimus	*A. congestus*	*A. lombardoi*	*A. rosengurttii*
A. amboinicus	*A. crassipes*	*A. looseri*	*A. rotundifolius*
A. ambigens	*A. crispus*	*A. macrocarpus*	*A. roxburghianus*
A. anacardana	*A. cristatus*	*A. macrocaulos*	*A. ruber*
A. anardana	*A. cristulatus*	*A. macrostachyus*	*A. rubescens*
A. anderssonii	*A. crocatus*	*A. majör*	*A. rubricaulis*
A. angustifolius	*A. cruentus*	*A. mangostanus*	*A. ruderalis*
A. annectens	*A. cuspidifolius*	*A. mantegazzianus*	*A. rudis*
A. arenicola	*A. deflexus*	*A. margaritae*	*A. ruebelii*
A. aragonensis	*A. delilei*	*A. melancholicus*	*A. salicifolius*
A. arardhanus	*A. desfontanii*	*A. miamiensis*	*A. sanguineus*
A. arctioideus	*A. diacanthus*	*A. microphyllus*	*A. sanguinolentus*
A. artineanus	*A. diandrus*	*A. miniatus*	*A. scandens*
A. arvensis	*A. diffusum*	*A. minimus*	*A. scariosus*
A. ascendens	*A. dinteri*	*A. minör*	*A. scleropoides*
A. aschersonianus	*A. dioicus*	*A. mitchellii*	*A. schinzianus*
A. asplundii	*A. divaricatus*	*A. monstrosus*	*A. sclerantoides*
A. ataco	*A. dubius*	*A. moquinii*	*A. sparganicephalus*
A. atropurpureus	*A. dussil*	*A. morosus*	*A. spathulatus*

A. atrosanguineus	*A. edulis*	*A. mucronatus*	*A. speciosus*
A. aureus	*A. emarginatus*	*A. mucronatus*	*A. spinosus*
A. australis	*A. enervis*	*A. muelleri*	*A. spiratus*
A. bahiensis	*A. esculentus*	*A. muricatus*	*A. splendens*
A. batalleri	*A. eugenii*	*A. myrianthus*	*A. squamulatus*
A. bellardii	*A. farinaceous*	*A. necticus*	*A. squarrulosus*
A. bengalensis	*A. fimbriatus*	*A. neglectus*	*A. standleyanus*
A. berlandieri	*A. flavus*	*A. nepalensis*	*A. strictus*
A. berchtholdi	*A. floridanus*	*A. nettii*	*A. sylvestris*
A. berchtoldii	*A. frumentaceous*	*A. obcordatus*	*A. taishanensis*
A. bicolor	*A. filicaulis*	*A. obovatus*	*A. tamariscinus*
A. bernhardi	*A. flexuosus*	*A. oleraceus*	*A. tamaulipensis*
A. bigelowii	*A. floridus*	*A. obtusiflorus*	*A. tarraconensis*
A. blitoides	*A. frutescens*	*A. officinalis*	*A. tenuifolius*
A. blitonius	*A. furcatus*	*A. olitorius*	*A. tenuis*
A. blitum	*A. galii*	*A. ozanonii*	*A. thellungianus*
A. bouchonii	*A. gangeticus*	*A. pachystachys*	*A. thevenoei*
A. bengalense	*A. giganteus*	*A. pallidiflorus*	*A. thunbergii*
A. brandegeei	*A. glaucus*	*A. pallidus*	*A. timeroyi*
A. brasiliensis	*A. glomeratus*	*A. palmeri*	*A. torreyi*
A. brownii	*A. gracilis*	*A. paniculatus*	*A. tortuosus*
A. budensis	*A. graecizans*	*A. paolii*	*A. tricolor*
A. buchtienianus	*A. grandiflorus*	*A. parganensis*	*A. tristis*
A. cacciatoi	*A. greggii*	*A. paraguayensis*	*A. trivialis*
A. californicus	*A. guadeloupensis*	*A. parisiensis*	*A. tuberculatus*
A. campestris	*A. hierichuntinus*	*A. parodii*	*A. tucsonensis*
A. canariensis	*A. haughtii*	*A. parvulus*	*A. undulatus*
A. cannabinus	*A. hungaricus*	*A. patulus*	*A. urceolatus*
A. capensis	*A. hunzikeri*	*A. pedersenianus*	*A. velutina*
A. capitatus	*A. huttonii*	*A. pendulus*	*A. venulosus*
A. caracam	*A. hybridus*	*A. perennis*	*A. vernus*
A. caracasanus	*A. hypochondriacus*	*A. persicarioides*	*A. verticillatus*
A. caracu	*A. inamoenus*	*A. persimilis*	*A. violaceus*
A. cararia	*A. incarnates*	*A. peruvianus*	*A. viridis*
A. cararu	*A. incomptus*	*A. polychroa*	*A. viscidulus*
A. cardenasianus	*A. incurvatus*	*A. polyflagellus*	*A. vulgatissimus*
A. carneus	*A. induratus*	*A. polygamus*	*A. warnockii*
A. caturus	*A. intermedius*	*A. polygonoides*	*A. watsonii*
A. carolinae	*A. interruptus*	*A. polystachyus*	*A. wrightii*
A. cathecu	*A. jansen-wachterianus*	*A. powellii*	*A. zanensis*
A. caturus	*A. japonicas*	*A. praetermissus*	
A. caudatus	*A. johnstonii*	*A. pringlei*	

The characteristics of some common Amarant species and their use cases are given below:

***Amaranthus hypochondriacus* L.:** It is cultivated mostly in India, Central Europe, Russia, Ethiopia, Mongolia. It is used as ornamental plant, human food and animal nutrition. It is annual and herbaceous, and the plant height can grow up to 3 m. Their stems are green and reddish purple. The inflorescences are dark red and purple in color. The seeds are white, pinkish white, black, reddish brown and bright colors. It is the highest yielding species among grain *Amaranthus*. It grows in tropical areas, dry conditions and high altitudes (Barba de la Rosa et al., 2009). High yield and quality (Keskin et al., 2020; Keskin et al., 2021; Temel and Keskin, 2022; Temel et al., 2020), use as human food, high amount of squalene (He et al., 2002) and because it is used as an additive to animal feeds (Oteri et al., 2021) has an important place. It can also be used as silage (Karimi Rahjerdi et al., 2015; Abbasi et al., 2018).

***Amaranthus cruentus* L.:** It is grown as a food in India, Mexico, Ecuador, Colombia and Guatemala. It is an annual, stems are erect and plant height can be up to 2 m. The inflorescences are greenish red, dark red and reddish purple. Seeds can be white or brown. White seeds are used as cereals; brown seeds are used as vegetables. At the same time, this plant is used to obtain red dyestuff. This species is resistant to dry and hot conditions. The grain and leaves are used as food, in the pharmaceutical industry, as an ornamental plant (Jimoh et al., 2018) and in the nutrition of chickens (Choct, 2006). This plant is also known as an invasive and weed. *Amaranthus cruentus* has high nutritional content, antioxidant capacity, and also high phenolic content (Karamac et al., 2019). Grain and hay are used in animal feeding. Green forage is also used for animal feeding by making silage (Olorunnisomo, 2010; Rodriguez et al., 2011; Gresta et al., 2020).

***Amaranthus caudatus* L.:** This species is widely found in Peru, Bolivia, and the Andes. The plant is an annual, stems are erect and plant height can be up to 2 m The stem and inflorescences are reddish or purple. The seeds are shiny and white, gray, yellowish and pink in color. It is a species that is generally used from its seeds. The plant is also used as an ornamental plant. The plant can grow in poor soils and arid conditions. It has been determined that the seeds have a high protein content and reduce the levels of total cholesterol, triglyceride and HDL cholesterol in the blood (Gamel et al., 2004). In addition, it has been determined that the protein content of the leaves is high (Carlsson, 1980).

***Amaranthus hypochondriacus*[a]**

***Amaranthus cruentus*[b]**

Amaranthus caudatus
(Original)

[a] (https://www.amazon.com/Amaranthus-PYGMY-Torch-Hypochondriacus-Bulk/dp/B0923XLLYM) [b](https://garden.org/plants/photo/301145/)

***Amaranthus tricolor* L.:** It is a species adapted to tropical, temperate regions. It is cultivated in South Asia and Africa. Usually the leaves are used as a vegetable. It is also widely used as an ornamental plant due to its beautiful appearance. It can be an annual or short-lived perennial, its stems are erect and plant height can be up to 1 m. It has green, yellow, red, pink and purple leaves. Seeds are blackish brown. This species is drought resistant.

***Amaranthus blitum* L.:** It has adapted to tropical and temperate regions. It is cultivated in India, East and Central Africa, Indian Ocean Islands, Greece, Japan and Western countries. It is an annual, stems are erect and plant height can be up to 90 cm. The stem is light green or purple color. The seeds are glossy dark brown or black. It is mostly used as a vegetable.

***Amaranthus dubius* L.:** It is grown as a vegetable in regions such as West America, Caribbean islands, Indonesia. Seeds of this plant is a very small and fast growing plant. It is the only tetraploid species of the genus *Amaranthus*. It is an annual, its stems are erect and plant height can be up to 1.5 m. The leaves and inflorescences are green, and the seeds are dark reddish brown and black. It has been determined that *Amaranthus dubius* can be used as an alternative feed source in the diet of rabbits due to its high protein content (Molina et al., 2018). Its seeds are used as grains and its stems and leaves are used as vegetables (Matteucci et al., 1999). In addition, it has high nutritional value and produces a high amount of green parts per unit area (Arellano et al., 2004; Montero-Quintero et al., 2011).



Amaranthus tricolor [c] ***Amaranthus blitum*** [d] ***Amaranthus dubius*** [e]

[c](https://www.amazon.in/Planthub-Amaranthus-Tricolor-Sparkle-Ornamental/dp/B07RT8PFNJ) [d](https://www.wildflowers.co.il//russian/picture.asp?ID=7110) [e](https://inpn.mnhn.fr/espece/cd_nom/445379?lg=en)

***Amaranthus viridis* L.:** It is a common weed in tropical and subtropical regions. It is widely used as a vegetable, animal feed, human nutrient and ornamental plant. It is an annual, its stems are erect and plant height can be up to 1 m. The leaves and inflorescences are green and seeds range from brown to black. Studies have shown that *Amaranthus viridis* has high antidiabetic and antihyperlipidaemic potentials (Deepthi et al., 2021).

***Amaranthus graecizans* L.:** This plant is found in tropical and subtropical regions in Africa, Southern Europe, Asia and the USA. It is an annual, its stems are erect and semi-erect, and plant height can be up to 70 cm. Its seeds are black color. It is generally consumed as a vegetable, and sometimes it is also used as an ornamental plant. This plant is also used as animal feed. It has been determined that it can be used as a natural antioxidant in human nutrition and in the food industry (Ishtiaq et al., 2014). It has been determined that *Amaranthus* *graecizans* plant has antinociceptive, anti-inflammatory and protease inhibitory activities (Ishtiaq et al., 2017).

***Amaranthus retroflexus*:** The plant originated in Tropical America and has now spread to most parts of the world. The plant is an annual, its stems are erect, and plant height can be up to 1 m. The stem is light green or reddish color. Seeds are shiny and black color. It is commonly known as a weed. It is also consumed as a vegetable. It has been determined that the green forage of *Amaranthus retroflexus* is not preferred by animals and its use as hay is not practical, therefore it would be more appropriate to use it by making silage. It has been determined that the silage quality of *Amaranthus retroflexus* can be increased by adding some additives or corn (Tan et al., 2012; Olorunnisomo, 2010). While high consumption of *Amaranthus retroflexus* caused deaths in cattle (Zadnik et al., 2008), no mortality cases were found in rabbits (Schamber and Misek, 1985). It has been determined that *Amaranthus retroflexus* can be used as an antioxidant source (Pacifico et al., 2008).

***Amaranthus viridis*[f]**

***Amaranthus graecizans*[g]**

Amaranthus retroflexus(Original)

[f](https://www.alamy.com/amaranthusviridis1jpg-amaranthus-viridis-l-image362458733.html)

[g](https://www.maltawildplants.com/AMAR/Amaranthus_graecizans.php)

***Amaranthus spinosus*:** This plant is widely found in tropical and subtropical regions. The plant is an annual or short-lived perennial, its stems are semi-erect, and plant height can be up to 1.5 m. They are also known as spiny *Amaranthus* because they have a pair of stiff spines where the leaves meet the stem. The leaves and inflorescences are green, and the stem is reddish. Male and female flowers are found in different parts of the plant (Bryson and DeFelice, 2009). Seeds are shiny and black. It is commonly known as a weed. It likes moist soils, and can also grow in dry soils. It has been determined that when *Amaranthus* spinosus leaves are used for feeding chicks after drying and grinding, significant increases in the nutritive value of meat and abdominal fat of chicks are observed (Ahaotu et al., 2018). In studies with *Amaranthus spinosus*, it has been determined that the plant has a protective role against liver damage thanks to the antioxidant and phenolic compounds it contains (Zeashan et al., 2008). Crude protein, oil, cellulose and mineral contents of *Amaranthus spinosus* were determined and it was determined that the plant can be used as an additive to the feed of goats and sheep (Hassan et al., 2020).

***Amaranthus hybridus* L.:** This plant is found in temperate and humid areas in North America, Mexico, Central America and South America. It is an annual, plant height can be up to 2 m. Its stem is green or reddish, the inflorescences are yellowish, green, reddish and purple, and the seeds are reddish brown. *Amaranthus hybridus* is commonly known as a weed and has spread in agricultural areas worldwide (Sauer, 1967; Holm et al. 1991). It has been determined that *Amaranthus hybridus* can be used in the nutrition of cultured fish due to its high protein, lipid, mineral and vitamin content (Mulokozi et al., 2020).

Amaranthus powellii**:** The plant is common in the North American region. It is an annual, plant height can be up to 1.5 m. It is found in degraded agricultural areas, agricultural areas, roadsides, railways and watersides. Its leaves and seeds are used as human food. In addition, it has been determined that *Amaranthus powellii* is suitable for silage production due to its nutritional content, feed value and microbiological properties (Filik and Filik, 2021).

Amaranthus spinosus[h]

Amaranthus hybridus (Original)

Amaranthus powellii[i]

[h](https://www.inaturalist.org/taxa/62917-Amaranthus-spinosus)

[i](https://davesgarden.com/guides/pf/showimage/149178/#b)

***Amaranthus patulus* L.:** The plant is an annual, plant height can be up to 75 cm. The flowers are dark green, the seeds are shiny and black. They are known as an important weed especially in agricultural areas where irrigated and hoe crops are grown.

***Amaranthus blitoides* S. Wats.:** It is an annual, its stems are erect, and plant height can be up to 60 cm. The leaves are 1-3 cm wide. The plant is common in central South and North America and Eurasia. It is an invasive species. The leaves range from green to dark green, the flowers are green and the seeds are black and matte.

***Amaranthus palmeri* S. Watts.:** This plant spreads quickly and is invasive. The plant has spread in many countries, especially in Mexico, Europe, Asia and Australia. It is an annual, its stems are erect, and plant height can be up to 2 m. The stem is green, the seeds are bright dark red and black.

3. ADAPTATION

Species in *Amaranthus* genus took their origins mainly from the warm regions of the world (South America and Africa). In addition, they are common in semi-tropical and other warm regions of the earth, and only locally in cold regions. This is due to the high capacity of Amaranths to adapt to low nutrient availability, a wide variety of soil moisture content, and growing conditions such as unfavorable temperature and lighting (Myers, 1996; Liu and Stützel, 2004; Schahbazian et al., 2006). Amarant species can produce thousands of seeds per plant when the conditions are suitable and they do not disappear for a long time (5-15 years) in the areas left to their own devices. Therefore, they can spread easily on roadsides, vacant lands and arid lands. In addition, they are widely seen in the areas where hoe plants are sowing, in vegetable and citrus gardens. Because of these characteristics, most Amarant species are seen as a difficult weed to control (Caselato-Sousa and Amaya-Farfan, 2012). On the other hand, Amaranths contain many edible species that can withstand extreme conditions. In particular, the use of seeds (*Amaranthus cruentus*) as a superfood in human nutrition dates back to about 6000 years ago. The leaves of some species are grown and consumed as vegetables and the seeds as grains by the Aztec, Maya and Inca civilizations. However, after the colonization of the Americas, the use of Amaranths declined significantly.

Leafy and vegetable amaranths are warm season crops adapted to hot-humid climatic conditions and can tolerate drought and high temperatures. They perform much better, especially in conditions where the corn plant is grown. It is suitable for cultivation throughout the year in tropical regions and in autumn, spring and summer seasons in temperate regions. Grain amaranths, on the other hand, are tolerant to drought and are grown in large geographic areas ranging from the tropical plains to the Himalayas. They can grow satisfactorily at altitudes up to 3500 m above sea level, but the short day plant species *Amaranthus caudatus* grow better on high hills. Most amaranths are day-neutral plants, but some grains are day-length sensitive. For example, the cereal Amarants such as *Amaranthus caudatus*, *Amaranthus cruentus* and *Amaranthus edulis* are known as short-day species. In addition, Amaranths react differently to changes in temperature and thermoperiodism. Most amaranth species can adapt to poor soils and water scarcity better than most cultivated plants (Pospisil and Pospisil, 2008; Barba de la Rosa et al., 2009; Rezaei et al., 2014). Especially since cereal amaranths show good performance in limited water, they can be grown in dry agricultural areas that receive less than 200 mm of annual precipitation. However, vegetable and forage Amaranths need moisture during the growing season and need to be irrigated frequently when necessary to obtain high yields. If the plant is not irrigated for a long time, it may cause regression in plant development and wilt in the plant. However, the return of precipitation or irrigation causes the plant to start growing again in a short time. On the other hand, the fact that the plant cannot receive water for a long time causes it to bloom early. (Ergun et al., 2014; Putnam et al., 2014).

Amaranths can easily grow in many different soil types, but they do not like wet and heavy-clay soils due to the risk of soil crusting. They grow best in well-drained sandy loam soils rich in organic matter and nutrients. On the other hand, vegetable and forage Amaranths need high soil fertility (in terms of nitrogen and potassium). The ideal soil pH for most Amaranth species is 5.5-7.5, but there are also species that can grow in soils with a pH up to 10.0. Most amaranth species can grow better in neutral and basic soils. In addition, some species are tolerant to salinity (especially *Amaranthus mantegazzianus* and *Amaranthus caudatus*) and high aluminum levels (eg *Amaranthus tricolor*) (Foy and Campbell 1984; Omami, 2005). Temperature is an important parameter for germination of seeds, development of seedlings and growth of plants. Therefore, the increased amount of light and temperature accelerate the development of plants. While the optimum germination and seedling growth temperature is 20-30 °C for most Amarant species (ISTA, 2010), it changes between 16-35 °C for grain Amarant species, 25-30 °C for *Amaranthus cruentus* and 25-35 °C for *Amaranthus hybridus*. In addition, amaranth seeds require a soil temperature between 18-25 °C for germination and an air temperature above 25 °C for optimum growth. However, the growth stops at temperatures below 18 °C in most species, while growth stops at around 8 °C in *Amaranthus hypochondriacus, Amaranthus hybridus* and *Amaranthus cruentus* species, which are not resistant to low temperatures.

The feed and grain species in the amaranth genus are grown directly as seeds, but vegetables and preferably seed types as seedlings. In addition, forage types can be sowing as a mixture with corn, sorghum, sudan grass, oat, vetch, bean, quinoa and Brassica species. Such mixtures are very suitable for silage use. Since amaranth seeds are very small, the field should be leveled and a good seedbed should be prepared. In addition, 5 ton of farm manure application per hectare during seedbed preparation will be appropriate in terms of providing high yields. In order to come into contact with the soil of the seeds, the soil should be crumbled, and the seedbed should be pressed before and after sowing. For optimum germination and good seedling development, soil temperature and moisture are as important as seed viability. Therefore, sowing should be done in a moist seedbed and when the soil temperature reaches 16-35 °C (Muthomi and Musyimi, 2009). Otherwise, significant yield decreases may occur in early or late sowing. Thousand grain weight varies between 0.5 and 1.5 grams. Depending on the condition of the seedbed, 1.2-4.0 kg of seeds should be sowing per hectare. Coated seeds must be used for sowing with seeders (for suitable sowing depth and suitable seed quantity) or for a goog establishing, it is appropriate to have 40-50 plants per m^2 (Putnam et al., 2014). According to the texture and moisture of the soil, the seeds should be sowing at an average depth of 1.0-2.0 cm and the seedbed should be kept moist until the seedlings emerge. (Myers, 1996; Svirskis, 2003). If a soil crusting has formed, it must be broken. Otherwise, the seeds emergence rate may decrease to 50% (Putnam et al., 2014). Narrow row spacing (30-40 cm) should be used in species that grow erect in sowing, and the row spacing should be increased up to 100 cm in species that grow semi-erect in order to obtain optimum yields and ease in harvesting (Chaudhari et al., 2009). However, the distance between plants is 5-30 cm according to the preferred harvesting method for amaranth species grown as vegetables, while the distance between the rows and intrarows are 75 cm and 23 cm in species grown as cereals, respectively (O'Brien and Price, 2008). Since amaranth seeds are small, seedling emergence is weak and this reduces the competition of seedlings against weeds. For this reason, weeds should be controlled during the seedling period. However, the species known as weeds make their development faster by using the environmental conditions (water, nutrients and light, etc.) more effectively.

Since amaranths produce a high amount of biomass per unit area, their response to nutrients such as nitrogen, phosphorus and potassium is high. For this reason, 20-25 tons of animal manure and 50:25:20 kg of NPK fertilizer per hectare are sufficient. However, the need for nitrogen is higher for the normal development and growth of plants. The amount of nitrogen (50-200 kg ha^{-1}) to be applied varies according to *Amaranthus* species and varieties (Putnam et al., 2014). In different studies, it was suggested that 45-90 kg nitrogen fertilization per hectare would be sufficient to obtain high forage yields (Myers, 1996; Genç and Acar, 2009). However, due to the risk of NO_3 accumulation in Amaranth, the use of high doses of nitrogen should be avoided. Amaranth species can be grown in arid, but their yields are higher (over 10 ton) in irrigated conditions. *Amaranthus hypochandriacus, Amaranthus blitoides* and *Amaranthus retroflexus* are more productive in irrigated lands. When grown in arid, they are short, have few leaves and mature very early. For this reason, their yield in arid conditions is around 3000-5000 kg ha^{-1}.

However, it has been reported that dry herbage yields close to 10 tons per hectare were obtained from Helios cultivar belonging to *Amaranthus caudatus* species (Temel et al., 2020). If the plants are to be considered as dry herbage, the stems should not be allowed to thicken and harden. In order not to experience decreases in yield and quality in amaranths grown for forage production, the air temperature should be high and the sun exposure should be long (Putnam et al., 2014). Otherwise, the plants quickly pass into the generative stage. Harvests for forage should be done in the clustering phase of the plants, but in amaranths grown for vegetables after 20 days from the transplanted the seedlings into the field (Svirskis, 2003). For silage, harvest is suitable during the milk stage. When making the first harvest, it is necessary to pay attention to the cutting heights. Harvesting the plants at a stubble height of 10-12 cm and in the appropriate period helps to slow down the weakening of the plant and to form a higher rate of shoots at the base. The grain yield of the Amaranth is quite high. Grain yield may differ according to species, variety and environmental conditions (Myers, 1996; Pospisil et al., 2006). Indeed, Keskin et al. (2021) reported that with the application of 100 kg N and 50 kg P_2O_5 per hectare, 412-3286 kg seed yields were obtained per hectare depending on the variety and growing conditions (irrigated and rainfed). Amaranth usually reproduces and spreads by seeds, and also produces a large number of seeds per plant. Therefore, once Amaranth is established, it is very difficult to remove it from the fields. Especially in late harvests, a large amount of seeds fall to the soil, and the seeds that fall can maintain their vitality in the soil for a long time (with dry and cool ambient conditions). However, aeration of the soil by plowing, exposure of the seeds to light and high soil temperature together with sufficient moisture help to reduce the stocks in the soil as it encourages germination in seeds.

4.YIELD AND QUALITY

The shortage of quality forage is an important problem especially in underdeveloped and developing countries of the world and also in regions where extreme ecological conditions are experienced. In these regions, farm animals cannot be fed adequately and in a balanced way due to their low roughage production. In addition, the amount and quality of the animal products obtained are also low due to the low quality of the roughage fed (Gallaher and Pitman, 2001; Olorunnisomo, 2010; Temel and Şimşek, 2011; Okçu, 2020). However, some animal farmers try to meet the quality feed needs of animals with more expensive concentrate feeds, but this is not economical, either. Therefore, for a profitable livestock and high animal production, it is of great importance to feed the animals adequately and to provide the required roughage cheaply. In this sense, the species in the *Amaranthus* genus have high tolerance to extreme climate and soil conditions, and they are seen as an important advantage in bringing marginal areas to production and using them as a food source for living things (humans and animals). Most of the amaranth species have been considered suitable as an alternative feed source in animal nutrition, as they produce high amount and quality feed material per unit area with low sowing norm (Acar et al., 1999; Svirskis, 2003; Alegbejo, 2013; Sarmadi et al., 2016; Leukebandara et al., 2019). As a matter of fact, Sterk (*Amaranthus paniculatus* x *Amaranthus nutans*) variety has higher fresh and dry herbage yields than different forage plant species grown in the same geography (Table 1) (Temel et al., 2020). It has been reported that the high seed (2991 kg) and straw yields (18.449 kg) per hectare were obtained from the Sterk variety grown for its grain (Keskin et al., 2021). Due to these properties, interest in Amarant species has increased in recent years (Peiretti et al., 2018) and many scientific studies have been carried out for different purposes.

Table 1. Fresh Forage Yield and Hay yields of Different Forage Crops and Amarant Plants

Yield Values	*Lotus corniculatus*	*Festuca arundinacea*	*Bromus inermis*	*Pisum arvense*	*Medicago sativa*	*Amaranthus paniculatus x A. nutans*
FHY (kg da^{-1})	2545.7	1884.5	1312.9	1654.3	4963.1	6355.6
DHY (kg da^{-1})	645.3	495.7	397.4	310.5	1269.3	1148.6

FHY: Fresh herbage yield, DHY: Dry herbage yield

There are many factors that affect the yield and quality of plants used as a feed source. These; It can be classified as plant characteristics, cultural practices and ecological conditions. Species-variety differences are important in plant characteristics, and forage yields may differ according to plants being early-late, plant height, branching and leafiness. In general, *Amaranthus retroflexus*, *Amaranthus hypochandriacus*, *Amaranthus hybridus* and *Amaranthus blitoides* are known as Amarant species with high forage yield in irrigated conditions. As a matter of fact, it has been reported that between 15 and 23 tons of hay yields per hectare from *Amaranthus cruentus, Amaranthus hypochondriacus* and *Amaranthus hybridus* species as an average of two cuttings in irrigated conditions (Rivelli et al., 2008). In a study conducted in Iğdır irrigated conditions, it was revealed that 55.333 kg ha^{-1}, 17.978 kg ha^{-1} and 63.556 kg ha^{-1} fresh herbage yields and 996.9 kg ha^{-1}, 384.0 kg ha^{-1} and 1148.6 kg ha^{-1} dry herbage yield were obtained from *Amaranthus caudatus*

(Helios variety), *Amaranthus hybridus* (Ultra variety) and *Amaranthus paniculatus x Amaranthus nutans* (Sterk variety) species, respectively (Table 2). In addition, it was observed that the leafy rate (27.94-38.25%) of the forage produced was high (Temel et al., 2020).

It is a known fact that ecological factors such as climate and soil have a significant effect on yield. In particular, drought stress (water deficiency) affects the plant morphologically, physiologically and biochemically (Anjum et al., 2011; Gao et al., 2020), causing a decrease in yields obtained from a unit area. Although Amaranths are tolerant to drought, not all species respond the same to drought stress. While some genotypes have higher water use efficiency, some genotypes may be lower (Liu and Stutzel, 2004). In addition, in amaranths used for vegetables, grains and feed, it has been revealed that with the increase of drought stress (due to lack of water), there are significant decreases in yields depending on the species and cultivars (Da Silva et al., 2019; Grantz et al., 2019). On the subject, Ahrar et al. (2020) the effect of different irrigation levels in 3 different forage amaranths was tested, and as a result of the study, it was determined that the fresh herbage and dry herbage yields with irrigation when 80% of the available water was consumed decreased by 62% and 50%, respectively, In addition, in a study carried out in the arid climate of Iğdır, it was determined that the yields obtained from Helios, Ultra and Sterk varieties differ according to irrigated and rainfed conditions, and the yields obtained in rainfed conditions are much lower (Table 2) (Temel et al., 2020). In the present study, it has been reported that the average fresh herbage yields of varieties belonging to different Amarant species varied between 45.622 kg ha^{-1} and 24.700 kg ha^{-1}, respectively, and dry herbage yields between 8431 kg ha^{-1} and 4930 kg ha^{-1}, respectively (Table 2). Therefore, it was observed that amaranth species and cultivars did not show the same response to ecological conditions and cultural practices, and the dry matter yields obtained from the unit area differed. For this reason, it is important to complete the adaptation studies according to the regions as soon as possible in order to determine the amaranth species and varieties with high forage yield.

Table 2. Some Forage Yield Components of Different Amaranth Varieties in Irrigation and Dry Conditions

Yield components	Irrigated			Mean	Rainfed			Mean
	Helios	Sterk	Ultra		Helios	Sterk	Ultra	
Panicle ratio	8.65	15.63	25.52	16.60	13.02	14.07	43.68	23.59
Stem ratio	53.62	46.17	35.67	45.15	58.63	54.58	32.20	48.47
Leaf ratio	37.73	38.20	38.82	38.25	28.35	31.35	24.12	27.94
Dry herbage yield	996.9	1148.6	384.0	843.1	674.9	693.1	111.0	493.0
Fresh herbage yield	5533.3	6355.6	1797.8	4562.2	3726.4	3052.3	631.4	2470.0
Dry matter ratio	18.02	18.07	21.36	19.15	18.11	22.71	17.57	19.46
Leaf numbers	68.7	128.6	77.5	91.6	55.0	92.5	38.9	62.1
Stem thickness	27.4	24.9	11.5	21.2	23.3	21.0	8.0	17.4
Plant height	106.3	101.8	62.5	90.2	77.2	81.5	50.2	69.6

On the other hand, although providing suitable ecological conditions, variety selection and irrigation are important factors in obtaining high forage yields, agricultural practices such as seed sowing rate and fertilization also have a significiant effect. In the previous studies, it was revealed that the yields obtained from the unit area were affected by the seed sowing rate (Sokoto and Johnbosco, 2017) and fertilizer dose applications (Abbasi et al., 2012; Dumanoğlu and Geren, 2019; Dlamini et al., 2020), and for different ecologies, the suitable seed sowing rate and fertilizer doses were tried to be determined. It is also important to know the appropriate sowing and harvesting periods according to the regions for a high yield roughage production from Amarant species and varieties.

In order to improve animal production, it is of great importance to know the feed quality as well as the amount of feed produced by the cultivated species and to investigate the factors affecting the quality. Because maximum animal product performances can only be achieved if the forage fed is of high quality. In order for the materials used in animal feeding to be used as a source of roughage, it must contain one or more of the organic or inorganic nutrients that the animals need daily for their survival and yield share. In addition, it is desirable that the materials used contain a certain amount of soluble carbohydrates and that their digestibility is high. Therefore, the quality of roughage preferred by animals is related to the conversion rate of the consumed feed into animal product. For this reason, the quality of forages varies depending on the nutritional value, digestibility ratio, desire to be consumed by the animal, and the effect of factors that reduce the feed quality (Collins and Fritz, 2003).

While most of the species in the *Amaranthus* genus are considered as annual weeds (Khan et al., 2019), some species are grown as vegetables, grains, fodder and ornamental plants (Svirskis, 2003; Mlakar et al., 2009; Venskutonis and Kraujalis, 2013; Adhikary et al., 2020). Especially, its seeds and leaves have been seen as a promising product in human and animal nutrition over all the world due to their high nutritional value (Becker et al., 1981; Ravindran et al., 1996; Zheleznov et al., 1997; Putnam et al., 2014). The leaves and edible green parts of some species (*Amaranthus dubious* L., *Amaranthus* *hybridus* and *Amaranthus tricolor* L.) are a good source for protein (15-24%), vitamin, mineral and dietary fiber and preferred as vegetables (Becker et al., 1981; Berghofer and Schoenlechner, 2002; Mlakar et al., 2010). Amarant species grown for their seeds (*Amaranthus caudatus* L., *Amaranthus cruentus* L. and *Amaranthus hypochondriacus* L.) have high amount and quality protein, mineral (calcium, iron and zinc), vitamins, carbohydrates and lipid compositions and can be used as a grain in human nutrition. The protein content of Amarant seeds used for this purpose is 12.35-21.00% and the digestibility of their proteins is approximately 90%. In addition, the lysine (0.34 g Lys/g N), phenylalanine, threonine and sulphurous tryptophan amino acid content of its seeds is much higher than grains (Zheleznov et al., 1997; Sleugh et al 2001; Svirskis 2003; Pospisil et al., 2006; Olaniyi et al., 2008; Arendt et al., 2013; Venskutonis and Kraujalis, 2013).

Another usage area of amaranth species is to be preferred as a feed source in animal feeding. Its seeds and all plant parts have high amount (15-24%) and quality protein content (in terms of amino acids containing lysine and sulfur), and it is a very nutritious feed for ruminants (Kadoshnikov et al., 2001; Sleugh et al., 2001; Pisarikova et al., 2006; Pospisil et al., 2008; Pospisil ve ark., 2009; Mlakar et al., 2010; He and Park, 2013; Putnam et al., 2014; Omondi et al., 2016; Temel et al., 2020; Keskin et al., 2020; Keskin et al., 2021; Temel ve Keskin, 2022). Lysine content is around 7.67% and is higher than barley, lupine, alfalfa, bird's-foot trefoil, mulberry and some millets. Especially lysine ratio of shoots of *Amaranthus caudatus* and *Amaranthus hypochandriacus* have higher than alfalfa (Svirskis, 2003).

On the other hand, the fibrous pulp remaining after the extraction of leaf protein concentrate prepared for young children is a suitable feed for animals (Carlsson, 1982). It has been reported that the addition of heat-treated Amarant seeds to the nutritional diet of chickens at certain rates will have significant effects on the growth and feed use of chickens (Connor et al., 1980; Laovoravit et al., 1986; Ravindran et al., 1996). Byron et al. (1999) determined the dry matter digestibility *in vitro* as 76.3% and 71.4%, and NDF ratios as 33% and 39% in *Amaranthus hybridus* and *Amaranthus cruentus*, respectively, and revealed that digestion rates vary according to species. In addition, Pond and Lehmann (1989), who compared the chemical composition of *Amaranthus cruentus* with alfalfa, reported that there are more cellular compounds in amaranth and therefore, the ratio of ADF, NDF, ADL and cellulose is lower than that of alfalfa, and the ratio of crude protein is higher (Table 3).

Table 3. Chemical Composition of amaranth and Alfalfa Grass

Characteristic (%)	Amarant	Alfalafa
Dry matter ratio	89.5	88.7
Cellular matters	76.8	70.4
Neutral detergent fibre	23.3	29.6
Acid detergent fibre	13.7	20.8
Cellulose	13.6	21.1
Acid detergent lignine	3.1	6.0
Crude protein	17.4	16.6
Energy (GE, kcal g^{-1})	4,0	4,4

Similarly, it was determined that the nutrient contents of the herbage obtained from *Amaranthus caudatus*, *Amaranthus hiybridus* and *Amaranthus paniculatus* x *Amaranthus nutans* species are close to alfalfa (19 varieties), forage peas (4 varieties) and bird's-foot trefoil species grown in similar (irrigated) conditions in the same geography, but higher than tall fescue and smooth brome (Table 4).

Table 4. Different Forage Crops Used as Forage and Some Forage Quality Characteristics of Amaranth Plant

Plants	CP Ratio	NDF Ratio	ADF Ratio	DMD	RFY
Lotus corniculatus	15.84	38.85	27.04	67.83	162.74
Pisum arvense	17.47	40.74	28.67	66.57	153.22
Medicago sativa	17.10	44.90	33.20	63.10	131.30
Festuca arundinacea	7.56	53.38	39.92	57.81	84.95
Bromus inermis	8.27	55.49	34.91	61.71	103.54
Amaranthus spp.	16.56	37.24	21.61	72.07	195.31

Sources: Akbay Tohumcu and Temel, 2020; Keskin et al., 2021; Temel et al., 2021; Temel et al., 2021. CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre

It has been revealed that the nutritional content and digestibility of the amaranth plant differ according to the growing conditions, variety and vegetative parts (Table 5). The results showed that the fodder quality of the leaves was much higher than the stems. As a matter of fact, leaves have more intracellular substances and thinner cell walls than the stem. Therefore, leaves are richer in terms of nutrient content and digestibility than the stem (Collins and Fritz, 2003). For this reason, it is important to prefer species or varieties with high leafiness in plants to be grown as a source of roughage. In addition, it has been determined that the feed quality (excluding crude protein content) of plants grown in dry conditions is higher, although it varies according to plant parts.

In another study, it was determined that the amaranth plant and its parts produced a higher quality feed material than the corn plant, which is widely used in animal nutrition (Olorunnisomo, 2010). In the same study, it was observed that dry herbage consisting of pure amaranth and amaranth-corn mixtures had a higher protein and ash content, but lower ether extract, crude fiber, NDF and ADF ratios compared to pure corn product. However, it has been determined that amaranth plant, which is considered as silage, has lower crude protein, NDF and ADF content and higher ash and ether extract content than amaranth hay (Olorunnisomo, 2010).

Table 5. Some Feed Quality Characteristics of Amaranth Varieties Grown in Irrigation and Dry Conditions According to Plant Parts

Quality values	Irrigated			Mean	Rainfed			Mean
	Helios	Sterk	Ultra		Helios	Sterk	Ultra	
LCPR	17.40	18.20	20.91	18.84	14.35	12.86	16.49	14.57
SCPR	11.03	11.72	11.41	11.39	12.20	10.56	11.11	11.29
YNDF	25.11	29.07	29.35	27.84	22.02	24.43	22.34	22.93
SNDF	42.51	44.30	49.95	45.59	38.89	39.70	43.48	40.69
YADF	11.72	10.92	9.36	10.67	10.45	9.72	8.42	9.53
SADF	30.61	32.37	34.79	32.59	27.25	28.14	31.10	28.83
YDMD	79.78	80.38	81.60	80.59	80.77	81.34	82.34	81.48
SDMD	65.05	63.70	61.80	63.52	67.67	66.98	64.67	66.44
YRFV	295.77	260.42	264.15	273.44	341.85	319.15	347.22	336.07
SRFV	142.52	133.93	116.20	130.88	161.95	161.35	140.28	154.53

L: Leaf, S: Stem, CPR: Crude protein ratio, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, DMD: Dry matter digestiblity, RFV: Relative feed value

On the other hand, depending on the variety and growing conditions, it was determined that the remaining Amarant stems after seed harvest had 3.63-9.97% crude protein content, 40.55-61.90% NDF content, 29.65-45.55% ADF content, 53.45-65.85% dry matter digestibility and 80.90-151.05 relative feed value (Svirskis, 2003; Pospisil et al., 2009; Keskin et al., 2020). When compared with the straw quality of many forage crop species and varieties, these available values show that the remaining Amarant stems after the seed harvest can be used as a source of roughage in animal feeding. In addition, its herbage is rich in minerals and vitamins (vitamins A and C) (Acar et al., 1999) and is sufficient to meet the needs of ruminants. According to Başbağ et al. (2010) found the raw ash content of *Amaranthus retroflexus* to be 21.2%. In another study, it was determined that the mineral content of *Amaranthus retroflexus* is richer than oat (Byron et al., 1999).

The biggest disadvantage of amaranth as roughage is that its green parts are not preferred by animals due to its low palatability and some nutritional disorders occur in animals that eat its herbage. The most important reason for this is the irregularity in mineral substance ratios and the high level of secondary compounds (anti-nutritional factors such as oxalates, saponins, phenols, trypsin inhibitors and nitrates) (Cheeke et al., 1981; Laovoravit et al., 1986; Gupta and Wagle 1988; Pisarikova et al., 2006). In this respect, it is inconvenient to use the Amarants in very early growth periods. This causes diseases such as swelling, rabies and decreased magnesium in the blood, as well as poisoning in cattle (Kerr and Kelch, 1998; Aslani and Vojdani, 2007). This situation is more common in animals grazing on newly established and Amaranth-infested pastures. Zadnik et al. (2008) reported that deaths occurred in cattle consuming large amounts of Amaranth for four consecutive days. In addition, pigs, sheep and goats are also affected by this plant. This danger is greater in plants grown under drought stress. Perirenal edema (edema) and toxic nephrosis occur in cattle fed with amaranth for a long time (5-10 days). The toxic substances have not yet been identified. However, oxalates, nitrate accumulation and phenological substances are suspected. Although heat treatment has been proposed as an effective way to reduce the effects of these factors in plants (Andrasofszky et al., 1998), this strategy may not be practical for processing large volumes of ruminant animal feed. However, these problems can be minimized by changes in cultural practices, supplementing with wheat and alfalfa grass to balance the ration of animals that eat amaranth abundantly, and choosing appropriate species and varieties in aquaculture. In addition, when their stems dried due to lignin accumulation, they harden like wood. Despite this, amaranth leaves are consumed willingly by animals as a dry herbage. The fact that the plant is tasteless and less preferred by animals can be solved by making pellets (compressed feed) after drying. In addition, this plant can be made into a favorite feed by animals by making silage. In Central Asian countries such as Tatarstan, Tajikistan, Uzbekistan, Turkmenistan and Kazakhstan, it is grown mixed with foxtail millet (*Panicum italicum*) and silage is made. When amaranth, rich in protein and minerals, and millet, rich in carbohydrates, are mixed, a very good silage feed is obtained. Amaranth alone is not a good silage plant. It should definitely be siled using additives or as a mixture (Tan et al., 2012). In addition, the high nitrate level and the imbalance of the Ca/K ratio limit the use of amaranths alone in the rations. However, mixing amaranths with other plants and giving them to animals will alleviate the nutritional disadvantages of using amaranths alone.

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CHAPTER 2

MOUNTAIN SPINACH (*Atriplex nitens* Schkuhr)

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1. INTRODUCTION

In areas where agriculture has been made for a long time, lands are exploited due to continuous production. Also, these lands have adverse effects such as erosion and desertification due to misuse in some areas. Consequently, people who cannot be fed with the impact of their increasing population are faced with a social problem such as migration. Another issue that increases these adverse effects can be climate change. In this case, it is not easy to maintain the nutrition of people and animals with classical methods and plants. Therefore, there is a need for innovations, alternative plants, and strategies for the solution. In addition, it should be considered bringing into agriculture in marginal areas and introducing new plants into production should be investigated.

Increasing production costs in agricultural products bring about the idea of popularizing the production and consumption of alternative crops with low prices, indistinguishable from their counterparts in terms of yield and quality. Nowadays, these searches continue in the world.

Mountain spinach (*Atriplex nitens* Syn *A. hortensis, A. sagittata*) which grows traditionally in some regions and is found naturally in our country, is one of the alternative crops. Mountain spinach, used wherever spinach is used, can grow in almost any soil type. It has been reported to be more tolerant than spinach in terms of resistance to heat, cold, and drought (Christman, 2003). Unfortunately, there are few references to mountain spinach, whose seeds are sold as vegetable seeds in Europe and the USA seeds are sold as vegetable seeds in Europe and the USA.

Mountain spinach used as food could be used as livestock feed after the blooming period and later (Acar et al., 2017). A study on halophytes in Uzbekistan stated that mountain spinach is one of the most suitable forage natural plants. In arid and salty environments, producers in rural areas can use it to feed their livestock (Hedge and Toderich, 2009). In addition, Karchout et al. (2011) reported that mountain spinach, a halophyte plant, has a high potential to be used as an ornamental plant, human food, and forage crop.

2. SYSTEMATIC AND MORPHOLOGY

Systematic

Kingdom *Plantae*,

Subkingdom *Tracheobionta* ,

Division *Magnoliophyta*,

Class *Magnoliopsida*,

Subclass *Caryophyllidae*,

Order *Caryophyllales*,

Family *Chenopodiaceae*,

Genus *Atriplex*,

Species: *Atriplex nitens* SCHKUHR. [Synonym *A. hortensis* L., *A. hotensis* L. subsp. *nitens* (Schkur) E. Pons; *A. acuminate* Waldst.

&Kit; *A. sagittata* Borkh.]. Chromosome number: 2n=18 (Bassets et al. 1983).

Other information about *A. nitens* is followed here: subsp. *hortensis* contains the cultigen and possibly also some wild forms subsp. *nitens* (Schkuhr) Pons (*A. nitens* Schkuhr, of some authors), a wild form considered more primitive than subsp. *hortensis* is found in the middle to southern Europe and west to central Asia and Siberia; it might best be reduced to a constituent of subsp. *hortensis*, subsp. *desertorum* (Iljin) Aellen is a wild group native to the southwestern and central parts of the Commonwealth of Independent States. The extent to which subsp. *hortensis* includes wild forms is unclear. Wild plants in the Orient and parts of central Asia have been assigned to this group. Three domesticated color variants have been recognized in this subspecies: whitish, green, and red (var. *atrosanguinea* of some authors). The whitish variant is considered sweeter and tenderer than the reddish form. The red variant is an attractive red-leaved ornamental for its edible young shoots and leaves (Munro and Small, 1997).

Morphology

Four common types of this plant are grown in different regions worldwide. They are reported as a pale green-yellow-leaved white type, dark red of the red kind of branch and leaf, stem, active development of the square well with a thick green variety, and a special type of copper-colored that farmers are to be dialed. Duke

(1997) reported that plant height could grow up to 250 cm, and leave length could be about 20 cm. Annual, 150—210 cm high, exceptionally to 360 cm, erect or often half-decumbent, widely branched from the base.

Figure 1. The green leave of mountain spinach (Original)

Figure 2. The Purple Leave of Mountain Spinach (Original)

Leaves are lacking the kranztype venation, alternate in the upper part of the stem, to at least 8 cm long and 7 cm wide in well-developed plants, triangular or ovate- triangular with a hastate base, almost entire or with irregularly spaced teeth, mealy at first, but later glabrous and green on both surfaces; petioles up to 3 cm long (Figure. 1-2).

Flowers in a terminal or axillary inflorescence become elongated and thick from the masses of large bracteoles (Figure. 3).

Monoecious; male flowers with a 5-parted perianth; female flowers di-morphic: some ebracteolate with a 5-parted perianth but most without a perianth but with two bracteoles. Bracteoles orbicular veins merge above the base, varying in size, most 10—15 mm in length when mature but some much smaller and not exceeding 5 mm.

The seeds of the perianth-bearing flowers are horizontal, biconvex, black, shiny, and about 2 mm wide. Those of the bracteolate flowers are vertical; the vertical seeds contained by the very small bracteoles are black, similar to those of the perianth-bearing flowers. But those have by the larger bracteoles flat, dull, yellowish brown, about 204 mm wide; seeds of both kinds with a membranous easily removed pericarp; radicle inferior and basal.

In diameter, pollen grains periporate, averaging 22 pans (19-25 pm) (Bassets et al., 1983).

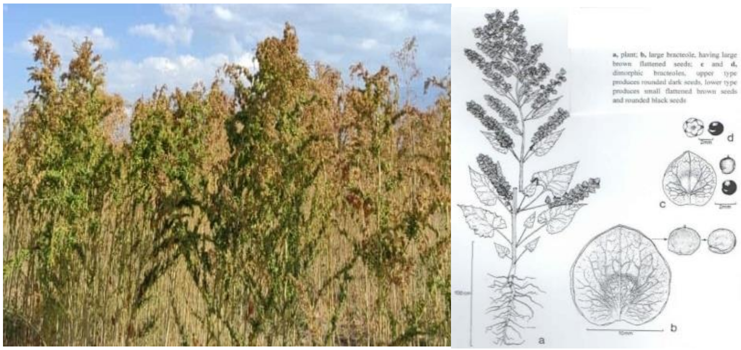

Figure 3. The Bunch of Mountain Spinach (Bassets et al. 1983).

3. ADAPTATION

Mountain spinach has been in a wide range of distribution areas worldwide. Our country is one of the natural growing areas, and it is grown in Ankara, Konya, Kayseri, Tokat, Erzurum, and Kars provinces in Turkey in given Figure 4 (TUBIVES, 2022).

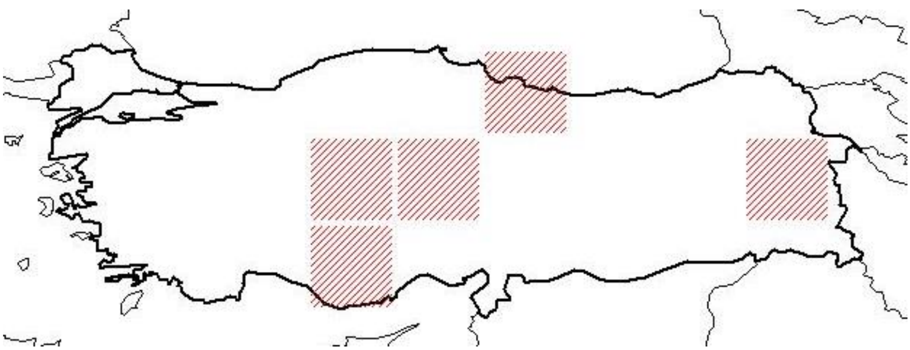

Figure 4. The distribution of Mountain Spinach in Turkey; A6, B4, B5, B9, C4 (TUBIVES, 2022)

Kochout et al. (2009) stated that environmental conditions could affect the growth of mountain spinach, while Rinchen et al. (2017) reported that mountain spinach populations collected from different locations in India had wide variation among the populations.

Mountain spinach being high adaptability, can develop rapidly in arid areas. Moreover, it reported that it grows adverse soil conditions such as salinity, heavy metal pollution, and calcification (Acar and Dursun, 2012; Dursun and Acar, 2015; Acar et al., 2017).

In farming, sowing can be done between the end of March and the beginning of April, and it is essential to plant early. Fodder yield decreases in late sowing (e.g., May, June).Sowing should be arranged in rows with 45 cm row spacing and 8-10 cm intrarow. It should be at 3- 4 cm of the sowing depth in sowing (Acar, 2012).

Figure 5. The first stage of growth in mountain spinach (Original.)

If the soil moisture is insufficient during germination and emergence, the emergence does not occur properly. For this reason, care should be taken to ensure that the seeds are in contact with the soil. The image of mountain spinach, which showed a successful emergence and growth, is given in Figure 5 and Figure 6.

Figure 6. The growth in mountain spinach (Original)

Mountain spinach does not need any fertilization during cultivation. However, researchers reported that no diseases or pets were observed in agriculture (Acar et al., 2017, 2019a).

Mountain spinach comes to harvest maturity about two months after planting when the blooming period and later (Figure. 7-8). For instance, mountain spinach sowing in April was harvested at different times, and a higher yield was obtained from the harvest on 16 June 2011 (Acar et al., 2017).

Figure 7. The Bolting in Mountain Spinach (Original)

Figure 7. The Blooming Period of Mountain Spinach (Temel and Keskin, 2022)

4. YIELD AND QUALITY

In a study conducted in Uzbekistan, fodder yield was determined to be approximately 42.05 t ha^{-1} in mountain spinach grown in low fertile soils (Akınshına et al., 2014).

Their fodder yields show the difference in dry and irrigated conditions. In dry conditions, mountain spinach grown without fertilizer in Konya (Turkey) obtained 54 817 kg ha^{-1} of fodder yield and contained 11.08% crude protein (Acar, 2012; Acar and Güncan, 2002). On the other hand, mountain spinach is grown without fertilizer in Iğdır (Turkey) ecological conditions obtained 110-170 ton ha^{-1} of fodder yield and 27-49 ton ha^{-1} of hay yield in irrigated conditions. However, in dry conditions, the fodder and hay yield was about 48-74 tons ha^{-1} and 15-26 tons ha^{-1}, respectively (Keskin and Temel, 2022; Temel and Keskin, 2022).

The investigation conducted in Iğdır reported that the seed yield varied in terms of sowing time, and it had been stated that seed yield is high as well as fodder yield in early sowing. Also, it ranged between 9500 kg ha^{-1} and 25900 kg ha^{-1} of seed yield, 5.97 g, and 6.46 g of thousand seed weight (Temel and Keskin, 2022).

Acar et al. (2019a) stated that sowing time affected the dry matter ratio in roots and leaves of mountain spinach (Figure. 9). The higher dry matter was obtained from the 4th sowing time, 8 March 2017.

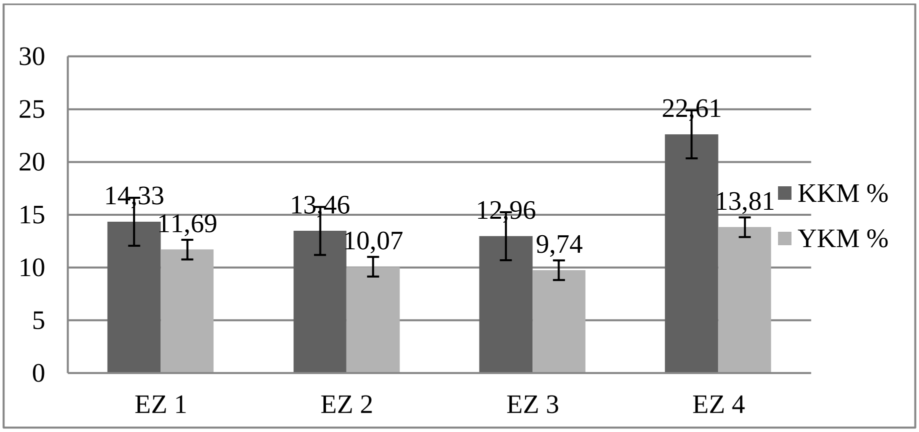

Figure 9. The Comparison of dry matter in leaves and roots of mountain spinach sowing at different times (EZ 1: 7 December 2016; EZ 2: 9 January 2017; EZ 3: 13 February 2017; EZ 4: 8 March 2017; KKM: Dry matter in roots; YKM: Dry matter in leaves) (Acar et al., 2019a)

In other research, Carlsson and Clarke (1983) stated that the leaves yield of mountain spinach was higher dry matter (i.e., 12.9%) and crude protein than spinach. In the research carried out in Konya (Turkey), the leaves of mountain spinach had 33.56% of dry matter, 14.54% of crude protein, and 45.45% NDF (Acar et al., 2019b). Mountain spinach leaves are rich in Ca, P, S, Mg, Na, and K elements (Uslu et al., 2020).

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CHAPTER 3

FORAGE KOCHIA (*Bassia prostrata* (L.) Beck)

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1. INTRODUCTION

There was about 1.82 billion ha of pastures and meadows in the world in 2020 (Anonymous, 2022a). Turkey has about 14.6 million ha of pasture and meadow (Demiroğlu Topçu and Özkan, 2017). The Central Anatolia Region having 33 percent of Turkey's rangelands, decreased up to 3.80 million ha for various reasons (Demiroğlu Topçu and Özkan, 2017; Yıldız, 2018). Decreasing both in pasture areas and in pasture yields causes increasing the feed inputs used in livestock. Therefore, rangelands should be improved to increase pasture yield to decrease the inputs. Therefore, we suggest using the shrub species to improve marginal rangeland having adverse climate (e.g., drought) and soil conditions (e.g., calcification, stony, salinity) in Turkey, especially the Central Anatolia Region. (Acar et al., 2013).

Scientists worldwide use bush and semi-bush species to improve rangeland to achieve success in less time. For example, successful improvement has been carried out on dry pastures in the western parts of the USA, on pastures with 70-110 mm rainfall in Jordan, and salt pastures in Russia by using forage kochia, a semi-bush in pasture improvement (Blauer et al., 1993; Harrison et al., 2000; Shamsutdinov and Shamsutdinov 2009; Bailey et al., 2010). Moreover, it uses firebreaks to protect pasture and forestry (Fig. 1-2). (Harrison et al., 2002).

In addition to being resistant to drought and salinity conditions, it protects soil and water with its deep root system (Fig. 3). Then, it uses as an erosion prevention plant (Fig. 4). Nowadays, forage kochia is used in combatting erosion in Karapınar, Konya (Turkey) (Koç et al., 2019).

Figure 1. Forage Kochia Greenstrip Stopped the Wildfire in Idaho (Photo by Mike Pellant)

Figure 2. Unburned Forage Kochia Plant after Wildfire (Photo by Mike Pellant)

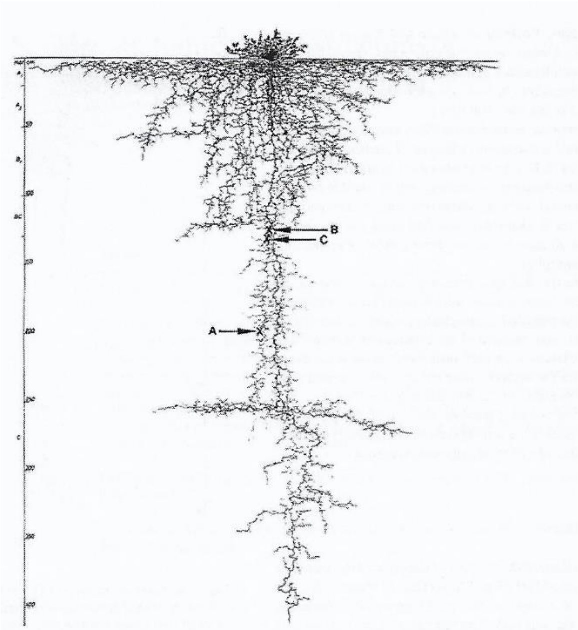

Figure 3. The Root and Stem of Forage Kochia [H/D/S= 23/410/346 cm, excavated in *Meliceto- Kockietum prostratae* on haplica- phaeozom in July 1990, on Glacial debris at Villeneuve, Aosta valley, Italy. A, B, C, D represented points from sections were taken for Plate 2 (Sobotik, 1996)]

Figure 4. Forage Kochia in Karapınar in 2018 (Koç et al., 2019)

Plantings of forage kochia can decrease densities of annual weeds, thus decreasing fire intervals of degraded rangelands while providing valuable forage to livestock and forage and cover for wildlife and upland game birds (Tilley et al., 2012).

2. SYSTEMATIC AND MORPHOLOGY

Forage kochia is reported as an accepted name in the genus *Bassia* in *the* *Amaranthaceae* family (Syn. *Chenopodiaceae*) (WFO, 2022a). *Kochia prostrata* (L.) Schrad. is agreed as a synonym of *Bassia prostrata* (L.) Beck (WFO, 2022b).

Forage kochia is a C4 subshrub. There are three different ploidy levels (2x, 4x, and 6 x) for forage kochia. This situation causes variations in morphological properties (Kitchen and Monsen, 2008). Immigrant variety is represented subsp. virescens ([Fenzl] Prat.) being a diploid (2n=18) and reaching 30 cm tall. However, Snowstorm is represented subsp. grisea (Prat.), being the tetraploid (2n=36), is taller than the Immigrant and reaching approximately 76 cm tall (Tilley et al., 2012). The plant height of forage kochia grown in Konya (Turkey) ranges between 20 and 100 cm, while the canopy diameter ranges between 25 and 120 cm (Koç Koyun and Acar, 2021).

Forage kochia has a woody stem at 10 cm of the soil surface (Fig. 5), and the woody stem has annual branches, simple or branched. Branches have densely light yellow-brown, light reddish, or gray-white pilose, densely white crisped pilose, or subglabrous. Significantly, new shoots could have been white pilose.

Figure 5. The Roots Belongs Forage Kochia Grown In Drought and Salt-Affected Soil in Konya- Turkey (Original, Photo by Nur Koç Koyun)

Leaves alternate, usually clustered on dwarf, axillary branchlets, sessile, linear, semiterete, 0.8-2 cm × 1-1.5 mm, spreading sericeous or densely appressed sericeous on both surfaces, base shortly attenuate, apex obtuse or acute; veins obscure (Fig. 6).

Figure 6. The Leaves of Forage Kochia Photo's (Anonymous, 2017)

Figure 7. The Photos of Stigma (L) with Pink (L) and Yellow (R) Anther (References: Anonymous, 2017 for left figure, 2017; Anonymous, 2022b for right figure)

The blooming period begins from July to September. Flowers bisexual and female flowers, usually 2 or 3 per glomerule, are arranged in spikes on the upper part of annual branches. Filaments filiform, slightly exserted. Anther color is yellow, orange, pink, or dark red (Fig. 7-8). Stigmas 2, purple-brown, filiform (WFO, 2022b). Forage kochia shows a cross-pollination. However, in forage kochia's selfing studies, Koç

Koyun and Korkmaz (2022) reported that the self-fertilization ratio is about 17%.

Figure 8. The Photo of Seed setting period (Anonymous, 2017)

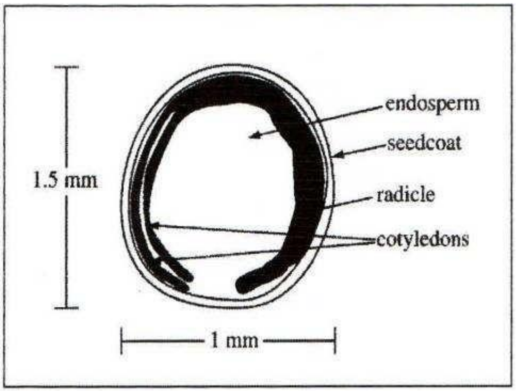

Figure 9. The Structure (L) and Appearance (R) of Seed (References: Kitchen and Monsen, 2008 for left figure; Koç Koyun, 2021 for right figure)

Seeds, in given Figure 9, are black-brown, subglobose, ca. 1.5 mm in diameter (WFO, 2022b). Thousand seed weight ranges between 2 g and 4 g (Acar and Koç, 2019; Koç Koyun and Korkmaz, 2022).

3. ADAPTATION

Forage kochia naturally grows in Asia, Europa, and North Africa (Acar 2013; Anonymous 2019). Primarily, it shows the distribution in the Center and East Anatolia in Turkey. It grows naturally in Turkey's Kars, Kastamonu, Ağrı, Erzincan, Erzurum, Kayseri, Konya, Sivas, and Van in given Fig. 10 (TUBIVES, 2022).

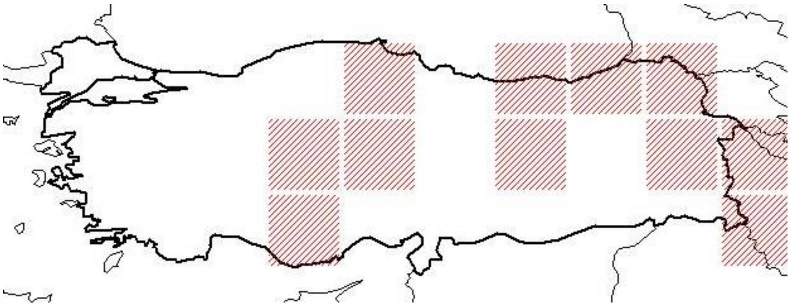

Figure 10. The Distribution Region of Forage Kochia in Turkey (A5, A7, A8, A9, B4, B5, B7, B9, B10, C4, C10) (TUBIVES, 2022)

Forage kochia is a xerophyte plant that grows quickly between -32°C and 40 °C after planting. It grows desert and semi-desert climates having 150-500 mm annual precipitation, and does not like flooding. It is possible to come across in Karapınar (Konya- Turkey), where the annual precipitation varies between 270 mm and 280 mm, having-20 °C during the winter season while above 35 °C during the summer season, and seen in wind erosion (Çetik, 1985; Acar ve Dursun, 2010).

Also, forage kochia shows tolerance to salinity. It can adapt to all kinds of soil: plant nutrient elements imbalance, salt-affected soil, high alkali, low organic matter, clayey, drained clay, and sandy textures. However, it does not like acidic soil (Tan and Temel 2012).

In farming, forage kochia crops as monoculture or mixed. Planting can be done directly with seeds or seedlings in agriculture. Sowing should be done in early spring, in other words, March and April, when the soil temperature reaches 8-10 °C if the seeds are used in monoculture. The seeds used in sowing must be fresh due to losing viability within 3-6 months. This situation can lead to failure in sow done at later periods.

The sowing process can be done with a machine or by spreading. Raking roller on seeds provides a contact of the seed with the soil after spreading.

The other sowing method is spreading on snow cover if there is no possibility of entering the field through the snow cover in early spring. The seeds begin to germinate at 2-4 °C, melting the snow. The sowing is good in the case being proper precipitation.

We suggest that row sowing due to being efficiently managed by agricultural practices. It should be 60-100 cm of row spacing, 40-50 cm of intrarow, and 0,5- 1,5 cm of the sowing depth in sowing. The seeds to be planted per hectare should be ranged between 1000 g and 5000 g.

The row spacing should be 15- 20 cm in legumes and grasses if it is to be planted in a mixture of legumes and grasses. In other words, 2- 3 rows of mixed plants can be planted between two rows of forage kochia.

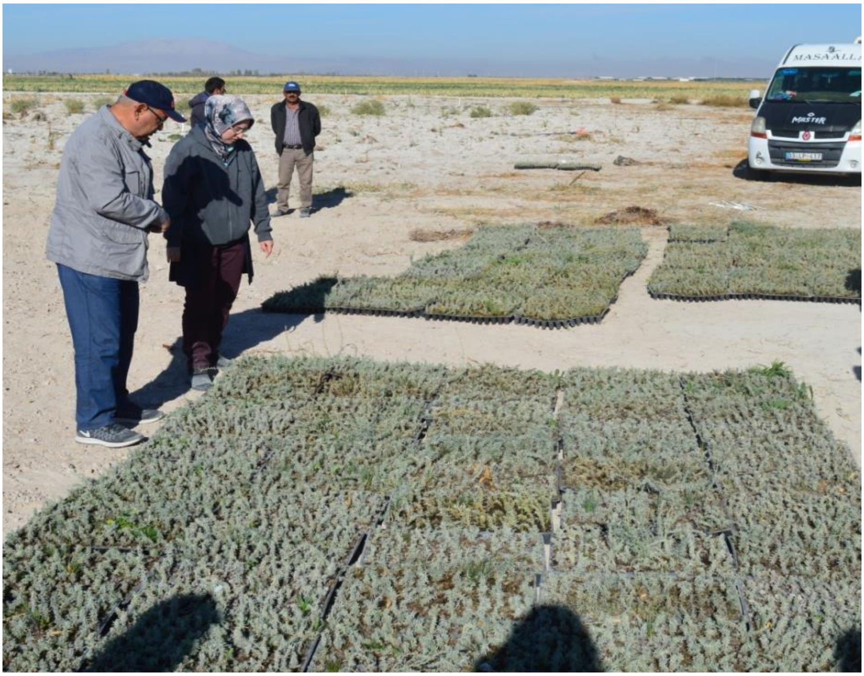

Figure 11. The Planting Forage Kochia in drought, salt affected and alkali soil, Kaşınhanı, Konya, Turkey (Koç Koyun, 2021)

If forage kochia farming is done in ecological conditions that are not proper, in other words, in marginal areas, forage kochia can be grown in plastic pods under greenhouse conditions (Fig. 11). Then, it may be planted in the appropriate seasons, in the rangeland, or as fodder plants. We suggest planting in the fall season, especially in October, in Center Anatolia's ecological condition. The distances, row spacing, and intrarow used in planting can be increased slightly compared to monoculture by considering the land condition. Furthermore, it can be increased up to 150 cm row spacing and 100 cm intrarow in monoculture, while row spacing can increase by about 200 cm in mixed sowing.

Forage kochia needs growing periods of 2-3 years if it grows naturally in nature. Similarly, the rangelands which made planting in the marginal area for pasture improvement should not be grazed for at least two years to the roots adhering to soil and adapting in a marginal area. However, the cut can be done during this period.

The branches can be grazed before blooming. The cutting for fodder can be done with the onset of blooming. The cut should be made at the height of 5-8 cm. It can grow 3- 4 times a season if the cutting is not done from the bottom.

Although their hay yield increases, feed values decreases as blooming progress in forage kochia. For this reason, we suggest cutting at the beginning of blooming in terms of the feed values. Also, it can be considered silage during this period (Tan and Temel, 2012).

4. YIELD AND QUALITY

The fodder yield ranges between 1000 kg ha^{-1} and 3000 kg ha^{-1}, depending on where it grows. Clements et al. (2020) stated that the Immigrant and Snowstorm varieties' forage yields were 1505 kg ha-1 and 2528 kg ha-1, respectively. In research to forage kochia in Anatolian origin material, Acar and Koç (2019) obtained a forage yield between 1070 kg ha^{-1} and 2580 kg ha^{-1} in S.U.F.A. Forage Kochia Demonstration Garden (Konya).

Koç Koyun and Acar (2021) reported that the fodder yield per plant cut in the blooming period ranged between 12 g and 112 g depending on forage kochia populations. However, the yield could rise depending on plant age in some references. For example, Acar and Dursun

(2011) weighed 810 g of fodder yield per plant of forage kochia, naturally grown for long years in Konya conditions.

The seed could harvest in the fall, especially late October and November. The seed yield changes among 100 kg ha^{-1} and 300 kg ha^{-1} and more also can be obtained more seed. Therefore, the seed yield may vary depending on region and variety. After the harvested plants are dried, their seed can be separated. The seed vitality can be preserved within 3- 6 mounts if the seed is obtained in the harvest year. However, it may maintain good germination for up to 3 years if the seeds are properly dried to 7% or less moisture and stored at 2.2 to 10ºC (Harrison et al., 2000).

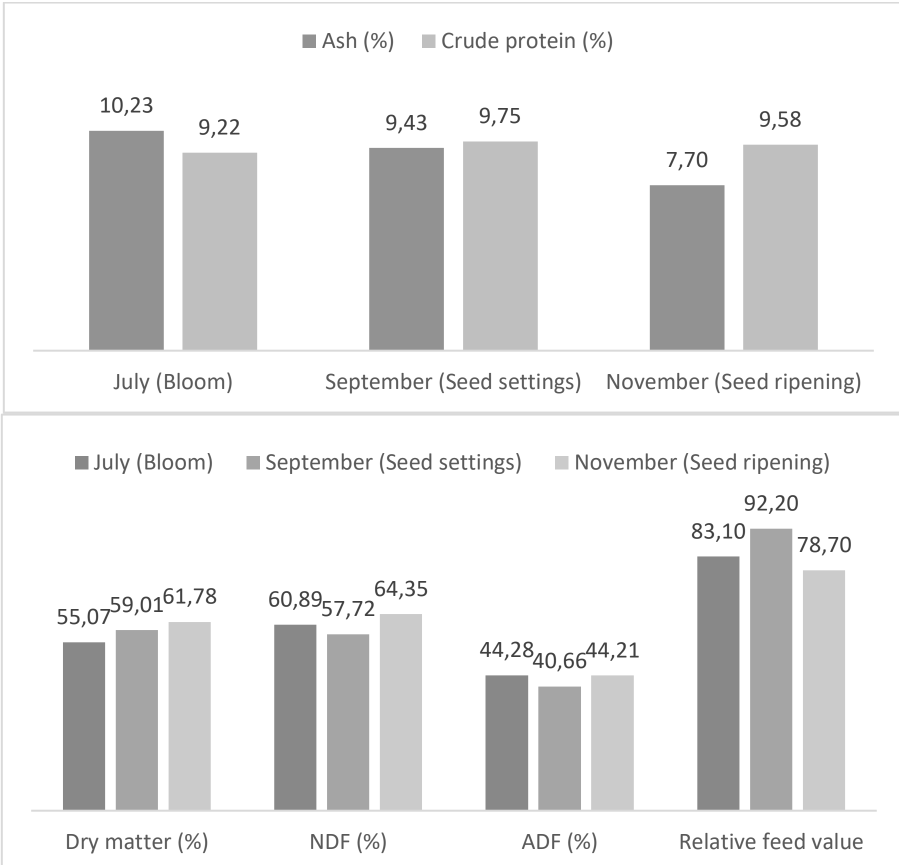

Figure 12. The Feed Value of Forage Kochia's Fodder Cut in Different Periods (Acar et al., 2021)

The feed value of forage kochia varies depending on the seasons and growth periods (Fig. 12). Forage kochia cut in time and good dried contains 8-18% crude protein. Waldron et al. (2006) observed the feed value of forage kochia in fall and winter. In November, December and January, they reported 9.6%, 5.7%, 4.7% crude protein, 55%, 63%, and 66% NDF values, respectively.

Shenkoru et al. (2015) investigated the feed value of forage kochia hay and reported that crude protein was 10-23%, NDF 38-54%, and ADF 19-32% in September and January, respectively.

Acar et al. (2021) reported that the highest dry matter content and NDF in grown naturally in Konya were obtained in the final cutting period at 61.78% and 64.35%, respectively. Furthermore, the same researchers stated that due to being placed third quality standard in September and fourth quality standard in the other periods, forage kochia proved to be a significant feed source by providing fourth quality standard to livestock in these critical periods.

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CHAPTER 4

FORAGE QUINOA (*Chenopodium quinoa* Willd.)

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1. INTRODUCTION

Rapid population growth and global climate change in the world have led agricultural scientists to new searches. In this context, efforts are made to develop and expand new plants with high resistance, yield and nutritional value. There are large lands in agricultural areas that are affected by salinity and drought stress. It is possible to increase the yield in problematic soils by increasing the salt and drought resistance of traditional crops with genetic applications. However, although the developments in this area are promising, they are slow and insufficient. An alternative option is the cultivation of naturally occurring xero-halophyte plants. Plants that are resistant to extreme conditions are used in food, feed and other fields in many countries. However, it is known that plants resistant to stress conditions are generally problematic plants in terms of nutritional value. The quinoa (*Chenopodium quinoa* Willd.) plant, which has attracted attention with its resistance to stress conditions in recent years, comes to the fore with its various uses (Figure 1).

Figure 1. Quinoa (*Chenopodium quinoa* Willd.) (Original)

Quinoa, the plant of the Andes Mountains, is expressed as the plant of the future in human and animal nutrition in the world. Known as a new plant in Turkey, this species has actually been cultivated and consumed by the indigenous peoples of South America for thousands of years. That's why it is called *Inca-grain* in some sources. Quinoa came to the agenda of the modern world in the 2000s. Two important developments played a role in the popularity of quinoa. The first of these is that the United Nations Food and Agriculture Organization (FAO) declared 2013 the year of quinoa. With this application, the organization wanted to draw attention to the fact that quinoa is a beacon of hope for the societies experiencing food shortages in the world. Another development that helped the recognition of quinoa was its use by NASA in the nutrition of astronauts. The seeds of the plant have high nutritional value. For this reason, it is also the subject of space exploration. These two important developments have increased the interest in quinoa and the trade volume in the world has increased. The interest in this plant, which is also being tested in Turkey, is increasing day by day.

Quinoa, which has just started to be heard in Turkey, has been grown and used in the world for a long time. It is not known exactly when quinoa cultivation began, but it is estimated that the natives of Central and South America have been interested in this plant for thousands of years. Cultivation of quinoa, which was initially collected from nature, started in 5000 BC. However, the cultivation of the plant has become widespread in the last 20 years. Today, especially South American countries such as Peru, Colombia and Chile; It is cultivated in more than 50 countries such as the USA, China, Canada and India. Quinoa farming started in many countries with the EU project "*Quinoa-A multipurpose crop for the EC's agricultural diversification*", which started to be implemented in Europe in 1993. The first variety developed in Europe is early maturing Carmen (Jacobsen, 2003). Today, intensive studies are carried out in many parts of Europe, including northern countries such as the Netherlands and Denmark, and new varieties are being developed.

The advantages of quinoa, which has important agricultural features, can be listed as follows.

1. Since it has a wide genetic richness, it is possible to find varieties suitable for very different climatic and soil conditions.
2. It can be grown in dry agricultural areas without irrigation.
3. Resistant to salinity is high.
3. It can be grown at different altitudes from sea level to high altitudes.
4. It is suitable for mechanized agriculture.
5. It can be produced at low cost.
6. Some varieties grow in a very short time.

This plant adapts easily to high altitude areas. It is grown in South America, from sea level to 4200 m altitude, under conditions where it is difficult for many plants to grow (FAO, 2011). This tolerance to altitude has expanded the use of quinoa as an alternative plant in the high altitude regions of the USA, Canada, European countries, North Africa and India (Gonzales et al., 2015). Drought resistance is quite good. It shows high resistance to soil salinity. Quinoa is used in many different fields such as human nutrition, animal feed, dyestuff, paper and cardboard production. The main importance of the plant is due to the high nutritional value of its seeds. Because it has high nutritional value, many sources refer to this plant as a miracle plant or superfood. Quinoa seeds contain high levels of protein, vitamins and minerals. The amino acid balance of the protein is good. It is a safe source of protein and carbohydrates for celiac patients as it does not contain gluten. Since it has high quality fiber content, it is widely used for dietary purposes in the USA and European Union countries.

Although quinoa is mostly used as human food, it can also be used as animal feed. Just as specially developed varieties are used for animal feed production, seed types can also be used for this purpose. The best example of this is the *Olav* variety developed in Denmark. This variety is used both in seed production and green forage production (De Braeckelaer, 1993).

It seems that quinoa, which occupies the agenda of agricultural scientists today, will continue to be talked about in the coming years. This plant, which has a very old history in the world, is new to the agriculture of many countries. Therefore, there is a lack of information on many issues. With the researches, new usage areas are emerging every day. The fact that it is a promising species for forage production in areas affected by drought and salinity stress also attracts the attention of animal producers. However, studies and publications on this subject are quite insufficient. In this section, researches on the use of quinoa as animal feed were compiled and the feed potential of the plant was revealed.

2. SYSTEMATIC AND MORPHOLOGY

Quinoa (*Chenopodium quinoa* Willd.) is a herbaceous plant belonging to the Amaranthaceae (formerly Chenopodiaceae) family. The systematics of the species in the plant kingdom is as follows.

Kingdom - Plantae
Section - Magnoliophyta
Class - Dicotyledons
Order - Caryophyllales
Family - Amaranthaceae
Subfamily - Chenopodiaceae
Genus - Chenopodium L.
Species - Quinoa (*Chenopodium quinoa* Willd.)
Syn. *Chenopodium canihua* O.F.Cook
Chenopodium ccoyto Toro Torr.
Chenopodium ccuchi-huila Toro Torr.
Chenopodium chilense Pers.
Chenopodium guinoa Krock.

According to the results of the research on quinoa phylogeny, it is accepted that the diploid ancestors of the plant are *C. standleyanum* and *C. album*. The resulting tetraploid ancestors are *C. berlandieri* and *C. hircinum*, *C. quinoa* and *C. nuttaliae* that exist today are thought to have emerged from these tetraploid ancestors (Figure 2; Tan and Temel, 2019; Jellen and Maughan, 2013).

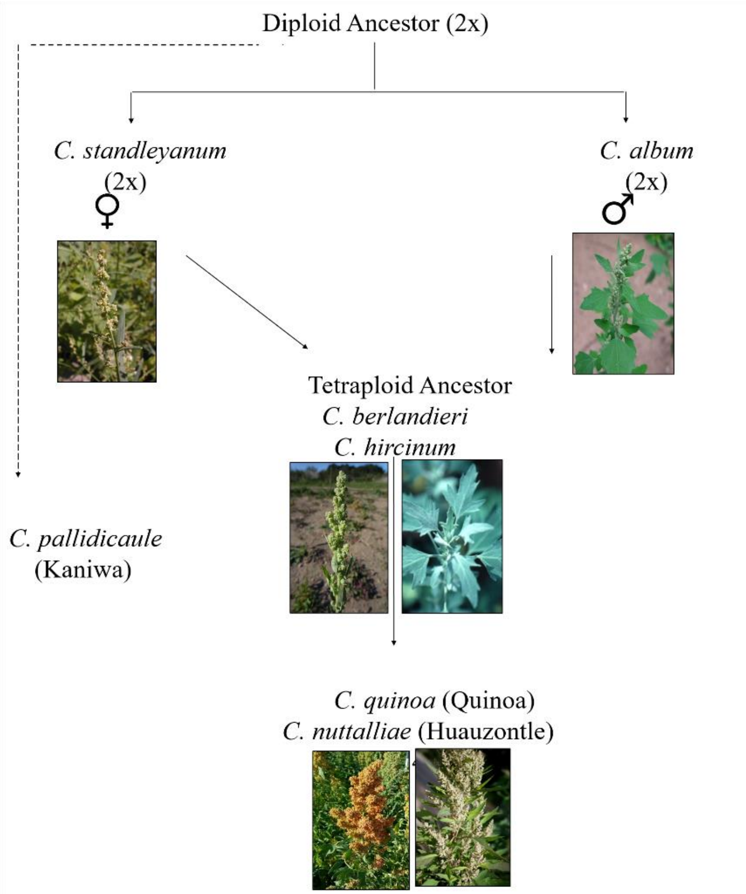

Figure 2. Origine of Quinoa (adapted from Jellen and Maughan, 2013)

Quinoa is an annual and seed-propagating species. It has a developed and branched pile root that can go 0.5-2.8 m deep, providing drought resistance. The plant grows up to 50-350 cm in height. The body is angular to rounded. As it matures, a spongy texture forms inside the stem. It has thick, upright, woody stems and broad leaves with alternating crowbar-like arrangement. Leaf shape is variable (polymorphic). The upper leaves are lanceolate, while the base is rhomboid. While the leaves are glabrous in some cultivars, both surfaces may be slightly hairy in some cultivars. On young plants the leaves are usually green; however, in some cultivars they turn yellow, purple or red as the plant matures (Figure 3).

Figure 3. Root, Leaves, Inflorescences and Seeds of Quinoa (https://todofrutossecos.es/Semilla-de-Quinoa)

The flower community forms clusters and blooms in July-August. The panicles are 30-70 cm long and densely flowered. Some varieties form ball-shaped, some varieties form long and abundantly branched panicles. The flowers are 3-4 mm in size. The flowers are usually hermaphrodite, with elongated anthers and a female stamen with a hairy 3-part stigma. It is largely self-pollinated, with a foreign pollination rate of 10-15% (Risi and Galwey, 1989). The clusters, which are initially green, become purple, pink, yellow or red with maturation. Fruits in clusters and achene form are formed on the cluster. There is a thin crust around the fruit (perigonium), which crumbles easily when rubbed. Seeds are rounded, 1-3 mm in diameter.

The seeds of quinoa are small, and the seed diameter is usually between 1.0-2.6 mm (Aguilar and Jacobsen, 2003). The 1000-grain weight varies between 1.98 g and 5.08 g depending on the variety (Reichert et al., 1986; Tan and Temel, 2018a). Seed size of quinoa is of great importance for the market value of the product. Very small seeds have low commercial value in the market. Generally, it is desirable that the thousand-grain weight of the seeds be over 2 g in the products offered to the market. Seeds can be black, orange, pink, red, yellow or white in color. The seed color is due to the saponin content in the husk. It is known that there are 66 different color tones in quinoa seeds. Therefore, quinoa seed pods are used in the production of organic fabric dye. The time from germination to seed ripening period varies according to varieties and environmental conditions. On average, this plant is considered to mature in 160-180 days in its homeland (Espindola, 1992; Mujica et al., 2001). Studies conducted in Turkey have revealed that quinoa seed formation can start from 90 days to 240 days (Tan and Temel 2018a, 2018b). There are thousands of local varieties in South America, the homeland of quinoa, and hundreds of varieties developed in different countries. Plant and seed morphological features of these genotypes show great variation.

3. ADAPTATION

3.1. Temperature

Quinoa is the plant of the South American continent. For this reason, although it varies according to the varieties, it develops in short day conditions. Germination starts around 5 ^{o}C and germination increases rapidly as the ambient temperature increases (Table 1). It reaches over 70% germination at 10 ^{o}C and maximum germination around 20-25 ^{o}C (Table 1; Tan and Temel, 2018a). The biggest reason for failure during the germination period is low temperatures (Geren et al., 2015). For this reason, early plantings made before the soil warms up cause insufficient germination and low plant density. This shows the importance of planting time. Studies show that it should be planted when the soil temperature reaches 8-10 ^{o}C. If there is sufficient moisture and temperature in the soil, germination starts within 24 hours and emergence is completed within 3-5 days.

Although quinoa is a C_3 plant, it responds well to temperature. The low temperatures at the beginning of the development periods also cause slow plant growth. However, it has been observed that with the increase in air temperatures, they grow rapidly and the plants approach physiological maturity (Maliro and Guwela, 2015). Therefore, high temperatures that may occur in the early development stages of plants cause plants to reach generative maturity more quickly. As a result of this, the plants cannot show sufficient grading and in parallel, their production is low (Maliro and Guwela, 2015).

Table 1. Germination Rates of Quinoa Varieties at Different Temperatures (%)

Cultivars	Temperature (°C)					
	0	5	10	15	20	25
Titicaca	0	10	77	83	96	100
French Vanilla	0	16	70	86	93	90
Moqu Arochilla	0	33	87	83	83	93
Mean	0	20	78	84	91	94

Very low and high temperatures are not suitable for optimum growth and development. During the growing season, temperatures of 15-25 °C are sufficient (Garcia et al., 2013; 2015). It needs cooling in order to enter the generative period and bloom. But it is not very resistant to low temperature. It starts to suffer from cold when the air temperature drops below 0 °C. Although there are significant differences between varieties, the threshold value for quinoa is -3 °C (Darwinkel and Stolen, 1997). It can withstand a maximum of -8 °C for 4-5 hours (Jacobsen et al., 2005). Its sensitivity is higher during the seedling and flowering period (Aguilar and Jacobsen, 2003). Tan and Temel (2018a) determined that quinoa maintains its viability at a rate of 50-95% at -2 °C, while some varieties can survive at a rate of 5-15% at -6 °C (Table 2). Falling the temperature to -4 °C during the flowering period reduces the seed yield by 65% (Jacobsen et al., 2003). It has been reported that in winter trial plantings in Turkey, it was damaged by low temperatures in January in Antalya (Anon., 2014).

Table 2. Survival Rates of Some Quinoa Varieties at Low Temperatures (%)

Cultivars	Temperature (^oC)				
	0	-2	-4	-6	-8
Titicaca	100	95	10	5	0
Oro de Valle	100	50	40	10	0
Mint Valle	100	90	15	5	0
French Vanilla	100	80	20	0	0
Rainbow	100	85	15	0	0
Sandoval Mix	100	75	30	5	0
Red Head	100	70	30	0	0
Moqu Arochilla	100	90	25	15	0
Cherry Vanilla	100	90	10	0	0
Qhaslala Blanca	100	75	25	0	0

Quinoa is also sensitive to high temperatures during flowering and pollination. Since high temperatures cause flower shedding and pollen to die, high air temperatures in this period reduce seed yield. Especially during the pollination period (65-100 days after planting), the air temperature should not be higher than 35 ^oC. This should be taken into account when determining the sowing time.

3.2. Water requirement

Quinoa adapts to places with annual precipitation of 150-2000 mm and relative humidity of 40-88% (Martinez et al., 2015; Gonzales et al., 2015). It consumes 250-400 mm of water during the growing season. It is resistant to steppe climate and drought. Root development is good in arid conditions (Gonzalez et al., 2009). It can be grown in dry agricultural areas by sowing early, but its yield is higher in irrigated fields. In a study conducted in Iğdır conditions, an average of 1104 kg/da hay yield was obtained from quinoa varieties in dry conditions, while it increased to 1476 kg/da in irrigated conditions (Table 3; Tan and Temel, 2017 and 2018a).

Table 3. Dry Hay Yields (kg/da) of Some Quinoa Cultivars in Irrigated and Dry Conditions in Iğdır

Cultivars	Dry	Irrigated
Titicaca	806	857
Rainbow	1169	1519
Read Head	1215	1766
Sandoval Mix	1235	1636
Cherry Vanilla	1142	1775
French Vanilla	1189	1633
Mint Vanilla	1575	1718
Oro de Valle	1311	1648
Qhaslala Blanca	711	1015
Moqu Arrochilla	687	1195
Mean	1104	1476

Quinoa can be easily grown in semi-arid regions under current precipitation conditions (Jensen et al., 2000; Geerts et al. 2008a) and small droughts do not cause yield reductions (Garcia et al., 2003). It has even been reported that it can grow in sandy soils that receive less than 200 mm of annual precipitation (Aguilar and Jacobsen, 2003). However, it should be irrigated if possible, especially during the development periods when precipitation is very limited, especially when it is sensitive to drought stress. A little irrigation during these periods will provide significant increases in yield (Geerts et al., 2008a; 2008b; Martinez et al. 2009). As a matter of fact, it has been found that a 208 mm amount of water that comes with irrigation and precipitation in sandy-loam soil gives high yields in quinoa (Flynn, 1990). Irrigation increases weed and seed yields, prolongs the flowering period and plant height, and ensures that the seeds are fuller and heavier (Table 4; Kır ve Temel, 2016; Kır ve Temel, 2017; Tan and Temel, 2018a).

Table 4. Yield and Some Properties of Quinoa Grown in Irrigated and Dry Conditions

Properties	Dry	Irrigated
Seed Yield (kg/da)	139.5	293.0
1000-Seed Weight (g)	2.40	2.56
Dry Hay Yield (kg/da)	770.6	1146.2
Time to Flowering (day)	82.5	88.0
Plant Height (cm)	93.8	112.5

In order to minimize the negative effects to be experienced before and after germination in quinoa, sowing must be done in an annealed soil. In cases where the annealing cannot be provided by precipitation, irrigation should be applied. This allows the seeds to germinate in a healthy way and the resulting seedlings to develop. Otherwise, a water shortage in the soil in the early vegetative period will cause the growth of plants to prolong (Jacobsen et al., 2003).

The water requirement of quinoa varies according to the development period of the plant, the amount of fertilizer applied and environmental conditions (precipitation, temperature and relative humidity). In general, there are certain critical periods in the development of plants when they are sensitive to drought stress. Knowing these periods will provide a great benefit in preventing yield losses that may occur. The periods when quinoa is most sensitive to drought stress (water) are seedling (post-plant emergence), flowering and grain filling periods (Jacobsen et al., 2003; Geerts et al., 2006). Water scarcity experienced according to the developmental periods causes yield decreases in plants, and excessive irrigation causes stress in plants. One of these periods is the seedling period, and the saturation of the soil with water during this period can reduce the total plant dry weight and leaf area more severely than drought stress. It has been reported that the saturation of the soil with water, both during the seedling stage and at the germination stage, has a negative effect on quinoa (Risi and Galwey, 1989; Gonzalez et al., 2009). In addition, unnecessary watering of seedlings can cause seedling settling disease and growth inhibition. For these reasons, it is necessary to avoid excessive watering during the initial development stages of the plant. In addition, it should not be forgotten that excessive irrigation will increase the risk of downy mildew disease.

3.3. Soil conditions

It can adapt to any soil. However, it grows best in loamy-sandy light and medium textured soils without drainage problems. It is grown in South America in poorly drained, poorly fertile or alkaline or acidic soils. However, heavy clay soils are not very suitable for quinoa cultivation. Soil pH tolerance limits are quite wide. Although it likes neutral soils more, it can grow at pH levels of 4.5-9 (Garcia et al., 2015). It grows comfortably in nutrient-poor soils with the help of mycorrhiza (mycorrhiza). Soils where quinoa will be grown should contain plenty of N and Ca, moderate P and a small amount of K. It is highly resistant to soil salinity, so it is considered a halophyt plant in many sources. It shows resistance to soil salinity by accumulating salt in its tissues. Therefore, it is effective in removing salt from the soil and rehabilitating saline soils.

Although the quinoa plant can be grown in low fertile soils, seed yields remain at very low levels in these soils. Since the amount of organic matter of sandy soils is low, their nutrient content is poor. Therefore, in such soils, either higher fertilization or the use of organic material sources such as barn manure, compost and humus are required. Studies show that yields increase with fertilization (Shams, 2012; Geren and Güre, 2017; Temel and Şurgun, 2019).

4. YIELD AND QUALITY

According to some experts, quinoa is one of the plants that can cure the hunger problem in the world. It is a plant with high nutritional value and good adaptation to difficult conditions. The use and trade of its seeds as human food, such as grains and legumes, is increasing day by day. This product, which has just started to be used in some countries, has been extensively consumed for many years in the USA and European countries. The decrease in rice production and the increase in costs due to reasons such as global climate change and drought have increased the orientation to alternative products such as quinoa. This plant, which has been used in human nutrition in the Americas for centuries, draws attention as the food and feed plant of the future in Europe (Jacobsen and Stolen, 1993; Bertero and Ruiz, 2010).

Quinoa is a plant that is usually grown for its seed, but it is also grown for its herb. Quinoa hay and straw have been used for centuries in the diet of cattle, sheep, horses and pigs in South America (FAO, 1994). Dry hay yield can reach up to 2400 kg/da in irrigated conditions in fields that are well cared for by choosing the right variety (Tan and Temel, 2017 and 2018a).

Variety selection is an important factor for high yield and profitability in quinoa grown for forage production. The fact that the varieties originate from different ecotypes and their genetic characteristics are not the same cause them to react differently to ecological conditions and applied cultural practices. This has a positive or negative effect on the amount and quality of the hay produced. For this purpose, the priority should be to carry out regional adaptation studies and to determine the genotypes suitable for the ecology of the region. In addition, the vegetation period of the region to be planted should be considered and accordingly, early, mid and late varieties should be selected. In general, in regions with low vegetation period, the average temperature and total temperature are low due to the high altitude. In addition, the year-round illumination period is low in these regions, but the temperature increases rapidly in a short time due to the high light intensity especially in summer. Under current conditions, it causes plants to reach physiological maturity without adequate grading and vegetative development. As a result, the yield values obtained from the unit area are lower. Regional adaptation studies have revealed that varieties differ in terms of forage yield and quality (Kakabouki et al., 2014). For example, in a study conducted with different quinoa varieties in Morocco, the amount of hay obtained varied between 470-1520 kg/da (Kaoutar et al., 2017). In another study, hay yields were found between 400-1100 kg/da (Carlsson et al., 1984; Soliz-Guerrero et al., 2002). Again, in a study carried out simultaneously in Erzurum and Iğdır, 14 different quinoa genotypes were examined and the amount of hay obtained as a result of the research varied according to the varieties and locations (Tan and Temel, 2017). In general, it is known that varieties with long development times are more productive. However, it is beneficial to choose early cultivars in high altitude areas such as the Eastern Anatolian Regions of our country.

Van Schooten and Pinxterhuis (2003) reported dry matter ratio of quinoa forage to be 26-28%, crude protein ratio to 13-22% and dry matter digestibility to be around 63-69%. The most important problem of quinoa as roughage is that it quickly hardens and has low palatability. When dried, it is not loved and eaten by animals. It also hardens on the stems when dried. For this reason, cutting time is of great importance for the hay quality of quinoa. The effects of cutting time and cutting height on the yield and quality of forage should be well known. The time of cutting varies depending on the variety used, the ecological conditions of the region and cultural practices. In general, as the harvest period is delayed in plants grown for roughage production, structural carbohydrates increase and since the plant produces new tissues, increases in yields and decreases in hay quality are observed. Similar results were also demonstrated in quinoa plant grown for hay production. Quinoa was harvested at different growth stages, and crude protein content decreased as the harvest period progressed, while NDF, ADF, green hay, dry hay and crude protein yields increased (Table 5; Üke, 2016; Temel and Yolcu, 2020). Researches generally recommend that quinoa be harvested during the flowering period in order to produce roughage. When the quinoa plant reaches maturity for forage, its above-ground parts (leaves, branches and stems) have high water content.

Therefore, the harvested herbs cannot be dried sufficiently in a healthy way, and their dried leaves can be easily broken and shed. As a result, nutrient-rich leaves are lost during drying and harvesting, making it difficult to use as a hay. For this purpose, it is more appropriate to use quinoa as a product and feed it to animals. Because quinoa hay has an extremely high protein and low fiber content when harvested close to the flowering period (Peterson and Murphy, 2015). It was determined that the protein content of the hay decreased by delaying the harvesting period in the forage harvests made in different development periods in Iğdır conditions, but the NDF, ADF, fresh hay, dry hay and crude protein yields increased. Tan (2020) reported that quinoa hay is at a level to meet the needs of dairy cattle in terms of macro and micro mineral elements. According to these results, the highest crude protein yields were obtained in the quinoa plant harvested during the full bloom period and it was determined that the most suitable harvest time for forage production was the full bloom period (Figure 4; Temel and Yolcu, 2020).

Figure 4. Full Bloom Period when Forage Harvesting for Quinoa (Original)

In the quinoa plant, the harvest period for weed should not be delayed, especially the advanced stage of maturation (after seed setting). In this period, ligninization increases due to thickening in the stem and stem parts due to the increase in the structural substance ratio, and serious yellowing and shedding occurs in the leaves in the plant body. In general, as the harvest period is delayed in forage plants, the leaf/stem ratio will decrease, and leaves rich in amino acids and mineral substances will contribute less to the quality of the feed produced. On the other hand, with the progress of maturation, there will be significant increases in the ratio of structural substances. The result is that the hay produced will have a lower nutrient content and less digestibility.

Table 5. Hay Yield of Quinoa Harvested at Different Harvest Times

Harvest Times	Hay Yield (kg/da)	Dry Hay Yield (kg/da)	C. Protein Rate (%)	C. Protein Yield (kg/da)
Vegetative Period	3794	933	20.0	183.9
First Flowering	4742	1207	19.1	228.2
Full Bloom	5449	1524	17.7	261.6

Although the cutting height is very important for forage plants that have a perennial lifespan and give more than one shape during the year, it is also important for the quinoa plant with a single-year lifespan. Because the cutting height is a feature that can affect the yield and quality of the forage. In general, although the amount of forage obtained in the forms made with high stubble is low, the quality is high, and the opposite situation occurs in the forms made with low stubble at the soil level. With the maturation of quinoa, especially at the end of the vegetative period, the main stem thickness and accordingly ligninization increase rapidly and the stems gain a harder structure Temel and (Yolcu, 20208). In addition, the branches that can cause an increase in yield, although it varies according to the varieties, are concentrated in the upper part of the main stem. In addition, depending on the planting frequency, the leaves on the lower parts of the plant turn yellow and fall off. Due to these existing reasons, care should be taken to leave at least 10-15 cm of stubble in the quinoa for a high yield and quality hay production.

Due to the carding problem of quinoa, its use by making silage has become widespread. Since it is easy to grow in many countries, it is used as a silage feed source. But silage quality is not as high as corn. In England, it is mixed with forage cabbage and is siled. For a proper fermentation, the dry matter ratio must be high. 3-3.5 months after sowing, quinoa produces silage material with sufficient dry matter content and high crude protein content (Van Schooten and Pinxterhuis, 2003). Plants must be shredded less than 1 cm for successful ensiling (De Braeckelaer, 1993). Podkowka et al. (2018) determined that direct silage of quinoa is difficult due to its low soluble carbohydrate content, therefore more successful silages emerged with additives or grafting. Thus, by making silage, it allows the quinoa feed to be stored for a long time without spoiling. Zom et al. (2002) suggested that 20% of quinoa silage should be included in the diet of dairy cows.

Quinoa seeds are a very valuable alternative to cereal grains due to the essential amino acids, oil profile, vitamin and mineral composition they contain (Gül and Tekce, 2016). Its seeds are an excellent feed for birds, poultry, fish and rabbits. In addition, a certain amount of quinoa seeds can be added to sheep and cattle feeds in order to increase the protein ratio. However, since it contains a high amount of saponin in its shell, the seed shell must be removed before feeding it to animals. The seed coat can be removed by washing, mechanical crushing or heating-cooking. The saponin-free varieties (sweet quinoa), which have been developed in recent years, are used in animal nutrition without removing the skin.

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CHAPTER 5

GUAR (*Cyamopsis tetragonoloba* (L.)

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1. INTRODUCTION

One of the greatest issues in the world today is the most efficient use of limited natural resources without exposing them to pollution, as well as the inability to produce adequate and balanced nutritional circumstances, which occur concurrently with the growth of the global population. Turkey relies heavily on natural pastures, plant residues and stubble, and low-quality fodder such as straw for animal feed (Kusvuran et al, 2011). Today, cereals provide a significant portion of our population's primary source of nourishment (233 person per kilogram per year). Protein-based foods, which are essential for proper nutrition and mental development, are consumed in extremely low quantities (21.8 person per kilogram per year) based on economic status (Avcioglu et al, 2000).

Given that at least half (30-35 g) of a person's daily protein need (75-80 g) must be satisfied by animal foods, it cannot be maintained that our people are well nourished (Ilgu and Gunes, 2002; Cankurt et al, 2010). Since plant residues and straw, which are of poor quality and have a low conversion rate to animal products, are insufficient to meet the feed requirements of animals, producers must select concentrated feed to fill the void. This appears as an extra input and the profitability level remains limited. Considering the overall number of animals in Türkiye, the yearly roughage need is approximately 50 million tons. In other words, only half of these animals' roughage requirements can be supplied (Kusvuran et al, 2011). Forage crops have an important place in animal nutrition due to reasons such as being a cheap source, containing essential nutrients for animals, being rich in minerals and vitamins, increasing the reproductive power of animals, and providing high-quality animal products-70% of which are feed inputs (Serin and Tan, 2001). One unit of improvement in animal feed not only improves their performance, but also raises the enterprise's profitability. In recent years, there has been a remarkable increase in the number of our culture and cross breed livestock compared to the domesticated livestock.

In Türkiye, according to TUIK data, the total number of purebred and crossbred dairy cattle climbed from 3.9 million in 2004 to 8.8 million in 2018. In 2018, the number of domestic dairy cattle was estimated to be 895 thousand units, compared to 2.0 million in 2004. Similarly, the number of purebred and crossbred cattle climbed from 962 thousand in 2004 to 2.6 million in 2018. Consequently, whereas the number of domestic cattle was 707 thousand in 2004, it was estimated to reach 310,000 in 2018. In the past 15 years, cultural breeds have increased by more than twofold, whilst domestic breeds have decreased by the same amount.

Additionally, in Türkiye, as of 2018, the total cultivated agricultural area is 19.7 million hectares, 15.4 million hectares of which are field crops, mainly cereals, 0.8 million hectares of vegetables are grown, and the remaining 3.5 million hectares is left fallow. Considering the 30-year data, it is seen that there is a remarkable decrease in both agricultural and arable land. Namely, the total cultivated agricultural area in 1988 was 24.8 million hectares, the cultivation area of field crops was 19 million hectares, the vegetable growing area was 0.6 million hectares, and the fallow area was 5.2 million hectares. As can be seen, in the last 30 years, there has been a decrease of 26% in the total arable farming area, a decrease of 24% in the cultivation area of field crops, a decrease of 49% in fallow land, and an increase of 28% in the area of vegetable cultivation (TUIK, 2019). If there was no 25% decrease in total agricultural area and arable agricultural land but a decrease in fallow areas, this situation could be considered a good sign in terms of agriculture. For many years, many studies have been carried out to reduce fallow areas. However, the decrease in both agricultural and fallow land suggests that a significant portion of these areas are no longer used for agriculture.

Guar (*Cyamopsis tetragonoloba* (L.) Taub., 2n = 14) is a self-pollinating annual plant species from the Legumes (Fabaceae) family (Arain, 2013). It is successfully grown in semi-arid areas, which have a limiting effect on the development of other plants. It comes to maturity in 14–16 weeks in areas with plenty of sun, moderate temperatures, and occasional rainfall during vegetation (Singh, 2014). It is found in natural vegetation in India and has been cultivated in this country and on the Asian Continent for many years. 80% of the world's guar production is provided by India, 15% by Pakistan, 5% by Sudan, and 4% by the United States (Varna, 2019). It is a type of summer legume that is generally used as a vegetable, fodder for cattle and ovine animals, and as green manure or a cover crop to improve soil properties (Rao and Shahid 2011, Rai 2015). It is a very rich feed source in terms of oils, carotene, phosphorus, calcium, and mineral elements, and the protein rate in its seeds is up to 42% (Kumar and Rodge, 2012).

Since guar is a legume that is successfully grown to meet the roughage needs of livestock, it also increases the productivity of the soil by binding atmospheric nitrogen for itself and the following products

(Bewal et al, 2009, Cebeci et al, 2016). In addition, it contributes to the aeration of the soil with its pile roots, and the root and above-ground residues that accumulate after harvest are decomposed in the soil in a short time, enhancing the organic matter content of the soil. Due to the protein, minerals, and high digestibility of the by-products remaining after gum extraction from the guard, they are utilized as feed for cattle, sheep, and fish (NRAA, 2014, Rai, 2015). In addition to being a cheap source of quality roughage in animal nutrition, it contains protein, oil, and cellulose necessary for the development of the rumen microflora and fauna of ruminant animals, is rich in minerals and vitamins, and improves the performance of animals while preventing many metabolic diseases related to feeding and high quality animal products. It is also important in terms of providing it (Alçiçek and Karaayvaz, 2003, Aydogan et al, 2015). The degree of digestion of feeds decreases due to the increase in the amount of cellulose and lignin as a result of the aging of the plant (Kusvuran et al, 2019).

The same is true for protein content. The mean decrease in protein content in legume plants was reported at 1 g kg^{-1} DM day^{-1}. With the progress of harvest time, a decrease is observed in the dry matter digestion values of legume forage crops (Christen et al, 1990). Harvest time, environmental conditions, and agronomic characteristics can be listed as the most important factors affecting the quality of forages (Aydogan et al, 2015). While stating that although there are some problems related to the spread of cultivation in irrigated farming areas, it can be successfully cultivated. Gresta et al. (2018) state that one of the most important problems seen in these areas is the prolongation of the time taken for the plant to mature and the delay in harvesting, especially if late varieties are preferred.

2. SYSTEMATIC AND MORPHOLOGY

The taxonomic classification of guar is shown below.

Domain: *Eukaryota*
Kingdom: *Plantae*
Subkingdom: *Viridaeplantae*
Phylum: *Magnoliophyta*
Subphylum: *Euphyllophytina*
Infraphylum: *Radiatopses*
Class: *Magnoliopsida*
Subclass: *Rosidae*
Superorder: *Fabanae*
Order: *Fabales*
Family: *Fabaceae*
Subfamily: *Paplionaceae*
Tribe: *Indigofereae*
Genus: *Cyamopsis*
Specific epithet: *tetragonoloba-(L.) Taub.*

Guar, also known as cluster bean, belongs to the Leguminosae (Fabaceae) family and is the most economically significant of the four species in the genus Cyamopsis. Guar evolved in the region between India and Pakistan and is a short-day erect or bushy annual plant. (Kays et al, 2006). It has 2n = 14 chromosomes and is self-pollinated. Gillette (1958) divided the genus Cyamopsis in to three races, viz. *C.*

tetragonoloba (L.) Taub, *C. senegalensis* Guill. and Perr. and *C. Serrata* Schinz. The haploid and diploid chromosome numbers of all three genera and species of Cyamopsis were reported to be n = 7 and 2n = 14. The status of intermediate forms between *C. serrata* and *C. senegalens*is was left unsettled, although it was suggested that the intermediate form may be the result of hybridization between the species (Pathak, 2015).

Clusterbean is an annual plant that grows to be 50-150 cm tall with a large tap root and well-developed rhizobium nodules on its laterals. The branching pattern of clusterbean may be upright, basal, or branched. In the erect category, most plants have zero to two branches; in the basal branching category, three or more branches are present at the base of the plant; and in the branched category, branching occurs along the main stem. It grows four to ten branches on branching cultivars, whereas unbranched cultivars have a single stem that is densely crowded with pods. The leaves are medium-sized, trifoliate, alternate, pubescent or glabrous, and borne on a long petiole, while the stem is tall and thin. Clusterbean has white or purplish-pink blooms that are 8–9 mm long. Compared to *C. tetragonoloba*, *C. senegalensis* and *C. serrata* have shorter plant heights (about 30 cm), smaller leaves, and smaller pods. Multiple pods/clusters are present, with an average of nine seeds per pod. The 100-seed weight of *C. senegalensis* and *C. serrata* ranges between 1.1 and 1.4 grams. These species' seeds are small and cylindrical, but *C. tetragonoloba*'s seeds are practically spherical. At maturity, pod breaking is also found in *C. senegalensis* and *C. serrata*, but not in *C. tetragonoloba* (Pathak, 2015).

Due to its cleistogamous character, clusterbean is an entirely self-fertile and self-pollinating crop. It has been shown that the extent of outcrossing ranges from 0.3% to 7.9%. The flowers of the axillary racemes are bisexual, somewhat sessile, and measure around 9 mm in length. Each inflorescence contains roughly 50 blooms, of which approximately 12.5% mature into pods. It is believed that a flower needs 35 days to mature from a bud (Menon 1973). The inflorescence is a raceme of around 9–13 cm in length for the branching variety and 15–20 cm in length for the upright or sparsely branched kinds. Typically, 40–60 blooms are seen in branching forms and 50–70 in sparsely branched, erect inflorescences (Pathak, 2015).

The calyx contains five sepals with uneven, linear teeth, whereas the corolla has five petals. The standard is round, the wing petals are elongated, and the keel petals are the same length and width as the wing petals. The ovary is linear, sessile, and contains six to ten ovules. The form is brief and narrow, but the stigma is head-shaped (Pathak, 2015). From the flower's bud stage till its demise, it undergoes a spectrum of colors ranging from white to dark blue. A mature bud's color changes from creamy white to pale pink or white. Just prior to blossoming, petals gain a pink hue. In general, the color of the flowers ranges from purple to pink. However, there are additional varieties with white blooms. In diadelphous stamens, there are ten stamens with opercular anthers. Anthers dehisce between 1.5 and 2 hours prior to flower opening, and pollen is capable of germination 2 hours before and 11 hours after flower opening. The flower blooms early in the morning and drops its petals the same day, but flowers that open later in the day drop their petals the following morning.

3. ADAPTATION

Clusterbean is harvested around 90–110 days after seeding. However, crop cycles vary between 60 and 90 days for determinant types and 120–150 days for indeterminant cultivars (NRAA 2014). Depending on the arrival of the monsoon, seeding is completed between the first and second weeks of July, or it may be delayed until August. Germination occurs within four to six days of seeding. Seed viability, seed size, seed vigor, soil type, soil moisture, soil temperature, and relative humidity all influence germination. Compared to tiny or medium-sized seeds, larger seeds result in more germination, longer shoots, and increased dry matter output (Renugadevi et al, 2009).

Guar is a plant that can grow in arid and semi-arid regions. The arid regions of India are the most common growing areas for gum beans. Temperature and humidity come first among the most determining environmental factors in guar cultivation. (Pathak and Roy, 2015). The lowest temperature for mastic bean cultivation is 8 °C, and the optimum temperature is 24–30 °C (Baligar and Fageria, 2007). It is beneficial for ideal plant emergence to start planting when the soil temperature reaches 10 °C, as is the case with cereals in hot climates. Guar can be grown in any soil condition. However, it is more productive in sandy-loam soil conditions with a pH range of 7.5–8.0 (Akcaman et al, 2017).

While guar has been reported to be tolerant to soil salinity in some studies, it has been found to be resistant to salt in some sources (Varna, 2019). Gresta et al. (2018) reported that 20–21 °C is the threshold value and 30 °C is the most appropriate temperature value for the healthy germination and emergence of guar seeds. According to the researchers, sufficient soil temperature can be reached in the semi-arid Mediterranean climate conditions in early May or June; however, even if sowing is done earlier, there may be delays in emergence, and thus the seed harvest may be delayed until October or November. In this study, guar was planted at the end of May, and there was no delay in emergence as the average temperature (16.9–21.6 °C) recorded in this period was sufficient for germination and emergence.

Although the optimal yearly rainfall for clusterbean varies between 400 and 800 millimeters (Yousif, 1984), it may be cultivated without irrigation in regions with 250 millimeters of annual precipitation (Undersander et al, 1991). In dry conditions, it is produced as a rain-fed crop, requiring 300–400 mm of precipitation in three to four periods. Pathak and Roy (2015) studied the climatic responses, environmental indices, and interrelationships between qualitative and quantitative patterns in cluster beans under arid conditions. They discovered that the crop gave good yields with a temperature regime of 36.7 °C, 11 h of sunshine, and water stress during the 32nd through 35th meteorological weeks of the cropping season under rainfed and natural climatic conditions. These climatic circumstances also favored the growth of the endosperm and, consequently, the gum content of clusterbean seeds. Sharma and Gummagolmath (2012) stated that in the Asian continent, where the cultivation is widespread, the plant's cultivation area, yield, and, accordingly, total production depend on monsoon rains, therefore, there are remarkable fluctuations in annual production amounts of guar.

Guar may fix atmospheric nitrogen through symbiosis with rhizobia bacteria found on soil. This improves soil fertility and decreases the need for costly nitrogen (N) fertilizers. Numerous studies on guar nodulation have documented the effects of external variables such as soil type, soil fertility, moisture regimes, and rhizobium inoculation (Ravelombola et al, 2021). The potential for enhancing clusterbean yield is substantial when balanced fertilization and good crop management are employed (Sharma and Singh, 2005). A number of studies indicate that 20 kg nitrogen/ha can result in greater grain/straw production, water usage efficiency, gum content, and net return relative to no nitrogen (Yadav et al, 1991). However, 30 kg N ha^{-1} was also suggested for increased seed yields, nitrogen absorption, and nitrogen concentration in seed and straw (Singh et al, 1993). It has been shown that 15–20 kg of nitrogen per hectare offers a crop a favorable start. Excessive nitrogen application results in a sluggish nitrogen fixation process. Phosphate has been regarded as the most effective fertilizer; however, its reaction may vary by area.

In some studies, a dose of 40 kg P_2O_5 ha^{-1} was found to be superior for various crop parameters, such as yield attributing traits such as plant growth, seed and stalk yield, dry matter accumulation, crop growth rate, leaf area index, and yield contributing traits, such as number of pods $clusters^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000-seed weight, and seed yield $plant^{-1}$ (Shivran et al, 1996). Nonetheless, according to a number of studies, phosphorus has little effect beyond 20 kg P_2O_5 ha^{-1} (Taneja et al, 1981) or 30 P_2O_5 ha^{-1} (Gill and Singh, 1981) under rainfed conditions. The fertilizer level of 25:94:75 (NPK kg ha^{-1}) considerably increased plant height, pod number per plant, pod weight per plant, seed number per pod, and seed yield. In addition, this fertilizer dosage triggered early flower initiation and reduced blossoming by 50% each day (Palankar and Malabasari, 2014).

The plant is extremely susceptible to waterlogging over its whole growth phase. As a result, water drainage is critical during the rainy season. In general, clusterbean calls for fewer irrigations. Depending on the distribution of rainfall, it is often cultivated without irrigation throughout the wet season. While summer crops are dependent on irrigation, two to three irrigations are sufficient for crop growth. According to research, one irrigation 60 days after sowing significantly increased grain yield compared to no irrigation (Pathak, 2015). Additionally, plant breeding initiatives are interested in the genetic variety of plants. The study of crop genetic diversity supports plant breeders in determining the genetic relatedness of genotypes within a population, developing crosses for population development, and acquiring a greater understanding of the evolutionary process of the crop. Regarding guar, Krishnan et al. (2011) suggested that this crop was first domesticated in the northern Indo-Pakistan region, while its wild relatives, *Cyamopsis serreta* Schinz. and *Cyamopsis senegalensis* Guill. and Perr., likely originated in Africa. Additional study is necessary to confirm these assertions. In addition, agricultural practices and environmental conditions affect the agronomic characteristics of guar. For example, Meftahizadeh et al. (2019) found that planting dates affect the number of leaves, days to vegetative phase, days to pod initiation, days to 50 percent pod set, plant height, and number of pods per cluster in guar.

Gresta et al. (2013) investigated the adaptation of four guar types to Mediterranean conditions. Also investigated were the effects of planting date on seed production, protein content, and gum content. Results suggested that cultivars that were planted earlier had greater levels of seed protein and gum. Rakovskaya et al. (2019) studied the impact of forty years of storage on the germination and hardiness of guar seeds. The 111 Guar accessions utilized for the investigation exhibited strong germination and seed viability at more than fifty percent. Also undertaken in the field to measure seed viability were the trials. The results indicated that guar seeds remained viable after lengthy storage. Photoperiod insensitivity is an essential feature in agriculture. It helps plants produce seeds regardless of the duration of sunshine. Teplyakova et al. (2019) reported the responses of 192 Guar genotypes to 19-hour day duration extensions. Among the examined genotypes, the number of days to blooming varied considerably. Based on the blooming period, this guar panel was separated into two groups (Ravelombola et al, 2021).

Agricultural output is significantly impacted by abiotic factors such as heat, dryness, and salt, which impede crop production. Under high stress circumstances, these environmental stressors contribute to physiological malfunction inside plant cells and plant mortality. Guar is resistant to heat and drought. Understanding the variance in morphological features of guar under stressful conditions can shed light on the probable tolerance mechanisms to these stressors, which may be applied to other crops (Ravelombola et al, 2021). Insects and pathogens can negatively impact guar output. Many stages of guar growth, according to reports, may be influenced by biotic stress. Newly developing diseases will pose an increasing danger to global guar production. Alcala-Brisen et al. (2018) reported the discovery of a new endornarivus in guar.

For the first time, Zaidi et al. (2017) discovered that the Tomato yellow leaf curl virus (TYLCV) was causing harm to guar plants in Pakistan. Gillaspie et al. (1998) identified a seed-borne potyvirus with the potential to affect guar output, while Kumar et al. (2010) found a new begomovirus recombinant affecting guar. The name of the virus is Cyamopsis tetragonoloba leaf curl virus (CyTLCuV). Alternaria leaf blight is brought on by Alternaria tenuissima. Samuel Paul Wiltshire is a significant foliar disease that affects guar.

Root rot affects guar as well. This disease is caused by the fungus *Fusarium solani* (Mart.) Celsius. Purkayastha et al. (2006) examined the resistance of six elite guar genotypes to four isolates of M. phaseolina, the causal agent of charcoal rot disease. The examination was undertaken both in a greenhouse and in the field. Charcoal rot damaged all phases of guar plant growth, according to the findings. In the susceptible genotype, plant mortality was seen; however, the severity of the illness was less severe in some genotypes. These data show that guar germplasm contains sources of inherent disease resistance.

4. YIELD AND QUALITY

Guar's feed yield and quality depend on the weather, how it is grown (fertilization, irrigation, spacing between plants, etc.), and the environment. The timing of planting has a significant impact on the crop's growth and, consequently, its seed production. Sharma (1984) evaluated the influence of sowing dates on the yield and quality of clusterbean, concluding that the greatest seed production may be obtained if the crop is seeded on July 5 as opposed to June 20 June, 20 July, or 5 August. Tiwana and Tiwana (1992) stated that, under rainfed circumstances in Bhatinda, Punjab, crops seeded on June 30 with 30 kg of seed ha^{-1} at 30 or 45 cm spacing might provide a greater mean seed yield. Numerous studies show that crops grown on July 10 had the highest seed yield, protein content, and gum content (Taneja et al, 1995). Under irrigated circumstances, clusterbean sowed with 20 kg seeds ha^{-1} and a row spacing of 30–45 cm at the end of June or the beginning of July produced the maximum seed production (Tiwana and Tiwana 1993). In most clusterbean-growing countries, the first week of July is the optimal period to sow the crop for greater seed yield.

Sowing time and plant density are the important factors for crop establishment in the field and yield potential. In addition, the optimal sowing date is essential for achieving a good yield due to climate change. The sowing time for guar might range from May to August (Gresta et al, 2013; Deka et al, 2015). According to reports, the early planting period resulted in much more grain than the late sowing date (Abbas-Nematallh et al, 2017). Kalyani (2011) found that, compared to other sowing dates (the first and second fortnights of July and August), the first fortnight of July was the best. In addition, Nandini et al, (2017) showed that seeding on the 10^{th} of July resulted in a greater number of pods $plant^{-1}$ and grains pod^{-1} than early or late sowing dates. Evaluation of 22 guar genotypes revealed that the gum content changed somewhat (from 28.47% to 32.89%) by ecotype but not by environment. The first two weeks of July sowing likewise resulted in a considerably greater crude gum content than plantings that were postponed (Kalyani and Sunitha, 2011).

In addition, diversity, growth habits, and agroclimatic conditions determine the optimal plant density and the correct plant shape (Lone et al, 2010). Siddaraju et al. (2010) observed that, among the three plant spacings (4515, 4530, and 6030 cm), the 4515 cm plant spacing produced the maximum grain production of guar. Cebeci et al. (2016), in their study conducted in Çanakkale conditions in 2015 in order to investigate the effect of different planting distances between rows (20, 40, 60, 80, and 100 cm) on guarda weed yield and some characteristics; reported that the spacing of the rows was effective in all of the examined traits except plant height and dry matter ratio, and suggested that guar should be planted in 20–40 cm row spacing if it is grown for grass. Researchers determined plant height at 94–102 cm, number of branches at 4.5-8.7, stem thickness at 8.0–11.6 mm, green grass yield at 1198–2324 kg da^{-1}, hay yield at 368–714 kg da^{-1}. Mahdipour-Afra (2021) reported that planting date and plant density affect guar growth and quantitative and qualitative yield, while most of the variables examined, including phenological ones and plant height, have a significant effect on plant density. In addition, the changes in grain yield, total dry matter, and harvest index were strongly influenced by the interaction between planting date and plant density. The researchers stated that obtaining a good grain yield from the gudan depends on the selection of the appropriate density and, of course, the planting date.

Long et al. (2012) concluded that in order to obtain the highest quality grass, the seeds in the pods under the plant should be harvested while they are still in the form of scars or when the seeds in the pods under the plant are of medium size. Researchers have determined that the average hay yield is between 324 and 1113 kg da^{-1}, the crude protein ratio is 9.5–21.0%, and the crude protein yield is between 62 and 111 kg da^{-1}. Pathak (2015) states that if guar varieties are grown for seed purposes, they reach harvest maturity between 90-100 days depending on the variety, rainfall amount, soil structure, and rainfall distribution. He reported that it was the most appropriate period to harvest 10 during the period. It has been reported that the plant does not need water in the early vegetation period due to the spring precipitation, but irrigation during the flowering and pod binding periods is necessary for high yield and performance.

Furthermore, guar has a reported crude protein ratio of 16-18% and a crude protein yield of 115-150 kg da^{-1}. It has been reported that the increase in structural carbohydrates such as NDF and ADF leads to a further decrease in in vitro dry matter digestibility, which is an undesirable feature in animal nutrition. Kushwah et al. (2017), in their study conducted in India in the 2014 growing season, determined the plant height at 107.5 cm, the seed yield at 187.5 kg da^{-1}, and the post-harvest residues at 418 kg da^{-1}. They concluded that it is more profitable and more productive to grow guar as a mixture, rather than purely for animal feeding purposes.

Guar is a notable crop amid legumes. Every part of the unusual plant known as the guar can be utilized in several ways. It provides a great potential to producers, consumers, environmentalists, and industrialists.

The crop is a popular cash crop in the dry and semi-arid region since it produces enough without requiring much care despite harsh weather conditions. Clusterbean utilizes heat and mild salinity to produce a high yield. It can enhance both desertification and the soil ecology. Meristematic-type rhizobium nodules connected to guar roots, which boost the crop's recovery capacity and aid in nitrogen fixation, are one of the plant's primary advantages. To provide farmers and consumers with guar that is commercial and capable of withstanding future environmental stresses, it is vital to engage in breeding initiatives aimed at developing improved guar cultivars.

The evaluation of the germplasm for higher nitrogen efficiency under heat, drought, and salt stresses, in addition to disease and insect resistance. In order to identify genotypes with high guar gum content that can be used as parents in guar breeding, it is necessary to examine the variety of guar gum content among the existing germplasm. In guar genetics and breeding, there is a notable absence of molecular markers. To accelerate guar breeding, it is necessary to establish genetic resources. It has the potential to be a key crop for resource-limited farmers who rely on marginal areas for sustenance. Due to the fact that it is drought-tolerant and not overly picky about growth circumstances, as well as its economic significance, it has an important place in the field of rural development.

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CHAPTER 6

TEF (*Eragrostis Tef* [Zucc.] Trotter)

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1. INTRODUCTION

Self-pollinating teff is used as dry grass, silage or pasture grass during the growing season. The teff plant, which is physiologically a C4 plant, is of African origin and is mainly used as a cereal. The tambourine plant is an allotetraploid (2n = 4x = 40) plant, which is approximately 60% larger than the rice genome (430Mb) and has a genome size of 730 Mb. Tambourine is a plant of the grass family with the smallest chromosomes ranging from 0.8 to 2.9 µm (Ayeleet et al, 1996). Tef (*Eragrostis tef*) has been cultivated and used as a food ingredient in Ethiopia for centuries. Tambourine, known as 'Yazotu', 'ashotu' or more commonly, is an annual herb that grows in Northern Ethiopia under the name "taf" or "khakshir" abroad. With its origins in the northern Ethiopian highlands, teff is an ancient grain variety with around 350 different species. Due to their ideal essential amino acid composition and mineral profile, ancient grain varieties can also be defined as “Super foods” (Kahlon and Chiu, 2015).

Tef, which is native to Ethiopia and Eritrea; It is used in the production of various traditional foods and beverages such as injera (flatbread), tella (opaque beer) and kitta (unleavened bread) (Zhu, 2018). Tef has very small grains; There are three different genotypes: red, brown and white. It is a cereal with the smallest grain size (less than 1 mm) in the world. Tef cannot be separated from its shell during grinding due to its very small grains and is used as a whole grain. Therefore, it is very rich in fiber (Shumoy and Raes, 2016). It has been stated that Tef plant can be used in the production of foods with low glycemic index since it has the highest gelling temperatures compared to wheat, quinoa, oat, buckwheat and sorghum (Shumoy and Raes, 2017).

There is evidence that the plant, whose homeland is Ethiopia, was grown as grain and animal feed in the high plateaus of Ethiopia around 5000 BC (Eckhoff et al., 1993, Hickman et al. 2013, NRC, 1996, Ketema, 1997). In Ethiopian conditions, tambourine cultivation was carried out in 2010 and 2011 on an area of 2.8 million hectares, yielding 126 kg of grain per decare (Fufa et al, 2011). In Ethiopia, tef is the staple food of more than 6 million small farmers and approximately 50 million people each year, accounting for approximately one-third of the total cultivated area and one-fifth of all gross grain production.

Recently, it has been cultivated in countries such as the United States, Israel, the Netherlands and Spain, South Africa, India, Australia and Kenya. Between 2005 and 2010 in the USA, it was stated that tef cultivation area exceeded 100,000 acres in studies conducted in Oregon, New York and other regions (Hunter et al, 2007; Roseberg et al, 2006; Roseberg et al, 2008).

In spite of its low productivity (the current national average yield of 1.5tha−1), the Ethiopian farmers who engineered domesticating the crop have continued growing it over the millennia with its acreage increasing through time. The continued extensive cultivation of tef is attributed to its relative merits compared to the other cereals with respect to both husbandry and utilisation (Ketema, 1997; Tefera and Ketema, 2001) The most important reason for the prevalence of tef plant is the absence of gluten (Gebremariam et al, 2014) or at a negligible level (Mebratu et al, 2016). It has been reported that very small tambourine seeds are hullless, mesh-like fibers are formed and have a flat seed surface.

2. SYSTEMATIC AND MORPHOLOGY

The tef plant, which is a high fiber and relatively high source of protein, manganese, iron and calcium, plays an important role in healthy weight loss and strengthening bones. Tef, which is the only cereal species cultivated among approximately 350 species belonging to the genus Eragrostis, has a significant effect on the grain color, plant habitus, flower status and the appearance of the spike clusters; in commercial marketing, they are grouped only according to grain colors (white, red/brown and mixed). The oval-shaped tambourine grain is not husked like barley or oat grain, but husked like wheat or rye, that is, bare.

Tef, which is more than other grains in terms of the essential amino acid lysine, is a good source of essential fatty acids, fiber, minerals (especially calcium and iron), polyphenols and phytochemicals such as phytates. It has been reported that there are approximately 350 annual and perennial species of tambourine (Conert, 1992; Sarı and Tiryaki 2018; Tefera et al, 2003). While it is shown as the plant species that tambourine is related to cultivated ragi millet (*Eleusine* *coracana*), sorghum (*Sorghum bicolor*) and maize (*Zea mays*) are shown as the most closely related cultivars as a subfamily (Sarı and Tiryaki, 2018). It has been reported that the closest plant species to tambourine are gin (*Setaria italica*) and sorghum (*Sorghum bicolor*) (Cannarozzi et al, 2014).

Taxon: Eragrostis tef

Family: Graminae (Poaceae)

Sub Family: Eragrostideae

Tribe: Eragrosteae

Genus: Eragrostis

Species: Tef

Various terminologies given to the tambourine by various researchers have given names and these are given in the Table 1 below. The currently most accepted binomial nomenclature is Eragrostis tef (Zucc.) Trotter. Based on the adjective tambourine, this name was proposed by Trotter in 1918.

Table 1. Binomial nomenclatures given to tef by various authorities at different times.

Suggested name	**Year**
Poa tef Zuccagni	1775
Poa abyssinica Jacquin	1781
Poa cerealis Salisb	1796
Cynodon abyssinicus (Jacq.) Rasp	1825
Eragrostis abyssinica (Jacq.) Link	1827
Eragrostis pilosa (L.) P. Beauv. subsp. abyssinica (Jacq.) Aschers and Graben	1900
Eragrostis tef (Zucc.) Trotter	1918

Source: Updated from Ebba (1975) and Ketema (1997).

Tambourine plant genus; The high rate of polyploidy and the complexity of the genome cause uncertainties in taxonomic classification. *Eragrostis tef* [Zucc.] was assumed to benefit from 14 wild species in the genus as progenitors and (Ingram and Doyle, 2003; Sarı and Tiryaki, 2018) the rate of polyploidy of the species in the genus was reported to be approximately 70%. It is known that tef plant, which has diploid, tetraploid and hexaploid genome structures in the genus with 10 basic chromosomes, is a tetraploid (2n=4x=40), annual C4 grassy (Graminea) plant with 40 chromosomes (Assefa et al, 2011).

It has been stated that there is a close relationship between the tambourine plant and the species known as finger millet or ragi millet (*Eleusine coracana*) among the cultivated plant species, and between sorghum (*Sorghum bicolor*) and maize (*Zea mays*) as subfamily 3 (Cannarozzi et al, 2014)

The tef plant, which can reach depths of 4-8 cm on average under field conditions, has a morphologically weak fringe root system (Assefa et al, 2011; Ebba, 1969). The stem of the plant, which has a stem thickness that can vary between 1-5 mm, is formed between the knuckles and the knuckles. The trunk mostly develops upright, but lying position is observed.

In general, the plant height varies between 25 cm and 135 cm (Ketema, 1997; Tadesse and Kebede, 1995) and has a vegetation period ranging from 90 to 130 days. (Ketema, 1993). Auricles consist of fine hairs in some genotypes, while in others they do not have a distinctive structure. While the length of the cluster varies between 11 cm and 63 cm (Ketema, 1997), the number of flowers in the spikelet varies between 3-17. (Assefa et al, 2011). Pollination in the plant starts from the top of the cluster in the early hours of the morning and lasts for a maximum of 2 hours (Tareke, 1981). The color of the seed coat varies from milky white to dark brown, and the most common seed colors are white, milky white, light brown and dark brown (Ketema, 1993).

Leaf area was recorded as 2-26 cm^2 and leaf blade length of 5 to 55 cm in tambourine plant. (Ketema 1993; Ebba 1975). In general, drought tolerance has been associated with increased leaf stretching properties (Balsamo et al, 2006). Tambourine shows high variation for excised leaf water loss, drought deficiency and leaf water potential, leaf relative water content and stomatal conductivity (Teferra et al, 2000).

Different responses to drought stress were observed among cultivars in relation to leaf canopy temperature at anthesis, with lower yields at higher temperatures (Takele, 2001). Earliness is very important for tambourine to prevent yield losses due to terminal drought. In areas with low rainfall, tef cultivars have a shorter life cycle (Woldeyhannes et al, 2020), while longer growing times and later maturation are associated with increased yield and yield-related traits (Assefa et al, 2002; Chanyalew et al. 2009; Jifar et al, 2015; Tefera et al, 2003; Tadele et al, 2013).

Tambourine formations mature in a period of 40 days from the earliest genotypes to the latest genotypes (Woldeyohannes et al, 2020) and it is therefore important for the improvement for high grain yields to focus on maturity groups targeting different agroecologies. The panicle length in the plant is 39 cm on average, the number of flowers in the spikelet varies between 3-17 depending on the genotypes. Each flower has internal glumes, three stamens and 1 female organ. It has been reported that the small tambourine seeds are hullless and have a flat seed surface formed by reticulated fibers that vary according to varieties or lines but can be seen under advanced microscopes (Kreitschitz et al, 2009). Although it has the smallest seed among the cereal plants, the seeds of the tambourine plant are rich in carbohydrates. (Belay et al, 2006).

3. ADAPTATION

The tef plant, which can adapt to very different climatic conditions, can grow in many growing conditions from dry to rainy conditions. Although the plant can grow even in areas with an altitude of 2800, it grows best at altitudes of 1800-2100 m (Evert et al, 2009; Miller, 2010). Tef plant shows good growth in places where the annual precipitation average is 750-800 mm, especially in areas with 450-550 mm during the vegetation period. The plant, which grows in tropical and subtropical regions, can show good growth at 10-27 °C. The plant, which is a hot climate plant, responds positively to the day length and can bloom for 12 hours (Uke, 2016).

Although it is generally resistant to dry and wet conditions, it can be damaged in long-term dry and oily periods. Since the seeds of the plant are quite small in the soil where Tef plant will be planted, a good seed bed should be prepared by plowing at least 2-5 times. Planting depth of 1-2 cm and 1.5 kg of seed may be sufficient for the plant (Sarı and Tiryaki, 2018). The reaction of tef plant, which is a wheat forage plant, to nitrogen is high, and 4-6 kg of N and 2-3 kg of P_2O_5 are sufficient per decare. (Sarı and Tiryaki, 2018). While giving the nitrogen fertilizer by dividing increased the grain yield, it had no effect on the straw yield (Alkamper, 1973). The absence of weed seeds in the seeds of the tef plant to be planted significantly affects the yield of the teff plant to be planted (Ketema, 1997).

The planted tef plant shows rapid growth within 2 weeks of growth. The period when the soil temperature rises at 5°C is expressed as the best period for weed control, and it is considered appropriate to carry out mechanical control 25-30 days after planting. More fungal and nematode-related diseases have been identified in the cultivated regions (Refera, 2001). Rust (*Uromyces eragrostidisy*) and Cluster blight (*Helminthosporium miyakei Nisikado*) are the most important diseases in this plant. (Cheverton and Chapman,1989; Stewart and Yirouu, 1967; Tareke, 1981). In addition to these diseases, tef borer (Mentaxya ignicollis), which causes great damage to the plant, especially in the leaf and early ripening period, has also been recorded as the most important pests of the plant (Sarı and Tiryaki, 2018).

4. YIELD AND QUALITY

The plant, which is rich in plant phytochemicals, has a very important capacity in meeting the green roughage needed in the middle of summer in terms of livestock. However, despite all the advantages of the plant, the consumption of tambourine has been limited to Ethiopia throughout the world. The leaf/stem ratio of the cultivated Tef plant is 73/27 and the digestibility of the grass is around 65% (National Academy of Sciences 1996). While the current NDF ratio in tef plant is higher compared to cereals, the ADf ratio is close to alfalfa and other cereals (Table 2).

Table 2. Comparison of tambourine with some other forage crops and cereals in terms of feed quality criteria (Source: Mosi and Butterworth 1985; Sarı and Tiryaki 2018)

Components *	Alfalfa Hay	Corncob	Oat Straw	Teff Straw	Wheat Straw
Dry Matter (%)	90,1	91,0	91,9	91,1	92,4
Organic Matter	89,5	88,2	91,9	90,8	89,5
Crude Protein	20,1	5,1	6,2	3,6	2,3
NDF	44,4	75,5	71,2	77,5	76,1
ADF	36,6	51,3	46,6	44,3	51,7
Lignin (Wood Extract)	4,8	4,8	6,6	5,1	6,4
Hemi-cellulose	7,8	24,2	24,6	33,3	24,3
Cellulose	31,8	46,5	40,0	39,2	45,3

*: kg da^{-1}.

With the progression of development in tef plant, which has around 13-16% crude protein, this rate decreases to 6.5% (Kaplan et al, 2016). Compared to the plants such as millet, sorghum, sorghum-sudan grass hybrid, which can contribute significantly to the elimination of our quality roughage deficit, it is important in terms of animal nutrition due to its thin-delicate stem structure and abundant leaves (Sarı and Tiryaki, 2018). The first cutting after planting is done after 50-55 days, and the second cutting is done after 40-45 days. It was stated that the cutting should be done when the plant reaches a height of 8-12 cm and that one should be very careful when pruning due to the weak root system of the plant (Roseberg et al, 2005).

In addition, the most important feature of tef plant compared to other products is that it does not contain gluten.

Tablo 3. Comparison of tef (*Eragrostis tef*) with other cereal crops (USDA, 2016)

	Gluten Free Cereals			Gluten-Rich Cereals	
Ingredient Values (gram / 100 grams)	Tef	Sweetcorn	Rice	Barley	Rye
Water	8,8	10,4	9,4	9,6	10.6
Energy (kcal)	367,0	365,0	354,0	342,0	338.0
Protein	13,3	9,4	7,5	12,5	10.3
Carbohydrate	73,1	74,3	76,3	73,5	75.9
Total fat	2,4	4,7	3,2	2,3	1,6
Raw Fiber	8,0	7,3	3,6	17,3	15,1
Candy	1,8	0,6	0,7	0,8	1,0

It is seen as an alternative plant in terms of the healthy nutritional needs of societies that consume high levels of carbohydrates in their daily diet, such as our country (Sarı and Tiryaki 2018).

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CHAPTER 7

LUPINES (*Lupinus* sp.)

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1. INTRODUCTION

Lupine (*Lupinus* sp.) genus has many annual species. In addition to its high protein and fat content, it is used in both human and animal nutrition with its rich nutritional components. Lupine increases soil fertility with its strong root system and rhizobium bacteria in its roots. According to written records; It was discovered in the late neolithic era, around 3500 BC.

During the Roman Empire, lupine was cultivated in the entire Mediterranean basin (Gladstones, 1998; Kurlovich, 2002). When it comes to 2000 BC, it is stated that white lupine was used for human and animal nutrition as well as for cosmetic purposes in Ancient Greece and Egypt.

With its use in human nutrition, its importance has increased and it has been included in breeding programs. 4% of the lupine produced today is used in human nutrition (as bread, cake, milk, sauce and snacks). Australia has an important place in lupine cultivation area and production. It exported 41% of its production in 2005-2006. It has made a difference by being included in the mixtures of bakery products, especially as an alternative to dry beans and soy, and has been among the products preferred in Germany, the USA and Australia. 95% of the lupine species cultivated in Australia were sweet varieties of blue lupine (Wolko et al., 2011).

World lupine production is 774,000 tons, of which 63% was produced in Australia. Other producing countries are Belarus, Poland, Germany, Chile and Russia. Lupine is Australia's 5th most important (wheat, barley, canola, and oat) crop. Lupine is an important plant with a cultivation area of 1,425,000 ha and a production of 1,968,000 tons in 1997 (Anonymous 2022a). In 2020 the Worlds total cultivation area of lupins was 888,000 ha and production 1,046,170 tons (Faostat, 2022). Sweet lupine is used extensively in human nutrition, especially in Egypt. There are 170 different types of lupine in the world. However, 12 of them are located in the Mediterranean basin. Along with white lupine, 5 different species are cultivated (Hondelmann, 1984). Besides grain production, it is used as a green manure plant.

Traditionally in Turkey, especially in Central Anatolia, it is used as a snack or meal after the bitterness is removed by boiling and roasted. The rate of methionine in the protein structure of lupine seeds is more than 1%. In addition, the ratio of lysine, loysine and serine, which are among the other amino acids that increase the quality of the protein, are at the level of 5%.

Figure 1. Boiled Lupine Seed (Anonymous, 2022b)

Wild and cultivated species are grown in a wide area from the poles to the regions with semi-desert climate. It also grows naturally in East Africa, Mexico, in the highlands of the Andes and Rocky Mountains, in the temperate climate conditions of the southeast of the USA and eastern South America. Gene centers of lupine species were examined in three different groups. It has been determined that the first of these is in North and Central America and the Andes Mountains of South America, the second is in lupines on the Atlantic coast in South America, and the third is in the Mediterranean-Northeast African origins have genetic similarity with each other (Wolko et al., 2011).

The number of local gene centers for lupine species originating from the Old World is quite high. Semi-cultured populations of coarse-grained lupine genotypes were found in the Mediterranean basin and the Nile valley. However, the Southern Balkans including Greece-Crete-Albania and former Yugoslavia, and the western part of Northern Greece, Southern Italy and Turkey are shown as perhaps the first center of genetic diversity of white lupine species.

Species selected from wild lupines collected from nature and planted were found in the Northern Mediterranean basin, the Mid-Atlantic (Azores) islands, the Canary Islands-North Africa (Morocco, Tunisia, Algeria) and the Nile Valley, Kenya and Ethiopia.

Wild populations of yellow lupine (*Lupinus luteus*) are less common than *L. albus* or *L. angustifolius*. True wild forms are not very common. Its origin is the Iberian peninsula, Spain, Portugal. It is stated that the net center of origin is the western part of Spain and Portugal.

The small-seeded wild form *Lupinus luteus* is found in regions with high rainfall in the northwest of Portugal and Spain, and in some sources it is found in Southern Spain, Southern Italy, Greece, Turkey, Moroccan coasts, Israel and Lebanon.

Local ecotypes of *Lupinus luteus* found in the eastern Mediterranean have spread with their wild forms. They are also grown as ornamental plants. It is accepted that they are very closely related species to *L. hispanicus*, which is considered as an ornamental plant. These species are found at high altitudes, usually in the high altitude regions of Spain and Portugal. In the southern and central parts of Spain, there is *L. hispanicus*. *L. hispanicus* is found at average heights, while *L. hispanicus* ssp. *bicolor* grows in northwestern Spain and northern Portugal in poorly drained soils at altitudes above 1500 m. According to some sources, it is also reported to occur in Turkey and Northern Greece. *L. hispanicus* is spread in sandy and sandy-loam soils with acidic or very acidic properties.

L. micranthus has spread on the Mediterranean coast. Over time, it has been replaced by immigration (Wolko et al., 2011).

There are 6 different species of lupine (*Lupinus*) in the natural flora of Turkey (Davis, 1970). Three of these species [white lupine (*Lupinus albus*), yellow lupine (*Lupinus luteus*) and blue lupine (*Lupinus angustifolius*)] are found in the natural flora, especially in the Mediterranean coastal belt. In addition to natural selection, white lupine has been found to have a wide genetic diversity in terms of morphological, agronomic and molecular marker levels (Gilbert et al.,

1999) as well as breeding studies (Lagunes-Espinoza, 2000; Mülayim et al., 2002; Jansen, 2006). Until recently, significant progress has not been made in lupine breeding and the expectations of the producers have not been met. Therefore, the cultivation of the old varieties continued. However, it started to gain importance again with the promising results in the studies carried out.

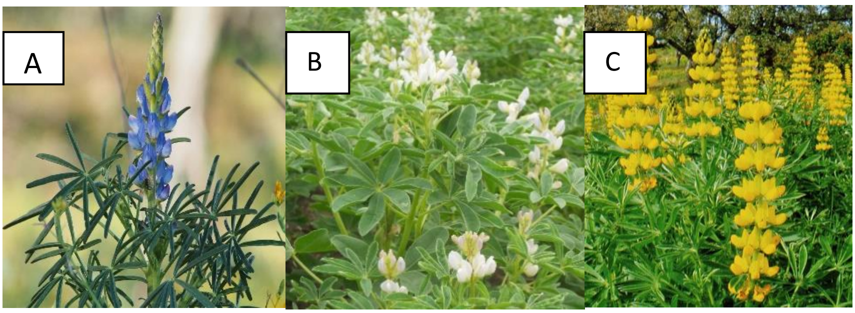

Figure 2. Flowers of the A) Blue Lupine (*Lupinus angustifolius*) (Anonymous, 2022c), B) White Lupine (*Lupinus albus*) (Original), and C) Yellow Lupine (*Lupinus luteus*) (Anonymous, 2022d)

White lupine (*Lupinus albus* L.) is grown in Isparta, Konya and Burdur in Turkey with names such as termiye, tirmis and jew bean. A significant part of the production area (approximately 25%) in Turkey is located in Doğanhisar (Deşdegin village) district of Konya province (Mülayim and Semerciöz, 1992; Özkaynak et al., 1994).

70% of the vegetable protein need in Europe is met from soy (Lucas et al., 2015). Research to reduce dependence on soy protein and meal has increased the interest in lupine species. The high protein ratio of white lupine is available as a protein source in rations as well as in human nutrition. It is possible to increase the amount of organic matter in the soil with its strong root system. In the studies carried out, an average of 450-650 kg/da seeds were taken from white lupine species grown in winter in the Thrace part of Turkey. Since it is an important protein source in animal nutrition, it has become widespread in recent years that white lupine can be considered as an alternative plant to soybean.

2. SYSTEMATIC AND MORPHOLOGY

Lupine is in the *Lupinus* genus of the *Luppineae* tribe of the *Papillionaceae* subfamily of the *Legumunacea* family. Within the genus *Lupinus*, the number of chromosomes varies from 2n=32 to 2n=96. Lupine species cultivated as forage crops are annual (Mülayim and Acar, 2009; Açıkgöz, 2021).

A strong and thick main root goes down to a depth of 1-2 m. Underdeveloped lateral roots spread to the upper layers of the soil. There are nodosites on the roots. Its body is thick, rounded and develops upright. It grows to approximately 1.20 – 1.50 cm. The stems become woody towards maturity. The leaves are located at the end of a long petiole consisting of 5-15 leaflets, combined in the center. In white lupine, the leaves are broad and large. The leaflets are oval, egg or lance-shaped and hairy, depending on the species. Auricles are narrow, pointed towards the tip, and their surface is covered with fine hairs (Mülayim and Acar, 2009; Açıkgöz, 2021).

Figure 3. White Lupine (*Lupinus albus* L.) (Original)

The flowers are bunch-shaped and located at the end of the stems. The number of flowers on the stems can vary. The flowers are large and sparsely arranged on a long stalk. The leaves are green in color. The color of the petals varies according to the species. For example, it is white in white lupine, blue in blue lupine, and yellow in yellow lupine. The state of the male organs is monodelphouse. Although it is a self-pollinating plant, it is cross pollinated at 9%.

Figure 4. White Lupine (*Lupinus albus* L.) (Original)

The pods are flat and 5-15 cm long. The number of pods per plant was determined as 11-19 in Thrace region (Orak and Tuna, 1994), in Ödemiş conditions 33.7 - 47.3 (Okuyucu et al., 2004), and in Germany 19-23.

Figure 5. Pods od White Lupine (*Lupinus albus* L.) (Original)

There are an average of 2-9 seeds in the pod. The number of seeds in the pod is 3.03-3.44 in Central Anatolia conditions (Mülayim and Semerciöz, 1992), 4.87-4.94 in Tekirdağ conditions, 3-6 in Germany (Schuster, 1992), 4 in Ödemiş conditions. They reported that it varies between, 2-4.4 (Okuyucu et al., 2004). The seeds are generally flat and the hilum is very prominent. Seeds can be in colors ranging from white, gray to brown. The weight of a thousand grains varies according to the species and is between 30-850 g (Mülayim and Acar, 2009; Açıkgöz, 2021). In some studies, thousand grain weight is 150-200 g (Gençkan, 1983), 188-254 g (Orak and Tuna, 1994), 289-339.8 g (Mulayim and Semerciöz, 1992), 120-180 g (Açıkgöz, 1995). 101-401 g (Özkaynak et al., 1992).

Figure 6. Pods and Seeds of White Lupine (*Lupinus albus* L.) (Original)

3. ADAPTATION

Lupines are generally grown in coarse, acid-neutral, slightly alkaline and well-drained soils. It is stated that *L. mariae josephi*, an old world origin lupine species, likes calcareous soils. White lupine shows good growth in moderately acid or neutral light to medium textured soils. Yellow lupine (*L. luteus*) grows slowly in sandy, acidic soils. *L. micranthus* has also been found in moderately acidic to moderately acid soils. However, it has spread extensively in sandy loam soils. It is mostly spread on coarse sandy, heavy and mostly calcareous soils. An important feature of lupine is that it can easily adapt to soil conditions that other plants cannot tolerate (Hill, 1977). It is more tolerant of salty and heavy soils than other species (Jansen, 2006). Lupine is used in the rehabilitation of abandoned areas with mercury mines in Europe. It has a special importance because it improves the structure of the soil where it is grown faster than other legumes. They tolerate some toxic, polluting compounds, heavy metal accumulation in the soil. It is grown in areas that are not suitable for legumes such as beans, chickpeas, cowpeas and peas.

Lupine species prefer moist and cool days after planting, and clear and sunny days during pod formation. High relative humidity in the vegetative period accelerates development. A temperature of 3-4°C is required for germination. Generally, lupine species are not sensitive to cold. Likewise, white and blue lupine species grown in Turkey are also cold tolerant. However, especially blue lupine begins to be damaged after -10°C. In white lupine, some varieties can withstand temperatures down to -13 and -14°C. There are summer and winter varieties of lupine. High temperature and drought damage the fertilization of flowers and reduce seed yield. It is not shade tolerant. It is resistant to drought (Mülayim and Acar, 2009; Açıkgöz, 2021).

Figure 7. Seedlings of White Lupine (*Lupinus albus* L.) (Original)

4. YIELD AND QUALITY

A seedbed cleared of weeds and crumbled is sufficient for sowing lupine. It is necessary to inoculate with the sowing Rhizobium lupini bacteria in areas where lupine has not been grown before. Lupine species are sensitive to phosphorus deficiency. In phosphorus-poor soils, 5-10 kg/da of P_2O_5 is sufficient. Optimum plant density and sowing rate in lupine vary according to varieties, climatic conditions of the region, soil structure and cultivation method (Açıkgöz, 2021). The amount of seeds to be planted per decare is 30-32 kg/da. Sowing with row spacing between 20-40 cm is recommended at most. Sowing depth is 2-4 cm (Mülayim and Acar, 2009; Açıkgöz, 2021). Lupine is sensitive to weeds, especially in the first development period. For this reason, weed control should be done immediately before sowing and after emergence.

Among the lupine species, yellow and blue lupine are used as green and dry forage, silage or green manure. Although lupine species have high forage yields, they are of low quality and not very palatable for animals. The alkaloids in it affect the quality especially negatively. In the chemical analysis, it was found that the herb is very rich in carotene in sweet white lupine varieties, and it is not much different from alfalfa in terms of other chemical compounds. However, it has been understood that animals do not prefer these varieties because of the thick stem of the plant and the hairiness of the leaves. Lupine is not suitable for hay production due to late drying of plants and shedding of leaves. It is recommended to be ensiled during the full pod ripening period. Due to the low dry matter content, it is recommended to be siled with cereals such as wheat, oats, etc.

Maturation does not occur in all pods of the plant at the same time. In this respect, harvest time is important for seed harvesting. In late harvest, pods may crack and grain loss may occur. It is not easy to determine the harvest time in lupine with cracked pods, and it should be harvested when half of the pods on the main stem are brown. Seed harvesting can be done by hand or with a harvester. Since there is no uniform maturation at harvesting by hand, the harvested plants are left to dry for threshing in bunches. The grains are separated from the dried plants with a threshing machine (Mülayim and Acar, 2009; Açıkgöz, 2021).

An average of 100-200 kg/da seed yield is obtained from lupine. 200-250 kg/da seed was harvested from lupine sown in winter in Thrace region (Orak and Tuna, 1994; Orak and Nizam 2003; Tenikecier et al., 2017). In the studies conducted in Ödemiş and Bayındır plains, 232 kg/da grain yield was obtained from white lupine, 271 kg/da from blue lupine and 150 kg/da from yellow lupine (Okuyucu et al., 2004). In another study, the seed yield of white lupine was determined as 250-300 kg/da (Salman et al., 2011).

Figure 8. A view from Lupine Field (Original)

The biological value of lupine seeds, which are high in protein, is lower than soy, but the energy value is close. The amino acid composition is also not much different from soy. For this reason, lupine has started to be emphasized in animal breeding. Lupine seeds are very rich in protein and oil. They are known as the most protein-rich legumes other than soy. Although the analyzes give different results, in general, the lowest (25-35%) crude protein content is found in blue lupine seeds and the highest (40-50%) in Andean lupine seeds. Its fat content is much higher than many legumes. Oil content of white lupine seeds varies between 8-14%. The oil rate was found to be 8-9% in the native white lupine seeds. It contains many unsaturated fatty acids. Most of them are oleic acid (Hill, 1977; Williams, 1984; Huyghe, 1997; Küsmenoğlu et al., 1997; Anonymous, 2013; Lucas et al., 2015).

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CHAPTER 8

BLUE FENUGREEK (*Trigonella caerulea* (L.) Ser.)

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1. INTRODUCTION

The blue fenugreek is named as blue-white trigonella, blue melilot, blue-white clover and curd herb in different countries in the world, it is known as Siminduh (сминдух) in Bulgaria, and utskho sunnel (უცხო სუნელი), a salty spice mix in Georgia and Caucasus (Rodov et al., 2010)

The plant has not been cultivated and today it is primarily used as a herb obtained by collecting/harvesting from nature or as a medicinal and aromatic plant by grinding the dried herb obtained after drying in the shade (Arslan et al., 2016). Differently from the fenugreek (*T. foenum-graecum* L.), which is cultivated and also known as buy grass, boy grass, pitlan grass or piltan grass in Turkey, it is called “Poy” in the Balkan countries and Thrace (Ateş, 2012; Ateş and Seren, 2020) milled blue fenugreek is used as a spice. The plant is indispensable for the production of Sapsago, Schabzieger and Serred Vert, which are Swiss and world-famous flavored green cheeses shade (Arslan et al., 2016).

Blue fenugreek is a herb used in the cuisines of the Alpine region, Western Europe, the Balkan countries, the Caucasus, especially in Georgia, the Thrace region of Turkey, and the regions on the Asian-European border, and it is rarely used outside of these regions. Leaves and flower heads are most commonly used in cuisines (Fedosiy et al., 2022). It is the most commonly used spice in making Brotwuerze, a rye bread made in the Alpine region, and it gives it a unique taste. The herb is chopped and subjected to a short-term fermentation process, as a result of which it acquires a very strong unique flavor (Katzer, 2008). This fermented minced herb is mixed into bread dough, sometimes dry herb is ground and mixed into bread dough.

Dry matter contains 0.09-0.11 % (w/w) essential oil and has essential oil components in different proportions (Tenikecier et al., 2022). Interesting phytochemical content can be obtained from the herb and its seeds in terms of steroids, flavonoids and alkaloids (Anonymous, 1994). In addition, diosgenin ($C_{27}H_{42}O_3$) (min. 0.2%) is dominant in the seeds of the plant and there are various steroidal saponins in different amounts (Skaltsa, 2002). Blue fenugreek is one of the species that has been attempted to be used especially as a source of the steroidal diosgenin (Hardman, 1969). However, its seeds contains choline ($C_5H_{14}NO^+$), semi-crystalline white saponin, various gums and animal lactation stimulating oil. Herbs and seeds of the plant also contain trigonelline ($C_7H_7NO_2$), which is known to have hypoglycemic and hypocholesterolemic properties (Allen and Allen, 1981; Skaltsa, 2002; Tenikecier et al., 2022).

Glycosides of furost-5-en-3β,22,26-triol connected with the sugars glucose, rhamnose ($C_6H_{12}O_5$) and xylose ($C_5H_{10}O_5$) in different orders of bonding were isolated from the seeds. (Kogan and Bogacheva, 1978). (25S)-Spirostadiene, diosgenin, gitogenin and its 25S-epimer neogitogenin, but not tigogenin, neotigogenin or yamogenin, were obtained (Bogacheva et al., 1976); methanol extract of the seeds yielded the 22-methyl ether of protodioscin, assigned as 3β-(α-L-rhamnopyranosyl) (1→4)-α-L-rhamnopyranosyl-(1→2)-(β-Dglucopyranosyloxy)-22-α-methoxy-25R)-furost-5-en (Bogacheva et al., 1976). The sterolic composition of the seeds of is characterized by lower amounts of cholesterol, pollinastanol and Δ^5-avenasterol, and high levels of sitosterol ($C_{29}H_{50}O$), sigmasterol and 24-methyl cholesterol. Low amounts of Δ^7-cholesterol, 24-methylene-cholesterol, Δ^7-campesterol, stigmastanol ($C_{29}H_{52}O$) and fucosterol ($C_{29}H_{48}O$) were detected (Brenac and Sauvaire, 1996). Kaempferol ($C_{15}H_{10}O_6$) and quercetin ($C_{15}H_{10}O_7$) were detected in hydrolysates from flowers of the plant (Jurzysta et al., 1988). The content of isoflavonoid phytoalexins are ratio 10:1 of medicarpine ($C_{16}H_{14}O_4$) and maackiain ($C_{16}H_{12}O_5$). Aesculentin ($C_9H_6O_4$), scopoletin ($C_{10}H_8O_4$) and coumarin ($C_9H_6O_2$) are found in the plant as phenolic compounds. Due to its coumarin content, it is diuretic, digestive, antispasmodic and slightly hypnotic (Fournier, 1948; Skaltsa, 2002).

The nitrogen-rich non-protein amino acid, L-(+)-(S)-canavanine ($C_5H_{12}N_4O_3$), although it seems to be unique to the *Fabaceae* subfamily *Faboideae*, does not occur in all species or genera. It is particularly abundant in a free state in the tribe *Trifolieae*. It was found in blue fenugreek, Arabian fenugreek (*T. arabica* Del.), fenugreek. L-(+)-(S)-canavanine is absent from *T. berythaea* Boiss. ex Bl., *T. schlumbergeri* Boiss. and *T. stellata* Forssk. (Birdsong et al., 1960; Bell et al., 1978; Skaltsa, 2002). The most important aromatic compounds of the plant are pyruvic acid ($C_3H_4O_3$), alpha-ketoisocaproc acid ($C_6H_{10}O_3$), alpha-ketoisovaleric acid ($C_5H_8O_3$) and alpha-ketoglutaric acid ($C_5H_6O_5$)

(Ates, 2016). Hardman and Fazli (1972) state that blue fenugreek is used in Switzerland for phytotherapy.

Blue fenugreek is also used as a forage crops (Taşdelen and Ateş, 2022). In the Balkan countries and southeast Europe, it is being evaluated by grazing animals in natural meadow-pasture areas or harvested for silage production.

It will also be able to benefit from its soil improvement after being domasticated. When it is plowed in the soil during the flowering period in places where the annual precipitation is 500-600 mm, it increases the organic matter of the soil and increases the soil fertility by gaining the nitrogen it provides with the help of the large number of nodules in its roots. Blue fenugreek when used as green-manure crop yield as much as 11.780 kg ha^{-1} of green matter. The green-manure crop can be grazed lightly in spring, or be turned under after the seed has been harvested. In addition, it can be preferred in crop rotation systems, because leaves the land with a short vegetation period (Tenikecier et al., 2022).

The bee species' visits are quite high, as the flowers, the attractiveness of the scent of the flowers and the high nectar production. Blue fenugreek is a species that can be important in beekeeping due to these characteristics (Figure 1).

Figure 1. Bee on blue fenugreek head (Original)

2. SYSTEMATIC AND MORPHOLOGY

Blue Fenugreek is in the subgenera *Trifoliastrum* of genus *Trigonella* L., *Fabales* order, legumes (*Fabaceae*) family, butterfly-flowered (*Faboideae*) subfamily, *Trifolieae* tribe, *Trigonellinae* sub-tribe. Only one of the approximately 135 species in this genus grows in Australia. Other species are distributed in the arid areas of western Asia, the Mediterranean region, northern and southern Africa and southern Europe (Akan et al., 2020). The primary origin of blue fenugreek is the Thrace region of Turkey, the Balkan countries, the Mediterranean region, the Caucasus and central, southern and eastern Europe (Ates, 2011; 2016, Arslan et al., 2016). The plant was first named *Trifolium caeruleum* L. by Linnaeus (1753). Blue fenugreek, also known as blue melilot (*Melilotus caeruleus* (L.) Desr.) (Ates, 2011; 2015, 2016; Ateş and Seren, 2020; Tenikecier and Ates, 2020; Fedosiy et al., 2022), differs morphologically from many species in the *Trigonella* L. genus (Ates, 2015). The plant has a taproot goes about 50-100 cm deep, the lateral roots do not get too long. Numerous nodules are formed on the lateral roots. There are 1-5 branches on the non-woody stem and its diameter is 3-6 mm. The stem that grow vertically is hairless and can be 10-125 cm in length (Figure 2).

Figure 2. Vertically growing of the blue fenugreek (Tenikecier et al., 2022)

The cross section of the stem is nearly round and hollow. The stem of blue fenugreek is less branched and slender and bear trifolioliate compound leaves. Leaves are two-ranked in alternate phyllotaxy, with slender stipules adnate to the petiole. The petiole is 0.5-9 cm long. At the junction of the petiole with the stem, there are lanceolate stipules 0.3-1 cm in length. The leaflets, which are oblong, or ovate-oblong and wedge-shaped towards the bottom, are attached to the petiole with pedicels. The pedicel of the middle leaflet, which is larger than the two leaflets on the sides, is longer, 2-5 cm in length and 0.5-4 cm in width.

The leaves are similar to alfalfa but differ from alfalfa and fenugreek by the complete toothed of the margins of all leaflets (Figure 3). The number of leaves on the main stem varies between 15-24 (Ateş, 2012).

Figure 3. Blue fenugreek leaf (Tenikecier et al., 2022)

Changes in some morphological characters of the plant in different groth stages are also seen in the researches. (Table 1).

Table 1. Some morphological chracters of blue fenugreek at different growth stages (Ates, 2011; 2015; Ateş and Seren, 2020; Tenikecier and Ates, 2020; Taşdelen and Ateş, 2022.)

	Growth Stages		
	Pre-bud	50% bloom	Full-bloom
Plant height (cm)	95.91	76.15-99.05	67.74-100.43
No. of leaves per main stem (pcs)	12.5	19.33	19.03-28.29
Leaf length (cm)	7.63	7.62-8.32	4.70-9.00
Leaflet width (cm)	0.85	3.68-4.20	1.44-2.63
Leaflet length (cm)	4.27	0.88-1.89	3.46-5.25

Blue, whitish blue, purplish blue and purple colored flowers that develop at the shoot apex with the transition from vegetative to the generative period, are head, in the early stage on 1-8 cm long stems coming out of the leaf axil (Figure 4). Each flower primordium is determinate and produces a calyx, a corolla, ten stamens, and a pistil. The corolla is 5-6 mm, and the calyx is 3 mm in length. The papilionaceous corolla is highly evolved and consists of five petals: a large standart (banner), two lateral wing petals, and two fused petals that from the keel. After pollinisation, this head form takes the appearance of raceme. The number of flowers in the racemes varies between 10-85. The number of flowering days varies between 180-220 days in winter sowing and 80-120 days in spring sowing. The oblong-shaped ovary contains 1-7 eggs. The pod (3-4 mm long), formed after self-fertilization, has an egg-like shape and a 1-2 mm long beak at the tip. Pods usually contain 1-2 seeds (Figure 4; Shu, 2010). Hard surface seeds are dull yellow, deep golden or yellowish brown color, with a high hardseededness ratio (85-98%) and the thousand seed weight varies between 1.8-2.3 g (Ateş, 2012).

Figure 4. The flower heads of blue fenugreek (Tenikecier et al., 2022)

Figure 5. The seeds of blue fenugreek (Tenikecier et al., 2022)

3. ADAPTATION

Blue fenugreek is an annual, cool and temperate season plant with 2n=16 chromosomes (Badrzadeh and Ghafarzadeh-namazi, 2009). It can be grown successfully in winter without irrigation in places where the winter temperature does not fall below -10°C and the annual precipitation is 450-1200 mm. Blue fenugreek, which is not very selective in soil conditions, grows well in deep, well-drained, lime and phosphorus rich soils with a 6-8 pH (Ates, 2011).

Planting should be done to soils that have been crushed with second-degree tillage tools, suppressed, weed-free, with sufficient moisture and plant nutrients, at least one month before the first frost date of autumn according to the climatic conditions of the region (in places where the temperature does not fall below -10 ° C) or in early spring.

Because of the seeds are small, sowing can be done using a suitable sowing machine. Sowing depth should be 1 cm and row spacing should be 20-25 cm. 30 kg ha^{-1} seed is sufficient for sowing (Tenikecier and Ates, 2020). Blue fenugreek rarely lodges when cultivated properly. With the sowing, 30-50 kg ha^{-1} nitrogen and 50-100 kg ha^{-1} phosphorus should be given in the soils that are deficient. Nitrogen fertilization is not recommended for the periods after sowing. In order to the seedlings formed after emergence are quite small (Figure 6), weed control should be done properly. On account of the seedlings formed after emergence are quite small (Figure 6), weed control should be done properly.

Figure 6. The emergence of blue fenugreek after sowing (Original)

4. YIELD AND QUALITY

The blue fenugreek is useful in livestock feed programs as herbage, temporary pasture, silage and soilage (green-chop). If stands are established in early fall, light grazing can begin in early spring, it should be grazed to heavily in the late spring. The highest quality herbage is cut from plants at the full-bloom stage (Figure 7). In this stage, 8-12 t ha^{-1} herbage yield and 0.5-4 t ha^{-1} hay yield can be obtained from the blue fenugreek. Its hay contains 17-21% crude protein, 31-45% NDF (neutral detergent fiber) and 28-33.45% ADF (acid detergent fiber) (Ates, 2011; 2015; Ateş and Seren, 2020; Tenikecier and Ates, 2020). Its hay contains potassium (K), calcium (Ca), phosphorus (P) and magnesium (Mg) between 2.40-2.55%, 1.48%-1.56%, 0.60-0.68% and 0.40-0.45%, respectively (Tenikecier and Ates, 2020).

Silage from blue fenugreek and blue fenugreek-grass mixtures are an excellent feed for ruminants. For maximum silage yields, it should be ensiled when it is slightly pass the full-bloom stage.

20-100 kg/da seed yield can be obtained from the harvest made when the pods in the racemes are completely dry.

Figure 7. The blue fenugreek at full-bloom (Original)

In addition, the herbage and hay yields and quality of the plant may change in different growth stages. Some quality characteristics and herbage and hay yields of blue fenugreek at different growth stages is given in Table 2. (Ates, 2011; 2015; Ateş and Seren, 2020; Tenikecier and Ates, 2020).

Table 2. Some quality characteristics and fresh and dry forage yields of blue fenugreek at different growth stages

	Growth Stages		
	Pre-Bud	%50 Bloom	Full Bloom
Leaf/Stem Ratio	0.94	0.77-0.88	0.57-0.94
Herbage Yield (t ha^{-1})	8.88	9.21-9.79	7.78-11.78
Hay Yield (t ha^{-1})	2.53	2.49-2.73	1.95-3.74
Crude Protein (%)	20.67	17.35-19.38	17.00-18.88
NDF (%)	39.09	40.19	40.00-45.22
ADF (%)	28.24	29.44	27.84-33.45

With high nutritional value, before grazing the blue fenugreek, pre-feeding should be done in order to eliminate the risk of swelling in ruminants, or it should be sown with a suitable grasses (*Poaceae* spp.) in mixture. Dry matter contains essential oil and has aromatic essential oil components in different proportions. This aromatic feature of the hay may impair the quality of animal products, it should be present in very small amounts in the rations.

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CHAPTER 9

COMMON REED (*Phragmites australis* (Cav.) Trin. Ex Steud)

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1. INTRODUCTION

Phragmites australis (Cav.) Trin. Ex Steud is an essential component of lakes, rivers, and wetland habitats (Shaltout et al., 2006). Additionally, this plant species extends in all water-containing environments, including irrigated or bottomlands and drainage channels (Ozer et al., 1999). It is a cosmopolitan, perennial macrophyte species capable of generating high biomass. It is the most typically grown plant species in wetlands built for wastewater treatment universally due to its high biomass production and nutrient uptake (Tanaka et al., 2016). Wetlands have a critical role in preventing flooding, improving water quality, providing ideal conditions for fishing and hunting activities, and functioning as a source of fossil fuels such as coal and oil. As enclosing a transition feature between terrestrial and aquatic ecosystems, wetlands are excessively rich in biodiversity and constitute a critical function for plants that spread in these areas (Leblebici et al., 2013). Reeds (Typha), common reeds (Phragmites), water lilies (Nymphaea), and tamarisks (Tamarix) are the most prevalent plant species in these environments (Yildiz Karakoc, 2017). Common reed has recently received mounting attention due to its high levels of nitrogen (N), neutral detergent fiber (NDF), potassium (K), and magnesium (Mg) content, as well as its capacity to yield high-quality roughage (Tanaka et al., 2016). However, the common reed plant is commonly utilized in our country to construct roofing materials and some ornaments in addition to using it as buffaloes and sheep feeding material living in swampy areas (Buyukkilic Beyzi and Sirakaya, 2019). This plant's high concentration of bioenergetic components, especially cellulose and hemicellulose, makes it suitable for biofuel production (bioethanol) (Elhaak et al., 2015). Some European nations consider it a biofuel source due to its high energy content (4509 kcal kg^{-1}). The plant also serves as a raw material in the paper industry due to its high cellulose content (Williams et al., 2013; Lewandowski et al., 2003; Williams et al., 2007; Mack, 2008; Angelini et al., 2009; Kering et al., 2012). Yet, it also induces quality degradation in the habitat for larvae and young fish (alevin) (Hudon et al., 2005). Besides, even if it is used successfully in wastewater cleaning, it is a weed actively fought against by using different methods due to the harm it causes to the economy in many parts of the world (Clayton, 1967; Tursun et al., 2006). For instance, common reed (*Phragmites* spp.) is among the weeds that concerned as a problem in railways (Saefl 2001). Additionally, several weeds, including common reed plants, may damage the mechanical parts of airplanes near airports. In particular, these plants are host to several bird and insect species, which are undesirable in the vicinity of the airfield. Twenty-six phytophagous insect species host the common reed plant in total (*Phragmites australis*) (Tscharntke, 1999). A study conducted in Minnesota, USA, reported that red-winged blackbirds host on a common reed (*Phragmites* spp.) (Faulkner, 1966). Dense reed stands reduce the quality of wetland habitats for migratory waterfowl, lowering the overall diversity of bird species. Moreover, it makes wetlands more prone to fire (Mal and Narine, 2004). On the contrary, its roots and rhizomes typically hinder soil erosion (Kelin, 2011). *P. australis* is also among the plants with the lowest potential for global warming and greenhouse gas emissions. *P. australis* in wetlands alone can reduce greenhouse gas emissions by approximately 33% (Yapicioglu and Gulsen, 2021). As a C3 plant, the common reed is a facultative halophyte that grows well in high salinity up to 30%, accumulating amino acids and sugars to sustain their osmotic potential and cell turgor (Srivastava et al., 2014). The waxiness of the leaves, the shape-density of the inflorescences, and the way of growth display remarkable morphological heterogeneity owing to the plant's genetic diversity. Its chromosome counts vary widely from 2n = 24 to 2n = 96; however, the most common number is 2n = 48. There may be striking physical distinctions in the appearance of plants, even across adjacent clones (Shaltout et al., 2006).

2. SYSTEMATIC AND MORPHOLOGY

2.1. Systematic

P. australis (Cav.) Trin. Ex Steud species is a member of the Poaceae family belonging to the Arundinoideae subfamily and Phragmites genus (Srivastava et al., 2014; Packer et al., 2017). The genus Phragmites' name originates from the Greek word 'phragma,' referring to fence or compartment. The term the Australis for species denotes ‘south’ in Latin, referring to the warm regions where the species was first identified (Shaltout et al., 2006). The genus Phragmites retains four species (*P. australis, P. japonicus* Steud., P. karka (Retz.) Trin. Ex Steud. and *P. mauritianus* Kunth.) recognized by the World Checklist of Poaceae, IUCN and The Plant List (Packer et al., 2017).

2.2. Morphology

The emergence process in ordinary populations commences in the late summer with bud sprouting, which forms a horizontal rhizome adjacent to the base of one of the rhizomes from the previous season. The rhizome elongates about 1 m (0.1-2.0 m) before the tip becomes vertical and remains dormant near the surface until the bud emerges in spring. This cycle is resumed annually. A few buds may endure to sprout in the late summer from around the top of the vertical rhizomes from the previous year (approximately 20 cm) and emerge as second-year stems (shorter and thinner than the first year) or horizontal rhizomes. Depending on the degree of degeneration, side buds may develop rhizomes or aerial shoots horizontally or vertically (Packer et al., 2017). The plant reproduces by rhizome and seed (Buyukkilic Beyzi and Sirakaya 2019). It is attainable to grow mature common reed stems from the underground stem or buds of the plant within three years. The spread of the rhizomes by water, animal, and people may eventuate in dispersion in areas where water currents are slower so that new shoots emerge. With above-ground stem formation, the plant's spreading pace, which potentially reaches up to 2 m with rhizomes, may escalate to 5 m per year (Haslam, 1973). Haslam (1972) reported that the plant's underground parts produce over 200 rhizomes m^{-2}.

2.2.1. Stem

The plant height may range from 3 to 9 m depending on the climate and variety (Buyukkilic Beyzi and Sirakaya, 2019). Shaltout et al. (2006) reported that the plant height varies between 2.5 and 4.5 m (occasionally 6 m) in dry conditions, albeit longer in wet conditions. Plants collected in the summer and winter from various locations ranged in height between 1.50-3.80 m and 2.10-4.80 m, respectively (Elhaak et al., 2015). The plant stems are hollow, simple,-and erect with a 5-15 mm diameter thickness. Stems have hollow internodes. The dead stems from the previous year's development and frequently remain standing (Klein, 2011).

2.2.2. Rhizomes, Aerial Stems, and Stolons

Each node bears a small, scale-like leaf and bud. Internodes are usually 5-25 cm long; however, they are potentially longer on horizontal rhizomes. The widest rhizomes are horizontal rather than vertical, and primary rhizomes are typically larger than secondary branch rhizomes. These immense, horizontal rhizomes usually culminate with vertical rhizomes, and the ratio of these two types varies depending on hydrology, nutrients, ecotype, and potential genotype. For instance, extensive and complex rhizome system predominates vertical rhizomes in favorable habitats in the wetlands of Breckland and the Netherlands. A dense mass of rhizomes grows 20–100 cm below the surface (Figure 1 d; Packer et al., 2017). They potentially retain their viability for 3 to 10 years (Mal and Narine, 2004). For instance, their average vegetation period extends 3-6 years or even longer in East Anglia and northwest Scotland (Haslam, 1972). The growing potential of its rhizomes ranges from 2 m to 20 m per year (Batterson and Hall, 1984). Even in areas where *P. australis* succeeds in growing in open water, the rhizomes may develop into aerial stems at the soil surface. Sclerenchyma-reinforcing tissue is present in aerial stems, which in most climates harden over the summer to become brittle stems before withering in the fall. In milder regions, longer stems may survive two consecutive years without experiencing frost. Vertical shoots may occasionally descend to the ground or the water surface, laying there as stolons. An individual stolon potentially grows up to 10 m tall with more than 70 stem shoots per stolon (Fig. 1e). In wet habitats, the plant may generate stolons along the water in late spring (May) in southern Europe (i.e., Malta) and midsummer (July) in England (Packer et al., 2017).

2.2.3. Leaf

Rhizome and stem nodes are capable of producing leaves. These leaves on the rhizomes are scale-like and smooth. Initially, aerial stems also develop scale-like leaves (Packer et al., 2017). Leaf shape varies from linear to lanceolate linear. Leaves are usually 15-40 cm long, 1-4 cm wide and have a spiky structure (Figure 1a). They tend to shed as they mature. The leaf sheath is glabrous or finely pilous with a flexible texture. The leaf ligule is 0.2-0.6 mm long and covered by a pilous structure (Figure 1b; Kelin, 2011). There are many stomata on the upper and lower surfaces of the leaves (Packer et al., 2017).

2.2.4. Clusters, Flowers, and Seeds

Flower clusters are violascent while young, albeit straw-colored in the mature, measuring 15-35 cm long and 6-20 cm wide (Figure 1c). The spikelets are 10-18 mm long and pose a hairy texture with 6-10 mm long on their stems. Each spikelet possesses 3 to 10 blooms (Fig. 1 f). The measures of lower glumes measure 3-7 mm in length, whereas the upper glumes are 5-10 mm (Fig. 1 g). The seed length is approximately 2-3 mm. Each shoot may yield up to 500-2,000 seeds; however, they often retain a low germination rate (Kelin, 2011). Naturally, the seeds have the potential to maintain their viability for five years (Mal and Narine, 2004).

2.2.5. Root

Numerous horizontal rhizome nodes (but not all) give rise to roots (2-4 mm in width). Root mass may extend from 50 cm depth in flooded areas to 4 m depth where hydrology fluctuates considerably. There are short and narrow roots in vertical rhizomes (Packer et al., 2017).

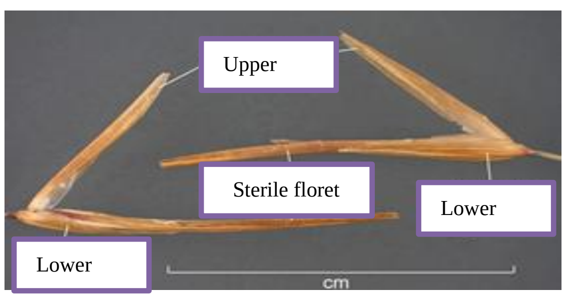
a) Leaf

b) Long-hairy ligule

c) Young (left) and mature (right) inflorescences

d) Rhizomes

e) Stolons



f) A six-flowered spikelet

g) Two-spikelet with glume and a sterile flower

Figure 1. *Phragmites australis* a) Leaf (Fewless, 2003), b) Long-hairy ligule (Klein, 2011), c) Young (left) and mature (right) inflorescences (Fewless, 2003), d) Rhizomes (Fewless, 2003), e) Stolons (Fewless, 2003), f) A six-flowered spikelet (DiTomaso, 2007), g) two-spikelet with glume and a sterile flower (DiTomaso, 2007).

3. ADAPTATION

P. australis is a species that transitions between two closely related habitats, aquatic and terrestrial ecosystems, and is usually observable in swamp wetlands (Srivastava et al., 2014). *P. australis* is the most widespread and flowering plant globally and is found prevalently in North and South America, Europe, Asia, Africa, and Australia Continents. Its adaptation extends from Eurasia to 70º north to across the Southern Temperate Zone. This plant abundantly prevails in temperate zones, particularly in the Old World; however, it is also prevalent in subtropical regions (Holm et al., 1977; Shaltout et al., 2006). However, the regions where it is most common are typically the Mediterranean, the Middle East, and India. Lakes and wetlands called the 'Region of Lakes' are the natural habitat of this species in Turkey. Lakes of Kayseri Yay, Afyon Eber, and Ankara Mogan are among those zones. Additionally, the species is potentially visible in the cities of Bolu, Istanbul, Iğdır, Kars, Ardahan, Kastamonu, Hakkari, Bitlis, Adıyaman, Afyonkarahisar, Burdur, Erzurum, İzmir, Kocaeli, Konya, Balıkesir, Kütahya, Malatya, Manisa, Muğla, Rize, and Tekirdağ (Baytop, 1969; Dogan, 2017). Apart from these regions, the wetlands of the Aegean Region Gediz Basin are one of the regions where this species is most naturally found (Aydogan and Demiroglu Topcu, 2022a,b).

4. YIELD AND QUALITY

4.1. Forage yield and quality

Although the plant production ranges between 12-30 t ha^{-1}, it is achievable to harvest a yield of 12-18 t ha^{-1} in the case of 2-3 cuttings throughout the year (Grzelak et al., 2014). Kobbing et al. (2013) reported that *P. australis* corresponds to a feeding value of 13.31 kg per kilogram of oats, making it a viable fodder crop for grazing; or harvesting and storing in the spring and summer. Scientists have documented that domestic animals such as cows, sheep, and others have grazed the *P. australis* during spring and summer for centuries. Furthermore, the species was used extensively as a forage crop for buffalo, cows, sheep, cattle, goats, and donkeys in Scandinavia, the Netherlands, and China (Kobbing et al., 2013). Duke (1983) reported that *P. australis* retained 11.4% protein, 2.3% fat, 42.1% carbohydrates, 31.1% crude fiber, and 10.8% ash; consequently, it could be utilized as a high-quality forage crop for cattle and horses and harvested for its fodder. According to Baran et al. (2002), *P. australis* had a high Mg (2.65 g kg^{-1}), K (10.9 g kg^{-1}), and Mn (97.0 mg kg^{-1}) content, as well as a high dry matter (DM) digestibility (41.8%) that was greater than wheat straw (36.6%), albeit lower than meadow grass (50.2%). Takashi et al. (2016) studied the feed value of the common reed by 50, 110, 170, and 230 days of harvesting intervals by cutting it at various seasons (January, March, and May) to ensure its new shoot regeneration in wetlands in China. Researchers noted that common reeds provided the highest N content (50.2 ±g N m^{-2}) in the cutting that took place 170 days following the January harvest. Accordingly, the above-ground biomass regeneration attained its highest value (4503 ± 218 g m^{-2}) in the standard cutting process of 170 days after the January harvest. Additionally, the leaf area index (8.3±1.4) measured by the end of May was the maximum value after the January harvest. The study further revealed that the harvesting process, particularly during the early development stage, improves the capacity of the common reeds to be utilized as a high-quality forage crop. Buyukkilic Beyzi and Sirakaya (2019) reported that the crude protein, crude oil, crude ash, NDF, acid detergent fiber (ADF), and acid detergent lignin (ADL) contents of the common reed plant ranged as follows according to three different harvest periods: 10.63-17.30%, 2.05-2.57%, 7.65-8.75%, 64.0-70.75%, 33.26%-37-14, and 3.11-4.20%, respectively. Additionally, metabolic energy value ranged between 2.10-2.15 Mcal kg^{-1} DM, whereas the relative feed value was between 78.72-90.49. Researchers have indicated that the common reed displays comparable attributes to several coarse fodders, such as alfalfa, in terms of its crude protein, metabolic energy, and relative feed value. They also noted that the plant had its highest nutritional value in mid-June, posing the potential to be used in silage mixtures in the early stages of development due to its high energy and protein content. In a study assessing the potential use of the common reed leaves in rabbit feeding, Kadi et al. (2018) analyzed the DM, crude ash, crude protein, ADF, NDF, and ADL values in the samples taken after flowering at the end of autumn and identified them as 932 g kg^{-1} DM, 121 g kg^{-1} DM, 102 g kg^{-1} DM, 642 g kg^{-1} DM, 380 g kg^{-1} DM ve 107 g kg^{-1} DM, respectively. In a study exploring the effects of various harvesting dates on the common reed (1 June 2020, 15 June 2020, and 1 July 2020), Aydogan (2021) discovered that the '1 July 2020' harvest period resulted in the maximum plant height (286 cm), leaf width (3.75 cm), and leaf length (64.58 cm), and the highest DM rate (56.67%), forage yield (8895.3 kg da^{-1}), and dry forage yield (5292 kg da^{-1}).

4.2. Silage quality

The nutrient content of the common reed is significantly affected by different harvesting times. Its nutrient substance resembles that of legume fodder (alfalfa). It is a plant considered to have the potential to be used in silage mixtures in its early development stages owing to its high energy and protein content (Buyukkilic Beyzi and Sirakaya 2019). Shahsavani et al. (2014) reported that the quality of fermented common reed silage has low quality and is not optimal for storage and feeding (pH value >4.3). Silage's natural moisture level, amount of fermentable carbohydrates, and the existence of lactic acid bacteria (LAB) are all factors that affect its quality (McDonald et al., 1991). In addition, the harvesting period and fertilization rate may critically affect the silage quality by altering the chemical composition of grasses (Asano et al., 2015). It is widely accepted that the quality of fermented silage deteriorates when the amount of water-soluble carbohydrates in the material drops below 10% of the DM. Asano et al. (2018) indicated that the water-soluble carbohydrate content of common reed is far below the value required to make good-quality silage; as a result, additives are necessary while using it in the silage process. Silage additives, which possess cellulases and LAB, as well as a substrate such as molasses for LAB maturing, are frequently used to improve silage fermentation. The cellulase enzyme is utilized in ensiling to escalate fiber degradation and generate substrates like water-soluble carbohydrates (Weinberg et al., 1995). Therefore, the use of LAB, water-soluble carbohydrates and cellulase in the silage-making process expectedly improves the fermentation quality of the silage. Some *Lactobacillus* and *Lactococcus* species are effective as LABs in enhancing the silage's fermentation quality due to their high lactic acid productivity and tolerance to acidic conditions (Cai et al., 1999). Furthermore, the log value of the LAB concentration in the material required to achieve high-quality silage was ≥5 logs CFU/g in fresh material (McDonald et al., 1991). Asano et al. (2018) noted that it was unlikely to make high-quality silage from the straw without the use of additives since the composition and amount (<5 log CFU g^{-1}) of LAB in the straw was insufficient to sustain lactic acid fermentation regardless of plant growth stage or harvesting season. However, they further claimed that fermentation quality elevated after employing the *Lactobacillus* species and a substrate (molasses), resulting in a high quality in the common reed silage. Iranmanesh (2014) stated that mixing mulberry leaf with reed silage to eliminate protein and energy deficiency, adding barley flour to enhance fermentation parameters, and using enzymes (cellulose and xylanase) to break lignocellulosic bonds and make the material more susceptible to microbial digestion improved the silage quality, chemical composition, and in vitro organic matter content of the silage. As a result, such additional applications improve digestibility, metabolic energy, and fermentation activities.

El-Talty et al. (2015) stated that lambs were in good health and performance throughout the feeding experiment with common reed silage, concluding that this material was nutritious and suitable for lamb feeding. They reported that the difference between lambs fed with common reed plants and other rations was negligible in terms of gaining live-weight and daily live weight; therefore, common reed silage with adequate protein and energy delivered balanced rations reflecting the regular growth performance of lambs. They also indicated that supplementing the common reed silage with various nutritional additives to adjust its protein level and increase its palatability may be advantageous and cost-effective. According to Hassan et al. (2009), using alfalfa-common reed silage ration at various rates did not eventuate in a significant difference in the live weight gain of lambs and no adverse effects on the health of the lambs. When using alfalfa-common reed silage rations, they noted that the live weight gain of lambs was 168, 168, and 165 g/day during the first four weeks and 174, 175, and 171 g/day between the 4th-8th weeks, respectively. In 4-6 month-old male lambs fed by common reed fodder, however, Saeed and Al-Sultani (2017) found that the total weight gain was 6.08 kg, averaging a daily weight gain of 86.86 g. Wang et al. (2022) found that feeding cattle with various ratios of corn-common reed silage + concentrate feed increased the daily live weight gain, decreased feed conversion ratio and serum glucose levels, and altered the rumen microbiota and metabolic functions of cattle. They further claimed that common reed silage might partially substitute corn silage for beef cattle breeding and that replacing 30% corn silage with the common reed in the ration improved cattle growth performance and their beef quality in terms of enriching the energy and metabolic productivity of the protein. Common reed silage possesses high silage attributes in terms of chemical composition, digestibility, metabolizable energy, and fermentation qualities, according to Buyukkilic Beyzi et al. (2022). They also remarked that using the common reed plant as silage material was highly effective in reducing saponin, which retains an anti-nutritive consequence. Contrary to the other studies, Volesky et al. (2016) emphasized that common reed silage was the least preferred feed compared to other silages by goats, conceivably due to its high fiber content. Monllor et al. (2020) reported that common reed silage should be added to the ration along with a starch source, such as grain, owing to its high NDF concentration, which might increase the ration's slightly low energy content.

4.3. Use of common reed fodder in animal rations

There is a growing concern about the sustainability of the livestock industry due to the ever-increasing population, finite animal feed resources, climate change, and ensuing pandemics (Kayouli, 2007). Feed and food production are closely interrelated. An increase in one of them will result in a decrease in the other since they compete for a limited area of arable land. Therefore, it is crucial to discover nonconventional plant resources to feed animals and investigate the prospects of their usefulness in livestock (Moussa et al. 2011). In this context, the common reed is an advisable alternative feed source that can replace high-quality, nutrient-dense summer feeds with sheep and goat farming due to its proper feeding value (Shehata et al. 2006; El-Talty et al. 2015). In recent years, the common reed has drawn attention as both an alternative feeding source and a bioenergy origin due to its capacity to deliver highly productive DM and its potential to supply coarse fodder for ruminant animals (Asano et al. 2017). Baran et al. (2002) reported that the common reed plant is a critical soil stabilizer in many ecosystems, functioning as productive nutrient storage by steadily accumulating sizable quantities of biomass. They further noted that it posed a high potential for utilization as a partial substitute for coarse fodder, especially as a source of nitrogen (N), potassium (K), and manganese (Mn). Similarly, Buyukkilic Beyzi et al. (2022) stated that the common reed is a significant source of calcium and potassium content. They also indicated that the common reed retains 3% oil content, similar to other roughage, a low concentration of saturated fatty acid, and that palmitic acid was the primary fatty acid in this category. Al-Sodany et al. (2012) remarked that the green parts of *P. australis* stand as a high-quality roughage in terms of net energy (4.18 MJ kg^{-1}) and digestible protein (5.85%) substances, and the organic components and nutritional values of the green parts in the feeds typically used in ruminants were within the desired intervals (NRC 1984). Tanaka et al. (2016) stated that the common reed plant poses the potential as a source of roughage for ruminants owing to its high concentrations of total digestible nutrients in the early growth stage, and its nutritional values are similar to sorghum. As well-established, amino acids, the building blocks of proteins, are the end products of protein digestion and intermediate protein catabolism. Consequently, amino acids play an essential role in protein feeding. Therefore, the amino acid composition of the common reed plant is similar to clover (alfalfa), notably in terms of lysine content, and usually retains a high quality (except for methionine) amino acid composition (Buyukkilic Beyzi et al. 2022). Papathanasiou et al. (2021) reported that the nutrient composition of the common reed plants is comparable to feedstuff frequently used in ruminant feedings, such as wheat straw, and retains significant potential as an alternative or complementary forage plant if used with the proper quantities or processing. Ahmet et al. (2002) stated that the plant is delectable green fodder and is used successfully in feeding farm animals (livestock). Aydogan and Demiroglu Topcu (2022 a) noted that since the reed plant's DM content, a crucial parameter in the feed ration, varies significantly depending on the harvesting period; hence, it is conceivable to regard it in the category of substitutive (saver) feedstuff by being harvested during particular periods by the requirements of the animal species. Similarly, numerous studies have also documented that the common reed plant can be utilized successfully in the nutrition of farm animals (Tag El-Din 1990; El-Nagar 1991; Mokhtarpour and Jahantigh 2018). The plant contains a moderate level of crude protein (approximately

12.7%) (De la Cruz 1983). Analyses revealed that the chemical composition of the common reed plant was similar to or superior to those of alfalfa, according to Farghaly et al. (2022). Consequently, they claimed that ruminants could rely on this plant as a substitute feeding source to cope with the green fodder shortage, especially in the summer season. However, it barely competes with the arable lands required for food production. Yet, the common reed plant naturally grows on the lake and gulf coastlines, river banks, and nutrient-rich peatlands, in addition to deeper waters if clean enough. Therefore, feeding strategies supported by such additional plants will increase milk and meat production at a reasonable cost, relatively replenishing the gap in protein and energy depletion (El-Talty et al., 2007; Allam et al., 2007). However, the high NDF content (~70% of DM) imposes restrictions on the consumption of common reed plants alone (Mashayekhi and Ghorbani, 2004). Volesky et al. (2016) stated that adding energy is necessary for a better nutritional balance if fed to cattle exclusively for an extended period due to its poor digestibility. Okano and Minemori (2014) also suggested that the digestibility of the common reeds is exceedingly poor for ruminants due to their high lignin concentration; as a result, feeding animals without supplementing it in the combination of other additives such as *Ceriporiopsis subvermispora* and rice bran is not recommended. As all other plant wastes possess high fiber, albeit low protein, the nutrition content of the common reed may also be curable through diverse approaches such as chemical, mechanical and biological processes (Abebe et al., 2004). Among chemical processes (sodium hydroxide, ammonia, urea), urea appears to stand out as the most effective method for treating low-quality roughage, as it is widely available, easily transportable, and safer to use (Smith, 2002; Abebe et al., 2004). Non-protein nitrogen (NPN) chemical known as urea is added frequently to concentrate feeds or rations as a supplement in ruminants' diets. NPN is utilized by rumen bacteria in ruminants to produce amino acids and proteins, providing high-quality animal protein (Bach et al., 2005). According to Mokhtarpour and Jahantigh (2018), common reed used in sheep diets can be treated with urea to improve its digestibility and crude protein intake. However, they noted that despite the numerically higher digestibility of DM and NDF in urea-treated straw, it did not provide a significant advantage over urea supplementation. They also stated that common reeds with 2% DM urea additive increased feed efficiency compared to untreated common reeds with urea; as a result, they referred to it as a proper nutrient to use in sheep rations, albeit not recommended as a sole source of feedstuff. Farghaly et al. (2022) reported that feeding male lambs, aged 5-6 months and weighed approximately 19 kg, with 40% alfalfa or 40% common reed fodder in addition to 60% concentrate feed did not yield any difference in terms of live weight, daily average weight gain, and feed conversion ratio ($P>0.05$). However, the feed consumption of the common reed-fed lambs was approximately 21.43% lower than the alfalfa species (440 g versus 560 g) ($P<0.05$). Compared to alfalfa, common reed consumption also eventuated in higher water consumption ($P<0.05$). Statistically, there was no significant difference between groups in terms of blood metabolites (total serum protein, urea, globulin, glucose, and cholesterol concentrations) in alfalfa or common reed feeding ($P>0.05$). All lambs survived healthily throughout the experiment and reached slaughtering age. Feeding the lambs with different roughage sources did not significantly affect the gross composition of the longissimus muscle ($P>0.05$). The differences in waterholding capacity and boiling-off loss parameters of the longissimus dorsi muscle between lambs-fed diets based on alfalfa and common reed feeds were statistically insignificant (P>0.05). Yet, eye muscle area (EMA) and cutting force appeared to decline in lambs fed with common reed-containing feedstuff compared to the alfalfa group (P<0.05), while the chemical composition of the longissimus dorsi muscle of lambs was not affected by altering roughage sources (P>0.05). Nevertheless, compared to the common reed group, the alfalfa group retained a statistically higher oil and collagen content and numerically lower moisture. According to the literature, lambs fed with alfalfa produced significantly reddish meat in color (15.49 versus 13.57) than those nourished by common reed plants (P<0.05). They ultimately concluded that common reed fodder could replace up to 40% of the typical alfalfa feedstuff used in lamb feeding rations without causing a negatory impact on growth performance. They further claimed that common reeds could enhance carcass qualities similar to alfalfa feed. Additionally, they stated that the common reed plant has the potential to improve the meat quality of lambs owing to its fat-reducing effect and collagen content and increasing tenderness with the favored meat and fat color. Therefore, studies proposed utilizing common reed fodder in ovine rations to eliminate the rising cost or shortage in the availability of traditional green fodder. Contrarily, Guda (2018) remarked that the common reed plant's nutrient concentration could vary based on the environmental factors of the common reed cultivation locations, indicating that it would be safe to retain it as feedstuff when grown in surroundings with the right environmental factors; however, its usefulness as feeding material could diminish when cultivated in areas putting the plant under stress.

4.4. Heavy Metal Contents in Common Reed

Al-Sodany et al. (2012) claimed that *P. australis* might have potential applications as a biological barrier against the spread of heavy metal pollution and as a forage plant in lakes. In areas where *P. australis* spreads, heavy metals may accumulate in various regions of the plant; however, such concentrations are not high enough to pose issues. Studies conducted in multi-regions of our country where this plant is prevalent have reported no significant concern about heavy metal contents in the plant leaves and stems. For instance, Hayta and Erkan (2019) conducted research to identify the dominant species of Ahlat Reeds, *P. australis*, *Typha angustifolia*, and *Lythrum salicaria* species and the heavy metal concentrations in the surrounding sediments. Accordingly, their analyses revealed that the Mn, Fe, Ni, Cu, Zn, Cd, Pb, and Ca element concentrations did not reach the levels that would cause toxicity. The researchers also discovered a decreasing trend of heavy metal concentration in *P. australis* plant parts as follows: Mg>Ca>Fe>Zn>Mn>Cu>Cr>Ni>Cd>Pb in the root, Mg>Ca>Ca>Mn> Zn>Fe>Cu>Ni>Cd>Pb in the stem, and Mg>Fe>Ca>Zn>Mn>Cu>Pb>Cd in the leaves. In another study, Kaya (2019) analyzed the heavy metal concentrations in diverse parts (root, stem, and leaf) of *Typha latifolia*, *Phragmites australis*, and *Polygonum lapatifolium* species and heavy metal concentrations of bottom mud samples in Ankara Stream passing near the Sincan Organized Industrial Zone. Accordingly, the study found that *P. australis* were capable of accumulating heavy metals in the roots due to their vast intercellular air spaces, that the heavy metal concentrations determined in the roots, stems, and leaves were below the risk limits, and that the detection limit of critical heavy metals, especially cadmium and lead, was significantly low.

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CHAPTER 10

BUCKWHEAT (*Fagopyrum esculentum* Moench)

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1. INTRODUCTION

Buckwheat is a plant of Asian origin, which is different from grains, but is defined as grain-like (pseudocereal) in terms of some properties. It was first cultivated in China, then in Europe and North America. Over the years, it has also been produced in regions with colder climates. Its production in Turkey was started within the scope of R&D and training activities in the 2000s. In a study, it was reported that the average age of buckwheat producers in our country is 45.57 years, education level is 8.38 years, and the number of family members is 4.49. It has been observed that the general agricultural experience of these buckwheat producers is 24.26 years. However, it was determined that their experience in buckwheat cultivation was 1.70 years on average. From this, it is concluded that buckwheat is very new in our country and its production is not known much. Buckwheat is a perennial shrub-like plant in the genus Fagopyrum from the sorrel family. It has a delicate fibrous root system. Buckwheat grains are called “Groat” and these grains look like grain group plants. Although it resembles them, it has no kinship with grains. Buckwheat is used in erosion control on sloping lands, in the cosmetic industry, green manure, paint industry, and in the production of products such as vinegar, tea, and spirit.

Figure 1. Buckwheat illustration (Japanese agricultural encyclopedia Seikei Zusetsu 1804)

According to the United Nations Food and Agriculture Organization (FAO) data, the highest buckwheat production in 2020 was in Russia with 892,160 tons. China, which produced the most buckwheat in the world in the past years, ranks second with 503.998 tons in 2020.

In the research conducted on the total amount of buckwheat produced in Turkey, no information could be found in the data of FAO and Turkish Statistical Institute. In the table below, buckwheat production amounts for 2020 are given in tons by country.

Table 1: Buckwheat Production *

Country	**Production (ton)**
Russia	892.160
Chinese	503.988
Ukraine	97.640
USA	86.397
Brazil	65.117
Japan	44.800
Kazakhistan	40.094
Belarus	28.300
Tanzania	25.772
Nepal	11.724
Total	1.810.816
*FAOSTAT,2020	

2. SYSTEMATIC AND MORPHOLOGY

There are 8 types of short flower sets and 7 types of tall flower sets in buckwheat. There are 26 known species of the genus Fagopyrum from the large flower group. Of these, *Fagopyrum esculentum* (Buckwheat) and Fagopyrum tataricum (Tatar Buckwheat) are the two most widely grown species. Buckwheat is widely used in human and animal nutrition at a rate of almost 90.0%. The bitter taste of Tatar buckwheat limits its production and is often used as a green manure, erosion control and nectar plant. The buckwheat plant is a plant with a pile root structure and small lateral roots on it. The leaves are 2-8 cm long, broad, oval and triangular. Its flowers are 6 mm in diameter, in the form of clusters, and vary in color from white to pink. The flowering period of foreign pollinated buckwheat continues for a long time (30-45 days). In a study conducted in China, it was determined that the branch length of buckwheat plant was smaller with increasing frequency and late sowing, and the relationship between branch length and total biomass yield was found to be significant. The nutritional value of the buckwheat hay is close to the commonly grown forage crops except alfalfa and sainfoin, and similarly, the protein content of the buckwheat grain is close to the forage crops other than legumes. Its silage is close to corn silage and easily digestible. In a study conducted in Baltistan ecological conditions of Pakistan, maturation was delayed and lodging increased in buckwheat with the increase in nitrogen ratios, while maturation accelerated and lodging decreased with the increase in phosphorus ratios, generally in parallel with increasing nitrogen and phosphorus doses, grain yield, plant height, number of fruits per plant, thousand grain weight. It was determined that the biological yield and harvest index increased, the interaction of nitrogen and phosphorus had a significant effect on thousand grain weight, grain yield and plant lodging, and phosphorus doses applied in different amounts caused an increase in grain yield and yield elements in buckwheat. In a study, plant cultivation practices, the number of fruit per plant, the number of seeds in the fruit, the plant growth rate and seed yield at the time of sowing, the thousand grain weight, harvest index and plant growth rate of nitrogen applications, the seed yield, plant growth rate, the sowing time and nitrogen doses together. and it was determined that it affected the number of seeds in the plant. If buckwheat seeds are to be stored, they should be dried so that the grain moisture is between 13-16%. More than 16% humidity causes the seeds to become moldy, while less than 13% humidity makes them hard for grinding and lowers the market price. Buckwheat has beneficial effects for human health due to its phenolic compounds and antioxidant activities. The phenolic compounds contained in buckwheat are 2-5 times more than barley and oat seeds. In addition, it has been determined that the antioxidant activity of buckwheat husk and bran is 2-7 times higher than that of barley, triticale and oat seeds. Buckwheat, with its rapid growth feature, provides suppression of weeds to preserve moisture and nutrients in the soil. Buckwheat residues have an allelopathic effect on grass germination. This effect indicates that buckwheat contains compounds that suppress the growth of other plants.

Figure 2 .Buckwheat and flower **(**https://en.wikipedia.org/wiki/Buckwheat, https://ceb.wikipedia.org/wiki/Fagopyrum_esculentum)

Buckwheat is an alternative plant that is considered in crop rotation systems by dissolving the unusable phosphorus in the soil with its roots. It converts the unusable form of phosphorus due to calcium into usable form and makes it available to plants. This tremendous ability has only been reported in buckwheat. It not only increases dissolved phosphorus in the soil, but also helps the next crop to use dissolved phosphorus. It also helps to suppress soil aeration, soil erosion and weed growth during vegetative flowering. It enables weeds to use nitrogen less with the allelochemicals in its leaves and stem. Buckwheat (*Fagopyrum esculentum* Moench) is one of the most popular crops in recent years and its cultivation area is increasing day by day. Research on this subject should continue without slowing down in order to examine the cultivation-related characteristics of buckwheat, which is increasingly cultivated (Güllap et al., 2021) and to determine the yield-related characteristics more clearly.

3. ADAPTATION

Buckwheat; Unlike basic grain groups such as wheat, barley, oats, rice and corn, it adapts rapidly at high altitudes in the short term. Buckwheat is partially selective in terms of climate demand. It grows without any problems in places with mostly humid and cool climates. It germinates very soon (3-5 days) after planting. The minimum germination temperature should be more than 7 ºC, also germination was observed at temperatures up to 40 ºC. Buckwheat is grown in warm climates. It is sensitive to temperature changes during its development. During the germination stage and at the end of the growing season, it is sensitive to frost and low temperatures and cannot survive if it reaches freezing temperatures in spring and autumn. The soil temperature must be 8-10 °C for it to sprout, and it also needs high humidity. Its growth period is between 8-14 weeks and since it needs low temperature for its development, this makes it possible for buckwheat to grow in the north and at high altitudes (0-4200 m). Flowering time, dry air, high temperature or extreme cold adversely affect flowering and seed setting. Buckwheat grows in a humid and cool climate with the highest yield. High temperatures and dry air cause the flowers to burst when they bloom and can adversely affect seed formation and fertilization. It was concluded that the plant height of buckwheat was between 50-150 cm, the total biological yield was 8.5 tons/ha and the grain yield was 3-4 tons/ha. Buckwheat is an annual plant that can be grown in cool climates, in soils low in minerals or organic matter, in short, in conditions with all kinds of disadvantages. Example; Buckwheat can be produced very well even in soils that are so infertile that almost no plant can be grown in a region in China. Buckwheat is highly resistant to low yielding and acidic soils (pH: 5-7), and tolerates soil acidity more than other grains. Light to medium textured, well-drained soils such as sandy loam, loam and silt loam are the best soils for buckwheat to grow. Good yields are not obtained in very dry, very humid soils with high lime content. In regions where humidity is low, air temperature is high and dry wind is dominant, buckwheat grain yield is low.

Sowing Time

Buckwheat can be planted any time after the threat of deadly frost has passed. In other words, the appropriate planting time should be done as early as possible after the late spring frosts and when the weather is cool. A buckwheat planted in April and mid-July starts to germinate 3-5 days after sowing and gives seeds within 1 month. It is harvested when it reaches 75-95% seed maturity. Buckwheat, whose seeds are obtained by maturing in 8-14 weeks, should be stored with their shells in order to keep them intact. If it is to be stored without a shell, it should be stored for a short time. It was determined that the yield increased as the planting time was taken earlier. The vegetation period of buckwheat varies in different months in different regions and according to the climatic conditions of the area. It is a broad-leaved annual herb that grows rapidly in field conditions. It was determined that the length of a buckwheat planted at 20-25 cm intervals at the end of March and the beginning of April and harvested in September-

October varies between 60-120 cm. The recommended number of plants per decare of buckwheat, which can be used for the nutritional needs of both humans and animals and has different usage areas, is between 170-180 thousand and the amount of seeds to be sown is 5-6 kg/da. In the research on spring and summer plantings in Nepal, it was stated that the plant heights obtained from summer plantings ranged between 43-115 cm, and the plant heights of buckwheat obtained as a result of spring plantings varied between 24-109 cm. In Samsun conditions, the highest grain yield in buckwheat was achieved in sowing made between 21 May and 2 June, regardless of varieties.

Figure 3. Flowering buckwheat, mature and immature seeds **(**https://en.wikipedia.org/wiki/Buckwheat**)**

4. YIELD AND QUALITY

Buckwheat is one of the most suitable alternative plants for ecological agriculture, which is grown without the use of artificial fertilizers, pesticides and other chemicals. Soil preparation should be done carefully for a good emergence in buckwheat. First of all, the seed bed should be prepared for the preservation of moisture and the intake of necessary nutrients. The soil is then plowed, usually in the fall. In the spring, field preparation should be done with tools such as disc harrow and harrow. In case of grazing when planting is done late, this process can be repeated. The best quality results are obtained by sowing seeds on a well-prepared seedbed and free of weeds. Both scattering and machine planting are done in buckwheat cultivation. Excess seeds are used in scattering and it is between 7.0-13.0 kg per decare. In sowing with seeder, the seed used is less. Although it is mostly cultivated with grain seeder, many seed drills are also used in buckwheat cultivation. The recommended row spacing for sowing with seeder is between 15-20 cm. Since the branching of buckwheat is too much in some varieties, sparse planting should be done. Scatter cultivation is not recommended except when buckwheat is used as a source of nectar for honey production or for cover purposes. Harvest can be done with a combine harvester after 85-90 days from sowing and when 75% of the grains in the plant turn brown. If the buckwheat plant is to be used as animal feed, it is recommended to be harvested at 75% seed setting stage, if it is to be used in functional food, herbal tea and etc., it is recommended to be harvested at full bloom and 25% seed setting stage. In a study conducted in Bangladesh, 21 genotypes of buckwheat were examined and it was determined that the plant height was maximum 84.57 cm, at least 66.29 cm, and the number of branches per plant was 27.47 and at least 13.53. The excess amount of nitrogen in the soil causes the plant to lie down and the lying plants cannot stand up again. Seed yield also decreases in high nitrogen soils. The lack of nitrogen in the soil accelerates the wilting of the plant. Nitrogen doses were found to have a positive effect on seed yield and yield components. As a result of the research, it was determined that 11.48 kg nitrogen should be applied per decare in order to obtain optimum seed yield in buckwheat cultivation in soils with low organic matter and semi-arid climate conditions. Turkey is suitable for buckwheat production in terms of climatic conditions and its cultivation is important in order to obtain useful foodstuffs. The most important feature of buckwheat is its rapid growth (vegetation period 8-12 weeks). It should be watered 2-3 times during this short vegetation period. The maturation of the buckwheat grain shows heterogeneity according to the plant morphology, at the time of harvest, flowers, green and mature grains are present on the plant at the same time. This feature is the most important reason for the low grain yield. The grain yield of buckwheat was determined as 159.2 kg/da (Kara, 2014), 125.4 kg/da (Okudan and Kara, 2015) and 145.7 kg/da (Kara et al., 2016) and 132.3 kg/da (Kara and Telli, 2016) by the researchers. has been reported. Ripening proceeds from the bottom to the branches above. Uniform maturation does not occur while flowering continues. At harvest time, the flowers on the plant can be both green and mature grains at the same time. It takes a long time for the seed to mature in buckwheat. The most important quality criteria of buckwheat; color and taste. Freshly harvested buckwheat seeds are light green in color. In old seeds the color is reddish brown. Freshly harvested grains have a typical buckwheat flavor, while older grains have a bitter taste. The taste of buckwheat seeds is slightly bitter (Kawakami, 1994), and the most striking features are that they have high nutritional value and do not contain gluten. In a study conducted in Konya in 2007 and 2008, they obtained the highest stem yield with 1783.80 kg/da in 20 cm row spacing and the highest seed yield with 101.11 kg/da in 40 cm row spacing in the first trial year. Buckwheat germ proteins have a balanced and nutritionally higher amino acid content than other grains. Unlike grains, its seeds are not monocotyledonous (moncotyledonous), but dicotyledonous (dicotyledonous).

Use of Buckwheat

The most important feature of buckwheat among other plants is that its protein structure does not contain gluten. Flour made with the seeds of the buckwheat plant is an important food source for celiac patients due to the secondary metabolites it contains. It has been stated that these people's diet with gluten-containing products creates major health problems and poses a problem for patients with low purchasing power due to the high prices of gluten-free food. A product with less than 20 mg/kg of gluten (prolamine proteins) can be considered gluten-free. Gluten-free foods such as bread, pasta, and biscuits are already produced from pseudocereals called grain-like grains. Examples of these are amaranth, quinoa and buckwheat. It was observed that the pasta quality of the noodles made with pseudo-cereal flours increased. There are gluten-free breads and biscuits made from amaranth and buckwheat in North America and Europe. It has been reported that noodles, pancakes, pancakes, cakes, crackers, breakfast cereals, bread and biscuits can be made from buckwheat flour, which is more cultivated than others. The green leaves of buckwheat are used as a vegetable. Buckwheat tea is made from the leaves of this green vegetable. Buckwheat grains extracted from the husk can be used in rice and juicy dishes, similar to lentils. There are sources that state that buckwheat is also used in the production of alcoholic beverages and vinegar. An average of 75% of buckwheat used as human food is ground into wheat flour. It has been determined that buckwheat and bran flour are used in the production of bakery products to enrich the mineral, protein and essential amino acid content. An increase was observed in the amount of protein, vitamins, minerals and fiber in bread with the addition of buckwheat. Considering the processing qualities of the dough and the nutritional and sensory properties of the breads, using buckwheat whole flour with SSL (staling retarding surfactant) gave the best results. It has been determined that the softening phase of the dough made from buckwheat flour containing high fatty acids (palmitic, oleic, linoleic) is late and the products obtained from it are of high quality and have a long shelf life. Buckwheat is a plant that has been included in diets as an alternative product, especially preferred because of its high nutritional value and beneficial to health. Buckwheat flour; It has diabetes, hypertension and high cholesterol lowering and balancing properties. The protein content of spelled buckwheat flour is lower than that of spelled buckwheat flour. It contains protein with high nutritional value and significant amounts of dietary fiber, vitamins (vitamins B1, B2 and E) and mineral substances.

Allergen Effect; Buckwheat contains insignificant amounts of prolamine proteins, which are toxic to celiac patients. Buckwheat contains protein with a molecular weight of 24 kDa, which binds with immunoglobulin-E (IgE; type I immune reaction) and has therefore been stated to have a high food allergen potential. If patients have a buckwheat specific IgE antibody level of 1.26 kUA/L or higher, inhaling or ingesting even a small amount of buckwheat can cause dangerous allergic reactions. Especially in Asian countries where buckwheat is consumed excessively, buckwheat is among the allergenic foods.

Buckwheat is used as fodder in sheep and cattle breeding and egg poultry farming. It is stated in different studies that it can be added to the rations and added up to 1/3 of the total mixture. Buckwheat plant increases the rate of organic matter in the soil, corrects its physical structure, also preserves the moisture in the soil and can be used as green manure. The use of buckwheat as feed in farm and poultry is about 5-6% of other uses of buckwheat. Quality roughage can be obtained from buckwheat by both drying and withering and siloing.

Buckwheat can be used as a nectar source in honey production. It is possible to produce up to 175 kg of nectar in a season under suitable conditions.

Buckwheat contains many compounds that reduce harmful cholesterol in the blood, strengthen capillaries and main vessels, maintain their flexibility, and reduce high blood pressure. Buckwheat has been used medicinally since the 1930s. Buckwheat contains antioxidants such as "rutin" and "quercetin", which has vascular tonic, blood pressure lowering, vasodilator and anticoagulant effects in the blood. It can be used intravenously or as a tablet. In addition to the protective effect of Rutin substance against cardiovascular diseases, it also has anti-cancer, balancing high blood pressure, anti-inflammatory and many other benefits. The most important task of quercetin, another effective phenolic compound, is; to speed up metabolism. In this way, it is ensured that the fat in the body is burned and the body is purified from toxins. In addition, rutin and quercetin have antioxidant activity and protect buckwheat, which contains polyunsaturated fatty acids, against oxidative deterioration. Rutin has a relaxing effect on smooth muscles, preventing the risk of stroke caused by vascular occlusion, and has a protective effect against retinal hemorrhage. Fagopyrin (Fagopyrin) is a complex compound found in buckwheat. This compound is sensitive to light in light-skinned animals exposed to sunlight. On the other hand, fagopyrin compounds are used in the treatment of Type 2 diabetes patients. Quercetin compound also has antiviral and antibacterial effects.

It can be used as green manure in about 6-8 weeks after sowing buckwheat. It has an important place as green manure as it produces a significant amount of dry matter. When suitable conditions are provided, the amount of dry matter per hectare was determined as 3 tons.

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CHAPTER 11

FORAGE WATERMELON

(*Citrillus lanatus var. citroides*)

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1. INTRODUCTION

Forage watermelon is known by several names such as citron watermelon “fodder melon”, ‘‘cow-melon’’, ‘‘tsamma melon’’, ‘‘camel melon’’, “citronmelon”, “stock melon” and “preserving melon” (Stephens, 1994; Robinson and Decker-Walters, 1997; Laghetti ve Hammer, 2007; Shaik et al., 2017; Ngwepe et al., 2019). Forage watermelon, which is known by different names, is used for different purposes such as making jam and pickles, cooking, water supply in arid areas and obtaining pectin, apart from feeding animals.

Forage watermelon seeds are used not only for animal feeding, but also for obtain oil for the medical and cosmetic industries and for consume as a snack (Kobitev, 1956; Övezmuradov, 1972; Laghetti and Hammer, 2007; Lauoku et al., 2007; Minsart et al., 2008; Acar, 2009; Anonymus, 2011a; Anonymus, 2011b; Wehner, 2011). The genus and species of edible watermelon and forage watermelon are the same, but their varieties are different. The chromosome number of forage watermelon and edible watermelon is the same (2n=22), crossing occurs between both (Kobitev, 1956; Övezmuradov, 1972; Bullitta et al., 2007; Stephens, 2009; Nesom, 2011; Anonymous, 2013). It has been stated that forage watermelons (*Citrillus lanatus* var. *citroides*) are highly resistant to root knot nematodes, which seriously affect the yield of edible watermelons and can be an important source for the development of resistant edible varieties (Thies and Levi, 2003).

There are some morphological differences between forage watermelons and edible watermelons, especially in fruits. In forage watermelons, the peel is hard, thick and durable, the flesh is yellow-white or greenish, and the flesh is firm and retains its juice for a long time after ripening (Acar et al., 2015). Forage watermelon fruits have low water-soluble dry matter (BRIX) amounts. The amount of pectin is high (Acar et al., 2019a). It is stated that it is added to fruit juices to gel it faster due to its high pectin content (Anonymous, 2011a). It has a structure that does not break easily with its elastic structure and hard rind, and changes from oval to cylindrical in shape (Acar et al., 2019a).

It is known that the storage life of edible watermelons is very short. One of the most important differences of the forage watermelon is the storage life of the fruits. The storage period and ease of storage of ripe fruits makes forage watermelon advantageous (Kobitev, 1956; Acar, 2006; Anonymous, 2011c). There is no significant loss in the nutrient content of forage watermelon during storage (Anonymous, 2011c). Since watermelons produced as feeders are not consumed in a short time, they also need a long storage life. It has been determined in studies that the storage life of forage type watermelons can be kept for longer than one year in room conditions if there is no physical damage or injury. In his study, Tokat (2020) observed the fruits of the forage watermelons harvested in September 2017 under room conditions until November 2019 (14 months) without spoiling. The purpose of growing forage watermelons is to provide the roughage needed by farm animals during the winter period. Therefore, storing the forage watermelon intact during the period from autumn to spring under farmer conditions will be sufficient in terms of storage life, which equals around 6 months. Studies so far show that forage watermelons can be stored during this period (Tokat, 2020).

Forage watermelon is an annual plant and has the potential to easily enter the crop rotation. In addition, the forage watermelon is suitable for mechanization in terms of being able to easily cultivate with the existing agricultural machinery parks of the farms. The fact that the unit area yield is high, it is a source of juicy forage, and most importantly, unlike the edible watermelon, without much loss (weight loss of 7.7% - 15.0% in room conditions in 210 days) (Geren et al., 2011; Simić et al., 2012) and being stored without spoiling, forage watermelon makes it a good alternative roughage source.

Especially the fruit of "*Citrullus lanatus var. citroides*" is used for animal feeding in former Soviet Republics such as, Turkmenistan, some former eastern bloc countries, Africa and others such as Brazil. (Kobitev, 1956; Popov et al., 1957; Övezmuradov, 1972; Anonymous, 2007; Silva et al., 2009; Anonymous, 2010a; Anonymous, 2010b; Anonymous, 2011c; Anonymous, 2011d) The fruits of the fodder watermelon are given to the farm animals alone, as well as mixed with straw, corn stalk, hay. (Kobitev, 1956; Övezmuradov, 1972; Anonymous, 2007; Acar, 2009; Anonymous, 2011e; Anonymous, 2011f). In addition to its fruits, the green above-ground parts (stem, leaf) are also used in silage together with silage plants (Kobitev, 1956; Övezmuradov, 1972; Acar, 2009; Anonymous, 2011d; Anonymous, 2011e; Anonymous, 2011f). It is stated that forage watermelon is grown abundantly in farms in the south and southeast of Russia and 10 kg / day is added to the rations of the cattle and 3-4 kg / day to sheep (Anonymous, 2007). Likewise, in the north of Brazil, it has been stated that forage watermelon is used in animal feeding and it provides convenience in terms of storage and 25-30 t/ha fruit yield is obtained (Anonymous, 2011c). Kobitev (1956) reported that he obtained 76.9 t/ha yield from Dishim, which is the forage watermelon variety in Turkmenistan. In the research carried out in İzmir between 2009 and 2010, an average fruit yield of 8761 kg/daa is obtained from forage watermelon grown as a second crop (Geren et al., 2011).

There is a need for studies on the development of high-yielding and stress-resistant superior varieties of forage watermelon, the application of modern agricultural techniques and their use in animal feeding. When these studies are carried out, the forage watermelon cultivation area will increase.

2. SYSTEMATIC AND MORPHOLOGY

Systematic

Cucurbitaceae is an important family that includes species such as watermelon, melon, squash and cucumber. The genus Citrullus is taxonomically complex and its taxonomy has not yet been unanimously accepted by all taxonomists (Laghetti and Hammer, 2007). Watermelons are among the most important vegetable crops worldwide, but targeted breeding is hindered by problems with *Citrullus* taxonomy (Renner et al., 2017).

The genus *Citrullus* (*Cucurbitaceae*) consists of three diploid species (2n=22): (i) *C. lanatus* (Thunberg) Matsumura and Nakai, including the cultivated watermelon widely grown in several parts of the world, (ii) *C. lanatus var. citroides*, a wild form found in South Africa and also cultivated in other parts of the world mainly for feeding animals, and

(iii) *C. colocynthis* (L) Schrad, found in the north and southwest areas of Africa and Asia, which can be divided into two different races, one found on the Mediterranean coast, the other found in the deserts of Negev and Sinai, and *C. ecirrosus*, which is endemic to the Namibian desert (Zamir et a1., 1984; Assis et al., 2000).

Forage watermelon is believed to be native to South Africa (Dane and Liu, 2007; Minsart et al., 2008). The edible watermelon and the forage watermelon, which have the same genus and species but different varieties, also have the same chromosome number, moreover hybridization occurs between these two species (Övezmuradov, 1972). In addition to natural hybrids, artificial hybrids are obtained between forage and edible watermelon (Acar, 2009). In terms of genetic structure, fodder characters (such as fruit colour, peel thickness) are dominant over the edibles, and it is stated that they adversely affect the quality of edibles (Övezmuradov, 1972; Acar, 2006; Assis et al., 2000).

Pandey et al. (2019) conducted a study to determine the polymorphism in watermelon lines collected from different regions and countries using RAPD and ISSR methods. As a result of the research, it is determined that Turkmenistan citron genotypes differed from Lanatus genotypes in Turkey and that there was a high level of heterozygosity among genotypes in Turkey.

Acar et al. (2019b) determined the genetic diversity of 25 watermelon genotypes obtained from Turkey and abroad by using ISSR (Inter Simple Sequence Repeats) method. As a result of the analysis, they observed a divergence profile between genotypes. In watermelon breeding, they have obtained important information especially for the studies of expanding the genetic base of cultured watermelons.

Morphology

Forage watermelon is annual, has a strong root system and is partially resistant to drought. The tap root occurs first, and then the lateral roots. Depending on the soil structure, it can go 100-150 cm deep (Övezmuradov, 1972; Günay, 2005; Acar, 2006). Forage watermelon growth habit is horizontal on the soil. The stem grow on the ground, spread over the soil and have creeping and climbing features (Günay, 2005; Acar, 2006) (Figure 1c,d,j,k,l). It has stronger, thicker and hairy stems than the edible watermelon (Acar, 2006) (Figure 1d,h). The main stem length of the forage watermelon can be up to 8 meters (Tokat, 2020). The number of stems in the plant varies between 4 and 9 depending on the nutritional status (Günay, 2005; Acar, 2006). Body colour is light green or green (Fig. 1c,g,j). The leaves are mostly rounded with toothed edges with three to four pairs of lobes, a rough surface, deeply divided by branches extending to the sides (Laghetti and Hammer, 2007) (Figure 1i).

Citron watermelon is monoecious with male and female flowers borne on the same plant rendering high level of cross pollination (Wehner, 2008; Ngwepe et al., 2019) (Figure 1d,e,f,g). Pollination takes place by insects, especially bees. The flower consists of 5 sepals, 5 petals and 5 stamens (Figure 1d,e,f,g).Petals are yellow, broad (3-8 mm long) and flower tubes 3–5 mm long (Laghetti and Hammer, 2007) (Fig. 1d,e,f,g). The tips of the petals are tapered (Fig. 1d,e). The surface of the ovary in the female flower is hairy (Figure 1d,h).

The shape of the fruits varies from round to oval to cylindrical Figure 1i-o; Figures 2a-h; Figure 3 a-i). Forage watermelon planted in Konya has a long cylindrical appearance (Figure 3 g, h, i). Its fruits are different from edible fruits, the rind is thick (1 – 5 cm) (Tokat et al., 2020; Tokat, 2020), hard and tight structure, the flesh (pulp) colour of the fruit (the fleshy part of the fruit) is in white-yellow tones or light green (Figure 2 a-h; Figure 3 a-i). Forage watermelon differs from edible varieties in that its fruit flesh is elastic, fibrous, hard and contains less sugar. Although there are differences in the colour of the skin of the fruit, it can be light green, yellow-white in colour and green striped or with very little light green stripes or spots or unlined (Figure 2 a-h; Figure 3 a-i). Fruit flesh is firm in all forage varieties. As with edible watermelons, watering is not seen in the fruit flesh immediately after waiting. Fruits have a flat, smooth surface (Popov et al., 1957; Övezmuradov, 1972; Assis et al., 2000; Günay, 2005; Acar, 2006; Bullitta et al., 2007). Dry matter ratio in fruit varies between 2.5-6.0% in Turkmenistan varieties (Övezmuradov, 1972; Acar, 2006). The seeds are embedded in the fruit flesh, the rind is hard and it’s tip is protruding. There are differences in size. Figure 2 a-h; Figure 3 a-i). Although the colour of the seed coat changes, it is in the form of green or shades of green in Turkmenistan varieties (Figure 4 a,b). 1000 grain weight can be between 130-250 g or less or more (Övezmuradov, 1972; Acar, 2006). While those mentioned here are mostly seen in genotypes of forage watermelons from Turkmenistan, there are changes in forage watermelons in various parts of the world (Brazil, India, USA, Russia, etc.) according to cross pollination (Assis et al., 2000).

Figure 1. Forage Watermelon in Different Phenological Periods (Original)

a b

c d

e f

g h

Figure 2. Different Shapes, Skin and Fleshes of Watermelon Fruits (Original)

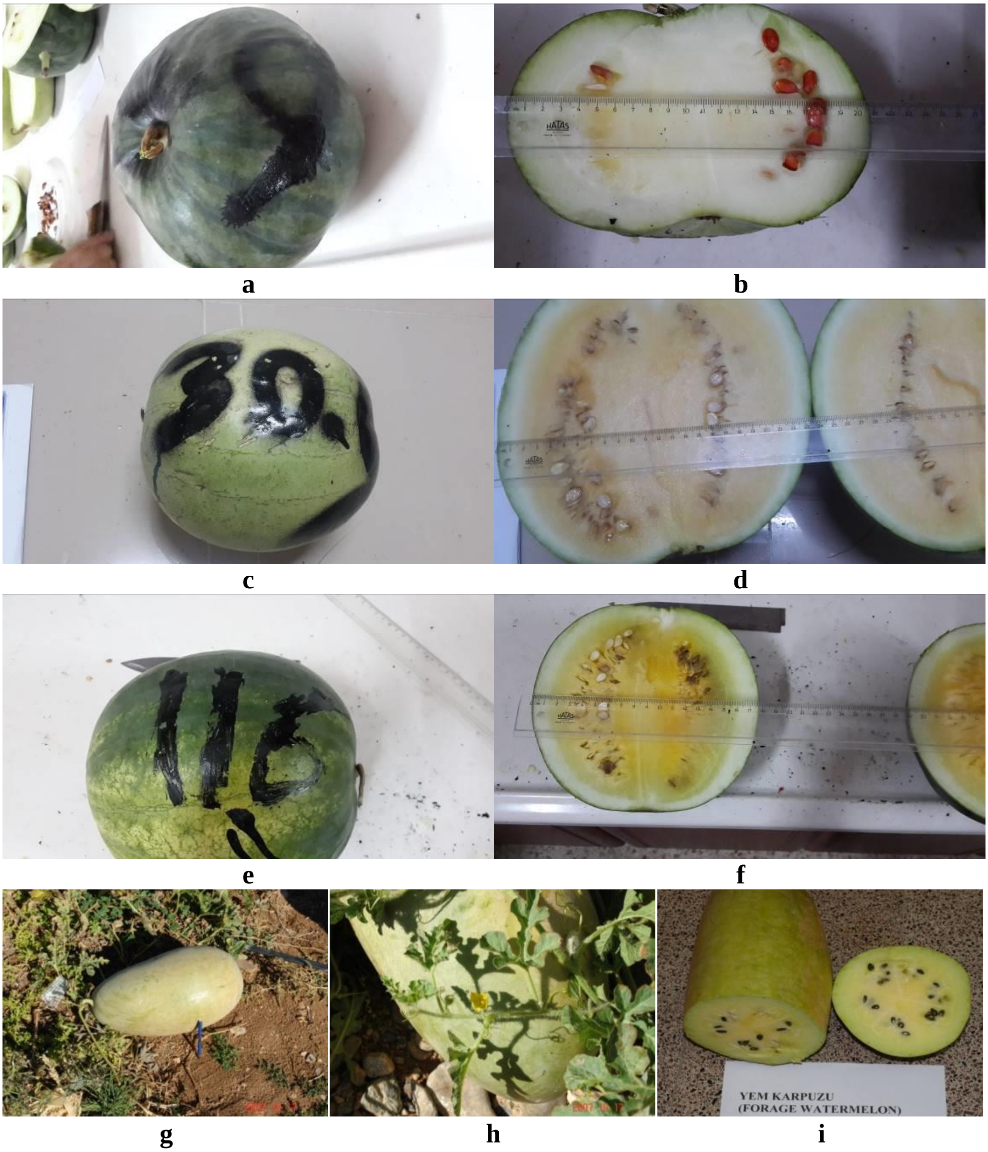

Figure 3. Different Shapes, Skin and Flesh of Watermelon Fruits (Original)

a

b

Figure 4. Different Sizes and Colours of Watermelon Seeds (Original)

3. ADAPTATION

Forage watermelon is suitable for warm and hot climates. Since it is damaged by cold, it should be planted and grown after frosty days. A temperature of 20-25 ^{0}C is ideal for optimum growth. It is stated that it is not suitable to be grown in very cool regions. It prefers more loamy-sandy, lame-sandy and alluvial soils. It can make good use of ground water. Forage watermelon prefers neutral pH level the soil pH to be neutral. However, when soil acidity is around pH 5.0, it is beneficial to increase it to 6.0-6.5 by liming. It is less selective than edible watermelon in terms of soil demand (Popov et al., 1957; Assis et al. 2000; Günay, 2005; Acar, 2006).

Cultivation

Seeds are sown when the soil temperature is 10-14 ^{0}C. Although it varies according to the regions, it is cultivated in late April or May (Popov et al., 1957; Övezmuradov, 1972; Günay, 2005; Acar, 2006).

Sowing method: Planting is done in various ways (spreading, row sowing). Today, it is mostly planted in rows, and the spacing should be 1.5-2.0 m and 0.5-0.8 m above the row. Sowing depth is 2-4 cm. Sowing in rows can be done directly with a seeder or by using single or double seeders on the backs of the furrows opened with furrow openers. After planting in the furrow, these furrows are used for irrigation and top fertilization (Övezmuradov, 1972; Günay, 2005; Acar, 2006).

If a soil crust has formed on the soil surface after planting; this needs to be broken up or softened by sprinkler irrigation to facilitate exit. When they have 2-4 leaves after emergence plants should be diluted. When the plants have 5-10 leaves, weed hoe should be done and the throat part (junction of root and stem) can be filled. Weed control can also be done chemically. Hoeing should be done 2 or more times, according to the need, without damaging the plant. Irrigation can be used to temper the soil before planting in arid areas. Irrigation can be 4-6 times depending on the need (Övezmuradov, 1972; Günay, 2005; Acar, 2006). There is a positive relationship between irrigation and yield, and it was stated that irrigation was done 9 times in some parts of Turkmenistan (Övezmuradov, 1972). The number of irrigations varies according to soil characteristics and climate. Acar et al. (2014) in their study to determine the effect of different irrigation levels on yield and yield components of forage watermelon; They stated that if the farmers want to get high yields, they should irrigate more, but if the water resources are limited or they want to reduce the irrigation costs, it is more appropriate to use less water and the highest water use efficiency is obtained from the limited irrigation application. The response of the forage watermelon to organic fertilizer is good, and organic fertilizer (manure organic fertilizer) should be given before planting if possible (1-5 tons/daa). Since it grows better in more light soils (sand, loamy sand, sandy loam, etc.); fertilization is important. Especially in the vegetative development period, the need for nitrogenous fertilizers and in the generative period phosphorus and potash fertilizers are high. Although it varies according to the soil, 10-15 kg of pure N, 15-20 kg of K and 10-15 kg of P_2O_5 are used per decare, and it can be sprinkled according to the fertilizer growing system and given to the quarry or into the furrow (Övezmuradov, 1972; Günay, 2005; Acar, 2006).

Forage watermelons are more resistant to diseases. However, in cases where diseases or pests are seen, chemical control should be done by considering the harvest date (Assis et al., 2000; Acar, 2006).

Although the harvest is done at various times in edible watermelons, it is done at once in forage watermelons (Günay, 2005; Acar, 2006). Harvest time varies according to the early and late varieties of forage watermelon. It is stated that this period is between 90 and 130 days in Turkmenistan, between the end of August and September (Övezmuradov, 1972). It is harvested in September in Konya (Acar, 2006). The part of the forage watermelon that is used by storing is its fruit. After the fruit of the forage watermelon is harvested, the above-ground green parts (branches, leaves) can be shredded together with other silage plants and used as silage. It has been determined that fruit yield varies between 3500-8500 kg/decare depending on the variety and growing conditions (Övezmuradov, 1972; Acar, 2006). Due to the fruit feature of the forage watermelon, it is easy to transport and can be stored for a long time without spoiling. Ripe fruits in Konya remained intact for 1-1.5 years. This feature shows that the fruits of the forage watermelon can be used for 1 year to meet the need for juicy fresh feed. Forage watermelon is especially recommended for feeding dairy cattle (Popov et al., 1957; Övezmuradov, 1972; Acar, 2006).

4. YIELD AND QUALITY

The main part of the forage watermelon used by storage is its fruit. Fruit yield varies according to the variety grown, climatic conditions and applied agricultural practices.

In a study conducted in İzmir between 2009-2010, the average fruit yield of forage watermelon grown as a second crop was 8761 kg/decare, 2.5 fruits per plant, average fruit weight 3443 g/plant, fruit dry matter ratio 4.48%, seed number 344.3 units/ fruit, seed yield was determined as 48.9 g/fruit, and the weight of a thousand grains is determined as 147.1 g (Geren et al., 2011). They stored watermelons from the same study for up to 210 days and found weight loss every 30 days. Accordingly, they reported that the weight structures on the 30th, 60th, 90th, 120th, 150th, 180th and 210th days are 3.63%, 4.92%, 7.80%, 8.64%, 10.75%, 12.50% and 14.74%, respectively, and that the fruits could be stored for 210 days without spoiling (Geren et al., 2011).

Kocaöner (2014) determined the number of fruits per plant as the lowest 2.35, the highest 2.62 and the average 2.52, the average fruit weight per plant the lowest 4931 g, the highest 5568 g and the average 5243 g; The lowest fruit yield is 17100 kg/decare, the highest 17850 kg/decare and the average is 17387 kg/decare, fruit length is between 21.2 – 46.9 cm; fruit circumference is between 36.7 – 69.3 cm, rind thickness is between 20.1 – 27.5 mm; BRIX rate in fruit is between 1.4 – 2.3 %; dry matter ratio in fruit is between 2.7 and 6.23%; The number of seeds in the fruit was between 303 and 637, the seed yield was between 64.9 and 115.7 kg/fruit, and the weight of a thousand seeds was between 156.0 and 201.5 g. He reports that the weight loss in the large-fruited watermelon group is twice as high as in the small-fruited group, with an overall loss of 34% at the end of a 270-day storage period.

Kavut et al., (2014) conducted a study to determine the effect of different plant frequencies on fruit yield, some yield characteristics and storage time in forage watermelon. As a result of the study, they stated that plant density was effective on fruit weight, fruit number and size. The highest fruit yield in forage watermelon was obtained in planting (189.32 tons/ha) made to 210 x 50 cm (9524 plants/ha). They determined that the ripe fruits obtained could remain for more than 6 months without any decay and without any significant loss in nutritional quality.

Kocaöner Şenel and Geren (2015) in their study with forage watermelon in the Aegean Region of Turkey, the number of fruits was 2.52/plant, the fruit weight was 5243 g/plant, the fruit yield was 17387 kg/daa, the fruit length was 35.4 cm, the rind thickness was 21.9 mm, water soluble. dry matter rate was 1.8%, fruit dry matter rate was 4.36%, number of seeds was 486/fruit, seed yield was 86.8 g/fruit, and the weight of a thousand seeds was 175.1 g. The researchers reported that the forage watermelon did not deteriorate during the 9-month storage period, the weight loss varied according to the fruit size, and there was an average of 22.8% in 210 days of storage, 27.4% in 240 days, and 34.3% in 270 days.

The fruit of the forage watermelon is used for making silage together with sorghum and corn, as well as fresh consumption as forage, and it is given mixed with hay or straw. It is a special advantage that the fruits can be stored for a long time without spoiling, and they are used as juicy fresh feed within a year. It has also been stated that the green leaves and branches remaining after the fruits are harvested can be used for silage production together with other silage plants (Acar, 2009).

Acar et al. (2015) determined some characteristics and feed values of forage watermelon fruits of varied sizes. According to the fruit size and the analysis is done with seeds (without removing the seeds in the fruit) or seedless (without the seeds in the fruit), the dry matter ratio (DMR) varied between 4.32 – 8.27%, raw ash ratio (RAR) 6.35 – 10.89%, crude protein ratio (CPR) 4.47 – 13.58%, crude oil ratio (COR) 1.77 – 11.69%, NDF 33.6 – 81.84%, NFC 15.82 – 48.71% and ADF 27.19 – 41.85% (Table 1).

Table 1. Changes in Feed Value of Different Sizes of Forage Watermelon (%) (Acar et al., 2015)

Fruit size		DMR %	RAR %	CPR %	COR %	NDF (%)	NCF (%)	ADF (%)
Small	without seeds	4.32	10.33	10.76	4.46	35.04	39.41	29.88
	with seeds	6.65	7.07	13.58	11.69	51.84	15.82	41.85
Middle	without seeds	5.38	10.89	9.85	3.60	33.07	42.59	27.19
	with seeds	8.25	6.35	11.33	8.29	46.46	27.57	37.25
Large	without seeds	5.66	8.45	7.47	1.77	33.60	48.71	27.53
	with seeds	8.27	7.90	11.24	4.14	35.19	41.53	28.75
Average	without seeds	5.12	9.89	9.36	3.28	33.90	43.57	28.20
	with seeds	7.72	7.11	12.05	8.04	44.50	28.30	35.95

In their study to determine the combination capabilities of forage watermelons, Santos et al. (2017) found average fruit length as 29.39 cm, fruit length/fruit diameter ratio as 1.73, rind thickness as 1.32 cm, fruit width as 21.66 cm, number of fruits per plant as 8.30, fruit weight is 3.12 kg, the fruit yield per plant as 25.07 kg, the number of seeds per fruit as 692.16 and the dry weight of the seeds as 86.59 g.

Due to the high oil (28-30%) and protein content of the seeds of forage watermelon, they are given to animals together to increase the nutritional value of the fruits (Anonymous, 2011a; Anonymous, 2011d). The sizes of the seeds vary (Zorobi et al., 2006). Watermelon seeds are a food source for farm animals. In a study, it was stated that the dry matter in watermelon seed was 16.8% crude protein, 61.5% NDF, and its effect on milk yield and quality in cattle is experimented (Shayo et al., 1997).

Acar et al. (2012) conducted a study to determine some physico-chemical properties of forage and edible watermelon seeds. According to the results of the study, linoleic acid 63.19 – 72.03%, oleic acid 17.55 – 24.65%, Cd 0.02 – 0.09 mg/kg, Ca 465 – 1166.63 mg/kg, K 6660.77 – 8271.24 mg/kg, Mg 3277.27 – 3916.89 mg/kg, Na 74.61 – 337.78 mg/kg, P 5075.75 – 8396.93 mg/kg and 1920.60 – 2871.26 mg/kg, Fe 90.58 – 230.09 mg/kg, Cr 0.37% – 1.46 mg/kg, Mn % 6.08 – 11.31 mg/kg, total phenol content varied between 0.13 – 0.30 mg GAE / 100 mg.

Other Area of Usage

Forage watermelon is used as human food in different parts of the world, as well as being used as feeding animals. In addition, due to its low sugar content, it can be consumed by humans as a diet watermelon. The pectin a wide range of uses as a natural food additive in the world. In the food industry, it is used as a thickener and preservative in jams and desserts due to the pectin it contains, in jam making (Bullitta et al., 2007). Fresh and small fruits are used in pickle making. In addition to the use of seeds as human food, the oil obtained is used as a skin care product in the cosmetic industry. Likewise, the seeds are used in traditional medicine. Since some of the forage watermelon is resistant to root diseases and pests especially seen in edible watermelon, it can also be used as a rootstock grafting material for breeding edible watermelon

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ISBN: 978-625-6955-82-0