

LEGUMES PROCESSING AND POTENTIAL

EDITED BY
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PREFACE

Legumes well recognized an important food crop for the globe and it is playing vital actions in developing countries. it is considered one of the the main sources of proteins, starch, fiber, vitamins, and minerals for the human diet, being .Climate change has the potential to impact the quantity and reliability of legumes production, quality of seeds. However, the underlying mechanisms have not been fully cleared. This book summarizes the highlighting the importance of nutritive value legumes crops, the present improvements and some of future directions for enhancing the processing for nutritional quality. Accordingly, recent technologies that have greatly increased food supply on the legumes productivity and quality, highlighting the need for Global food security. Furthermore, Other related subjects, to supply an updated and universal demand of the importance of legumes in human feeding.

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CHAPTER 1

RED CLOVER (*Trifolium pratense* L.)

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INTRODUCTION

The Fabaceae is one of the largest and economically most important families of flowering plants (Dall'Agnol et al., 2021), and it includes the most valuable genera of agriculture of forage crops in the world. One of these genera is the genus clover (*Trifolium* sp.), and this genus is an important member of this family after alfalfa (*Medicago* sp.) and vetch (*Vicia* sp.). The genus clover (*Trifolium* sp.) incorporates about 250 species, and approximately 20 of them are grown economically (Dluhošová et al., 2018). Red clover (*Trifolium pratense* L.) is considered one of the most significant forage legume crops in the temperate climate regions of the world (Herrmann et al., 2008; Jing et al., 2021). It is mostly present in meadows and pastures in Europe, Asia, and Africa and is used as a cultivar (Możdżeń et al., 2020). It is a valuable source of forage for ruminants, pigs, and poultry in the form of green forage, straw, silage, or dry forage while being a plant that provides forage on the farm throughout the year and is rich in valuable nutrients (Przybylska et al., 2021). Red clover can also be used as a green manure crop to enhance soil fertility (McKenna et al., 2018).

Forage legume crops play a significant role in both maintaining soil fertility owing to their biological nitrogen fixation (BNF) ability and increasing the productivity of farm animals since they are a source of high protein forage (Jones et al., 2020). Therefore, the use of legumes is promoted in terms of agricultural sustainability (Lüscher et al., 2014; Özyazıcı and Açıkbaş, 2021). In this context, red clover draws attention among forage legume crops as a significant alternative plant. In this chapter, important information is provided regarding the important agricultural characteristics of growing red clover (*T. pratense* L.).

1. CLIMATE AND SOIL REQUIREMENTS OF RED CLOVER

Red clover, which is a short-lived perennial (2-4 years) species (Heuzé et al., 2015), has cultivation tolerance in a very wide pH range (5.0-8.5) in terms of soil reaction. However, the optimum soil pH range for red clover cultivation is 6.0-7.6 (Rice et al., 1977). On the other hand, the resistance of red clover to low pH levels depends on the available amount of plant nutrients in the soil (Heusinkveld, 1948). In this sense, in areas with a soil acidity problem, the application of lime ($CaCO_3$) according to soil analysis can ensure more stable feed production by creating positive effects on the development of red clover.

There must be a sufficient amount of macronutrients such as phosphorus (P) and potassium (K) in agricultural soils where red clover is cultivated. Phosphorus is an important plant nutrient, especially for the development of roots and nodules in legumes. Therefore, the application of phosphorus to the soil, particularly in the first year of establishment, according to the results of soil analysis, will affect the longevity of red clover.

Although red clover is resistant to poor drainage conditions, well-drained soils are more suitable for its optimum development (Wyngaarden et al., 2015). Loamy, silty-loamy, and well-drained clayey soils with a high water-holding capacity are ideal soils for red clover cultivation (USDA, 2002).

Red clover can also germinate at temperatures as low as 5 °C (Clark, 2007). The optimum temperature requirement of red clover, which prefers cool and humid climatic conditions, during growth and cultivation is 18-25 °C (Frame et al., 1998; Heuzé et al., 2015), and it can also maintain its vitality at temperatures varying between 7 and 40 °C (Frame et al., 1998). However, its growth slows down at temperatures above 32 °C (Gist and Mott, 1957). It grows in areas with a total annual precipitation regime of over 350 mm. In this sense, its optimum precipitation amount is 550 mm and above (Frame et al., 1998). In this climatic zone, the red clover plant develops quite well (Figure 1).

Figure 1. Red clover growing in temperate climate zone

2. USAGE AREAS OF RED CLOVER

2.1. Use for Herbage Production

Red clover grown for herbage production provides quality roughage with a high nutritional value for livestock enterprises. Although herbage yield and quality vary according to ecological conditions, climate comes into prominence as the ecological factor influencing yield in red clover. Humidity leads the climatic factors, and red clover is more fertile in areas where humidity distribution is better during the growing season (Leto et al., 2004). Moreover, it is reported that more yield is achieved from *T. pratense* L. in mountainous regions with medium altitudes such as 400-700 m compared to low- and high-altitude areas (Užík and Mištinová, 1978; Gospodarczik and Nowak, 1989; Leto et al., 2004). Some data on hay yield and crude protein (CP) ratio obtained from red clover under different climatic and soil conditions are presented in Table 1.

Red clover should be harvested for the first time during the 50% flowering period for both high hay yield and high protein yield. If the following harvests are performed toward the full flowering period, high-yielding and quality herbage can be obtained (Heusinkveld, 1948).

Red clover can be grown solely or in a mixture with grasses for herbage production. In this sense, red clover is one of the most grown legumes in short-term mixtures (Cave et al., 2014). In cultivations of legume-grass mixtures, a more balanced roughage is obtained for animal nutrition. Furthermore, owing to the nitrogen (N) provided by legumes, grasses in the mixture can stay green for a longer time. This also provides significant advantages for enterprises due to the prolongation of the green forage period. From this aspect, the red clover plant is an important component of the long-term green forage period.

Table 1. Forage yield and CP ratio of red clover in different soil and climate conditions

Precipitation regime (mm)	Soil structure	Forage yield (t DM/ha)	CP (%)	Reference
195.5	Loamy, pH= 7.4	8.42		Tosun et al. (1980)
296.0	Clay-loam, pH= 7.75	6.41	17.9	Özyazıcı and Manga (1996)
450	Loamy, pH= 7.6	11.33		Gökkuş et al. (1999)
836-1230	Alluvium-colluvium's brown soil, brown acid soil	8.9-9.9	15.7	Leto et al. (2004)
338	Chernozem soil	8.1-12.2	14.9-18.7	Vasiljević et al. (2005)
	pH= 5.3	4.8-7.2		Cupic et al. (2007)
	Endocalcari-Endohypogleyic Cambisol, pH= 7.2-7.3	16.6-17.8		Liatukas and Bukauskaitë (2012)
374.5-669.4	Alluvial soil, pH= 4.8	6.3		Stevovic et al. (2012)
374.5-680.3	Alluvial soil, pH= 4.8	10.4		Tomić et al. (2012)
888.5	Clay-loam, pH= 6.9	9.10		Sürmen et al. (2013)
287.1-504.3	Eutric Cambisol, Silt clay-loam	19.29	16.3-18.5	Tucak et al. (2013)
743-1066	pH= 6.6	1st harvest: 6.2-6.4 2nd harvest: 4.4-4.5 3rd harvest: 3.3-3.2 4th harvest: 0.87-0.90 Total: 14.8-15.0		Clavin et al. (2016)
439.7-1011.5	Clay-loam, pH= 7.35-7.91	13.29	18.9	Alay et al. (2017)
	Clay, pH= 6.2	5.6-11.7	18.7-19.9	Sousa et al. (2020)
1037.2-1379.8	Andisol, family Typic Hapludands Loam, pH= 6.21	6.2-15.9		López-Olivari and Ortega-Klose (2021)

Red clover (*T. pratense* L.) is mostly grown as mixes with grasses such as timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.), tall fescue (*F. arundinacea* Schreb), and perennial ryegrass (*Lolium perenne* L.) (Stockdale et al., 2003; Amdahl et al., 2016a). Moreover, when grown as a mixture, Italian ryegrass (*L. italicum* L.) has been reported as the most ideal species for mixture cultivation with red clover (Mandić et al., 2004; Simić et al., 2011; Tomić et al., 2012).

It is stated that the mixture cultivation of red clover with grasses such as tall fescue (*F. arundinacea*), meadow fescue (*F. pratensis*), timothy (*Phleum pratense*), smooth bromegrass (*Bromus inermis*), orchardgrass (*Dactylis glomerata*), and crested wheatgrass (*Agropyron cristatum*) provides dry matter (DM) yield over 100% when compared to sole cultivation, and the highest, steadiest and most balanced hay yield is achieved from the red clover-tall fescue mixtures by years and seasons (Goranova and Mihovski, 2006). Italian ryegrass mixed with red clover produces 41% more yield than Italian ryegrass in monoculture; such a mixed growing system also suppresses weeds, and therefore high-quality roughage can be obtained (Ryan-Salter and Black, 2012).

Red clover increases the amount of CP and calcium (Ca) of the mixed-grass in mixtures (Lunnan, 2000) and results in higher live weight gain and increased reproductive performance in cattle by enhancing the palatability and digestibility of the feed mixture (Huss-Danell et al., 2007; DeWhurst et al., 2009).

2.2. Use for Silage

Vanhatalo et al. (2009), stating that red clover (*T. pratense*) is the main forage legume crop used in the production of silage in Northern Europe, emphasized that it might play a more important role in silage production in the future due to its ability to fix elemental nitrogen in the air. Many researchers have reported that red clover may be a promising and important crop for the production of silage with high protein content (Vanhatalo et al., 2009; Moorby et al., 2016; Elgersma and Søegaard, 2018).

Red clover with a high CP content has a high buffering capacity (BC) and low water-soluble carbohydrate (WSC) content (McDonald et al., 1991; Jones et al., 2003). Therefore, the silage of red clover, which has been harvested and from which silage has been made, especially during the early vegetative period (King et al., 2012a, 2012b) when the DM content is low and the BC ratio is high, and its preservation as silage is difficult (McDonald et al., 1991; Buxton and O'Kiely, 2003). Hence, to obtain a well-fermented (nutrient, microbial, and aerobic stability) silage feed with red clover, silage should be made at appropriate mixing ratios with grasses, and/or chemical and biological (bacterial inoculation) additives should be applied (Jones et al., 2003; Đorđević et al., 2021). Moreover, to prevent losses during wilting, red clover should be ensiled at 25-35% DM. Heusinkveld (1948) suggested making silage of red clover with high protein and low sugar content by mixing it with phosphoric acid, molasses, and ground corn.

Protein degradation is undesirable during ensiling. While 44-87% of the CP in alfalfa silage is broken down into non-protein nitrogen (NPN) during ensiling, this rate varies between 7-40% for red clover silage (Papadopoulos and McKersie, 1983; Muck, 1987). It has been reported that this low NPN formation in red clover silage originates from the effect of the polyphenol oxidase enzyme, which is contained at a high rate in red clover (Albrecht and Muck, 1991; Jones et al., 1995; Lee et al., 2008; Van Ranst et al., 2011).

In silages made with alfalfa and red clover harvested in the early and late periods, the DM, CP, acid detergent fiber (ADF), neutral detergent fiber (NDF), Ca, P, pH, lactic acid (LA), acetic acid (AA) and butyric acid (BA) ratios of alfalfa silages were determined as 41.9%, 16.7%, 35.4%, 44.8%, 1.08%, 0.31%, 4.64, 7.28%, 2.63%, and 0.06%, and ratios of red clover silages were determined as 42.6%, 17.9%, 31.5%, 40.4%, 1.09%, 0.28%, 4.63, 7.74%, 2.05%, and 0.01%, respectively, as an average of the harvest stage and two years. The same study reported that in the digestibility of NDF, slowly digested NDF fraction was higher in red clover than alfalfa. On the contrary, it was reported that the undigested NDF fraction was lower, and the potentially digestible ratio was higher in red clover. The researchers indicated that these results did not support the hypothesis stating that red clover has lower NDF digestibility properties than alfalfa, and red clover yielded similar or slightly better milk yield compared to alfalfa when both were harvested for silage on the same day (Hoffman et al., 1997).

A study comparing red clover and alfalfa silages determined that red clover had lower rumen degradable protein (RDP), CP, and ADF, higher rumen undegradable protein (RUP), and similar NDF as an average of harvest schedules compared to alfalfa (Grabber, 2009). Some similar studies reported that red clover silage provided higher amounts of RUP to the intestinal flora than grass (Merry et al., 2006; Vanhatalo et al., 2009) and alfalfa (Brito et al., 2007) silage. These properties of red clover silage increase its potential to reduce the use of soybean meal and rapeseed meal as protein sources in dairy farming (Westreicher-Kristen et al., 2021).

In the mixed silages of perennial ryegrass (*L. perenne*) and red clover (*T. pratense* L.), Moorby et al. (2009) reported that the DM ratio of the silage, WSC, ether extract, and LA ratio decreased, while the NDF, ADF, AA and BA ratios and pH value increased in parallel with the increased red clover ratio in the silage. The same study reported that increasing the red clover ratio in dairy cow rations increased feed intakes and milk yield, reduced the fat and protein concentration in milk, increased PUFA (polyunsaturated fatty acids) for health, and had very little effect on the organoleptic properties of milk. The researchers also indicated that the optimum milk yield was obtained when cows were fed with silage in which 66% of the roughage components in the ration consisted of red clover.

In a study carried out with silage mixtures of corn and red clover in different proportions, the CP concentration of the ration increased and the starch concentration decreased as the ratio of red clover silage in the mixture increased. In the same study, the highest feed DM intake, milk yield, and milk protein yield, and the optimum feed intake were obtained in silage roughage with equal proportions of corn and red clover (Moorby et al., 2016).

In a study conducted to determine the quality characteristics of silages obtained by ensiling the sole, binary (50+50%) and ternary (40+30+30%) mixtures of chicory (*Cichorium intybus* L.) and some companion crops (*L. perenne* L., *D. glomerata* L., *T. repens* L., *T. pratense* L., *Medicago sativa* L., and *Lotus corniculatus* L.), it was revealed that pure red clover silage was of "medium" quality, the binary silage of red clover and chicory was of "good" quality, and the ternary silage of red clover and other plants was of "medium" quality according to Flieg's scoring. In the same study, the CP, ADF, NDF, LA, AA, BA, K, P, Ca, magnesium, sodium, iron, zinc, manganese, copper, and molybdenum contents of sole red clover silage were determined as 17.98%, 26.37%, 37.02%, 1.87%, 0.22%, 0.02%, 2.43%, 0.34%, 1.03%, 0.75%, 0.13%, 50.95 ppm, 5.31 ppm, 14.31 ppm, 1.31 ppm, and 0.11 ppm, respectively (Can et al., 2020).

Red clover, harvested and silaged in two different development stages (the onset of flowering and 50% flowering), was subjected to bacterial treatment including *Lactobacillus plantarum* and *Pediococcus* spp., and silage quality was examined. According to the study results, inoculation containing these bacteria improved the chemical, energy, and fermentation parameters of silages, and the obtained silages had lower ADF, NDF, ammonia nitrogen in total nitrogen (NH_3-N/TN), AA, BA, and pH content, and higher DM, CP, total digestible nutrients (TDNs), relative feed value (RFV), and LA content compared to the control group. Moreover, the researchers emphasized that the administration of the microbial inoculant in the appropriate harvest stage might contribute to less nutrient loss in roughage and improve the silage quality (Đorđević et al., 2021).

Red clover (*T. pratense* L.) chopped in a blender for silage was treated with pre-fermented juice (PFJ), and the effects of PFJ on red clover silage were analyzed. The addition of PFJ to the silage increased the LA ratio and decreased the pH and AA ratios of the silage. These satisfactory fermentation parameters also contributed to the improvement of in vitro digestibility of dry matter (IVDMD) of the silage (Sun et al., 2021).

In some other studies, higher intake characteristics and improvement in milk yield were identified in silages made with red clover compared to grass silage (Bertilsson and Murphy, 2003; Al-Mabruk et al., 2004), alfalfa silage (Broderick et al., 2000), and corn silage (Hazard et al., 2001).

2.3. Use as a Cover Crop

It has been reported that the establishment rate of red clover, which starts growing 7 days after cultivation (Clark, 2007), is equal to that of alfalfa (Blaser et al., 2011) and even superior (Smith et al., 1975). Among clover species, red clover has the highest below-ground biomass (Kirchmann, 1988). These characteristics provide a significant advantage in using red clover as a cover crop.

Red clover is used as a cover crop to protect the soil, improve soil health, and minimize risks under biotic and abiotic stress conditions (Gaudin et al., 2013). With a low light compensation point of approximately 140 μmol s^{-1} m^{-1}, red clover is reported to have the potential to be grown under winter wheat with its shade-tolerance property (Liebman et al., 2001). In this context, shade tolerance and the ability to accumulate biomass at low light levels are among the most important advantages of using red clover as a cover crop (Gist and Mott, 1957).

Furthermore, red clover grows slowly in the first establishment year. Therefore, it is reported to be suitable for under-sowing, especially in grains (Känkänen and Eriksson, 2007). Additionally, some characteristics such as the ability to fix the free nitrogen of the air to the soil, suppressing weeds, and flower morphology that attracts many pollinators are important factors playing a role in the prominence of red clover as a cover crop.

In polyculture agriculture, in which corn (*Zea mays* L.) is continuously grown for silage in sloping lands and the majority of the year is not protected against erosion, annual ryegrass (*L. multiflorum* Lam.) and medium red clover (*T. pratense* L.) practices, and practices of intercropping, a combination of the two, have been reported as the most effective applications in terms of soil coating and DM production of plants (Scott et al., 1987).

The use of legumes as cover crops in corn agriculture has been stated to provide potential benefits in terms of reducing the use of nitrogen fertilizers, and the use of red clover for this purpose results in significant economic gains (Stute and Posner, 1995).

In a study in which red clover was used as a cover crop, it was reported that red clover produced much more aboveground biomass and biomass N than the winter fallow, red clover cultivated before corn increased the aboveground biomass N accumulation of corn by 32-38%, and high corn grain yield was achieved (Gentry et al., 2013). In Southern Ontario, to improve the sustainability of the agroecosystem, cultivation of red clover (*T. pratense*) under wheat (*Triticum* spp.) is a recommended practice in corn-soybean-wheat rotation (Wyngaarden et al., 2015), and the benefits of similar practices in terms of soil fertility and crop yield have been documented by some other studies (Dapaah and Vyn, 1998; Drury et al., 2003; Miguez and Bollero, 2005; Henry et al., 2010; Gaudin et al., 2014).

Moreover, the use of red clover as a cover crop may play an important role in improving soil quality, reducing soil erosion, suppressing weeds, diseases, and pests, and increasing the yield and quality of crops.

2.4. Use as a Green Manure Crop

With their BNF capacity, legumes add nitrogen to the soil. In this respect, they are an important component of sustainable agriculture systems. Green manuring for sustainable agriculture and the use of green manure crops to this end play an important role in improving soil fertility, reducing chemical fertilizers and herbicides, and increasing the yield and quality of products. In this sense, red clover is one of the most popular green manure crops in many parts of the world, such as Korea (Cho et al., 2010), Northeast Iowa (Liebman et al., 2012), and Estonia (Lauringson et al., 2013). With biomass N yield ranging between 51-196 kg/ha (Ross et al., 2009; Talgre et al., 2012; Kanatas et al., 2020), red clover can be said to be a potential green manure crop.

Liebman et al. (2012) reported that the N fertilizer equivalent to 70-121 kg N/ha was provided for corn in the green manure application with alfalfa, and this amount was 87-184 kg N/ha in the application in which red clover was used as a green manure crop. The researchers drew attention to the fact that such saving practices would become more important nowadays when fossil energy sources are decreasing and fertilizer prices are increasing.

Talgre et al. (2012) suggested that the stem (4.09 t/ha) and roots (3.28 t/ha) of red clover added a significant amount of DM to the soil, this amount was equivalent to the biomass added with lucerne and white melilot, green manure application with red clover provided significant yield increases in following products, and the green manure effect continued even in the third year.

In a study conducted under the climate conditions of Greece, it was stated that red clover (4.14 Mg/ha) produced significantly more biomass than white clover (*T. repens*) (3.26 Mg/ha), green manure applications with both clover species improved corn grain yield and other agricultural parameters influencing yield, and they were beneficial practices in increasing productivity in corn agriculture (Kanatas et al., 2020).

According to the reports of some other studies, red clover, as a green manure crop, improves grain protein content and wet gluten ratio in spring wheat (Talgre et al., 2009) and has the potential to be used as an important component of a sustainable weed management system (Ohno et al., 2000; Ohno and Doolan, 2001; Liebman and Gallandt, 2002).

2.5. Other Usage Areas of Red Clover

Red clover (*T. pratense* L.) is a high-quality forage that can be grazed or grown for hay (Figueiredo et al., 2007) and is a valuable component of permanent grasslands (Herrmann et al., 2008). In this sense, red clover is an excellent rangeland plant for livestock enterprises. On the other hand, it can cause bloating like alfalfa when grazed alone. However, the mixtures of grass and red clover are very unlikely to cause bloating. Furthermore, heavy/intensive grazing of red clover in autumn should be avoided to allow adequate storage of spare nutrients in the roots for protection against the winter cold, for the continuation of normal metabolic activities at low temperatures, and for ensuring regrowth in spring (Heusinkveld, 1948).

Red clover is also one of the important forage legume crops that can be used in artificial meadow establishments. In irrigated conditions, red clover yields better than alfalfa, and mixtures of red clover + grass give a higher hay yield than alfalfa + grass mixtures. It is also stated that high hay and CP yield has been obtained from the mixtures of red clover with red fescue (*F. rubra* L.), timothy (*Phleum pratense* L.), and meadow fescue (*F. pratensis* Huds.) (Serin et al., 1998).

Red clover, like other legumes, provides nitrogen to the soil by transforming atmospheric nitrogen into a form that plants can use. Moreover, by providing organic matter to the soil, it ensures a suitable environment for the root development of the plants that follow it. It plays a role in increasing the activity of microorganisms in the soil and in improving the physical properties of the soil by increasing the water holding capacity, aggregate stability, and infiltration rate of the soil. Owing to these properties, red clover is a very reliable product for organic agricultural systems and can significantly contribute to the improvement of soil fertility.

3. SEED YIELD AND PROBLEMS IN SEED PRODUCTION

Forage legume crop varieties generally produce seeds with low seed yield and/or low viability. Despite the development of red clover varieties with high forage yield and quality in recent years, these varieties have high production costs and insufficient seed yield. It is possible to increase the seed yield to some extent with optimum cultural practices in irrigation conditions and fertile soils. However, the negative correlation between forage yield and seed yield (Steiner et al., 1997) is considered as one of the obstacles to improving the seed yield property. The seed yield of red clover is explained by the components of seed yield, inadequate pollination, fertility problems, genomic regions associated with seed development and seed yield, and seed breeding (Vleugels et al., 2019).

Some genetic problems in red clover lead to differences in seed production. Red clover is a natural diploid and has both diploid and tetraploid varieties. The tetraploid red clover is taller and has thicker stems and wider leaves. It produces more forage yield compared to diploid red clover (Żuk-Gołaszewska et al., 2010). Tetraploids also has larger flower heads and bigger seeds. Furthermore, tetraploid red clovers are more resistant to root nematodes and crown rot (*Sclerotinia trifoliorum*) (Taylor and Quesenberry, 1996; Vleugels et al., 2013; Amdahl et al., 2016a). The main disadvantage of tetraploid red clover varieties is their low seed yield compared to diploid red clovers (Sjödin and Ellerström, 1986; Vestad, 1990; Boelt et al., 2015; Amdahl et al., 2016b; Jing, 2017). This low seed yield in tetraploids has been explained with poor pollination due to flower morphology (eg. longer corolla tube), lower number of ovules per plant, seed yield per flower head, and developmental irregularities before and after fertilization (Büyükkartal, 2003; Boelt et al., 2015; Amdahl et al., 2016a, 2016b).

On the other hand, some essential nutrients that play a role in the symbiotic nitrogen fixation of legumes have an indirect effect on seed yield. In this sense, cobalt (Collins and Kinsela, 2011) and boron (Blevins and Lukaszewski, 1998) have been said to increase nitrogen fixation and thus play a role in legume growth. Plant growth and metabolism may be associated with cobalt concentration, especially in the production of red clover seeds in acidic soils, where certain macro and micro elements required for plants are less available (Palit et al., 1994). In fact, Tomić et al. (2014) reported that foliar application of cobalt had a positive effect on seed yield and components of red clover varieties, and significant increases were observed in the number of flowers per plant, the number of seeds in the flower, and thus seed yield in cobalt applications when compared to the control group. The same researchers emphasized that foliar application of cobalt should be performed in the early stages of development in the first and second harvests of red clover to stimulate nodulation and nitrogen fixation in time.

Sufficient boron levels in the soil affect the increase in the number of fertile flowers, development of fruits and seeds in the plant (Rashid et al., 1994; Noppakoonwong et al., 1997). In the study conducted on red clover, foliar application of boron had a positive effect on seed yield and yield components in all varieties. It has been reported that these applications can increase seed production in less favorable weather conditions that inhibit pollination and fertilization, and in acidic soils, especially during flowering (Tomić et al., 2015).

In Western and Central Europe, diploid red clover varieties produce about 400-500 kg/ha of seeds, depending on location and variety (Boller et al., 2010). In the USA (Oregon), this amount usually varies between 600 and 1200 kg/ha (Anderson et al., 2019). Tetraploid varieties produce 20-50% fewer seeds than diploids (Amdahl et al., 2016a; Petrauskas et al., 2018). It is necessary to perform activities to improve seed yield in tetraploid varieties so that red clover can hold on to the seed market despite competitive prices (Vleugels et al., 2019).

There are some difficulties in pollination and/or insufficient pollination in red clover due to the nature of its flower structure. In red clover, the corolla tube is long, about 10 mm. Especially bumblebees (*Bombus* ssp.) can easily reach the nectar under the corolla tube owing to their long tongues, and pollination occurs (Wermuth and Dupont, 2010). For this reason, wild bumblebees (*Bombus* ssp.) play an important role in the pollination of red clover (McGregor, 1976).

It is crucial to improve some agricultural practices to increase seed yield in red clover. When macro elements such as P and K, which are especially effective in seed yield and quality, and micro elements such as molybdenum and boron, which play a role in nitrogen fixation, are found to be deficient in the soil, it is important to apply them to the plant or soil at the appropriate time and in the appropriate amount. Moreover, irrigation, particularly in arid areas (Anderson et al., 2016), and weed and pest control (Wermuth and Dupont, 2010) are included in the important agricultural practices of seed production. Again, the application of plant growth regulators that promote more intense flowering is also another recommended practice in red clover (Anderson et al., 2016).

Another common practice is pollinator supplementation, especially in large seed production areas (Rao and Anderson, 2010), to provide optimum pollination.

Breeding of high-yielding varieties is considered another solution to enhance seed yield in red clover (Vleugels et al., 2014, 2019).

On the other hand, it should be remembered that seed yield is a complex property shaped by the interaction of environmental and some agricultural practices in addition to the genetic characteristics of the plant. Even though many studies investigating various aspects of seed yield in red clover have been conducted in recent years, the problems in the seed yield of red clover remain unclear (Vleugels et al., 2019).

4. GENETICS AND GENOMICS OF RED CLOVER

Red clover (*T. pratense* L.) is a forage legume plant with diploid (14 chromosomes) (Trněný et al., 2019) and tetraploid (Amdahl et al., 2016a) genome constitutions. It is also a self-incompatible species, causing wide heterogeneity in the genome (Kongkiatngam et al., 1995).

The genetic structure of red clover is still not clearly defined. The most up-to-date genome assemblies cover approximately 348.8 to 440 MB in length over 7 haploid chromosomes. There were 169 reported genes with several functions, 60.487 protein groups, and 246.086 nucleotides according to the latest National Center for Biotechnology Information report (NCBI, 2021). There are relatively few studies, dissecting the genome and allelic constitution of red clover compared to more common legumes, such as alfalfa (*M. sativa*). Most of the studies evaluated genetic diversity of small populations with RFLP (Restriction fragment length polymorphism), AFLP (Amplified fragment length polymorphism), RAPD (Random amplification of polymorphic DNA), VNTR (Variable number tandem repeat), SSR-Microsatellite polymorphism (Simple sequence repeat) or few with SNP (Single nucleotide polymorphism) markers (Jones et al., 2020).

Similar to other crops, red clover breeding also has common goals, including but not limited to higher herbage or hay yield, better abiotic and biotic stress tolerance, and improved quality traits. Many of the goals are not easily achieved, due to limited allelic diversity in the domesticated gene pool (Campos-de-Quiroz and Ortega-Klose, 2001) and morphological limitations on identifying novel alleles (Li et al., 2019). Red clovers' complete self-incompatibility makes them an obligate cross-pollinating species, resulting in a diverse population structure. Even though there is a wide gene pool of alleles in the natural populations of red clover, identifying allelic sources through morphological assessments is quite difficult. Tools of modern genetic and genomic approaches may enhance the identification and selection process for breeding and backcrossing studies. The use of genetic markers may allow the identification of novel alleles for abiotic and biotic stress tolerance as well as improved agronomic and quality attributes.

Since the early 1990s, there have been several dozens of studies reporting genetic diversity in red clover using RFPL (Isobe et al., 2003), RAPD (Kongkiatngam et al., 1996; Ulloa et al., 2003; Greene et al., 2004), and AFLP (Herrmann et al., 2006; Pu et al., 2020) markers over the 90s to 2000s; and SSR (Paplauskiene et al., 2005; Dias et al., 2008a) and SNP (Li et al., 2019; Jones et al., 2020) markers in more recent studies. One of the early studies in red clover evaluates chloroplast genome diversity (Milligan, 1991). According to their results, there was higher intrapopulation diversity, compared to inter-populations. Even though the plastid genome does not represent nuclear genetic diversity, still was an indicator of available resources in the evaluated population. Similarly, Kongkiatngam et al. (1995) compared morphological, isozyme, and RAPD markers on two cultivars, from Canada and Europe. They compared RAPD and isozyme diversity over 80 plants per cultivar and within-cultivar diversity was found to be high. Grljusic et al. (2008) was also compared morphological and RAPD markers and reported results in a similar direction but with different levels of diversity dissections. The number of cultivars and clones they studied was quite limited, so the ability of RAPD and morphological markers would have been limited due to population size restriction. Campos-de-Quiroz and Ortega-Klose (2001) applied RAPDs to evaluate 16 different elite breeding lines for genetic diversity. According to their results, there were 0.66 Nei genetic similarities with a range of 0.60 to 0.77, suggesting a moderate to high genetic diversity among these lines. Another RAPD study by Greene et al. (2004) evaluated a total of 33 wild populations of red clover collected from the Caucasus Mountains and Russia to compare the morphological and RAPD marker differences. 14 out of 15 morphological parameters were highly polymorphic and coincided with climate regimes. On the other hand, RAPD data obtained from 10 random 10-mer primers did not follow the same trend. Since the number of accessions to be evaluated with morphological markers was quite limited, switching to DNA-based markers would be the time and cost-effective approach. Ulloa et al. (2003) compared 20 breeding populations and cultivars from Chile, Argentina, Uruguay, and Switzerland. Pairwise genetic distances were calculated using all combinations. According to analysis molecular variance (AMOVA), they obtained a mean polymorphism level of 74.2% across populations and 80.4% within the population. This is also another example of available diversity residing in gene banks and populations.

In a germplasm screening and pre-breeding project, Helgadottir et al. (2001) evaluated a total of 83 populations of red clover. 35 of these populations were tetraploid, while the rest was diploid. They screened for fusarium, sclerotinia, and frost resistance. They suggested that germplasm collections should be the starting point of pre-breeding studies. In a different study for genetic relationships analysis, Semerikov et al. (2002) compared Russian cultivars of red clover with western European and American cultivars, as well as with wild populations from the Ural region. They obtained little or no gene flow between domesticated and wild gene pools. Additionally, according to allozyme diversity, Russian cultivars of red clover seem to originate from the western European gene pools. In a similar study, Dias et al. (2008b) evaluated a set of 78 red clover accessions from the core collection of the National Plant Germplasm System (NPGS) of the United States Department of Agriculture (USDA) and one population from Brazil with isozyme markers and RAPD primers. They showed that there was a high genetic diversity on the NPGS core collection and isozyme markers provided a clear distinction between European populations and high latitudes, while the rest of the accessions in the evaluated core set did not have a clear difference based on biochemical markers. On the other hand, RAPD data showed a clean diversity among the collection evaluated.

The era of simple sequence repeats (SSR) or microsatellite markers were started around the second half of the 2000s for red clover (Paplauskiene et al., 2005). It was followed by the in-depth study of Sato et al. (2005), who screened all 440 MB of red clover genome and identified a total of 7159 primer pairs, of these 1305 SSR primers were successfully utilized on genetic diversity evaluation of a red clover mapping population. The number of markers and accessions can be considered as the highest compared to previous reports. In 2006 Herrmann et al. (2006) published a quantitative trait loci (QTL) study on a two-way pseudo-testcross population using 42 SSR and 216 AFLP loci. They identified a total of 38 QTL related to seed yield components. Kölliker et al. (2006) provided a brief report of SSR polymorphism on a set of 24 red clover and eight white clover (*T. repens*) genotypes. They reported 0.71 and 0.88 observed and expected heterozygosity levels, respectively, and suggested the use of these SSR primers in marker-assisted selection (MAS) studies. Ahsyee et al. (2014) also evaluated a small set of accessions (40 genotypes) using 15 different SSR markers. They indicated considerable levels of genetic diversity among accessions that were evaluated.

To generate a consensus map in red clover, Isobe et al. (2009) screened six different mapping populations using 1414 SSR, 181 AFLP, and 204 RFLP loci. The average distance between loci was 0.46 cM and the total map length was 836.6 cM. Their results were reported to be in line with the specific maps, while 1144 red clover individuals from these populations were screened using 462 randomly chosen SSR markers, resulting in 9.17 and 0.69, the number of alleles and polymorphism information content (PIC), respectively. Istvanek et al. (2014) made a *de novo* assembly of red clover genome, for comparisons with similar leguminous genomes and to dissect genome constitution. They obtained ~314.6 Mbp genome length, with relatively higher repetitive sequences, retrotransposons, and DNA transposons in red clover compared to other legume genomes. A total of 47398 protein-coding genes and 64761 predicted genes were reported. Genes related to resistance, leghemoglobins, and nodule-specific cystein-rich peptides were identified and compared with other sequenced species. A similar but more recent genome assembly is reported by De Vega et al. (2015). They provided a chromosome-scale reference genome for red clover and observed a close synteny with *M. truncatula* dating their divergence to around 23 million years. 40868 genes were annotated and several gene clusters were identified in relation to biochemical pathways important for forage quality and livestock nutrition. Additionally, a genotyping-by-sequencing (GBS) study was used to sequence 86 genotypes (Jones et al., 2020). They also proved that *M. truncatula* and red clover are historically related. Another GBS study evaluated natural populations of red clover totaling 640 plants from 70 natural populations from Europe and Asia. According to their cluster analysis, populations were grouped into four main clusters, namely Asia, Iberia, the UK, and Central Europe. Linkage disequilibrium decay rate was reported to be fast but bottleneck was not significant according to their analyses. A homolog gene (*VEG2*) was found to be associated with flowering time. They suggested that natural populations of red clover are sources of novel allelic diversity.

Over the last decade, several gene-level studies were published. In 2010 Riday and Krohn (2010) identified the loci for gametophytic self-incompatibility (*GSI*). First, they created a bi-parental population using a parental line with a self-incompatibility gene to identify the nearest loci to the target gene. After reducing the marker distance within a 2,5 cM length, a second population was generated to closely address the *GSI*-locus. Further analyses revealed a tight linkage at 2.5 and 4.7 cM between the GSI-locus, RCS0810, and RCS4956 markers. Another gene-level study was reported by Vleugels and van Bockstaele (2013). They aimed to identify clover rot (*Sclerotinia trifoliorum*) resistance genes using wild accessions, landraces, and domesticated genotypes. Resistant and susceptible parents were crossed and 15 populations were generated out of the crosses. The lines were inoculated with the spores and disease resistance levels were phenotypically scored. According to their results, 3 major and several minor effect genes were effective on the resistance to clover rot. As far as we know, one of the few gene cloning reports was done by Hu et al. (2015), using a reverse transcription-polymerase chain reaction. In their study, they cloned the isoflavone synthase (*IFS*) gene using *Agrobacterium tumefaciens* strain LBA4404. They successfully cloned and validated the *IFS* gene. An in-depth RNA-Seq study by Chao et al. (2018) revealed the gene expression patterns of leaf senescence. 35067 genes and 481 differentially expressed genes were identified. Gene expression patterns of some genes were similar to Arabidopsis, *M. truncatula*, and rice. Genes related to signal transduction, transportation, hormone metabolism, transcription factors, and senescence were upregulated, while nutrient cycling, lipid and carbohydrate metabolism, and hormonal response were downregulated. Many other genes related to synthesis, metabolism, and transduction of hormones were identified. Finally, 207 genes with a direct role in leaf senescence were highlighted. Trněný et al. (2019) studied phenotypic and genotypic variation for nitrogen fixation in red clover. 86 key candidate genes were sequenced using hybridization-based sequence capture and two genes were identified; *ethylene response factor required for nodule differentiation* (*EFD*) and *molybdate transporter 1* (*MOT1*). Powdery mildew (Erysiphe) is an important biotic stress factor in red clover. To identify QTLs related to powdery mildew resistance, Pu et al. (2020) analyzed 151 red clover hybrids and parental lines, a resistant (Ganong *PR1*) and a susceptible (Minshan) cultivar. Seven linkage groups were generated with 149 AFLP markers and 640.5 cM map length was achieved. Five QTLs affecting resistance to powdery mildew were located on linkage groups 4 and 5 with 29% to 90% phenotypic effects.

Red clover, one of the most important forage legume species, has a relatively small genome size (440 MB) compared to other forage legumes and Poaceae family members. There were several studies with RFLP, AFLP, RAPD, SSR, or SNP markers to reveal genetic diversity or identify target loci/gene(s). In addition to dissecting diversity in natural populations, landraces, and cultivated material, interspecific hybrids and gene identification may enhance the speed of breeding and gene pyramiding for agronomically important traits (Repkova and Nedelnik, 2014). Red clover is already successfully crossed with *T. sarosiense* Hazsl., *T. medium* L., *T. alpestre* L., *T. ambiguum* M.Bieb.

and *T. diffusum* Ehrh. However, most of the above crosses only evaluated the morphological appearance of the hybrids. A more recent interspecific hybrid was made between *T. medium* and *T. pratense* (Repkova et al., 1991). Most of the above studies were related to the identification of genetic diversity, very few with QTL analysis and gene expression or cloning. Genetics and genomics of red clover are still not well known and there is a need for more studies with QTL identification of agronomically important traits, locating and cloning of such genes, and gene manipulation with modern approaches such as the CRISPR-CAS9 system. Red clover is a good candidate to improve forage and hay yield production. However, with the current speed of classical breeding, breeding cultivars with multiple genes for abiotic and biotic stress factors is a challenge. Therefore, agronomists and breeders should benefit from the tools of modern biotechnological approaches.

5. POSITIVE ASPECTS OF GROWING RED CLOVER

(1) Red clover adapts to a wide range of soil and climatic conditions (Leto et al., 2004; Drobna, 2009; Ortega et al., 2014).

(2) Red clover is tolerant to acidic conditions (Smith et al., 1985; Sato et al., 2005).

(3) Red clover has a high annual BNF capacity (Leto et al., 2004; Pirhofer-Walzl et al., 2012; Dhamala et al., 2017). For this reason, it plays an important role in decreasing the use of nitrogen fertilizers (Abberton and Marshall, 2005; Przybylska et al., 2021) and makes it possible to obtain high-value protein yield (Przybylska et al., 2021).

(4) Red clover has a CP content of about 18%, equivalent to that of alfalfa and white clover (Stockdale et al., 2003).

(5) Red clover produces forage with a high nutritional value for ruminants (Leto et al., 2004). Red clover generally contains CP far above the nutritional requirements and thus plays a role in the improvement of performance in livestock (Lüscher et al., 2014).

(6) Red clover has high levels of enzymatic polyphenols, which directly improve nitrogen use in beef and dairy cattle and ruminants (Van Ranst et al., 2011).

(7) Some varieties have higher forage yields than alfalfa (Drobna, 2009).

(8) Red clover is more tolerant to drought than white clover (Jing et al., 2021). Annicchiarico et al. (2015) explain this situation with the development of a stronger root system in red clover, especially in the first year of establishment, compared to white clover. Due to this property, it is predicted that red clover will be a sought-after legume species of pasture mixtures in the face of drought stress increasing on a global scale (Lüscher et al., 2014).

(9) Red clover provides better yield than alfalfa in areas not suitable for growing alfalfa due to high soil acidity and/or excessive humidity/poor drainage problems (Smith et al., 1985; Bertrand et al., 2016) and is widely grown in such areas as forage for dairy cattle (Hoffman et al., 1997).

(10) The cost of growing red clover is much lower than some other forage crops (Harasim and Harasim, 2010; Staniak et al., 2017).

(11) The high polyphenol oxidase content of red clover slows down the degradation of proteins in the silage and thus decreases N losses from plant tissues (Lee et al., 2004; Sullivan and Hatfield, 2006).

(12) Red clover is a valuable rotation crop, especially in organic agriculture, where synthetic nitrogen fertilizers are not utilized (Taylor and Quesenberry, 1996).

(13) Red clover is a plant with a high competitive capacity.

(14) Red clover is moderately tolerant to drought (Heuzé et al., 2015) and highly tolerant to shade (Wyngaarden et al., 2015).

(15) Red clover fields attract beneficial insects (Bottenberg et al., 1997; Wyngaarden et al., 2015).

(16) Red clover helps reduce greenhouse gas emissions by decreasing synthetic fertilizers and improves soil structure with its BNF capacity (Moorby et al., 2009; Wyngaarden et al., 2015).

(17) Red clover increases carbon sequestration (Wyngaarden et al., 2015). Red clover increases the organic carbon content of the soils since it provides a significant amount of organic matter to the soil via both above- and below-ground components.

(18) Red clover has a polyphenol oxidase (PPO) enzyme system. This enzyme protects membrane lipids against degradation both in roughage during ensiling and in the ruminant's rumen. The protection of lipids against degradation is important because they may help improve the fatty acid profile of ruminants for consumer health (Van Ranst et al., 2011). In this context, another advantage of red clover is the less degradation of the protein in the rumen, compared to proteins in other plants (Broderick et al., 2004).

(19) Red clover has a good forage value in every period since much less reduction is observed in quality with advancing maturity (Lüscher et al., 2014).

6. NEGATIVE ASPECTS OF GROWING RED CLOVER

(1) The competitiveness of red clover against weeds is weak since it grows slowly in the seedling stage (Acar and Ayan, 2000).

(2) On the other hand, it is a matter of concern that the main product is hindered due to high competitiveness during the growing season (Wyngaarden et al., 2015).

(3) Both seed yield and seed production tended to decrease in the last decade (Jing et al., 2021), and certified seed production is insufficient (Żuk-Gołaszewska et al., 2019).

(4) Red clover is not very resistant to grazing. Therefore, it is used by being harvested 2-4 times in a season (Boller et al., 2010).

(5) Farmers worry that even the yield equivalent to grass yield obtained from forage grass crops with chemical nitrogen fertilization will not be obtained from red clover in some cases, and this yield will gradually decrease in a couple of years (Clavin et al., 2016). This situation is among the most important reasons why the cultivation of red clover is not common. In other words, the lack of stable yield of red clover over the years is considered the biggest obstacle in front of it.

(6) To preserve red clover in the form of straw, it must be dried and withered for a long time. In this case, it has a risk of being exposed to adverse weather conditions. This drying difficulty in red clover is regarded as a disadvantage in its storage as straw (Owens et al., 1999).

(7) Fresh red clover forage contains phytoestrogen. It is reported that this substance adversely affects the development and function of the reproductive organs, particularly in sheep (Hloucalová et al., 2016).

7. CONCLUSION

Nowadays, along with global warming, ecological deterioration is increasing rapidly, and the sustainability of all production systems offered to living organisms is at significant risk. In this sense, within the scope of agricultural sustainability, systems including legumes with biological nitrogen fixation capacity are considered ideal systems for minimum risk management. Special importance is attached to red clover, one of the forage legume crops, in traditional and modern livestock systems as a forage crop with global significance. Together with its characteristics such as high biomass production, high protein content, and ability to fix atmospheric nitrogen, red clover is also an important component of both short-term rotations and the cultivation system of grass-legume mixtures.

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CHAPTER 2

COMMON VETCH (*Vicia sativa* L.)

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INTRODUCTION

Winter and early spring is the most difficult period for livestock enterprises for the production of forage protein due to low feed availability during this period which results with more quantities of purchased feeds and increased production costs. Common vetch (*Vicia sativa* L.) fits well to this period and is an important forage due to its multiple usages as hay, pasture legume, grain, silage, green manure and cover crop. This crop also is recieving continuous global academic interest mainly on subjects of its agronomy, quality and alternative utilisation.

Here in this review, reader may find informations on these subjects on *Vicia sativa* from international articles published in last 10 years.
The temperate herbaceous genus *Vicia* L. is a member of the legume tribe *Fabeae* of the subfamily *Papilionoideae*. *Vicia* genus includes 166 annual or perennial species found mostly in Europe, Asia, and North America, and rarely in South America and Africa (Raveendar et al., 2015).

Vicia sativa subsp. s*ativa* (common vetch) is a diploid and self-pollinating annual legumes with short growth period, good nutritional value (Liu et al., 2014). Common vetch has a predominant zygomorphic flower. Its flower consists of 21 concentrically positioned organs: 5 sepals in the outermost, then 5 petals and 10 stamens, and 1 carpel in the core (Liu et al., 2013). Existance of many subspecies and accessions of vetch species made its taxonomic researches difficult. But its pollen morphology is important in the phylogeny of the plant. Ratios of equatorial to polar axes of pollen grains is significantly different for different subspecies and can be used for taxonomic studies (Dong et al., 2020).

Figure. 1. Economically important four vetch species: *Vicia narbonensis* (upper, left), *Vicia pannonica* (upper, right), *Vicia sativa* (lower, left) and *Vicia serratifolia* (lower, right) (Mikic, 2016)

Integrating protein rich forages into livestock feding systems is required for sustainable farming. Generally, winter period is the most difficult period for the production of forage protein to replace purchased feeds (Marley et al., 2016).

Vetch is an important forage due to its multiple usages as hay, grain, silage, and green manure (Chung et al., 2013). This crop can provide hay when feed availability is low during winter and early spring (Dong et al., 2019). Common vetch can be used as a pasture legume and is a source of highly digestible protein and minerals for animal diets (Aouida et al., 2019). As a cover crop and green manure it provides soil protection between cultivation seasons and increase soil nutrient and organic matter content in rainfed zones (Tenopala et al., 2012). It is one of the widely distributed and main forage crop in Mediterranean zone (Bechkri and Khelifi, 2017).

Despite agronomical benefits, cyano-alanine toxin content reduces its agronomic value (Kim et al., 2015). Detrimental cyanoalanine toxins exist in seeds and other plant parts (Chung et al., 2013). Cyanogenic antinutritional factors which reduce its palatability hinders its utilization as a feed for monogastric animals (Aouida et al., 2019). Also sensitivity of this crop to hard winters is another value reducing feature (Chung et al., 2013).

Agronomy

45 common vetch (*Vicia sativa* ssp. *sativa* L.) accessions were cropped during four seasons in North-West side of Syria to determine days to flowering and pod maturity, harvest index, yields and quality of hay, grain and straw in a study conducted by Larbi et al., (2011). Flowering stage was the harvest time for the determination of hay yield. Maturity time was the harvest time for the determination of grain yields, straw yields and harvest index (HI). Accessions significantly varied for days

to flowering (78–96 days), days to pod maturity (132–140 days), harvest index (0.17–0.37), hay yields (2245–3383 kg/ha), straw yields (2572–4028 kg/ha) and grain yields (808–1743 kg/ha). Accessions significantly varied for concentrations (g/kg DM) of hay CP (141–188), hay ADF (262–287), hay NDF (364–435) and hay IVOMD (725–782). Accessions also significantly varied for concentrations (g/kg DM) of straw CP (62–127), straw ADF (334–353), straw NDF (387–505) and straw IVOMD (437–511). Grain CP (266–316) also significantly differed among accessions. HI was in correlation with days to flowering and grain yield in Mediterranean environments (Larbi et al., 2011). Zoghlami Khélil et al., (2014) studied the phenology and agronomic features of seven common vetch genotypes for two years in contrasting ecologies. Variation was found significant between genotypes for seed weight, seed number, seed yield and earliness. Positive significant correlations were determined between "seed yield-seed number", "flower number-seed weight" and "flower number-seed yield". Highest seed yield was 1232 kg/ha. Huang et al., (2021) determined in their study that late-maturing varieties harvested latest pod-filling stage produces highest forage and protein yield.

Vicia sativa is an important forage legume for drought prone regions as a protein source and as a food but can be affected by drought stress negatively. Vetch have evolved distinct metabolic pathways in the aboveground part and underground part as a response to drought (Min et al., 2020). Drought stress during reproductive period, sharply reduce yields. Supplementary irrigation is an efficient method stabilize the yields under limited water availability (Heydarzadeh et al., 2020). Seed dispersion and loss of seeds by pod shattering is common in *Vicia sativa*. It is an important problem limiting the reproduction of the species in the field and usage as a crop (Kimet al., 2015). High quality seeds is very important for crop production. Li et al., (2017) determined that relatively low temperatures are required for *Vicia sativa* during seed development stage for the production of high quality seeds.

In a study conducted in Northwestern China to determine Rhizobia diversity infecting *Vicia sativa* plants, soils from six different locations in the northwest of China were sampled by Zhang et al., (2019). *Rhizobia sophorae*, *Rhizobia laguerreae* and 2 novel genospecies of *Rhizobium* were associated with vetch. In a study conducted by Zolotarev, (2016), inoculation of common vetch with *Rhizobium leguminosarum* biovar-viciae with molybdenum and/or boron micronutrient applications were tested. Molybdenum and boron interactions on the plants were nonadditive. Molybdenum treatment were increased the symbiotic interaction efficiency and yields (17-20%).

Figure 3. Field grown *Vicia sativa* in Australia (Nguyen et al., 2020).

Parasitic plant *Cuscuta campestris* is a serious worldwide problem for the production of broad leaved crops. *Vicia sativa* is highly susceptible to this parasitic plant and no resistant genotypes yet identified (Cordoba et al., 2021). Anthracnose is an important fungal disease of common vetch affecting stems and leaves of plants (Wang et al., 2020). Vetch is widely cultivated and a very important crop in China. Xu and Li, (2016) analysed the diseases reports on vetch by the end of 2015 and determined that 14 fungal diseases of vetch were reported from 28 countries. 10 of these 14 diseases infect the leaves and stems, 3 infect the roots and 1 infects the plants systemically. Four fungal pathogens (*Alternaria alternata*, *Aphanomyces euteiches*, *Pythium debaryanm*, *Verticillium dahliae*) were only infected *Vicia sativa* abroad, and two (*Epicoccum nigrum* and *Stemphylium botryosum*) were only infected *Vicia sativa* in China. In China, 10 fungal diseases of *Vicia sativa* have been detected in 10 provinces. In addition, six seed-borne fungi were detected in *Vicia sativa* seeds in China, and four of them are known to have negative effects on seed germination and seedling growth.

Quality

Vicia sativa plant is used mainly for animal feed. Its seeds contain relatively high amount of starch. Acid treatment does not effect granular structure of the starch. Due to this interesting property it can find different uses in industry which may improve its value (Bet et al., 2016). Mao et al., (2012) was conducted an experiment with common vetch to determine the influence of temperature on its fatty acid concentration. Moderate temperature (23/18°C) was significantly increased contents of lipids, stearic acid, palmitic acid, arachidic acid, oleic acid, behenic acid, linolenic acid and linoleic acid. Lipid and fatty acid contents of vetch varied with environmental conditions.

Although legumes are widely consumed by humans and are important source of nutrients, widely cultivated vetches are not generally used as human food due to non-nutritional factors (phytic acid, stachyose, raffinose, phenolics, flavonoids and condensed tannins). Usually, the non-nutritional factors are removed by cooking (Hernandez-Aguirre et al., 2020). Vetch seeds cost less compared to alternatives for feding farm animals. Can be partially or totally replaced with soybean meal and/or partially replaced with cereals in the animal diet due to high protein, energy and minerals content with high digestibility. To be used in non-ruminant diets or to increase their utilizing efficiency, non-nutritional factors are need to be inactivated by pre-processing methods (Huang et al., 2017).

Alternative utilisation

Common vetch is an interesting tool for phytoremediation. It has an efficient phenol-induced-oxidative-damage-protection-mechanism and due to this, it can tolerate and remove high levels of phenol concentrations without serious phytotoxic effects (Ibanez et al., 2012). Effects of copper on germination of *Vicia sativa* were investigated in a study of Muccifora & Bellani, (2013) and determined between 10^{-4} and 10^{-3} M. Plants were germinated at excess Cu but, arrested plantlets radicle growth.

Soil loss and runoff rates can be high in agricultural land which generally reduce soil fertility which may transform lands into bare soils. In a study of Rodrigo-Comino et al., (2020), common vetch was found suitable for vineyards (*Vitis vinifera* L.) to reduce soil and water losses as a cover crop.

Common vetch is a traditional medicinal plant for bronchitis, asthma, skin infections, urinary diseases. It has also antipoison, antiseptic, aphrodisiac, antipyretic and antirheumatic properties. Saleem et al., (2014) tested n-hexane extract of Common vetch as an antibacterial agent for *Bacillus atrophaeus*, *Escherichia coli Staphylococcus aureus*, *Staphylococcus epidermidis* pathogen bacteria. Phytochemical and

HPLC analysis revealed existance of a number of bioactive compounds exhibiting antibacterial activity.

CONCLUSIONS

Common vetch fits well to winter and early spring forage protein production aim to reduce purchased feeds and costs in livestock enterprises. *Vicia sativa* L. has multiple usages as hay, pasture legume, grain, silage, green manure and cover crop. Antinutritional factors can be overcomed by pre-processing and a s a novel method microwave heat treatment of seeds might be tested. Species needs improvements related to increase its tolerance to hard winters and to reduce pod shattering. Its tolerance to drought may increase its place in crop cycles fastly on the age of accelerated anthropogenic global climatic changes but fungal diseases may be the problem in this new stage.

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CHAPTER 3

FORAGE PEA [*Pisum sativum* ssp. *arvense* (L.) Poir.]

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INTRODUCTION

The biological and economic sustainability of livestock is interrupted by the scarcity of forage resources in the Mediterranean region and many areas of the world (Baxevanos et al., 2017). Low-cost roughage that protects animal health and adds value to the animal product (Broderick, 1995; Yolcu et al., 2016) is an important component of forage rations in livestock enterprises. In this sense, legumes grown in field agriculture are an important part of roughage with their high protein content.

The peas included in the Leguminosae (Fabaceae) family are used both as human food and animal forage in many parts of the world. Nowadays, all cultivated peas are presented under the species *Pisum sativum* L., and this species is divided into two subspecies. *P. sativum* ssp. *sativum* has white flowers and is called edible peas and grown for its green and dry grains. *P. sativum* ssp. *arvense* is expressed as field pea or forage pea and has purple flowers and is grown for herbage and seed forage (Açıkgöz, 2001; Manga et al., 2003). Forage pea [*Pisum sativum* ssp. *arvense* (L.) Poir.], which is an annual cool-season forage legume species (Sayar and Han, 2016), is mostly grown in the winter season (Lal et al., 2018).

Forage pea, which is used as animal forage, green manure, and cover crop, is a high yielding forage legume crop with high crude protein content and is a catch crop for short-term rotations, intercropping with other non-legumes and intermediate crops due to its biological nitrogen fixation capacity (Fraser et al., 2001; McPhee, 2005; Tan et al., 2012).

In this section, information is provided about the general principles of forage pea [*P. sativum* ssp. *arvense* (L.) Poir.] cultivation and some important characteristics of it are presented.

1. ADAPTATION OF FORAGE PEA

Forage pea adapts well to cool and semi-arid climates and is also resistant to cold. Seedlings are tolerant of spring frosts (Schatz and Endres, 2009). However, its drought resistance is not very high (Açıkgöz, 1991; Manga et al., 2003). It grows well in clay and clay-loam soils with neutral character.

Furthermore, important plant nutrients such as boron and molybdenum should also be available in the soil. These elements are especially effective in the increased biological yield of forage pea.

2. CULTURAL TREATMENTS IN FORAGE PEA CULTIVATION

2.1. Soil and Seedbed Preparation

In this respect, the general principles of forage crops also apply to forage peas. Although its seeds are coarser compared to those of many other forage crops, it is essential to prepare a clod-free and weed-free soil and seedbed to achieve regular and uniform germination and emergence.

Moreover, pea seed requires a high amount of moisture for germination. Thus, excessive tillage should be avoided in spring to prevent the seedbed from drying out (Schatz and Endres, 2009).

2.2. Fertilization

Fertilizer management is highly important for obtaining high yielding and superior quality forage in forage crops, as in many other crops. Since forage pea is a legume crop, it especially needs macronutrients such as phosphorus, potassium, and magnesium and micronutrients such as iron, copper, zinc, manganese, and molybdenum. Therefore, a suitable fertilization program is important. For this, soil samples should be first taken from the field and analyzed appropriately before sowing. It is necessary to pay attention to applying the recommended type and amount of fertilizer according to the analysis results of the soil samples.

Forage pea is a legume crop. It can get most of the nitrogen it needs from the atmosphere by a symbiotic relationship with Rhizobium bacteria in the soil. In this sense, peas are among the products with high biological nitrogen fixation capacity, and in this way, they can provide 80 percent of their total nitrogen requirements under optimum growth conditions (Schatz and Endres, 2009). Nevertheless, if vetch or forage pea has not been previously grown in the field to be cultivated, the soil or seed should be properly inoculated with the appropriate bacterial strain (*Rhizobium leguminosarum*) for the occurrence of this relationship. Furthermore, it would be appropriate to give nitrogenous fertilizer at the beginning along with sowing (Manga et al., 2003); however, it should not be forgotten that giving the amount of nitrogen to be applied according to the organic matter level of the soil, again taking into account the soil analysis results, will be correct fertilization management.

2.3. Sowing Time

Sowing time is an important cultural practice in both herbage and seed production. In climates where winters are harsh and cold, winter damage is high since late sowing reduces the power of emergence and seedling power. Therefore, early sowing of forage peas in winter is recommended (toward the end of September) in areas with a continental climate. In other words, autumn sowing should not be done late to minimize the winter damage in forage peas. On the other hand, it is appropriate to do winter sowing of forage peas in October or November in ecologies with relatively milder climates. Summer sowing should be done in March-April, depending on climate and soil conditions (Anonymous, 2019).

In a study conducted in Iğdır ecology of Turkey, where the long-term average temperature was approximately 13.1 °C and the total mean annual precipitation was 406.9 mm, it was emphasized that the number of seeds per pod, straw yield, seed yield, and biological yield were higher in the field pea in spring seed sowing compared to autumn sowing, and that forage peas should be sown at the beginning of March for seed production under regional conditions (Keskin et al., 2021a). In another study conducted in the same region with forage peas, seed crude protein ratio, straw crude protein ratio, straw dry matter (DM) consumption, and relative feed value (RFV) were higher in spring sowing compared to autumn sowing (Keskin et al., 2021b). Similar results were also found under the conditions of the Central Anatolia Region of Turkey, and higher seed yields were achieved in summer sowing of forage peas compared to winter sowing (Konuk and Tamkoç, 2018).

2.4. Sowing Rate

It is recommended that 80-100 seeds per m^2 (Erkovan et al., 2020) can be used in winter main crop cultivation and 150 seeds (Türk et al., 2011) can be used in summer sowing. Uzun et al. (2017) reported that the most appropriate seeding rate for forage yield in forage peas was determined as 125 seed/m^2.

In particular, the nutrient content of forage crops may vary considerably according to the row spacing (Alatürk et al., 2021). Although the distance of row spacing in sowing varies for herbage or seed production, it should be 20-40 cm (Manga et al., 2003). In a study conducted under Izmir-Turkey conditions, plant height values of 155.9 and 144.6 cm, green herbage yields of 4360 and 3398 kg/da, and dry matter yields of 782.4 and 595.2 kg/da were determined for row spacing of 20 and 40 cm in forage pea (Kavut et al., 2016). According to the results of another study conducted in Çanakkale-Turkey ecology, it was reported that forage pea should be sown with a row spacing of 12.5 cm (Alatürk et al., 2021).

2.5. Sowing Depth

By considering the soil and environmental conditions, the appropriate sowing depth should be between 3-10 cm according to the soil moisture content (Schatz and Endres, 2009; Özköse, 2017; Anonymous, 2019).

2.6. The Other Cultural Practices

Depending on the climate and soil conditions, water of life can be provided during sowing to ensure regular and adequate emergence. In general, it may not need water during the development period in winter sowing. However, for crop productivity, it is important to do irrigation regularly depending on the development of the crop and precipitation in summer sowing.

Field pea has weak competition with weeds, especially in the first month after sowing (Schatz and Endres, 2009). Therefore, when weeds are seen from the emergence of seedlings, the necessary control should be made. Likewise, the fight against diseases and pests should not be neglected (Anonymous, 2019).

2.7. Harvest Time

In the sole sowing of forage peas, harvesting can be done at the onset of full flowering or pod setting for high forage and crude protein yields. There is no problem with the herbage quality of forage peas in the harvesting to be done in this period. Manga et al. (2003) and Özeroğlu (2021) reported that the forage pea dry matter harvested in the full flowering period contains approximately 20% crude protein. Moreover, although forage pea dry matter contains higher amounts of acid detergent fiber (ADF) and neutral detergent fiber (NDF) compared to the previous development period, "good" quality forage can be obtained in terms of RFV in the full flowering period (Özeroğlu, 2021). Tankuş (2020) reported that high yield and quality forage could be obtained by harvesting forage peas during the filling period of lower pods.

3. IMPORTANCE AND USAGE AREAS OF FORAGE PEA

3.1. Use as Herbage, Seed Feed and Straw

In field agriculture, it is important to increase the rate of forage crops with annual species that are suitable for winter sowing, resistant to cold, and do not require much irrigation. In this sense, forage pea is a remarkable crop for many ecologies. In forage peas commonly produced for roughage or seeds (Önal Aşcı et al., 2015), herbage and seed yield varies significantly according to ecological factors such as soil and climate, and varieties. In many studies conducted in different ecologies of Turkey, the yield potential of forage pea varieties suitable for winter and summer sowing was revealed and made available to farmers (Table 1).

Forage pea is very tasty and nutritious for animals. Depending on the ecological conditions, the varieties used, the harvesting stages, and other cultural treatments applied, forage pea has a crude protein ratio ranging between 9.7-19.9% and a crude protein yield ranging between 15.8-190.6 kg/da (Türk et al., 2011; Uzun et al., 2012, 2017; Kaplan and Gökkuş, 2018; Cacan et al., 2019; Açin, 2020). ADF, NDF, and RFV, which are among the important quality criteria of the forage crop herbage, varied between 26.60-37.20%, 29.50-48.93%, and 116.2-216.1, respectively, in forage pea dry matter (Uzun et al., 2017; Kaplan and Gökkuş, 2018; Cacan et al., 2019; Açin, 2020). With regard to these parameters, roughage can be obtained at the "good", "very good," and "highest quality" standards from the forage pea. With this aspect, forage pea is also an important part of short-term crop rotation systems that can be grown for high-quality roughage in both main crop and interval

Table 1. Forage pea yield and prominent varieties in different ecologies

Location	Climate (Total rainfall / temperature)	Soil property	Variety	DMY (t/ha)	SY (t/ha)	Reference
Isparta-Turkey (summer sowing)	177-189 mm 13.1-13.9 ºC	Clay-loam pH= 7.1 OM= 1.2%	Gölyazı	5.50		Türk et al. (2011)
Bursa-Turkey (winter sowing)	608-872 mm 12.1-12.5 ºC	Clay pH= Nötr OM= Very little	Kirazlı	7.95		Uzun et al. (2012)
			Gölyazı		3.62	
Diyarbakır-Turkey (winter sowing)	384-487 mm 10.3-11.1 ºC	Clay-loam pH= 7.8 OM= 1.45%	Özkaynak	5.39		Seydoşoğlu (2013)
			Kirazlı	5.39	3.07	
Kızıltepe Plain, Mardin, Turkey (winter sowing)	428.0 mm	Clay loam pH= 7.83 OM= 1.22%	Kirazlı	5.56		Sayar and Han (2016)
Bingöl, Turkey (summer sowing)	832.6 mm 13.1 ºC	Loamy pH= 6.37 OM= 1.26%	Gatem 101		1.80	Çaçan et al. (2018)
Banja Luka and East Sarajevo-Republic of Srpska (summer sowing)	647.0 mm 12.5 ºC	pH= 6.39-6.97 OM= 2.05-4.12%	Saša	8.61		Đurđić et al. (2018)
Erzurum-Turkey (winter sowing)	350-414 mm 4.2-6.2 ºC	Clay-loam pH= 7.6 OM= 2.6%	Töre	9.43	2.67	Kadıoğlu and Tan (2018a)
			Özkaynak	8.78	2.97	
Erzurum-Turkey (winter sowing)	350-414 mm 4.2-6.2 ºC	Loamy pH= 7.64-7.70 OM= 2.03-2.75%	Özkaynak		2.89	Kadıoğlu and Tan (2018b)
Bingöl, Turkey (winter sowing)	690.4 mm 7.7 ºC	Loamy pH= 7.22 OM= 0.26%	Servet	4.18	1.39	Karaköse (2018)
Konya-Turkey			Ulubatlı (summer)	10.15-11.89		Konuk and Tamkoç (2018)
			Ulubatlı (winter)	4.73		
			Özkaynak (winter)	4.21		
			Kirazlı (summer)		1.71-2.42	
			Özkaynak (winter)		1.16-1.38	
Aydın-Turkey (winter sowing)	296 mm 11.0 ºC	Loamy pH= 8.1 OM= 1.10%	GAP Pembesi		2.15	Sürmen et al. (2019)
Siirt-Turkey (winter sowing)	890.0 mm 9.9 ºC	Clay loam pH= 7.53 OM= 2.22%	Özkaynak	9.25		Açin (2020)
Iğdır-Turkey (Average of summer and winter sowing)	335-353 mm 14.4-15.1 ºC	pH= 8.16 OM= 0.95%	Kirazlı		2.86	Keskin et al. (2021a)

OM: Organic matter, DMY: Dry matter yield, SY: Seed yield crop cultivation. Thus, Kaplan and Gökkuş (2018) recommended that forage peas should be grown in the winter intermediate period to obtain both high yield and quality roughage in pepper cultivation.

Forage pea seeds are very valuable (Manga et al., 2003). Due to the high crude protein content of forage pea seeds (17.4-26.5%) (Uzun et al., 2012; Keskin et al., 2021b), they can be used as a protein supplement, especially in the rations of dairy and beef cattle.

The straw (straw and pod residues) remaining after the seed harvest of forage peas is more nutritious and high quality than cereal straws and can be used in animal feeding (Manga et al., 2003; Keskin et al., 2021b). Although it varies according to varieties and cultural practices, it was reported that straw crude protein, NDF, and ADF ratios and RFV of the forage pea varied between 6.54-11.91%, 39.1-51.2%, 30.2-39.8%, and 105.5-147.2 (Çaçan et al., 2018) and between 6.35-8.09%, 46.5-62.5%, 33.6-39.1%, and 89.7-127.0 (Keskin et al., 2021b), respectively.

3.2. Use for Silage

Roughages constitute a significant part of the operating costs of livestock. Especially the use of protein-rich alternative forage crops as supplements should be considered to meet the cost by increasing the quantity and quality of animal production. In this sense, ensiling and growing silage crops are important because the nutritional quality of silage is extremely important in milk production and is a key factor in reducing production costs (Rondahl et al., 2011). Forage pea, which provides high forage yield in a relatively short growing season and also has a high crude protein content (Fraser et al., 2001), is an alternative plant material that can be used for silage.

The harvesting stage of the forage peas to be ensiled is important. It was reported that satisfactory fermentation was achieved in forage pea silages, especially if they were harvested in the later stages of maturity (i.e., pod fill or after) (Fraser et al., 2001). Rondahl et al. (2011) reported that it was difficult to ensile forage pea harvested at the beginning of pod setting due to their high buffering capacity and low water-soluble carbohydrate (WSC) level. The researchers stated that quality silage could be obtained from grasses that were harvested later, which also depends on the variety.

Nevertheless, silages made with protein-rich forage peas have difficulty in ensiling alone. Therefore, the silage of forage peas by mixing with different grass species at appropriate proportions will be the right practice in terms of providing both high-quality roughage and ease of silage storage. In this context, while Fayetörbay et al. (2011) recommended that 50-75% cereal products should be mixed into forage peas, Aykan and Saruhan (2018) recommended that at least 50% barley should be added to the silage mixture made from forage pea + barley mixtures, Gelir (2018) recommended the 25% forage pea + 75% triticale mixture silage, Doğan and Terzioğlu (2019) recommended 75%+25% and 50%+50% forage pea+barley mixture ratios, Seydoşoğlu (2019) recommended 75% forage pea + 25% barley mixture silage, and Gülümser et al. (2021) recommended the mixtures of forage pea and oat at the rate of 80+20% and 60+40%.

Another way to obtain quality silage from forages, such as forage peas with high protein content but low WSC content (Borreani et al., 2006), is the use of some additives (Ni et al., 2017; Soycan Önenç et al., 2017). To this end, the use of lactic acid bacteria (Borreani et al., 2009), essential oils of oregano and cinnamon (Soycan Önenç et al., 2017), molasses (Canbolat et al., 2019) in forage pea silages with low WSC improves the forage value and fermentation properties of silages. Rondahl et al. (2011) conducted their study with *P. sativum* ssp. *arvense* L., cv Timo and *P. sativum* ssp. *hortense* L., cv Capella varieties, and they reported that crops with DM content below 150 g/kg should be treated with at least 6 L/ton FM (fresh matter) acid (2:1 mixture of formic and propionic acid) to provide stable fermentation.

3.3. Importance of Forage Pea in Intercropping Systems

In forage crops cultivation, grass-legume intercropping systems are preferred more than monoculture systems since they produce higher quality forage (Eskandari et al., 2009; Kocer and Albayrak, 2012). Forage pea is an alternative forage crop that leaves a clean field rich in nitrogen and organic matter for the next crop with its biological nitrogen fixation capacity, is suitable for intercropping, and can be grown especially in the winter intermediate period. Kwabiah (2004), who emphasized the importance of intercropping of crops in the same field to optimize the efficiency of the use of production resources, indicated that forage pea-barley and forage pea-oat intercropping system provided significant advantages in terms of forage yield and optimum use of land. Likewise, Dordas et al. (2012) reported that high crude protein yield was obtained from pea-oat intercrops (at a seeding ratio of 80:20), and it had the best land-use efficiency.

In the cultivation of forage crops in the form of intercropping, the species and varieties included in the mixture and the cultural treatments applied are important, and the mixture ratio also affects the amount and quality of the forage obtained. Kocer and Albayrak (2012) conducted their study in the Isparta-Turkey ecology, and they determined that higher yield and quality forage was obtained from a mixture of forage peas, barley (*Hordeum vulgare* L.), and oats (*Avena sativa* L.) at 65:35 seeding ratio. In a study carried out in Ordu province located in the Central Black Sea Region of Turkey (Önal Aşcı et al., 2015), when total digestible dry matter and crude protein yields were evaluated together, it was reported that when triticale was harvested in the milk-dough stage, T75:FP25 and T50:FP50 mixture ratios (triticale:forage pea mixture ratios) of forage pea (*P. sativum* L.) and triticale (*xTriticosecale* Wittmack) produced high yields. Kara (2016) determined that one of the most suitable mixtures for winter intermediate crop production under Aydın-Turkey ecological conditions was 75% forage pea + 25% oat mixture. Ay et al. (2017) reported that the mixture ratios and harvesting periods significantly affected the amount and quality of the forage obtained in autumn sowing under Kırklareli-Turkey conditions and that the highest hay yield was obtained in the 50% forage pea + 50% wheat mixture sowing and at the dough stage of the wheat. Ay and Mut (2017) determined that the mixtures of 30% oat + 70% forage pea and 40% barley + 60% forage pea could be successfully grown in early spring sowing under regional conditions, considering the hay yield and protein yields of the mixtures under Yozgat-Turkey ecological conditions. Göçmen and Özaslan Parlak (2017) reported an increase in crude protein ratio with the increase in legume ratio in barley and triticale mixtures. In the same study, it was recommended that barley and triticale be grown as a 50%:50% binary mixture with forage peas in terms of herbage yield and quality. Yavuz (2017) recommended the mixture of 30% forage pea + 70% oat to obtain high hay yield under Kırşehir-Turkey ecological conditions, and when the quality criteria were evaluated together with the yield, they reported that 60% forage pea + 40% oat or 50% forage pea + 50% oat mixtures harvested at the beginning of flowering could also be grown. Seydoşoğlu (2020) reported that when barley was harvested in the milk stage, a higher herbage yield was obtained in the sowing of 75% barley + 25% forage pea mixture. Alhumedi (2021) reported that 75% forage pea + 25% oat seed mixture under Mediterranean climate conditions might be the most suitable mixture in terms of herbage yield and quality and effective use of ecological resources.

3.4. Use as a Green Manure Crop

The inclusion of legume crops in crop rotation systems as green manure crops is an important practice, which is beneficial in terms of both crop yield and soil fertility. Green manuring has many known benefits such as adding nitrogen to the soil, increasing the organic matter content of the soil, improving the physical, chemical, and biological properties of the soil, increasing the yield and quality of the crops sown after it, and the control of diseases, pests, and weeds.

Nevertheless, green manuring is not a widely accepted/common practice for farmers who are not engaged in organic farming and livestock. Although it directly provides nitrogen to the next crop, growing green manure crops is usually not considered economically appropriate by traditional farmers (Thiessen Martens and Entz, 2011). Therefore, growing green manure crops and applying green manure, especially in the idle period during which winter and summer main crops leave the land, are more acceptable by farmers. In this intermediate period, crops to be grown for green manuring must leave the land in a short time and have a high green manure value. Green manure crops that can be used for this purpose should also have high dry matter production and high forage value, which is important in terms of grazing and/or cutting green manure crops in periods with forage shortage. To this end, forage pea, which is an annual crop and has high biological nitrogen fixation capacity and a good forage value, has significant potential as an advantageous crop.

Mahler and Auld (1989) reported that Austrian winter pea green manure provided the soil with fertilizer equivalent to 94 kg/ha N.

In the green manure application performed with forage pea, it was determined that significant increases were achieved in the grain yield and grain crude protein ratio of the corn crop compared to the control (without green manure and chemical fertilizer). In the same study, it was determined that the grain crude oil content was higher in sunflower crop grown after the forage pea green manure application compared to the sunflower growing system with chemical fertilizer in the traditional system and that the grain crude protein ratio was significantly different compared to the control. It was observed that when forage pea is harvested for herbage, the remaining parts (roots and stubble parts) did not affect the yield of the upcoming crops; however, there were increases in the protein ratio in corn and fixed oil ratio in sunflower (Özyazıcı and Manga, 2000).

In another study conducted with forage pea varieties, it was reported that forage pea had a significant forage and green manure value with an average green forage yield of 37.6 t/ha, an average dry matter yield of 8.6 t/ha, potential forage crude protein yield of 1531 kg/ha, and potential forage nitrogen yield of 245 kg/ha (Mihailović et al., 2007). It was reported that the green manure application performed with forage pea, especially at the beginning of flowering, affected the grain yield and quality of winter wheat and provided significant nitrogen to the soil. Nevertheless, it was also emphasized that the nitrogen yield of the soil might increase in the long term due to the high BNF in the green manure application performed with forage pea, especially in the pod setting period (Miller et al., 2011).

Tautges et al. (2018) reported that the biomass yield of 977 kg DM/ha and the biomass nitrogen of 29.1 g/kg was achieved with winter pea green manure. The researchers reported that this yield did not provide enough nitrogen for the next wheat crop. However, considering the total nitrogen content in the surface soil, the green manure application contributed more to soil fertility than conventional fertilizer application in the long term.

Forage pea is a forage legume crop with high aboveground biomass, although it varies according to variety, soil, and climatic conditions. Forage pea, which is especially grown in the winter intermediate period, can be used for green manuring in periods without forage shortage. Forage pea should be mowed at approximately 20% flowering stage and buried in the soil for green manuring. Then, it should be ensured that the crops are thoroughly mixed with the soil by pulling the disc harrow.

Not only the aboveground parts of legume crops but also their underground parts (root + stubble part) have significant potential green manure value in terms of nitrogen and organic matter (Özyazıcı and Manga, 2000; Özyazıcı et al., 2009). Therefore, cutting forage pea and mixing the remaining root and stubble parts into the soil in the period with forage shortage will provide significant benefits in terms of soil and crop yield.

4. POSITIVE ASPECTS OF GROWING FORAGE PEA

(1) Forage pea grown in winter is an important component of cereal-based rotation systems.

(2) It makes atmospheric nitrogen usable with its biological nitrogen fixation capacity. Thus, it both increases the yield and quality of the crop that comes after it and reduces the need for inorganic N fertilizer inputs.

(3) It reduces potential diseases, weeds, and pest circulation in continuous cereal systems (Percze, 2006).

(4) Forage pea herbage and seeds are rich in crude protein content and most mineral elements. Due to its high nutritional value, it is an alternative crude protein source in animal production.

(5) Forage pea with a high nutritional value is rich in fiber, protein, vitamins (folate and vitamin C), minerals (iron, magnesium, phosphorus, and zinc), and lutein (Urbano et al., 2003).

(6) It is a crop that can be considered within the scope of good agricultural practices since it minimizes the use of pesticides and chemical fertilizers.

5. NEGATIVE ASPECTS OF GROWING FORAGE PEA

Its ground seeds can be given to laying hens as an additional protein source. However, it is relatively deficient in methionine, like other legumes seeds. In this case, synthetic methionine should be added to the diet during egg production. Nevertheless, its seeds also contain anti-nutritive factor, which causes live weight loss (Davidson et al., 1981).

6. CONCLUSION

Forage pea is among the four most important legume species, along with soybeans, peanuts, and dried beans worldwide. This crop has a potential role in the nutrition of ruminants and monogastric animals since it is an important source of protein, energy, vitamins, and minerals. Its aboveground biomass can be used as fresh forage, hay, grain, straw, and silage and is an important component of rotations, including intercropping systems and green manuring. Nowadays when the importance of agricultural sustainability is gradually increasing, systems including legume crops will always play a key role in an efficient and healthier life. In this sense, due importance should be given to the cultivation of forage pea, which is used both as human food and animal forage in many parts of the world, and its seeding rate in forage crops should be increased.

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CHAPTER 4

FORAGE COWPEA (*Vigna unguiculata* L. WALP)

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INTRODUCTION

Origins of cowpea are South Asia, India and Africa. Cowpea (*Vigna unguiculata* L.) is a legume plant cultivated for forage, green pods and grains in tropics and subtropics. Cowpea is growing in conventional cropping systems in the drier tropic regions of Asia, Africa and Central America. Although cowpea can be grown under dry condition, irrigation highly promotes its vegetative growth. Cowpea produced highest forage yields in sandy loam soils under proper irrigation regime. Adaptation of cowpea to drought, high temperatures and other abiotic stresses conditions is better compared with the other crops grown in the same conditions. However, growth and development of many cowpea cultivars are affected by drought and high temperatures, especially during floral development and can serve as an excellent source of dietary protein in animal feeds.

There is big gap between forage production and livestock demand in Turkey. Forage deficiency is biggest during winter months and mid-summer period because of drying pastures. So, there is a need for new warm-season forages to fill forage gap in this period. In general, solutions to forage shortages during the summer months have included the use of perennial and annual warm-season forage species for pastures, hay, or silage.

Cowpea can be a valuable forage crop with fairly high crude protein content and digestibility. Preservation of cowpea as hay is the most convenient way to maintain all the year round for animal feed supply chain. Preparing of hay from cowpea is simple by dairy farmers with little infrastructure requirements. Cowpea can also intercropped with maize and sorghum for a higher yield and quality compare to sole cropping.

Leaf ratio of cowpea in fresh forage and hay is high as 40-45%. Some parameters is varied in forage cowpea has as follows; 27-30% ADF, 33-36% NDF and 17-20% CP (Atış and Yılmaz, 2005; Boz, 2006, Ayan et al., 2012, 2016). The mature grain contains 20 to 25% of protein, 1.3 to 1.5% lipid and 5.1 to 5.8% crude fibre (Tshovhote et al., 2003).

Cowpea is generally used in human and animal nutrition and as a green manure crop. Fresh forage and hay, silage (especially with sorghum and millet) and dried grains are used in animal nutrition. Alone sowing is mostly used for fresh forage and/or hay; mixed plantings are grown for silage. In addition, the green beans, dry grains, fresh shoots and leaves of cowpea grown in a mixed form with corn, sorghum and many millet species are consumed as human food, and the residues from the grain harvest are used as animal feed. It is cultivated for similar purposes in many parts of the world. In Turkey, forage cowpea can be grown as both main and double crops for hay and silage production in the agricultural system.

TAXONOMY and PLANT CHARACTERISTICS

When the textual and archaeobotanical sources about cowpea are examined, its use by humans dates back to ancient times.

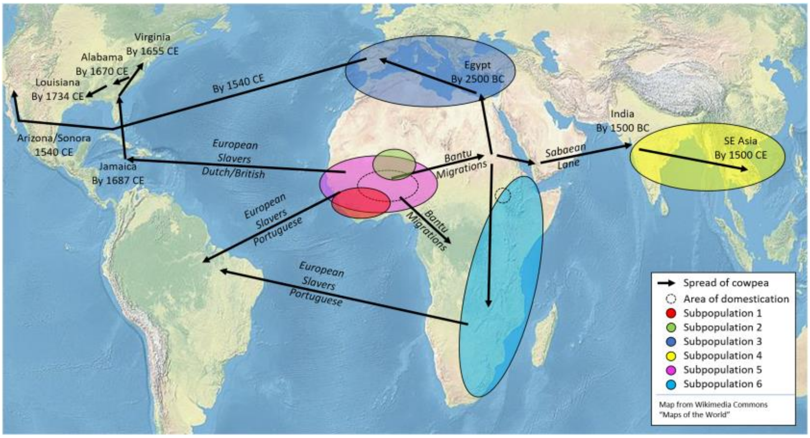

Figure 1. The ways of spreading the cowpea to the world (Herniter et al., 2020)

Cowpea were first cultivated in the African continent and spread to different parts of the world from West and East Africa. It was spread by the Bantu located in West Africa south to the equatorial rainforests and east across the Sahel region to Sudan and Ethiopia. Later, it was divided into three different branches. The first branch united with those from East Africa and extended to South Africa. The second branch spread northward near the Nile in 2500 BC and then into the Mediterranean Basin by 400 BC. It was brought to the United States by the Spanish from this region. The third branch crossed to the east, over the "Saba road" in Yemen, reaching the west coast of India in 1500 BC, and spread from there to Southeast Asia. In the 16th century AD, cowpea was brought from West Africa to the Americas by slave ships to colonial slave societies, including Brazil, the Caribbean, and South America. At the same time, the Spanish brought colonies to the southwestern United States and north-western Mexico (Figure 1).

Cowpea (*Vigna unguiculata* (L.) Walp.) is belongs to *Fabaceae* family, *Vigna* genus, *Catiang* division. There are two botanical varieties of cowpea; *Vigna unguiculata unguiculata var. unguiculata* and its wild form, *Vigna unguiculata unguiculata var. spontanea*. The botanical characteristics of the spontaneous botanical variety of cowpea are similar to the cultivated cowpea. However, it differs from the cultured cowpea as the pods are small and discrete, the seed is ten times smaller and seed coat is hard, thick and waterproofs (Padulosi, 1993). *Unguiculata* botanical variety, which has the largest group of cowpea, is basically divided into five groups according to its pod, seed and ovule characteristics (Table 1).

Table 1. Botanical varieties of cultivated cowpea and its features

Variety groups	Features
Unguiculata	There are more than 16 ovules in the pod. Grain and feed types grown in Africa includes this group.
Melanophthalmus	The pod contains less than 17 ovules and has a black belly core. It is usually grown in America.
Biflora (Catiang)	The pod contains less than 17 ovules and has short and erect pods. It is usually grown in India.
Sesquipedalis	The pod is long. Especially in China, fresh pods are consumed.
Textilis	It was used for fibre in Africa in ancient times. It is a rare form with a very long stem.

(OECD, 2016)

Plant Characteristics of Cowpea

Cowpea is an annual, herbaceous and warm season legume plant. Cowpea, which is mostly grown for its grains, is grown in Africa for its leaves as vegetables or whole plant parts as fodder crops, and in eastern Asia for its fresh pods (Boukar et al., 2015).

Root: Cowpea has a strong taproot and lateral roots branching from the main root. Root length can reach 2.4 m two months after planting. There are nodules formed by Rhizobium japonicum bacteria in their roots (Barnard, 1969).

Stem: In cowpea, the stem is soft and herbaceous. It differs greatly among varieties in terms of stem, height, thickness, branching and cross-sectional shape. Branching of the main stem may be along the entire main stem. There are purple anthocyan spots on the body, especially between the knuckles. The body type is classified as erect, semi-erect and horizontal. Plant height was between 80-200 cm depending on the stem type.

Leaf: The first leaves formed on the stem are opposite and two in number. The surfaces of the leaves are glossy and flat. Cowpea leaves have the appearance of compound leaves. The middle leaf has formed two leaflets mutually symmetrical at the end of the main stem. Leaf shapes are oval and round. It can be seen on leaves with a pointed tip, oval at the bottom, and inverted egg-shaped leaves. The petiole is 5 to 25 cm long.

Flower: Cowpea flowers are on the leaf axils. The flowers are in the form of panicles. There are 6-12 flowers in a bunch. The flower stalks are short, the main panicle is long. Sepals are angular and green. Sometimes the sepals may be purple in colour due to anthocyanin. The petals are tubular, conjoined below, and slightly bell-shaped above. Petals differ in shape, size and condition. The petals consist of flag, fin and keel, may be white yellow and slightly purple or even blue in colour. The flag leaf is quite large and wide. As in other leguminous vegetables, there are 10 male organs in the flower, 9 of which combine to form a tube. The tenth male organ is in the middle and free. The stigma remains inside the tubular male organs. The female organ is hairy and flat. The stigma is round. Flowers are fertilized in the early morning hours depending on environmental conditions. During the fertilization period, high humidity and temperature are of great importance. Fertilization occurs 7-8 hours before the flowers open. Therefore, a high rate of self-fertilization is observed. 60-70% of the flowers formed on the plant are poured before they open. During fruit set, 10-20% of flower drop occurs. Only 10-20% of blooming flowers can produce fruit.

Fruit and seed: Cowpea pods are usually flat, thin and long. The tip of the pod is straight, slightly beak or pointed beak. The pod length generally varies from 8 to15 cm. The fruit color of the pod is green. The pods turn yellow at dry grain maturity. In some varieties, the pod may be brown or purplish in color. There are 1-10 seeds in a single row in the pod. The seeds are relatively large (2 to 12 mm long) and weigh between 50 and 300 g/1000 seeds. Seed coat (testa) can be straight or wrinkled. There is a wide variation in seed color. Seed color can be white, green, red, brown, black, mottled and spotted.

 

USAGE

Forage Production

It is reported that in many regions of the world, cowpea hay for animal nutrition is of high quality, its digestibility is close to alfalfa, and cowpea can be consumed both as fresh forage and hay. In addition, the importance of including cowpea in field farming systems is emphasized in order to add nitrogen to the soil (Muli and Saha, 2001).

Forage cowpeas, like many other annual legumes, should be harvested for forage production during the pod-filling period or about 70 - 90 days after sowing. Cutting should be made from a height of about 10 cm. Consider the regrowth feature, mowing should be 1 – 2 cm above the main stem. It is a great advantage that when the cowpea plant is dried, its stems do not break and the leaves do not fall. The first cut of cowpeas, which is well looked after, can be cut about 60 days after planting, and the second cut or the second growth can be grazed after 90-100 days. The yield of the first cutting is much higher. Hay yield is very variable. In Samsun and Amasya conditions, hay was taken in amounts varying between 4-16 tons/ha. In the second harvest, the yield decreases to 1.5-2.0 tons/ha (Ayan et al., 2012, 2017). It has been determined that cowpea forage can be grown as a double crop in Samsun conditions and the total hay yield varies between 4.85-8.02 tons/ha (Omar et al., 2018). In İzmir conditions, cowpea hay yield varied between 3.0-6.0 tons/ha (Okuyucu and Okuyucu, 1994). 1.5-6.0 tons/ha of hay was taken from cowpea planted pure in Çukurova and Hatay conditions (Kızılşimşek, 1994; Atış and Yılmaz, 2005; Boz, 2006). Fresh forage yield is up to 28 tons/ha in Çanakkale (Alaca and Özaslan Parlak, 2017). Yield ranged between 1.5-4.0 tons/ha in Isparta conditions (Ünlü and Padem, 2005). Cowpea hay yield was found to be 2.0-4.0 tons/ha in Van conditions and 1.63 -7.91 tons/ha in Şanlıurfa conditions (Erman and Çığ, 2009).

The leaf rate of cowpea fresh forage or hay is as high as 40-45%. The ratio of ADF to 27-30%, NDF to 33-36% and crude protein in hay varies between 17-20% (Atis and Yılmaz, 2005; Boz, 2006; Ayan et al., 2012, 2016).

In the study, carried out on 5 genotypes in the northern plains of Ethiopia, the hay yield was 5.67-11.9 t/ha, the crude protein ratio was 17.7-18.6%, the ADF ratio was 47.1-57.2%, the NDF ratio was 56.3-60.7%, and the in vitro digestibility as an average of three years reported that the rate varies between 55.1-60.2%. Researchers stated that cowpea is an excellent protein source for both animals and humans. In addition, cowpea protect the soil from erosion and increase productivity of the land thanks to the nitrogen it attaches to the soil (Gebreyowhans and Gebremeskel, 2014).

Silage Production

Many researchers have determined that the quality values of silage, especially crude protein ratio, increase in sowing of cowpea mixed with corn, sorghum and sunflower, despite the decrease in yield (Kızılşimşek, 1994; Sarıçiçek et al., 2002; Boz 2006; Alaca and Özaslan Parlak, 2017; Torun 2018). Cowpea can be processed to silage pure or mixed with different plants. Positive results were obtained from pure cowpea silages made with or without adding inoculants (Ayaşan and Karakozak, 2012).

Cowpea is an indeterminate summer annual legume that can climb, tolerate some shade, and fill in the gap as a summer annual forage crop, so we can consider adding it to a stand of forage sorghum and maize. Protein yield in intercropping was greater than sole maize crop. Intercropping as compared to sole cropping had the highest quantity and quality forage yield, and the best planting ratio was 100% maize+100% cowpea and harvest at doughy stage (Dahmardeh et al., 2011). In a study conducted in Çukurova, the highest fresh forage and hay yield was determined in 1M+2B mixture (Etebari and Tansı, 1994). it is concluded that both forage quality and quantity of forage millet mixed with cowpea can be obtained by growing two rows of millet with one row of cowpea (2M:1C) (Islam et al., 2018).

A study was carried out to determine the yield, yield characteristics, and some quality characteristics of different corn and cowpea mixture cultivation under Samsun conditions. As a result; the highest fresh forage yield was in alone corn treatment plots with 82.3 tons/ha, it was followed by 1 corn + 2 cowpea with 76.4 tons, 2 corn + 2 cowpea 56.2 tons, and alone cowpea treatments with 56.0 tons. The mixture with the highest LER (Land Equivalent Ratio) value was 1 corn + 2 cowpea with 1.69 value. It is concluded that 1 corn + 2 cowpea mixture is more suitable for dry matter production for the coastal region of Samsun (Kanca and Acar, 2021).

Seed Production

Cowpea is largely self-pollinate plant. After the plants turn yellow and the grains reach harvest maturity, the plants are harvested by hand. The plants that are left to dry are then threshed by hand or by using some threshing machines. After the seeds are cleaned and fumigated, they are stored.

Grain yield is very variable in cowpea varieties produced as edible grain legumes. The world average is about 2000 kg/ha. In studies carried out in many parts of our country, grain yields ranging from 500 kg/ha to 3000 kg/ha (Ceylan and Sepetoğlu, 1980; Gülümser et al., 1989; Peksen and Artık, 2004; Basaran et al., 2011; İdikut et al., .2019). There has been not enough studies on seed yield of forage cowpeas. Grain yield Ülkem forage cowpea Cultivar ranged between 1200 and 1400 kg/ha (Ayan et al., 2016).

CULTIVATION

Due to its resistance to high temperature cowpea can be grown as an alternative in summer in the Mediterranean and Aegean coasts and South-eastern Anatolia Region, where beans cannot grow (Özdemir, 2002). Due to its general character, it likes heat. It is affected by low temperature during the growth period, leaves and young branches are damaged in severe frosts. Depending on the severity of frost, plant death may occur. The best growing temperature is between 20-30 °C. 5-10 ° C difference between day and night temperatures is important for plant growth (Günay, 1992).

Cowpea sowing is done after the last frosts of spring, when the soil temperature is 8-10 ºC, from at the end of April and beginning of May. After the winter cereal production, cowpea can be grown as a double crop. For this purpose, cowpea is planted after the harvest of cereals. Delays in sowing time cause a decrease in yield (Azkan, 1994). Since the soil is cold and wet in early planting, most of the seeds rot or are eaten by earthworms, resulting in poor output. Best germination occurs when the soil temperature is at least 19 °C for three days after planting (Osipitan et al., 2021).

Cowpea can be grown without the need for irrigation in places where the annual precipitation is 600 mm or more (Akçin, 1988). However, in periods when the weather conditions are dry, irrigation is required to ensure germination and emergence. In addition, irrigation before flowering provides an increase in yield. Although cowpea performs better in irrigated conditions than in dry conditions, it can be easily grown in lands without irrigation as it is a drought-resistant species

(Ünlü and Padem, 2005). For this reason, it has an important place in underdeveloped countries where drought is seen.

Soil demand of cowpea is quite wide. It can be cultivated easily from sandy soil to clay soil, from fertile soil to less fertile soil and even in acidic soils under adequate rain or irrigation conditions (Gençkan, 1992). Nitrogen, phosphorus, and potassium fertilizers are rarely needed and, if applied, are often used in lesser quantities than are required for other agricultural crops. Anatolia is not the homeland of cowpea and therefore there is no natural *Rhizobium* bacteria effective in cowpea in our soil. Therefore, cowpea seeds should be inoculated with fresh cultures of the appropriate bacterial species before planting. The effective bacteria type in cowpea is *cowpea rhizobium* bacteria. As in all leguminous plants, in cowpea, a suitable growth environment must be prepared and maintained to increase the nitrogen fixing capacity of the nodules, the appropriate temperature for the nodules is at least 20 °C (Osipitan et al., 2021). If nodulation is sufficient, cowpea can meet its nitrogen requirement symbiotically. Under suitable conditions, cowpea has a nitrogen fixing capacity of 40-80 kg per hectare (Meena et al., 2015).

There are some critical periods in terms of moisture demand in cowpea (Davis et al., 1991). Irrigation at the beginning of the flowering period helps to set the pods. Since it requires hot and dry air in the grain formation phase, irrigation is not done. In the period between emergence and flowering, excess water causes wilting of the plant and yield decreases. Good drainage is very important for cowpea.

Although it is a self-pollinating plant, cross pollination can occur by insects in very humid conditions (Almakinders et al., 1999). Depending on honey bees and other insects, cross pollination may occur at a rate of 1-2%. Generally, the cross pollination rate does not exceed 5% (Azkan, 1994).

Cowpea cultivation has been increasing both in our country and in the Central Black Sea Region in recent years. However, it is still cultivated in a very limited area. It is not found strange by the farmers because of its vegetative characteristics and its similarity to beans in terms of cultivation.

Cowpea can be planted alone or mixed with some other crops like maize, sorghum, millet. Alone sowing can be done mostly for fresh forage or hay and mixed sowing for silage. For silage, mixed cultivation can be made with corn plant and high quality silage with high protein content can be obtained.

As a result of the main crop studies conducted in Samsun, it is suggested that forage cowpea can be grown with 30-50 cm row spacing (Ayan et al., 2012 and Ayan et al., 2017). It was determined that dry matter yield, crude protein, crude oil and crude ash contents were higher, and crude fibre contents were lower when cowpea was sown in 45 cm row spacing. It also provided the highest net income and benefit-cost ratio. Some researchers stated that cowpea varieties planted with reduced row spacing of 30 cm to obtain high quality fresh forage yield more productive than wide row spacing, while the opposite may be true for spread sowing cowpea varieties (Iqbala et al., 2018).

20 cm 35 cm 50 cm 65 cm

DISEASES AND PESTS

Root rot, wilt, leaf blight, leaf spot, powdery mildew, virus diseases and nematodes in cowpea cause yield and quality losses, depending on climatic conditions. It is difficult to combat these diseases with medicine. It is recommended to use resistant varieties and to take cultural measures. Crop rotation is the most appropriate control method for nematodes. *Phytophthora* stem rot is the major disease of cowpea and can devastate susceptible varieties under wet and water logged conditions. Plants yellow-off and begin to die-back in patches. Need at least a 4-year break before sowing cowpea again in an infected paddock. Other fungal diseases include fusarium wilt, powdery mildew, charcoal rot, and S*clerotinia*, the bacterial disease, tan spot, and cowpea mosaic virus cause problems in cowpea crops (Anon, 2008).

Cowpea is very susceptible to insect damage. Bean fly attacks seedlings in some areas, often causing death of plants. *Heliothis*, aphids, mirid bugs, green vegetable bug, flower thrips and alfalfa seed web moth should be closely monitored during flowering and pod fill periods. Insect damage is also observed during the storage. Aphids and seed beetles (*Bruchus sp*.) are the most important pests of cowpea. *Thrips* cause damage to flowers and flower buds, *Hemiptera sp.*, *Maruca testulelis, Laspeyresia ptychora* to flower buds and pods. It is stated that *Thrips* causes 50%, *Maruca* 40%, *Hemiptera* 35%, *Laspeyresia* 50% loss in grain product (Azkan, 1994). Spraying can be done against sucking lice and seed bugs. After the seed harvest, it is absolutely necessary to fumigate against *Bruchus* growth.

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CHAPTER 5

BIRDSFOOT TREFOIL (*Lotus corniculatus* L.)

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INTRODUCTION

Choice of forage species influences protein amount and quality in cattle diets. Improved quality of cool-season grass feeds by addition of legumes has a prooved application. Birdsfoot trefoil (*Lotus corniculatus* L.) is an old world legume species adapted to a wide range of environments. Difficulty in harvesting sufficient quantities of seed of this temperate climate crop is one of a factor limiting widescale production of birdsfoot trefoil.

Here in this article, progresses obtained in the last decade related to Birdsfoot trefoil given in international articles are reviewed.

Birdsfoot trefoil (*Lotus corniculatus* L.) is a perennial legume forage native to Mediterranean basin. This forage species is well adapted to marginal regions (Lazaridou et al., 2017). Genus *Lotus* include about 100 species distributed in the Mediterranean basin, Eurasia, North America and South America (Li et al., 2019). *L. corniculatus* is in the genus *Lotus* (Leguminosae), the most important and widely distributed species in this genus. Genotypes of Birdsfoot trefoil form complex groups which are difficult to distinguish morphologically and biochemically (Alem et al., 2011). It is a tetraploid ($2n=4x=24$) plant and has tetrasomic inheritance for many traits, although it also has been reported to have disomic inheritance (Fjellstrom et al., 2001). *L. corniculatus* complex includes diploids (2n= 2x= 12) and tetraploids (2n= 4x= 24). Monophyly of the complex was supported by recent phylogenetic analyses (Kramina et al., 2018). “Super-Root” is a fast-growing root culture established in *L. corniculatus* which displays vigorous growth and high embryogenic capacity, allowing continuous root cloning (Puspasari et al., 2020).

Utilisation of the crop

L. corniculatus fits to fields in the major livestock production regions worldwide as a valuable forage species with its high ability to utilize nutrients and modest demands for growth conditions (Vasic et al., 2019). For example, in Uruguay, it is the main cultivated forage legume since 60s, well adapted to low P available soils and to pH values restricting alfalfa growth (Rebuffo & Cuitino, 2019). Birdsfoot trefoil is widely distributed in temperate regions of Europe, Asia Minor, North and South America, North Africa and Australia (Vuckovic et al., 2007). When grazed in pure stands, Birdsfoot trefoil helps rapid weight gain and high amount of milk production in ruminants than grass pastures. It has also high nutritive value if stockpiled (Hunt et al., 2014). It is a perennial herbaceous forage grown for hay alternative to alfalfa (*Medicago sativa* L.) under poor soil conditions (Moye Jr et al., 2017). Alfalfa is a very important forage crop with high protein content and palatability but doesn't grow strong in acidic soils and under humid enviroenments where birdsfoot trefoil grows well under these conditions (Niizeki, 2001). *Lotus corniculatus* performs well under flooding conditions where other forage legumes (white clover of alfalfa) cannot thrive (Striker et al., 2005). It is also well adapted to drought conditions (Inostroza et al., 2015). Birdsfoot trefoil is a nonbloating legume suited well to production of ruminants on pastures. This crop was found persistent with irrigation in cool, dry climates to other forages (Hunt et al., 2015).

Yield formation

Birdsfoot trefoil is an indeterminate flowering herbaceous plant producing great number of flowers during vegetative season. Long flowering period is the main factor stricting seed production. (Virteiu et al., 2014). Seed germination percentage of Birdsfoot trefoil is low due to high ratio of hard seeds content (Toth et al., 2012).

Genetical potential of Birdsfoot trefoil for seed yield is 1,2 t/ha but is cropped in some countries for 200 kg/ha grain yield. Pod shattering is limiting seed yield of crop. Seed maturation is uneven, begins at the base part of the plant, continue upward on plant, full ripen pods easily get break and drop off the seeds (Radic et al., 2013). Wide variability of seed size is both related to genetic and to enviroenmental conditions (Toth et al., 2015).

Figure 1. Birdsfoot trefoil (A) leaf with five apparent leaflets, (B) a seedling of an erect type, (C) bright yellow inflorescence and (D) seed pods (Casler & Undersander, 2019).

In a field trial sown at 20 cm inter-row spacing using 10 kg/ha of seeds conducted by Stevovic et al., (2013), highest seed yield was (409 kg/ha). Number of flowers/stem, number of inflorescences/m^2 and number of pods/inflorescence were significantly correlated positively with seed yield. In a study of Radic et al., (2011) including 20 local genotypes in Bosnia and Herzegovina, high correlations were found between biomass/plant with plant height and number of stems/plant. Seed yield was significantly correlated with the number of pods/plant. Association of phenotypic variation, morphologic traits and geographic characteristics were investigated for 15 wild *L. corniculatus* populations collected from different natural enviroenments in Slovakia. Significant variation was observed between populations for morphological characteristics. Main diversity sources were growth habit, stem length, number of internodes, stem thickness, number of stems/plant and leaf length. Most of the populations from lower elevation origined locations produced semi-prostrate plants containing high number of long stems and delayed flowering. Number of stems, stem length and number of internodes increased in population from West and South regions (Drobna,, 2010).

L. corniculatus has a special place as a protein rich forage in mountainous areas. There are many productive genotypes in natural populations, but their selection is problem due to entomofilia modes (Radic et al., 2014).

Secondary metabolites content

Birdsfoot trefoil is used as a forage crop globally due to its ability to grow in harsh environments and rich content of secondary metabolites (Wang et al., 2013). In south Brazil, *L. corniculatus* is a forage for ruminants and is a herb used to treat intestinal infection of ruminants (Dalmarco et al., 2010). It is widely grown in Egypt and has a long history as folkloric medicine. Aerial parts of the plant has significant immunostimulant and antioxidant activities and strong ability to induce lymphoproliferation (Abdallah et al., 2020).

A water-soluble heteropolysaccharide (Galactomannan) was isolated from seeds of population of Birdsfoot trefoil (yield, 1,65%) by Egorov et al., (2003). It contains condensed tannins helping to decrease bloating in ruminants and increase animal production (Giagourta et al., 2012). Condensed tannins content vary in concentration, structure and portion of soluble and protein-and fibre-bound fractions (Girard et al., 2018). Condensed tannin (proanthocyanidin) accumulation in regrowth vegetation of *L. corniculatus* has unpredictable nature and wider use of this species can be a problem due to variable condensed tannin levels possiblity of beneficial or detrimental effects on animal nutritioning. Increased carbon allocation to roots of clonal plants during low temperature preconditioning were increased condensed tannin and flavonol levels significantly in regrowth foliage. Instead, reduced carbon allocation to roots during high temperature preconditioning periods significantly decreased condensed tannin and flavonol levels (Morris et al., 2021).

Effective *Rhizobia* diversity of Birdsfoot trefoil was studied and several *Mesorhizobium* species are determined as endosymbionts of this legume, including *Mesorhizobium loti*. Great phylogenetic diversity of strains nodulating *L. corniculatus*, allow us to think that more diversity will be discovered as diversified ecosystems are searched (Marcos-Garcia et al., 2015).

CONCLUSIONS

Birdsfoot trefoil plant is characterized by elevated contents of secondary compounds. Stand establishment is critical fort his crop due to uneven germination, different sized seeds, seed hardiness etc. Fits well to non-suitable ecologies where the main legume froage crop alfalfa is not well performing.

No ststistics exists in FAOSTAT or TURKSTAT databases on this crop. Determination and publishing statistics and registered varieties of this species may improve adaptation of it to global forage production systems to increase diversification and sustainability of animal production worldwide.

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CHAPTER 6

SAINFOIN (*Onobrychis viciifolia* Scop.)

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INTRODUCTION

There are about 80-100 species belonging to the genus Onobrychis in the Papillionidae subfamily of the Fabaceae (Legumes) family (Sütçü, 2020). Among these species, *Onobrychis viciifolia* is the most cultivated sainfoin species. Sainfoin is a legume plant that has been cultivated since ancient times. It has been determined that sainfoin, which is one of the natural legume forage plants of South-Central Asia (Bhattarai et al., 2018), has spread to Southern France and Central Europe since the beginning of the 15th century (Carbonero, 2011). It has been determined by the researches that the sainfoin is widely found in the Near East flora, including our country (Çeçen et al., 2015; Tepe, 2019), and that about 70 species grow naturally in our country (İnce, 2007; Avcı, 2010), and 33 of them are endemic (Güner et al., 2012). The sainfoin, which has been used as a fodder plant by both the Seljuks and the Ottomans since BC in Anatolia, is called "görügen" or "koringa" in different regions (Sütçü, 2020). Today, however; The sainfoin is widely cultivated in Central and Eastern Anatolia and the Transition Regions (Ünal and Fırıncıoğlu, 2007).

The sainfoin (*Onobrychis viciifolia* Scop.) is a very important culture plant due to its importance in animal nutrition, fixation of nitrogen in the soil, increasing the water capacity, being located in artificial pasture facilities and natural pastures, preventing soil loss in sloping areas and being a good nectar plant besides adapting to arid conditions (Ekiz et al., 2011; Özbek 2011; Tan and Serin, 2013; Gökkuş, 2014; Dadaşoğlu and Tosun, 2017). It has been reported that sainfoin can be grown as silage among legume forage crops and the silage quality is good (Dumlu Gül and Tan, 2013). Since it is a foreign pollinated plant, fruits develop on the plant after its flowers are pollinated. Although the sainfoin fruit is in different shapes, it is generally semicircular and has the appearance of a flat pod. The skins of the fruits, which contain a single seed, are net-shaped, veined and form a protrusion on the semicircular edge. Seed; It looks like a bean, but its color is dark brown (Açıkgöz, 2013). In the sainfoin, the plant height is about 100-120 cm, the surface of the leaves is slightly hairy and there are 5-30 leaflets on the leaves. These, too, have a flat structure with a length of about 10-25 mm and a width of 3-8 mm (Okçu, 2009). As seen in Figure 1, its flowers are usually pink and in the form of a cluster, there are approximately 5-80 flowers on each cluster (Tasova and Özkurt, 2018).

Figure 1. Image of flower structure of sainfoin plant

Due to its rich and nutritious content, sainfoin is considered as a fodder crop especially for animal production (Delgado et al., 2008; Vasileva et al., 2019). According to researches; sainfoin, a legume containing concentrated tannins and phenolic compounds, has anthelmintic potential against gastrointestinal nematodes of ruminants (Carbonero et al., 2011; Veitch et al., 2011; Novobilsk´y et al., 2020; Sütçü, 2020). Although it is effective in preventing bloating (because it contains pro-anthocyanidins) and internal parasite infections caused by rumen gas (methane and ammonia gas) accumulating in the digestive organs of grazing-fed ruminants, increases protein use (Thill et al., 2012; Piluzza et al., 2014), and contains less minerals such as calcium and sodium than other legumes; It has been shown that it is rich in P, Mg and K (Altındal and Altındal, 2018), thus positively affecting animal health (Häring et al., 2007). In addition, according to previous research; Unlike other legume plants, sainfoin contains 20% more protein before flowering; It was determined that the amount of crude protein decreased at the beginning of flowering and during the full flowering period (Okçu, 2009; Özat, 2010).

While 1000 kg/da green herbage yield and 200-250 kg/ha dry herbage yield were determined from sainfoin in arid conditions (Figure 2); It was determined that 500-1000 kg/da dry herbage yield was obtained under irrigated conditions (Açıkgöz, 2013). The seed yield of the sainfoin is about 80-100 kg per decare; It has been determined that this yield can reach up to 150 kg in areas that can be irrigated or in areas where precipitation is sufficient (Ekiz et al., 2011). According to the statistical studies conducted in our country; In 2019, 1 781 789 tons of green herbage was obtained from 1 752 763 decares and 111 tons of seed was obtained from 2 025 decares. Herbage yield per decare was determined as 1 031 kg and seed yield as 55 kg (TUIK, 2019).

Figure 2. General view from the sainfoin field

The sainfoin, which can be grown in natural and artificial pastures, has the ability to go deep into the soil depending on its root structure (Figure 3). Because of this feature, it can reach underground water resources and sainfoin plant is preferred in lands with water problems (Çöçü, 2008; Okçu, 2009). In addition, it fixes nitrogen to the soil with the help of *Rhizobium* bacteria and increases the soil water capacity. It can be grown in arid and calcareous soils, making it preferred by farmers as one of the alternation plants. It was determined that more yield was obtained from alfalfa, another legume fodder plant grown on such soils (Tan and Sancak, 2009).

Figure 3. Use of sainfoin in pastures

On the other hand, sainfoin is a very valuable plant in terms of beekeeping (Figure 4). Since the flowering period of the sainfoin starts earlier than other leguminous plants and the scent of its flowers is attractive, it is included in the plants preferred by bees for honey, pollen and nectar production (Özbek, 2011; Koç and Akdeniz, 2017).

Figure 4. Honeybees visiting the sainfoin flower

Agronomy

The genus *Onobrychis* includes several agriculturally important legume forage species, the most common being the sainfoin (*Onobrychis viciifolia*) (Figure 5). *O. viciifolia* has a long history of traditional culture around the world, but its use has declined in western countries over the past decade. Its yield is low compared to other legumes and it is more difficult to maintain, but it is known to have valuable properties such as palatability and drought resistance (Carbonero et al., 2011).

Figure 5. General view of the sainfoin

In the study, which was carried out to determine the effects of different row spacing (15, 30, 45, 60 and 75 cm) and seed amounts (4, 8, 12, 16 and 20 kg/da) applied to the sainfoin on seed yield; it was determined that the number of clusters per plant varied between 3.52 and 4.89, the number of fruits per cluster varied between 11.25-24.30, the fruit weight per cluster varied between 0.16-0.58 g, the number of clusters per m^2 varied between 670.4-1858.3, 1000 fruit weight varied between 14.31-24.68 g, and the seed yield varied between 60.52-113.16 kg/da. According to the results obtained in the research, it was determined that 60 and 75 cm row spacing and 4-8 kg/da seed amount should be used for seed production in sainfoin in the Southern Marmara Region (Türk and Çelik, 2005).

Ertuş et al. (2012) reported that they examined some morphological characteristics of local sainfoin genotypes collected from different districts of Van province in Eastern Anatolia, along with grass and protein yields per plant. As a result of the study, there are significant differences between local genotypes, minimum and maximum values was determined 94-297 g/plant for green herbage yield, 29.5-79.5 g/plant for dry matter yield, 13.60-19.34% for leaf ratio, 8.7-28.8 mm for number of stem per plant and 6.0-9.1 mm for the main stem width. Crude protein contents and yields of leaves and stems were found to be in the range of 16.28-21.88% and 8.34-12.06%, respectively. While leaf ratio differences were not found significant among sainfoin local genotypes, differences were reported to be significant in terms of grass yield, dry matter yield, number of stems per plant, main stem width and crude protein content.

Stevovic et al. (2012) stated that they established a field trial including 3 sainfoin cultivars (Macedonka, EG Norm and Sokobanja population) to determine the appropriate row spacing for seed and forage production. In the experiment, cultivars were planted in 3 different row spacings (20 cm, 50 cm and 80 cm). Seed yield was determined over a 3-year period, while feed yield and quality were evaluated from the 2nd cuttings in the 2nd and 3rd years. The sparseness of the sainfoin over the years, the apparent competitiveness of the sainfoin and the great influence of weather conditions have caused significant differences in seed yield between years. In the 2nd and 3rd years of the experiment, all sainfoin varieties gave very high yields in wider row spacing. Sainfoin cultivars have responded differently to varying row spacing over the years due to differences in seed yield performance under different growing areas and available moisture conditions. Due to the low profitability of seed yield in terms of both seed and forage yield, it was determined that wider row spacing for strong cultivars and narrower row spacing for less vigorous cultivars could be applicable for seed yield.

Özaslan Parlak et al. (2014) conducted a study to determine the biological and morphological characteristics of sainfoin species (*Onobrychis caput-galli, Onobrychis gracilis, Onobrychis oxyodonta*) collected from the natural pastures of Çanakkale. In the study, 50 plant samples of each species were examined and as a result of the examination, wide variation was determined between the morphological and agricultural characteristics of all three species. As a result of the research; the plant height varied between 22.82-53.04 cm, the number of main branches varied between 5.00-47.00, the number of side branches in the main branch varied between 2.20-6.20, the diameter of the main branch varied between 1.38-2.31 mm, the number of leaves on the main branch varied between 3.20-11.60, the number of clusters on the main branch varied between 1.20-6.00, the number of flowers in the cluster varied between 3.40-9.30, leaf length varied between 6.86-11.91 cm, leaflet length varied between 6.98-12.88 mm, leaflet width varied between 2.71-3.93 mm, stem rate varied between 22.22-62.82%, leaf rate varied between 23.34%-45.09%, the flower ensemble rate varied between 6.92-29.49%, the dry matter yield varied between 1.00-4.04 g/plant and the dry matter rate varied between 19.12-44.37% in *Onobrychis caput-galli* species.

The same researchers reported that plant heights varied between 37.14-84-84 cm and 32.60-90.16 cm, the number of main branches varied between 7.00-53.00 and 5.00-54.00, the number of side branches in the main branch varied between 4.20-9.20 and 2.20-8.80, the diameter of the main branch varied between 1.55-3.02 mm and 1.70-3.36 mm, the number of leaves on the main branch varied between 4.40-15.40 and 4.00-19.60, the number of clusters on the main branch varied between 2.00-13.20 and 0.60-11.00, leaf length varied between 4.38-11.87 cm and 5.54-13.83 cm, leaflet length varied between 7.03-14.47 mm and 10.03-20.49 mm, leaflet width varied between 1.72-5.31 mm and 1.23-4.61 mm, the dry matter yield varied between 2.42-12.03 g/plant and 1.72-13.78 g/plant, the dry matter rate varied between 23.00-59.00% and 20.53-49.00%, stem rate varied between 25.18-73.42% and 24.40-65.20%, leaf rate varied between 8.40-48.53% and 4.00%-61.20%, the flower ensemble rate varied between 11.67-55.11% and 13.60-54.70%, the thousand grain weight varied between 8.00-12.25 g and 9.50-13.00 g, and the germination rate varied between 6.00-15.00% and 12.00-27.00%.in *Onobrychis gracilis* and *Onobrychis oxyodonta* species, respectively (Özaslan Parlak et al., 2014).

A study was conducted to examine the yield and some agricultural characteristics of Koç 1461, Emre, Yunus, Fatih, Mehmetalibey and Hilal sainfoin varieties registered by TİGEM's Altınova and Gözlü agricultural enterprises, and Özerbey and Lütfübey varieties used as standard varieties. In the study conducted in 2014 and 2015, it was reported that the yield and some agricultural characteristics of the cultivars changed depending on the years and locations. As a result of the research; it was determined that the green herbage yield ranged between 2077.3-2674.9 kg/da, the dry herbage yield ranged between 456.9-575.1 kg/da, the number of flowering days ranged between 135.0-140.8 days, the main stem length ranged between 90.5-100.8 cm, the main stem thickness ranged between 5.7-6.7 mm, the main stem thickness ranged between 5.7-6.7 mm. the number of stems ranged between 15.0-18.0, the lying situation ranged between 1-3 (according to the scale of 1-5), the sparseness rate ranged between 18.9-20.7%, and the winter hardiness rate ranged between 92.5%-95.3% as the average of years and locations (Koç ve Akdeniz, 2017).

Sainfoin (*Onobrychis viciifolia* Scop.) is a bloat-free, perennial forage legume plant adapted to the northern temperate regions of the world. According to the results of a 2-year study conducted near Saskatoon, Canada in order to determine the phenotypic variation of 38 sainfoin entrances from 21 different countries; it has been reported that the winter survival rate is 54%, the dry matter yield is 164 g/plant, the regrowth is 3.6 (1=slow, 5=rapid), the seed yield is 29 g/plant, the thousand grain weight is 22.6 g, the plant height is 60 cm, the growth rate is 2.3 cm/day, the spring vigour is 3.6 (1=poor, 5=good), the days of flower is 38 and the stem number is 59 as the average of the sainfoin entrances (Bhattarai et al., 2018).

Quality

Leguminous forage crops are important forage crops all over the world. Because these species produce high quality forage where they are adapted and in good maintenance conditions. There is no other family that produces a balanced feed of energy, protein and minerals for high-yielding animals, other than legumes. For this reason, legumes are among the most important plant groups that provide the nutritional needs of animals both among the cultivated species and in natural vegetation (Dumlu Gül and Tan, 2013). As a matter of fact, the forage plant species grown in our country include sainfoin (*Onobrychis sativa* L.), alfalfa (*Medicago sativa* L.), vetch (*Vicia sativa* L.), fodder pea (*Pisum arvense* L.) and bitter vetch (*Vicia ervilia* (L.)). Wild.) forms a large part of the production (Anonim, 2011).

In the study carried out in order to determine the yield and quality characteristics of sainfoin genotypes in two locations consisting of Selcuk University Faculty of Agriculture trial area (Konya) and Turkoba Village (Polatlı/Ankara); hay yield, crude protein rate and crude protein yields, which are known as the most important characteristics in forage crops, were determined as 3.28-4.96 t/ha, 10.08-13.55% and 355.0-602.3 kg/ha, respectively (Avcı et al., 2011). In the study conducted by Kaplan (2011) to determine the chemical composition of sainfoin (Onobrychis viciaefolia) dry grass harvested from Afşin, Tekir, Pazarcık, Baskonus and Kapıçam during the flowering period; It has been reported that the crude protein, NDF, ADF and concentrated tannin contents of sainfoin dried vary between 11.39-17.70%, 43.31%-47.64%, 35.61%-43.30% and 4.19-9.95%, respectively. According to the results of the study; The sainfoin obtained from Afşin and Başkonus has significantly higher crude protein content than the Tekir, Pazarcık and Kapıçam sainfoins; The NDF content of the sainfoins obtained from Pazarcık and Kapıçam was significantly higher than the sainfoin obtained from Afşin and Tekir; the ADF content of sainfoin hay from Kapicam was significantly higher than those of sainfoin hays from Afsin, Tekir, Pazarcik and Baskonus, and the CT content of sainfoins from Pazarcık was significantly higher than those from Afşin, Tekir, Başkonus and Kapıçam detected. There are significant differences in the chemical composition of sainfoin harvested during flowering between growing areas.

A study was conducted to determine the nutrient and energy contents of sainfoin and vetch from forage crops planted in Kars province in two different periods and the differences between the periods. In the study, samples were taken from 5 different planting sites from sainfoin and vetch plants in June and July. As a result of the research; There are significant differences in the organic matter, crude protein, crude fiber, crude ash, ADF, NDF and metabolic energy levels of the sainfoin between June and July; It was determined that organic matter, crude fiber, ADF and NDF levels of sainfoin increased significantly, and crude protein and metabolic energy levels decreased. As a result, it was concluded that the nutrient levels of these forage plants, which are cultivated and have an important place in the nutrition of ruminants, change at different cutting times and the nutrient levels in forage plants should also be taken into account in determining the cutting times (Aksu Elmalı and Kaya, 2012).

Sainfoin is a non-bloating temperate forage legume with a moderate-to-high condensed tannin content. In a study consisting of approximately 46 sainfoin genotypes from Central Europe, Eastern Europe, North

America and Asia; the chemical compositions of the genotypes were examined and it was determined that the dry matter ratios of the genotypes varied between 88.5-95.2%, the crude ash ratios varied between 3.8-6.5%, ADF ratios varied between 23.5-44.5%, NDF ratios varied between 33.8-58.5%, crude protein ratios varied between 7.7-16.6% and condensed tannin ratios varied between 0.6-2.8% (Hatew et al., 2014).

In the study carried out to determine the morphological and agronomic characteristics of some sainfoin species (*Onobrychis caput-galli*, *Onobrychis gracilis*, *Onobrychis oxyodonta*) collected from Çanakkale natural pastures; 50 plant samples from each species were examined and as a result of the examination, a wide variation was determined in terms of nutritional values of all three species. As a result of the research; NDF ratios varied between 32.67-44.93%, 58.29-60.45% and 43.65-53.05%, ADF ratios varied between 25.36-36.80%, 48.38-51.28% and 36.09-44.17%, and ADL ratios varied between 6.18-9.20%, 15.18-23.73% and 10.08-12.77% in *Onobrychis caput-galli*, *Onobrychis gracilis* and *Onobrychis oxyodonta* species, respectively (Özaslan Parlak et al., 2014).

In the research carried out to investigate possible changes that may occur in forage yield and quality parameters of sainfoin (*Onobrychis sativa* Scop.) grown in Artvin province conditions depending on some soil characteristics and different altitudes; Depending on the altitudes, plant height of the sainfoin varied between 56-64 cm, green herbage yield varied between 269-1734 kg/da, dry herbage yield varied between

108-693 kg/da, dry matter ratios varied between 92.14-92.48%, crude protein ratios varied between 16-17%, NDF ratios varied between 44.0-46.5%, and ADF ratios varied between 32-34% (Temel and Özalp, 2016).

Ülger and Kaplan (2016) conducted a study to compare the nutritional properties of grasses of local sainfoin (*Onobrychis sativa*) populations cultivated in Sivas, Kayseri and Kahramanmaraş provinces. According to the data obtained from the research; it has been reported that crude protein ratio of sainfoin populations varied between 12.73-15.90%, crude ash ratio varied between 5.95-7.63%, dry matter ratio varied between 19.41-22.39%, condensed tannin ratio varied between 2.07-4.70%, ADF ratio varied between 32.01-41.79%, NDF ratio varied between 42.57-53.89%, and crude oil ratio varied between 0.69-2.02%. According to the results of the research, it has been determined that there are significant differences between populations in terms of nutrient content and it has been reported that the sainfoin population from Kayseri Bünyan stands out from other populations with its high protein and metabolic energy and low ADF and NDF content.

In the research conducted to evaluate the germplasm of sainfoin (Onobrychis viciifolia Scop.) in terms of agricultural morphological characteristics and nutritional value; nutritional values of 38 sainfoin accessions from 21 different countries were examined and it was reported that crude protein ratios ranged between 13.4%-17.5%, NDF ratios ranged between 35.6%-45.8% and ADF ratios ranged between 34.9%-41.6% (Bhattarai et al., 2018).

In the research carried out to determine the effect on the chemical composition (ADF, NDF, crude protein, crude ash, crude oil, condensed tannin) and mineral content of Erciyes Sainfoin harvested in different vegetation periods (before flowering, full bloom and seed setting); With the progress of the maturation period, the ratios of neutral detergent insoluble fiber (NDF) and acid detergent insoluble fiber (ADF) increased, crude protein, crude oil and crude ash contents decreased, and as the maturation period of Erciyes sainfoin grass progressed, twenty-four hour gas and methane productions and metabolic energy (ME) and organic matter digestibility (OMD) were found to be significantly reduced. As a result, it has been suggested that the nutritional value of Erciyes sainfoin decreases with the progress of the maturation period and that Erciyes sainfoin grass should be grazed before and during flowering due to its high crude protein ratio and metabolic energy capacity (Ülger et al., 2018).

Alternative utilisation

Recent research shows that sainfoin has many other beneficial properties due to its unique tannin and polyphenol composition. Condensed tannins in Onobrychis species have been found to impart anthelmintic properties, increase protein utilization and prevent flatulence; It has also been stated that it may have the potential to reduce greenhouse gas emissions (Carbonero et al., 2011). Positive effects on wildlife nutrition and honey production can also be advantageous in the context of sustainable farming. As well as being a very good forage plant, sainfoin is a very important source of pollen and nectar for bees.

In the study carried out to determine the bee species that visit the sainfoin (*Onobrychis viciifolia* Scop.) plant in Erzurum and the surrounding provinces; It has been determined that more than 200 wasp species other than honeybees collect nectar and pollen from sainfoin flowers and contribute to pollination. As a result of the research; It has been reported that the sainfoin constitutes one of the important food sources of many, especially parasitoid species of the order Hymenoptera, as well as honey bees and wasps. In addition, it has been reported that sainfoin, which causes an increase in population densities as a suitable food source for natural pollinators in the ecological system, is a plant with combined yield characteristics that greatly contribute to the continuation of biological diversity (Özbek, 2011).

In a study conducted by Gökkuş (2014), it was reported that in establishing artificial pastures in arid areas, attention should be paid to both facility establishment technique and grazing management. In addition, it has been reported that sainfoin, which is resistant to grazing and drought in arid areas and is one of the important forage crops that can be used in artificial pasture facilities, can be added to the mixtures at a rate of 20% (Figure 6).

The interest of producers and researchers in the silage use of legumes, including sainfoin, has increased in the last 20 years. In the first applications, the fermentation of legumes was generally unsuccessful, but today the reasons for the failure of legume silage are largely understood. In places where hay production is difficult due to the precipitation regime, silage production is becoming widespread for the preservation of feed. With the developing silage technology, it has emerged that forage legumes can be used in silage form without any negative effects on animals (Dumlu Gül and Tan, 2013).

Figure 6. Sainfoin planted on artificial pasture

Dumlu and Tan (2009) determined that in silages made from important legume forage crops, only good quality silage was produced from sainfoin, according to physical evaluation, while alfalfa, clover and stone clover silages remained in the low value class. The researchers attributed this situation to the high dry matter ratio in the sainfoin and the corresponding decrease in pH.

In a study conducted by Turan and Seydoşoğlu (2020), the effects of alfalfa (*Medicago sativa* L.), sainfoin (*Onobrychis viciifolia* Scop.) and

Italian grass (*Lolium multiflorum* Lam) crops, which are plain and mixed in different proportions, on silage and feed quality were investigated. As plant material in the experiment; Kayseri clover cultivar, Lütfibey sainfoin cultivar and Caramba Italian grass cultivar were used. In the study, pure and different ratios (75:25%, 50:50% and 25:75%) silages were investigated pH, dry matter, crude protein, flieg score, acid detergent insoluble fiber (ADF), neutral detergent insoluble fiber (NDF), digestible dry matter (DDM), dry matter take (DMI) and relative feed values (RFV). According to the results of the research; The average pH value of silages was 4.89, dry matter rate was 38.35%, crude protein rate was 17.05%, flieg value was 86.52 points, ADF rate was 33.07%, NDF rate was 45.46%, DDM rate was 63.14%, DMI rate was 2.70% and RFV was 132.09.

In the study by Kaplan et al. (2019), oil contents, fatty acid compositions and mineral contents of seeds of twenty *Onobrychis viciifolia* genotypes (sainfoin) were investigated. In the study, the fatty acid composition of *O. viciifolia* genotypes had different saturated and unsaturated fatty acids; for saturated fatty acids, the genotypes of *O. viciifolia* contain palmitic and stearic acids as major components and minor amounts of myristic and arachidic acids; it has been reported that the main unsaturated fatty acids are oleic, linoleic and linolenic acids. As a result of the research; It was determined that the content of total saturated fatty acids varied between 10.50% and 14.28%, and the contents of total unsaturated fatty acids varied between 85.72% and 89.50%. Different amounts of Co, Mn, Fe, Cu, Ni and Zn were detected in sainfoin seeds; it has been reported that Co content of seeds varies between 13.53 and 114.83 ppm, Mn content varies between 28.14 and 97.20 ppm, Fe content varies between 113.7 and 277.7 ppm, Cu content varies between 7.19 and 12.24 ppm, Ni content varies between 1.14 and 19.73 ppm, and Zn content varies between 6.03 and 52.39 ppm.

The sainfoin (*Onobrychis viciifolia* Scop.), which has been cultivated in Anatolia since BC, is a perennial forage legume plant. Due to its rich and nutritious content, it is used extensively in many areas as well as being preferred in animal nutrition. In a study conducted by Dumanoğlu et al. (2021), seven different sainfoin genotypes with population (Adaklı, Doğanca, Genç, Yedisu) and variety candidate (Fatih, M. Ali Bey, Yunus) characteristics were examined. In the study, some physical properties (shape-size, surface area, mean arithmetic diameter-geometric diameter, sphericity, thousand-grain weight) of seeds belonging to sainfoin genotypes were determined. It is foreseen that the data obtained as a result of the study will contribute to increasing the planting possibilities of seeds without product losses in terms of mechanization and to the genetic improvement studies. According to the statistically analyzed results, sainfoin genotypes; it has medium dimensions and an oval shape; It has been determined that they have an average arithmetic diameter of 2,736 mm, a geometric diameter of 8,311 mm, a sphericity value of 2,516, and a thousand grain weight of 22.315 g. In addition, in terms of these examined characteristics, it was found that the cultivar candidate genotypes showed superior characteristics; among the local genotypes, only Yedisu genotype was determined to have better values.

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CHAPTER 7

ALFALFA (*Medicago sativa* L.)

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INTRODUCTION

Bibliometric analysis is the numerical analysis of the publications produced by individuals or institutions in a certain area, in a certain period and in a certain region, and the relations between these publications (Anonymous, 2021a). As it can be understood from the definition of bibliometric analysis, bibliometric analysis is based on the principle of publications and analysis of publications. Therefore, it is possible to make bibliometric analyzes in every field and to evaluate the publications and data in that field.

In our country, bibliometric analyzes were carried out in different areas. However, in general, it is seen that these analyzes are used more in social sciences and these analyzes are concentrated on publications such as journals and master's theses (Ayaz & Türkmen, 2018; Birinci, 2008; Polat et al., 2013; Yıldız Gülhan & Kurutkan, 2021). As well as bibliometric analyzes of theses published by any journal or any institute, bibliometric analyzes are frequently performed on publications in databases such as Web of Science and Scopus, which are accepted worldwide (Gedik et al., 2020; Özlü, 2021; Şeref & Karagöz, 2019).

Scopus is an abstract and citation database with full-text links made available by Elsevier in 2004. Scopus indexes content from 25,000 active titles and 5,000 publishers, selected by an independent review board (Anonymous, 2021b). The name Scopus is inspired by the Hammerkop bird (*Scopus umbretta*) (Burnham, 2006).

This study was carried out with the aim of evaluating and bibliometric analysis of publications related to alfalfa (*Medicago sativa* L.) in accordance with Scopus records.

MATERIAL and METHODS

The material of this study is Scopus records (Anonymous, 2021c). In Scopus, the publications with the phrase *Medicago sativa* in the "article title, abstract and keywords" are based. “ ” was used in the search and the search was made as “*Medicago sativa*”. As of 02.08.2021, it was seen that there were 18,066 records related to *Medicago sativa* and 13,383 of these records were related to the field of Agricultural and Biological Science. All the evaluations discussed in the findings and discussion section were made on these 13,383 records.

FINDINGS and DISCUSSION

1. Subject areas of publication related to *Medicago sativa*

In Scopus records, it is seen that a total of 18,066 publications were made about *Medicago sativa*. It is seen that 13,383 of these publications were made in Agricultural and Biological Sciences, 5,365 in Biochemistry, Genetics and Molecular Biology, 3,360 in Environmental Science, 1,568 in Immunology and Microbiology and 997 in Veterinary. Apart from these, it is seen that there are publications on *Medicago sativa* in many other fields (Table 1).

Table 1. Subject areas of publications related to *Medicago sativa*

Subject Area	**Number of Publications**
Agricultural and Biological Sciences	13 383
Biochemistry, Genetics and Molecular Biology	5 365
Environmental Science	3 360
Immunology and Microbiology	1 568
Veterinary	997
Medicine	844
Earth and Planetary Sciences	633
Chemistry	591
Engineering	443
Nursing	362
Pharmacology, Toxicology and Pharmaceutics	298
Chemical Engineering	290
Multidisciplinary	288
Energy	199
Social Sciences	193
Computer Science	88
Materials Science	72
Physics and Astronomy	71
Economics, Econometrics and Finance	43
Neuroscience	37
Mathematics	18
Arts and Humanities	14
Business, Management and Accounting	14
Health Professions	14
Decision Sciences	11
Dentistry	5
Psychology	2
Undefined	20

2. Number of publications on *Medicago sativa* by years

The first publication on *Medicago sativa* was made in 1866. This publication is “Note on the structure of *Medicago sativa*, as apparently affording facilities for the intercrossing of distinct flowers" by Henslow (1866) and was published in the "Journal of the Linnean Society of London, Botany" (Henslow, 1866). The second publication after this date was in 1914, and the third in 1929. In the following years, the number of publications increased regularly. In 1988, the publications on *Medicago sativa* exceeded 100, and by 1994, it was over 200. Since 2002, the annual publications are between 382 and 569 (Figure 1).

Figure 1. Number of publications on *Medicago sativa* by years

Perhaps the most important issue to be emphasized here is the rapid increase in the number of publications after the 1990s. This can be explained for two different reasons. The first is the rapid proliferation of computers all over the world after 1990 and the introduction of the internet into our lives. In this way, publications were printed faster and easier to reach many people. The second reason is that the importance given to forage crops is better understood. The most important factor that reveals the importance of forage crops is the rapidly increasing world population. As the world population increased, the number of animals kept by human beings also increased. The increase in the number of animals naturally necessitated the production of more forage plants. As a result, it has led to the emergence of more publications in this field.

3. Authors who published about *Medicago sativa*

The 20 people who published the most about *Medicago sativa* are given in Figure 2. The most published author has been Dixon R.A. Dixon R.A. continues his studies at the Department of Biological Sciences (USA) at the United States University of North Texas. Sheaffer C.A. is in second place. Sheaffer C.A., continues his studies at the University of Minnesota Twin Cities, Department of Agronomy and Plant Genetics (USA). Beauchemin K.A. took the third place. Beachemin K.A. works at the Lethbridge Research and Development Center (Canada).

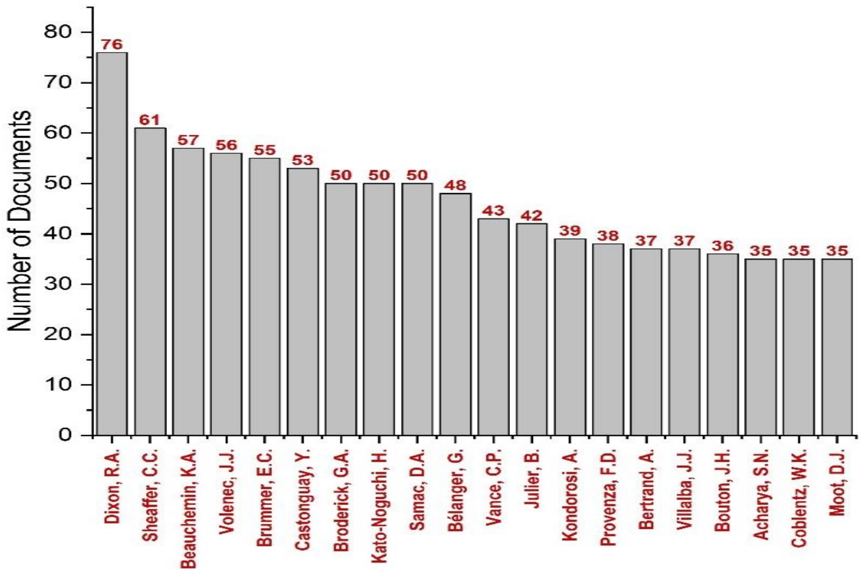

Figure 2. Authors who published and number of publications about *Medicago sativa*

4. Types of publications on *Medicago sativa*

The most common type of publication about *Medicago sativa* has been the article. The number of articles is 12,775 in total. This was followed by conference papers in the second place, review in the third place, and book chapters in the fourth place.

Document Type	Number of Publications
Article	12 775
Conference Paper	276
Review	177
Book Chapter	77
Note	37
Erratum	26
Editorial	4
Short Survey	4
Letter	3
Book	1
Conference Review	1
Retracted	1
Undefined	1
Toplam	**13 383**

5. Journals with the most publications on *Medicago sativa*

The names of journal which more than 200 publications related to *Medicago sativa* are given in Figure 3. Journal of Dairy Science made the most publications with 815. This was followed by the Journal of Animal Science with 483, Crop Science with 301, Agronomy Journal and Animal Feed Science and Technology with 293, and Plant and Soil with 252.

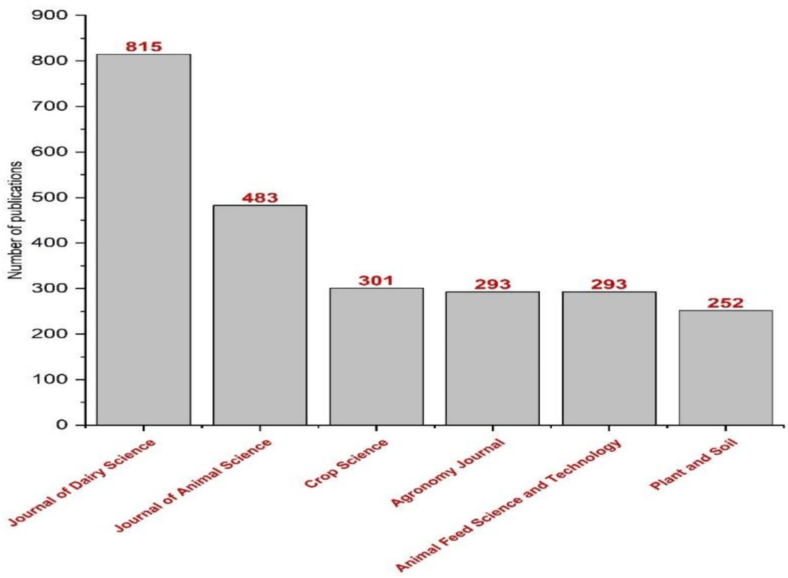

Figure 3. Journals with more than 200 publications on *Medicago sativa*

6. Affiliations that publish *Medicago sativa*

Scopus publications include 160 affiliations that publish related to *Medicago sativa*. Among these, affiliations that have published more than 200 about *Medicago sativa* are given in Figure 4. The most publications were made by the USDA Agricultural Research Service (886). This was followed by Agriculture et Agroalimentaire Canada with 616 and the United States Department of Agriculture with 560 publications.

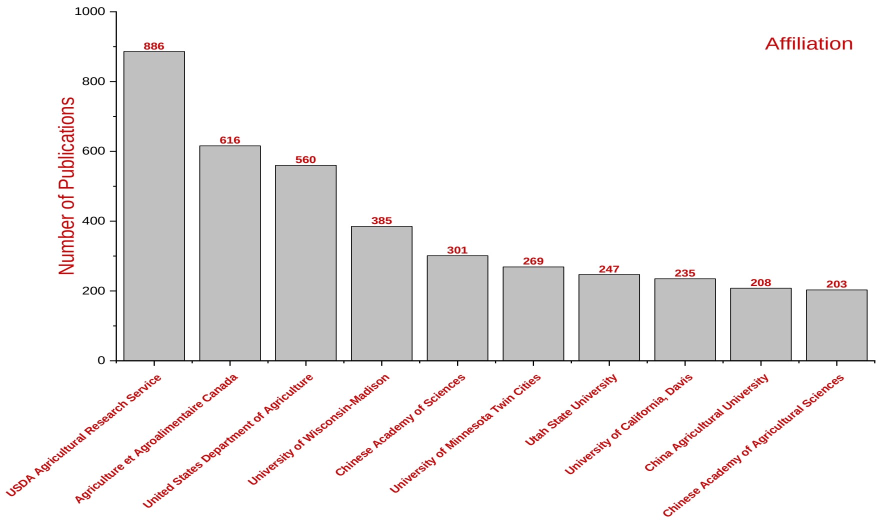

Figure 4. Affiliations that have the most publications over 200 on *Medicago sativa*

7. Countries with the most publications on *Medicago sativa*

In Figure 5, the names of countries over 100 publication are given. The highest number of publications was made by United States with 4,804 issues. This country was followed by China with 1,520 and Canada with 1,326 publications. Turkey ranks 16th with 216 numbers. In general, it is seen that the number of publications made by developed countries on the subject is high.

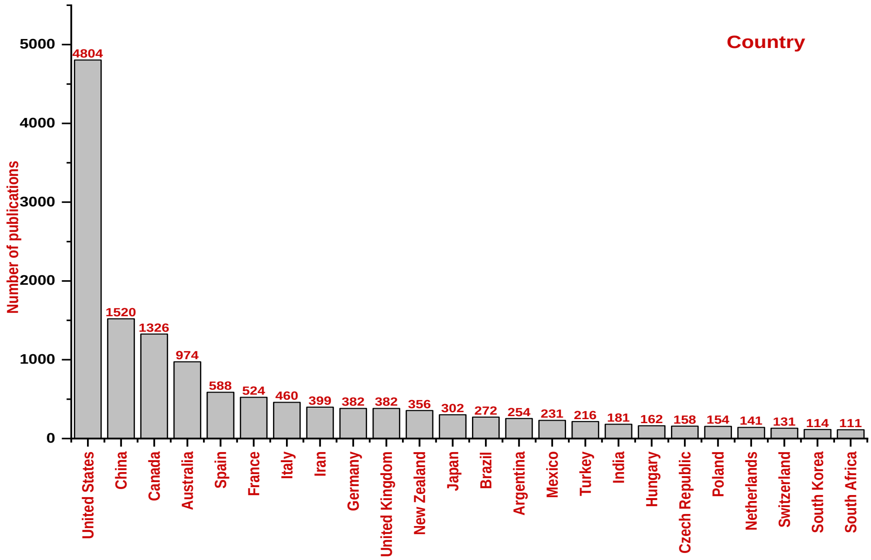

Figure 5. Countries with over 100 publications on *Medicago sativa*

8. Languages used by publications on *Medicago sativa*

12,681 of the publications on *Medicago sativa* were written in English. This language was followed by Chinese with 387, Spanish with 114 and Portuguese with 111. The number of publications written in Turkish is 14.

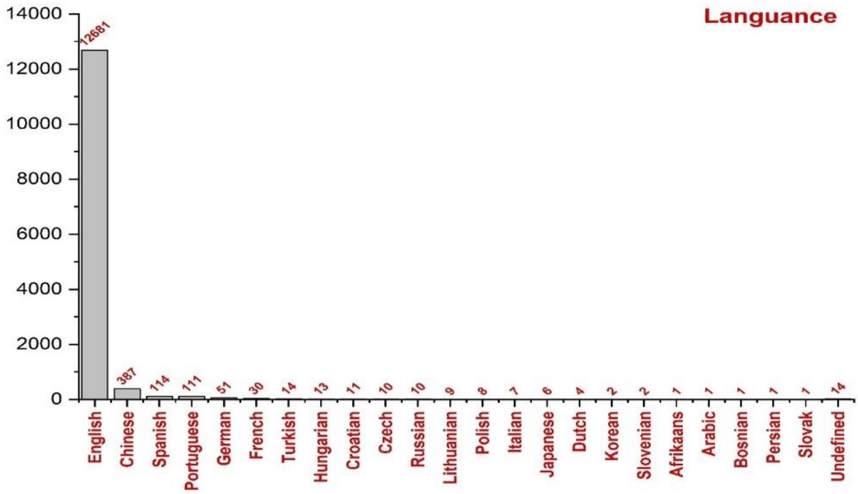

Figure 6. Languages used by publications on *Medicago sativa*

9. Institutions and organizations that sponsor the publications about *Medicago sativa*

The institutions and organizations that sponsor or fund more than 100 studies related to *Medicago sativa* are given in Figure 7. It is seen that the institution that supports the most publications is the National Natural Science Foundation of China (457 pieces).

This institution was followed by the U.S. Department of Agriculture (258 units), Government of Canada (211 units), Natural Sciences and Engineering Research Council of Canada (157 units), Ministry of Science and Technology of the People's Republic of China (128 units) and European Commission (127 units).

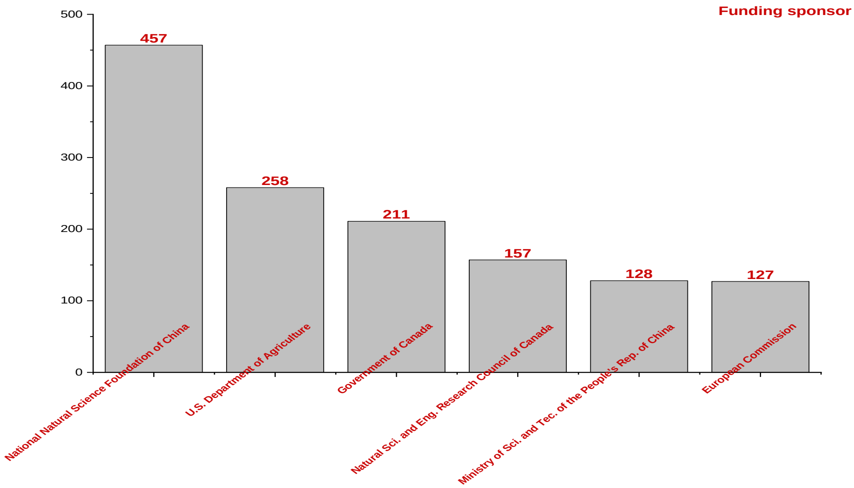

Figure 7. Institutions and organizations that fund or sponsor more than 100 studies related to *Medicago sativa*

CONCLUSION

As of 02.08.2021, 18,066 publications were made regarding *Medicago sativa*. 13,383 of these publications are related to the field of Agricultural and Biological Sciences. The first record of *Medicago sativa* was in 1866. Most publications began to be made after the 1990s. To date, Dixon R.A. has been the most publication person on *Medicago sativa*. At the beginning of the scientific studies on *Medicago sativa* are articles (12,775). The journal in which the most articles were published was the Journal of Dairy Science. The institution that made the most publications were the USDA Agricultural Research Service and the country that made the most publications were the United States. Naturally, the most publications were written in English, and the

National Natural Sciences Foundation of China was the institution that supported the most publications on *Medicago sativa*.

This publication is limited to publications that contain *Medicago sativa* in their title, abstract and keywords. In addition to *Medicago sativa* phrase in the title, abstract and keywords, a larger number of publications is encountered when the publications containing the phrase lucerne, alfalfa, medic or rarely clover are taken into account. It would be useful to conduct a study in this direction in the future.

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CHAPTER 8

CARIBBEAN STYLO (*Stylosanthes hamata*)

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INTRODUCTION

Stylosanthes hamata is among tropical forages used as legume for permanent pastures. Crop is suitable for cut-and-carry as green fee, or for hay. Species is also suitable for silvipasture systems or ley in cropping systems. It is widely used as pasture crop for raising cattle, sheep and goats. Under ideal conditions, can yield up to 17 t/ha dry matter in pure stands. Plant growth is limited when night temperatures decline to about 15 ºC. It has ability to nodulate freely with a wide spectrum of native rhizobia. Some species have anti-tick (ectoparasite *Boophilus microplus*) feature. Partial resistance to *Colletotriclzum gloeosporioides* (anthracnose) was determined in some accessions.

Here in this review, reader may find diversified information related to *Stylosanthes hamata*, abstracted from international published studies.
Stylosanthes is a forage legume cover crop native in tropical regions (t'Mannetje, 1984). Its natural habitats are mostly areas with low soil fertility (Tarawali et al., 1998). *Stylosanthes* (*Fabaceae*) genus includes 40 diploid and polyploid species (Kirkbride & Kirkbride, 1987). Five of these species (*Stylosanthes hamata*, *Stylosanthes guianensis*, *Stylosanthes scabra*, *Stylosanthes humilis*, and *Stylosanthes viscosa*) are widely used tropical forages. *S. hamata* and *S. scabra* are allotetraploids (2n = 4x = 40) and other three species are diploid (2n = 2x = 20). These five species are mainly self-pollinating but have outcrossing at low degrees (Stace & Cameron, 1984).

Stylosanthes hamata (L.) Taub., has prostrate or ascending stems and common in Caribbean region. Originally it was described as *Hedysarum hamatum* by Linnaeus and then transformed to *Stylosanthes* by Taubert. Chromosome analysis of *Stylosanthes hamata* accessions originate from Caribbean islands and was all diploid (2n=20). A morphologically similar *Stylosanthes* species accession collected from Venezuela in 1965 was misidentified as *Stylosanthes hamata* which was cropped as forage on low fertile soils in subhumid and dry tropics and registration as cultivar Verano in Australia in 1975. This morphotype was tetraploid and referred in the literature as "tetraploid *Stylosanthes hamata*". Different authors were recommended to treat the allotetraploid as a different species (Cook & Schultze-Kraft, 2021).

Figure 1. "*Stylosanthes hamata*" (Gündel F.D., 2013).

Stylosanthes hamata is native to USA (Florida), Anguilla, Cuba, Guatemala, Haiti, Jamaica, Puerto Rico, Nicaragua, , Bahamas, Brazil, Virgin Islands, Colombia, Peru and Venezuela. Species is cultivated/naturalized in USA, West Africa, China, India, Thailand, Australia (ACIAR, 2020).

RFLP analysis and cDNAs isolated from *S. humilis* provided molecular evidence for the genetic origin of natural allotetraploid *S. hamata* cv. Verano (2n = 4x = 40). Hybridization patterns suggest as probable progenitors of *S. hamata* cv. Verano were diploid *S. humilis* (2n = 2x = 20) and diploid *S. hamata* (2n = 2x = 20) species (Curtis et al., 1995).

Agronomy

S. hamata is mostly used as legume for permanent pastures. Suitable for cut-and-carry as green feed, or for hay if cut before dry season leaf fall when plants become increasingly stemmy. In Thailand, it is sown along roadsides for grazing by cattle at wet-season. In India, it is sown in silvipasture systems in undersowing *Eucalyptus* and *Dalbergia* forests. In West Africa and northern Australia it is used as a ley in cropping systems. Used as tea in folk medicines in Jamaica to treat kidney pains, colds and fever. In areas with a very long dry season, *S. hamata* behaves as an annual. Some forms have quite good flood tolerance. Plant growth is limited when night temperatures decline to about 15 ºC, even with warmer day temperatures. Hard seed ratios and embryo dormancy are high in fresh seed. Use of more germinable seed leads to more rapid establishment and markedly higher early yields.

Sowing rates of 1–4 kg/ha of seed are used. The tetraploids are promiscuous in their rhizobial requirements, nodulating freely with a wide spectrum of native rhizobia. It may still be advantageous to inoculate with effective commercial strains such as CB 756 or CB 1650. Application of 10–20 kg/ha phosphorus at planting and every 2 or 3 years after establishment improves both plant and animal performance. Molybdenum and sulphur may also be necessary in some situations. CP levels range from 17 to 24% in green leaf and 6–12% in the stem. IVDMD for whole tops are between 60–65%, comprising 66–72% for green leaf and 33–57% for stems. Nutritive value declines rapidly with the onset of dry season leaf drop. Under ideal conditions, can yield up to 17 t/ha DM in pure stands, but in mixed pasture, more commonly between 1-7 t/ha DM, depending on growing conditions, defoliation pressure and grass competition. Yield of between 7-10 t/ha per year have been recorded under a range of cutting frequencies, soils and rainfalls in cut-and-carry systems in Thailand. 'Verano' variety (released in 1973) is the first registered variety. After that, 'Amiga' variety (released in 1988) extended *S. hamata* range into drier and cooler environments (rainfall >500 mm, <23 °S) but both cultivars are poorly adapted to subtropical environments. It is similar to 'Verano' in flowering time, nodulation response, palatability, digestibility and nutritive value, but have greater longevity of individual plants (ACIAR, 2020).

Stylosanthes hamata is widely used as pasture crop for raising cattle, sheep and goats (Yi, 2000). It is cut and fed, used to make hay and stylosanthes leaf meal for feeding poultry, cattle and rabbits (Aduku et al 1989). *S. hamata* exhibits a high nitrogen fixing potential when inoculated with highly effective rhizobium (Gueye, 2002).

Figure 2. "Stylosanthes hamata" (Gündel F.D., 2013).

The ratio of hard seed in *S. hamata* was decreased from 44% to 17% by immersion in water at 55°C for five minutes followed by immersion in sulphuric acid for three minutes in the study of Nan et al., (1998).

Some species of Stylosanthes genus (*S. hamata*, *S. guaianensis*, *S. viscosa* and *S. scabra*) have anti-tick (ectoparasite *Boophilus microplus*) feature. The leaves and stems are covered with trichomes and they produce sticky secretion with an odour. Tick larvae on host are get trapped and killed with the secretion. Muro Castrejon et al., (2003) demonstrated that repellence ranged from 70-82% in *S. hamata*. 17

compounds were determined in *S. hamata* and identified as potential for repellence effect (Muro Castrejon et al., 2003).

Partial resistance to *Colletotriclzum gloeosporioides* (anthracnose) was determined in six tetraploid accessions and Verano variety of *S. hamata* (Iamsupasit et al., 1993).

Use of *S. hamata* could increase to sustain soil productivity (Woldeyohannes et al., 2007). Its roots make macropores in the compact layer of sandy soils. Lesturgez et al., (2004) demonstrated its potential in structural amelioration of sandy compact layers of soils (Lesturgez et al., 2004). Root systems of *S. hamata* was studied in Mali in two locations. Root biomass production of *S. hamata* responded to phosphorus (P) fertilization where 3,596 kg/ha with zero P and 4,161 kg/ha with P-supply. Above-ground biomass was 8,360 and 10,680 kg/ha, respectively. Root length density was relatively high for the whole root profile and specific root length increased from 35 m per g for the 0-20 cm layer to 100 m per g for the 130-140 cm layer, allowing *S. hamata* to use water (Groot et al., 1998).

The continuous mobility of phosphorus within the plant from shoots to roots even under P stress is an adaptive important feature of *S. hamata* in P deficient soils. P deficiency was studied by Smith et al., (1990) who determined that when P is limited, plants were directed resources to maintain root growth even under extreme P deficient plants. They observed that shoot growth was ceased and linear rates of root growth appeared (Smith et al., 1990). Effects of fertilisers on yield and quality of *S. hamata* cv. Verano were measured in three field experiments on woodlands in Queensland. Application of 30 kg/ha phosphorus increased annual yield during first four years. Maximum obtained yield (approximately 6000 kg/ha) in the second year (Hall, 1993).

Dry matter yield, nutritive value and persistence of *S. hamata* cut at different frequencies were compared. Shorter cutting intervals enhanced regrowth, but very frequent cutting reduced total dry matter and seed yields. A defoliation interval of three to six weeks is recommended (Tarawali et al., 1995).

Establishment of *Stylosanthes hamata* cv. Verano was observed in Thailand. Seeds were sown in August, early cutting was at 45 days after emergence and late cutting was at 75 days after emergence. Dry matter yields at early and late cutting stages were 5,300 kg and 7,500 kg/ha, respectively. Feed quality analysis and feeding experiments indicated that feeding values of Verano stylo were considerably high, and that the otimum stage for cutting is about one month after flowering when nutrient yield was high (Wilaipon, 2004).

Field experiments were conducted in Nigeria, during rainy seasons to determine the effect of three different sowing methods (broadcasting, dibbling and drilling). Samples were randomly taken at 2, 4, 6, 8, 10, 12 and 14 weeks after sowing. Herbage yield (kg ha-1) was determined at the end of the 14th week. Dibbling method produced taller plants, with wider canopy spread and more leaves and stands for Stylosanthes hamata cv. Verano production at 50×50 cm inter and intra-row spacing in semi-arid agro-ecology in Nigeria (Malami et al., 2012).

Seed collection of Stylosanthes hamata cv. Verano after harvesting is difficultt due to seed shedding. Seed harvesting can be made by sweeping the seeds from the ground. Seed production potential of the crop was studied in India. Seeds were sown at 10 kg/ha in lines 30 cm apart. Fertilizer P and K application (80:30) and liming were conducted. It required 82 days from sowing to green harvest and additional 34 days for seed harvesting. Total green yield was 2,4 tonnes/ha. Total seed yield was 124 kg/ha (Mariyappan, 2007).

Stylosanthes hamata cv. Verano grown in rows of 20-40 cm produced three years average seed yields between 820-930 kg/ha. A considerable amount of seed (44%) shattered and was collected by sweeping the interrow spaces (Khara et al., 1990).

In a field study in India, *S. hamata* seeds were soaked in water or gibberellic acid and pelleted with diammonium phosphate, clay, rock phosphate, biogas slurry, superphosphate, or clay + manure. Plant establishment and green forage yield were significantly increased by soaking in gibberellic acid compared with water soaking. Among pelleting treatments, plant establishment was highest from biogas slurry, while green forage yield was highest from pelleting with rock phosphate in 1995 but pelleting treatments were similar in 1996. The interaction analysis showed that highest yield was obtained by soaking in gibberellic acid and pelleting with rock phosphate (Hosmani et al., 1998).

CONCLUSIONS

Strengths of *S. hamata* species are: 1) Can be oversown into native pasture or grown with sown grasses, 2) Grows on low fertility soils, 3) Highly persistent under grazin,. 4) Field tolerance exist for anthracnose disease.

Weakness of *S. hamata* species are: 1) Intolerant to waterlogging, 2) Frost sensitivity, 3) Restricted to tropical environments.

Many basic research are absent in this species. Instead, some diversified but shraply remote subjects were studied. Studies may be concentrate on morphology, yield components, fertilization, seeding rates, forage quality, phenologic periods especially under different ecologies to promote the crop production globally more.

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CHAPTER 9

HUNGARIAN VETCH (*Vicia pannonica* Crantz.)

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INTRODUCTION

Hungarian vetch (*Vicia pannonica* Crantz.), a forage plant, is a legume that is widely distributed in Minor Asia, Eastern Mediterranean and Europe as a gene source, and is named after Hungarian because its first cultural forms were recorded in Hungary. This plant is one of the leading forage plants that can be used in many areas such as quality animal feed, crop rotation conversion systems, protection and enrichment of biological diversity, soil improvement, development of pasture areas, erosion control, scientific breeding material. Hungarian vetch, which is an annual legume forage crop, is an ideal plant for forage and seed production, as it can develop quickly in early spring by making good use of early precipitation in heavy clay soils, arid conditions, hot and arid regions. This plant, with 15-17% crude protein content, generally has similar yield characteristics and nutrient content with other vetch species and can be used as a good and quality animal feed source by making good mixtures with *gramineous* forage crops.

Hungarian vetch is a plant that can grow up to 100 centimeters in height and develops semi-upright in terms of its vegetative characteristics. In addition, the entire above-ground part is covered with hairs and has 5-10 pairs of leaflets on a leaf. The leaflets are elliptical and their tips are semicircular, and the leaf axis ends with a leech. It has dull and grayish-green colored flowers and flowers emerge with a long stalk from 1-4 sparse cluster-shaped leaf axils. 1-4 clusters emerge from each seat and the pods are dirty white and purple in color and contain between 10-25 pods. Each pod contains 2-9 round, black, grayish black, light and dark brown seeds.

Hungarian vetch is a crop that can protect itself up to -16 ^{0}C cold during periods when snow does not form, prefers medium-heavy and heavy, lime-rich soils, and is suitable for cultivation in all areas where grain agriculture is made. Although the planting time in our country varies according to the micro and macro climate conditions, the most suitable planting time is usually between the beginning of September and the end of November in the fall. Planting of the crop can be done with special forage plant drills, combined or pneumatic drills or by hand as a primitive. The sowing depth is between 3-6 cm, the distance between the rows is between 35-45 cm and 6-12 kg of seeds are used per decare. Since the plant is in the legume forage crop group, it meets a significant part of the nitrogen need through *Rhizobium* bacteria, but fertilization can be made with 2-4 kg/da N and 6-8 kg/da P_2O_5 as a one-time pure substance with planting. In order to obtain forage from Hungarian vetch, the harvesting time is considered as the period when the grains in the lower pods of the plant are shaped, well-grown and fill the pods. Harvesting time to obtain seeds from Hungarian vetch is the period when the lower pods of the plant turn brown and turn yellowish brown. Hungarian vetch harvesting is done with hand tools, mower and combine harvester. In the harvest for forage, although it varies according to the regions, the yield of 600-2750 kg of green forage yield and 150-550 kg of dry forage yield is taken per decare; in the harvest for seeds, 60-150 kg seed yield is obtained per decare. The most important expectations from animal feed; protein, ADF, NDF, Ca, Mg, P and K values are balanced and nutritional value is high. From this point of view, it is obvious that Hungarian vetch is an important forage crop.

SOME STUDIES MADE ON HUNGARIAN VETCH IN RECENT YEARS IN TURKEY

In a study examining some properties of 50% Hungarian vetch and 50% wheat mixture planted in autumn and grown in arid conditions, according to different cutting times; it was reported that the dry matter, crude ash and organic matter values of both plants did not change according to the cutting time, the NDF and ADF ratios increased, and the crude protein ratios increased until the 20 July cutting period. It has been reported that fresh forage yield was statistically significant ($P<0.01$) from the 6^{th} of July cutting period, in vitro dry matter digestibility decreased rapidly ($P<0.01$) depending on the progression of vegetation from the first form to the last form. It was stated that the most suitable cutting time in terms of the examined parameters was determined in the range of 30.10-36.68% of the dry matter of the mixture in milky stage (Aksoy and Nursoy, 2010).

In the study in which the seed yield and some characteristics of 4 Hungarian vetch lines and Aegean white varieties were investigated in Bingöl dry ecological conditions; They reported that 1635.81 kg/da of green herbage yield, 322.41 kg/da of dry herbage yield, 231.47 kg/da of straw yield and 50.27 kg/da of seed yield were obtained on average, although it varies according to the line and varieties examined. The average plant height is 46.20 cm, the number of main branches and side branches per plant is 2.50 and 2.15, the height of the lower pod is 30.05

cm, the number of pods per plant is 7.65, the seed is 2.56 per pod, and the thousand-grain weight is 36.60 g. They reported that Ege Beyazı variety and Hat-23 genotype could be recommended in order to get herbage yield (Bakoğlu et al., 2010).

In a study carried out to determine the appropriate mixing ratio and cutting time for Hungarian vetch+wheat and hairy vetch+wheat mixtures planted in Erzurum irrigated conditions in summer and autumn; it has been reported that with the increasing grain ratio in vetch mixtures, the vetch content of the mixtures decreased, the hay yield increased, and the height and hay yield of the plants increased with the advancing development period. It was stated that in order to obtain high yield from the mixtures, 70%-30% sowing rate should be used and the wheat should be harvested during the milky stage (Taş, 2010).

In a study carried out to determine the most appropriate gamma ray dose that can be used in mutation breeding studies in Hungarian vetch cultivars; it has been reported that the emergence rate is affected by gamma irradiation, and it causes significant reductions in seedling height, seedling root length, seedling fresh and dry weight characteristics, especially at a gamma ray dose of 140 Gy. Although the gamma ray dose used for cultivating of plant or creating variation in plants varies according to genotypes, the doses that can be applied without a decrease in viability were found to be between 80 and 120 Gy (Bağcı and Mutlu, 2011).

In a study examining the autumn and summer sowing performances of Hungarian vetch, hairy vetch and wheat mixtures in Erzurum dry conditions; it has been reported that the vetch content (39.2%) is lower in autumn plantings, plant height (72.3 cm in vetch and 93.0 cm in wheat) and hay yield (493.4 kg/da) are higher in autumn plantings compared to summer plantings. It has been stated that Hungarian vetch+wheat mixtures (525.2 kg/da) planted in autumn provide higher hay yield than hairy vetch+wheat mixtures (461.7 kg/da), and the highest hay yield from both mixtures is obtained from the milky stage. It was determined that the resistance to lodging and dry forage yield of vetch species increased due to the increase in wheat ratio in the mixtures. It has been reported that the highest dry forage yield was obtained in both Hungarian vetch and hairy vetch in the 70%-30% mixture with the highest percentage of wheat, and this sowing rate should be done in autumn and mowing during the milky stage (Taş, 2011).

In a study carried out with the aim of determining the fresh and dry forage yields of some annual forage plant mixtures suitable for Tekirdağ conditions; it has been reported that the highest forage yields in terms of fresh forage yield were obtained from lupine + vetch + Hungarian vetch mixtures, and this result was followed by lupine + large vetch + barley mixtures and lupine + common vetch + barley mixtures (Orak, 2012).

In a study in which 12 different Hungarian vetch genotypes were used in the climatic conditions of Kızıltepe district of Mardin province; it was reported that the number of 50% flowering days was between 142.6.-155.0 days, the natural plant height was between 44.90-54.33

cm, the main stem length was between 52.26-63.10 cm, the main stem number was between 2.23-3.06, the main stem thickness was between 1.62-2.27 mm, the green forage yield was between 1227-2336 kg/da, hay yield was between 295-575 kg/da and the nodules in the plant was between 8.63-28.38 pieces. In relations between features; it has been reported that there is a significant and positive relationship at the level of 0.01 between hay yield and green forage yield and the number of nodules in the plant, a significant and positive relationship at the level of 0.05 with the natural plant height, and significant and negative relationships at the level of 0.01 between hay yield and number of 50% flowering day. It was stated that the highest green and dry forage yield among Hungarian vetch genotypes was obtained from cv. Oğuz-2002 and cv. Anadolu Pembesi-2002 in Kızıltepe conditions (Sayar et al., 2012).

In the study carried out to determine the yield and yield components of 12 Hungarian vetch genotypes in Diyarbakır ecological conditions; it was reported that the time spent by the plant until 50% flowering in this region varied between 172.6-184.3 days and the plant height was determined between 46.3 cm and 55.1. In addition, it was determined that the length of the main stem ranged from 65.2 cm to 78.3 cm and the number of main stems was between 1.8-2.0. They found that the number of pods was between 15.6 and 29.5 and the number of seeds per pod was 2.5-3.2 in the properties examined in relation to the grain yield. On the other hand, green forage yield, dry forage yield, seed yield and 1000-seed weight was between 1986.3 kg/da and 3094.6 kg/da, 523.6

kg/da and 816.1 kg/da, 76.1 kg/da and 153.5 kg/da and 29.8 g and 47.2 g in their study, respectively (Seydoşoğlu, 2014).

In the study carried out between 2009 and 2010 in irrigated conditions in Erzurum; a dose of phosphate solvent bacteria (*Bacillus megaterium* M-3, 10-8 CFU/ml), two different doses (0 and 3 t/ha) chicken manure and 3 different doses (0, 50, 100 kg/ha P2O5) phosphorus fertilizer was used to determine effects on seed yield and yield components in Hungarian vetch. In the study, the average number of pods was 13.58, the number of main branches was 2.01, the number of seeds per pod was 4.58, the weight of 1000 seeds was 32.93 g, and the seed yield was determined as 1.59 t/ha. It has been reported that high yield can be obtained with 100 kg/ha P_2O_5 application in addition to phosphorus solvent bacteria and 3 t/ha chicken manure application for Hungarian vetch seed production in irrigated conditions with high altitude and phosphorus poor or medium soils (Fayetörbay et al., 2014).

In the study examined the morphological, biological and agricultural characters of M1 plants obtained by applying different doses of gamma rays (0, 40, 60, 80 and 100 Gy) to the seeds of three different Hungarian vetch cultivars (cv. Tarm Beyazı-98, cv. Anadolu Pembesi-2002 and cv. Oğuz-2002); significant reductions have been determined in germination rate, seedling height, seedling dry weight, seedling green weight, seedling root length, emergence rate, plant height, main stem length, number of main branches and number of pods, especially with 80 and 100 Gy gamma rays treatments. Compared to LD50 application, gamma ray doses were found to be the most effective doses in the M1 generation, especially 80 and 100 Gy doses (Bağcı and Mutlu, 2014). In a study discussed in which additive main effects and multiplicative interactions (AMMI) analysis of twelve Hungarian vetch genotypes over locations; in the genotype × environment interaction, environmental effects were dominant on the biological yield performances of the genotypes. The first two principal component axes (IPCA 1 and IPCA 2) were found to be statistically significant ($P<0.01$) and covered 74.81% of genotype × environment interaction. According to the findings obtained from biplot analyzes based on the AMMI model, it has been reported that the genotype with the highest stability value in terms of biological yield for all environments is the cv. Ege Beyazı-79 (Sayar et al., 2016).

In a study examining the effects of different irrigation levels on above-ground and underground organic mass production of Hungarian vetch and forage pea in Çanakkale ecological conditions; it has been reported that irrigation levels significantly affect plant height, above-ground green and dry mass, total mass, above-ground dry matter ratio and sub-soil mass in Hungarian vetch and forage pea. It was determined that the highest plant height, green and dry above-ground mass, dry matter ratio and underground mass of both plants were generally obtained from 75% irrigation level. It has been determined that the plants produce the least organic matter at the lowest irrigation level, and it has been reported that irrigation is required when the useful water in the soil drops to 75% of the field capacity in the cultivation of both plants (Özel et al., 2016).

In a study carried out to determine the effect of different salt concentrations on germination and plant growth in cv. Ege Beyazı-79; it has been reported that increasing salt doses significantly reduce the germination rate and prolong the germination period. It was determined that 25 mm of salt application promoted above-ground fresh weight, root length and root fresh weight, but salt application from 50 mm salt dose had a significant and negative effect. It has been detected that salt doses of 100 mm and above cause significant adverse effects on many properties (Aşcı and Üney, 2016).

In the study examined the yield and yield characteristics of Hungarian vetch lines and some cultivars at the Geçitkuşağı Agricultural Research Institute, it was determined that the differences between the averages in terms of green and dry forage yield were statistically insignificant. In terms of grain yield, the highest values were obtained from lines 3, 2, 1, 16, 6 and 7 with 98, 95, 94, 89, 70 and 65 kg/da, respectively. According to the results of 2014, the highest green and dry forage yield was obtained from line 6 with 2333 kg/da and 633 kg/da respectively, and the highest grain yield was obtained from line 3 with 238 kg/da (Erdoğdu et al., 2016).

In a study carried out to determine the yield and some quality characteristics of the forages obtained from three different sowing times and three different harvest times in common vetch, Hungarian vetch and hairy vetch; it was reported that the highest hay yield was obtained from the first sowing time and the last harvest time (589.00 kg/da and 568.00 kg/da, respectively) in hairy vetch and Hungarian vetch. It was stated that the highest crude protein yield was obtained from the first sowing time and sowing times had no effect on ADF and NDF ratios. It has been determined that hairy vetch and Hungarian vetch are more preferable than common vetch and it has been determined that the vetch species should be sown at the earliest period after the summer crop harvest and the harvest should be done on 20 May or 30 May in a way that will not harm the summer crop planting (Güzeloğulları and Albayrak, 2016).

In the study carried out with the aim of determining the most suitable Hungarian vetch cultivars (cv. Tarm Beyazı, cv. Ege Beyazı, cv. Oğuz, cv. Budak, cv. Beta, cv. Pembesi and cv. Altınova) for farmer conditions in Karakoyunlu district of Iğdır province; while there was no statistically significant difference between the cultivars in terms of green forage yield in 2011, it was reported that there were significant differences in 2012 and two-year averages. The differences in terms of dry forage yield and seed yield were not significant in terms of years, whereas the difference between cultivars was found to be significant in two-year averages. According to the two-year average results, it has been reported that the green forage yield is 2607-3107 kg/da, the hay yield is 644.7-741.3 kg/da, the seed yield is 86.09-101.1 kg/da and the crude protein ratio in hay varies between 18.87% and 20.05% (Budak, 2017).

In the study, the effects of four different doses of gamma rays applied to the seeds of three Hungarian vetch cultivars (cv. Anatolian Pembesi-2002, cv. Oğuz-2002 and cv. Tarm Beyazı-98) on some morphological and agricultural characteristics of M4 and M5 plants; it was reported that the difference between doses was significant ($P<0.05$ and $P<0.01$) in terms of natural plant height for M5 plants, main stem length for M4 and M5 plants in cv. Tarm Beyazı-98. It was stated that the doses applied on the main stem thickness and number did not cause a significant change in all three cultivars, and especially the number of pods in the plant showed a significant change according to the cultivars. As another important effect, it was stated that triple pod formation (lines OG602, OG605, OG801 and OG805) was observed in the axilla in cv. Oğuz-2002, and triple and quadruple pod formation in cv. Tarm Beyazı-98 (TB603, TB604 and TB1006 lines). In addition, while gamma doses increased the number of pods in these two cultivars (the highest line averages; TB604: 30.7 pieces and OG805: 60.8 pieces), it caused reductions in cv. Anadolu Pembesi-2020 (highest line average; AP605: 37.8 pieces) and gamma ray treatments had different effects on both the vegetative characters and cultivars studied in M4 and M5 generations. In general, in most of the traits examined in the M5 generation, it was determined that the differences occurred at 60 and 80 Gy doses in cv. Oğuz-2002, 60 and 100 Gy doses in cv. Anadolu Pembesi-2002 and cv. Tarm Beyazı-98 (Efe and Ünal, 2017). In the study, the effects of different seed rates, mixtures with different plants and different harvest times on the quality characteristics of Hungarian vetch; it was reported that the highest crude ash ratio was obtained from sowing of pure Hungarian vetch (HV). It has been reported that the crude ash yield ranged from 44.91 (pure wheat) to 65.99 kg/da (60% HV + 40 Triticale), and the ratios of macronutrients such as K, P, Ca and Mg were between 2.47-3.09%, 0.366-0.419%, 0.11%-1.31 and 0.09-0.27%, respectively (Gülümser and Acar, 2017).

In a study examining the effects of different tillage methods on hay yield, seed yield and some quality characteristics of Hungarian vetch; in zero, reduced and conventional tillage methods, it was reported that the average true main stem length was 93.84 cm, 94.01 cm, 93.32 cm, natural plant height was 63.88 cm, 54.26 cm, 54.81 cm, fresh forage yield was 25.67 t/ha, 27.07 t/ha, 27.60 t,/ha, hay yield was 6.92 t/ha, 7.10 t/ha, 7.36 t/ha, seed yield was 1.68 t/ha, 1.69 t/ha, 1.58 t/ha, respectively. It was determined that the P, K, Ca and Mg contents of the cultivars were sufficient in both research years (Karabulut, 2017).

In the study investigated the effects of four different phosphorus doses on the seed yield and yield characteristics of three different Hungarian vetch cultivars; it was reported that there was no statistical difference between the doses of phosphorus used, and the dose of 8 kg/da stood out in terms of seed yield. According to the average of years, stem diameter (1.34-2.00 mm), seed yield (48.43-166.73 kg/da) and biological yield (196.87-390.67 kg/da) were determined as statistically significant at the level of 5%, while the plant height (40.30-100.43 cm) and 1000 grain weight (28.25-44.65 g) was found to be statistically significant at the level of 1%. When the evaluation was made between the varieties, it was determined that there was a statistical difference of 1% in terms of seed yield, 1000 grain weight and germination rate, it was reported that characteristics of cv. Doğu Beyazı such as the seed yield (105.47 kg/da), 1000 grain weight (37.15 g) and germination rate (84.16%) was to be higher than other cultivars (Cebeci, 2017).

In a study carried out to determine the forage yield and quality of five Hungarian vetch cultivars; in Hungarian vetch cultivars, it was reported that the main stem length was between 48.8-76.3 cm, 50% flowering period was between 191.0-206.3 days, green herbage yield was between 1160.7-2600 kg/da, dry herbage yield was between 393.5-782.3 kg/da, crude protein rate was between 16.0-18.6%, crude protein yield was between 70.8-130.1 kg/da, the raw ash rate was between 8.95-11.83%, the ADF rate was between 30.01-37.14%, the NDF rate was between 39.05-46.79%. According to the average of the working years, it has been reported that cv. Oğuz-2002, cv. Anadolu Pembesi-2002 and cv. Ege Beyazı-79 can be recommended in terms of forage production for Kayseri and similar ecologies (Hashalıcı et al., 2017).

In a study carried out to determine the phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) contents of genotypes of some vetch species in Siirt conditions; in dry forage of Hungarian vetch, narbon vetch and common vetch, P ratio between 0.26-0.36%, 0.28-0.33% and 0.25-0.34%, K ratio between 2.13-2.57%, 2.59-3.09% and 1.89-3.25%, Ca ratio between 1.28-1.53%, 0.76-1.16% and 1.17-1.44% and Mg ratio between 0.23-0.26%, 0.35-0.44% and 0.31-0.36% were determined, respectively (Turan et al., 2018).

In a study investigating the effects of different salt concentrations on two Hungarian vetch cultivars in the germination and early seedling period; cv. Anadolu Pembesi-2002 and cv. Altınova-2002 were used as material. Doses of 0/unsalted, 50 mM, 100 mM, 150 mM and 200 mM were applied as different salt concentrations during the germination and early seedling stage. In this study, germination rate, germination index, mean germination time, shoot and root length and seedling fresh weight properties were investigated. According to the results of this study, cv. Altınova-2002 was determined to be more tolerant to high salt doses than Anadolu Pembesi-2002 (Ertekin et al., 2018).

In the study carried out to determine the quality parameters of the silage made from different mixing ratios of Hungarian vetch (*Vicia pannonica*) and Barley (*Hordeum vulgare* L.) grown in the ecological conditions of the Eastern Anatolia Region; ADF, NDF, KM, HP ratios, pH and RFV were 31.44%, 45.10%, 24.89%, 13.79%, 3.93 and 134.20, respectively, while LA, AA, BA and PA ratios were 1.56%, 0.60%, 0.42% and 0.06%, respectively. In addition, calcium, phosphorus and magnesium ratios were determined as 1.31%, 0.56% and 0.20%, respectively. According to the data obtained, it has been reported that pure Hungarian vetch (100% MF) and 70% Hungarian vetch plus 30% Barley mixed silages were superior to silages obtained from other mixtures (Turan, 2019).

In their study to determine hay yield and hay quality of different Hungarian vetch lines and varieties; They reported that Hungarian vetch showed significant differences ($P<0.01$) between genotypes on hay yield, hay quality and chemical components of hay of different years. In the investigated characteristics, the plant height of the Hungarian vetch genotypes varied between 90.16 cm and 105.20 cm, the green herbage yield between 1429.58 kg/da and 1936.22 kg/da, the dry herbage yield between 298.28 kg/da and 380.66 kg/da, the crude protein yield between 50.81 kg/da and 77.06 kg/da, crude protein ratios between 15.50% and 20.89%, crude ash ratios between 7.32% and 8.75%, ADF ratios between 34.32% and 40.74%, NDF ratios between 46.36% and 50.01%, dry matter digestibility ratios between 57.17% and 62.16%, dry matter intake ratios between 2.41% and 2.60%, and relative nutrition value between 106.73 and 124.65 (Kaplan et al., 2019).

In a study carried out on some Hungarian vetch lines and cultivars in Kırklareli ecological conditions; it was reported that the highest green forage yield was obtained at the beginning of flowering (1836.00 kg/da) and the highest hay yield was obtained during the full flowering period (401.00 kg/da). It was determined that the highest crude protein ratio was obtained at the beginning of flowering with 18.85%, the highest ADF, ADL and NDF ratios were obtained in the full flowering period with 37.02%, 6.49% and 47.20%, respectively. It was reported that in the first year of the study, the highest green forage yield was obtained at the flowering period of 50%, and in the second year, the highest green forage yield was obtained at the beginning of flowering (Tenikecier et al., 2020).

In a study carried out to determine the effects of Hungarian vetch and cereals on subsoil and above ground development depending on different mixture forms and ratios; it was reported that the highest seedling ratio was obtained from a mixture of barley and triticale of

Hungarian vetch and there were significant differences in leaf area indices. It was stated that the highest total biomass production was obtained from 1 Vetch + 3 Triticale plots, and the most suitable mixture form and ratio in terms of land equivalent ratio was 2 Vetch + 2 Oat plots. It was reported that the C/N contents of the soil were higher in the second year of the study and the most suitable mixture ratio was 2 Vetch + 2 Wheat plots, and the most suitable mixed planting was obtained from the mixtures formed with barley and oats with the lowest Hungarian vetch ratio (Alatürk, 2020).

In a study investigating the performance of Hungarian vetch, hairy vetch and common vetch with different organic fertilizer applications; leonardite, zeolite and animal manure were used as organic fertilizer sources. As a result of this study, it was determined that the effects of organic fertilizers on the yield and quality of vetch species were limited. However, it was stated that the results obtained could be guiding especially in terms of organic animal nutrition. However, it has been stated that the results obtained may be important especially in terms of organic animal nutrition (Ertekin et al., 2020).

In the study in which different ozone doses (control, 0.40 g/m^3, 1.60 g/m^3, 2.80 g/m^3, 4.00 g/m^3) and different temperatures (10 ^{0}C, 15 ^{0}C and 20 ^{0}C) applications were tried in Hungarian vetch seeds; it was stated that different germination temperatures positively affected the germination, root and seedling growth of Hungarian vetch seeds compared to the control, and ozone dose applications positively affected the seedling fresh and dry weight (Uslu et al., 2021).

In a study carried out to reveal the differences in yield, quality and nutrient content of Hungarian vetch according to different sowing times; it was determined that the first sowing times (09/19/2014 for 2014 and 09/17/2015 for 2015) gave the highest values in terms of plant height, green herbage yield and hay yield, while crude protein ratios did not indicate a statistical difference in terms of sowing times. It was reported that the lowest ADF and NDF ratios and the highest digestible dry matter and relative feed values were obtained from the first sowing time. It was stated that there was no difference between the sowing times in terms of Ca, Mg and K nutrients, and there was a decrease in the P ratio as the sowing time delayed. It has been reported that sowing of Hungarian vetch in the study area and in regions with similar ecological conditions, as early as possible from the second half of September, will provide advantages in terms of yield and quality (Çaçan et al., 2021).

In a study carried out to determine grass and seed yields and some agricultural characteristics of Hungarian vetch varieties in Uşak conditions; it has been reported that green forage yields vary between 1872.50-2607.50 kg/da, dry forage yields between 421.16-606.89 kg/da, crude protein ratios vary between 16.20-18.49% and crude protein yields between 68.30-111.33 kg/da. It was determined that the number of seeds per pod, biological yield, seed yield and 1000-seed weight ranged from 3.73 to 6.66 pieces, from 276.77 to 402.83 kg/da, from 75.67 to 103.44 kg/da and from 30.39 to 34.10 g, respectively. It has been reported that cv. Tarm Beyazı-98 and cv. Sarıefe should be preferred for quality and high forage yield in Uşak and regions with similar climatic conditions, and cv. Tarm Beyazı-98, cv. Sarıefe, cv. Kansur and cv. Altınova-2002 should be preferred for seed yield (Ülker and Yüksel, 2021).

CONCLUSION

Hungarian vetch that is widely cultivated in field agriculture and widely distributed in natural populations is an important forage crop with high quality forage values. Hungarian vetch, both wild and cultivated in our country; besides providing a high quality feed on its forages, it is also an important plant in terms of being used in mixtures, improving the soil structure, supporting the yield and quality of other plants in addition to the quality in mixed plantings. When the studies carried out in our country in recent years were evaluated, it has been determined that there are Hungarian vetch cultivars suitable for different regions, and it has been detected that these cultivars offer substantial yield and quality. In this respect, it is thought that Hungarian vetch has the potential to close the feed deficit in regions with continental climate in our country. There is also the potential to use Hungarian vetch to improve the pastures.

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CHAPTER 10

GRASSPEA (*Lathyrus sativus* L.)

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INTRODUCTION

As a result of studies related to the livestock sector, which provides animal foods that are of great importance in human nutrition, it is shown that approximately 70% of the expenses in livestock enterprises are caused by feed, and these costs directly affect the prices and consumption of animal products. In order to obtain quality and economical animal products, it is necessary to provide cheap and high quality feed for animals. In order to provide our people with adequate and lower cost animal foods, it is necessary to improve the pastures and increase the forage crops cultivation in field agriculture.

Leguminous forage crops are plants that should be emphasized more because they are rich in protein, contain vitamins and minerals in their structure, and enrich the fields they are planted in terms of organic matter. One of the forage plants among the legumes, which have many perennial and annual genera, is grass pea.

Grasspea (*Lathyrus sativus* L.) is a large genus of legumes (Fabaceae/Leguminosea) with 187 species or subspecies distributed in 15 divisions in the Vicieae tribe (Allkin et al., 1986). Considering the places where the genus *Lathyrus* shows species and variety richness, there are warm regions of the Mediterranean basin, Central Asia, North America and South America (Jackson and Yunus, 1984). In the flora of Europe, 54 (Tutin, 1981) and in the flora of Turkey 58 species, 18 of which are endemic, have been identified (Davis, 1970). Uzun and Genç (2001) report that there are 61 grass pea species and 71 taxa belonging to these species in the flora of Turkey with the records added in recent years.

Figure 1. A general view of the grass pea plant (Photo by Jean Hanson/ILRI)

The most cultivated *Lathyrus* genus in the world is *L. sativus*, which has many biological and agricultural advantages (Figure 1). *L. sativus* can grow even in places where the annual precipitation drops to 250 mm, and with this feature, it is one of the crop plants that can withstand the drought the most (Tekele-Haimanot et al., 1990). In addition to its drought resistance, it can also successfully grow in places where the annual rainfall is high or flooded. *L. sativus* seems to adapt very well to paddy fields because it can stay under water in the early period and is highly sensitive to drought in the late period (Kumar, 1997). With this feature, it provides great benefits in making both crop rotation and diet arrangements of people who have to be fed one-way with paddy in places where paddy farming is intense. (Haqqani and Arshad, 1995). *L. sativus* is generally grown in summer. However, in the Mediterranean, it is generally planted in autumn and the plants that spend the winter in rosette form grow rapidly with the rise in temperature (Campbell, 1997). *L. sativus* is a valuable plant for rotation and sustainable agriculture, as it can be grown easily under favorable conditions and can produce yields at an economic level without the need for fertilization and pesticide use. However, *L. sativus* is shown as a very important genetic resource for legume breeding due to its resistance to living and non-living stressors (Clulow et al., 1991).

Herbal Properties

Grass pea (*Lathyrus sativus* L.) is an annual and has a strong taproot (Figure 2). Its stems, which can grow up to 30-130 cm, are hairless. In older plants, the stem is hollow, oblique, climbing, and generally much branched at the base, with distinct wings. The cross section of the stem is 4-6 mm wide with the wing. The petiole is quite long and broad-winged. Tendrils are highly branched, the leaflets forming the leaf are 5-15 cm long and 3-5 mm wide. The leaflets are usually 5 or 7 strong and very thin parallel long streaks and bluish green. Stipulas almost as long as petiole or half its length, semi-arrow-shaped and dentated (Karadağ, 2009).

Figure 2. Young plant period and root structure in grass pea plant

Flower color is mostly white. But there are also pink or bluish ones. Their pods are flat, 3-4 cm long, 1-2 cm wide and 6 mm thick, with wings, yellow-gray color, thin streaks, and contain 1-6 seeds (Figure 3).

Figure 3. Flowering period in grasspea

The seeds are ax shaped angular. 7-15 mm long, 5-9 mm wide, 4-6 mm thick; they are gray, reddish-yellow, brownish or greenish in color (Figure 4). Colored seeds containing mostly brown spots are 150-180 g per 1000 grains.

Figure 4. Seed of common grasspea

White colored seeds are larger and reach 230-400 g per 1000 grains weight. Seeds can maintain their germination power for up to 6 years under suitable conditions. Although self-pollination is dominant in the plant, foreign pollination is also seen (Gençkan, 1983).

Figure 5. Common grasspea plant at harvest maturity

Alternative Use Areas

Lathyrus species are generally grown in the world as herbage, hay and grain fodder to feed animals, to improve soil structure as a green manure plant, and to feed humans as edible legumes or vegetables (Figure 5). However, these species are grazed in some periods and after grazing is interrupted, the growing plants are grown for seed. The use of *Lathyrus* species in human nutrition includes differences and special consumption conditions according to countries and regions. Generally, the dried grains are used as soup and ground into wheat flour in certain proportions to make bread, and the fresh leaves of the immature broad beans and grains are used as salads, vegetable dishes and snacks (Kumar, 1997). *L. sativus* (grasspea), *L. cicera* (red pea) and *L. ochrus* (Cyprus vetch) are the most important cultivated species of *Lathyrus* (Jackson and Yunus, 1984). *L. sativus* is generally used in human nutrition. *L. cicera* and *L. ochrus* are mostly produced for animal feeding. For this reason, *L cicera* is used as grain and forage, and *L. ochrus* is mostly used as forage. Apart from these mentioned genera, *L. tingitanus* is grown for grain feed, *L. latifolius*, *L. sylvestris*, *L. clymenum* for roughage around the world. Some species, especially *L. odoratus*, are used as ornamental plants (Campbell, 1997).

As a green fodder, grass pea has a slightly bitter, quick-hardening and woody feature and is suitable for sheep. At the time of flowering, crude protein content in grain is 24%. Fodder and straw are of great importance as fodder. While the white seeds are non-toxic, the dark and colored seeds are poisonous and contain Lathyrin, which is most likely composed of water-soluble amides and the amount varies according to the variety. The harmful effects of seeds, which contain approximately 28% crude protein, are eliminated, especially by boiling and steaming. Boiled and steamed seeds are generally used as livestock feed (Gençkan, 1983).

Negative Effects on Human and Animal Health

There are some substances that have negative effects on nutrition in grass pea species, as in many other legume plants (Urga et al., 1995). Three non-protein (NPAA) toxic amino acids have been identified in grass pea species. Three non-protein (NPAA) toxic amino acids have been identified in grass pea species. Of these, ß-N-oxalyl-L-α,ß diaminopropionic acid (ODAP) is present in 21 *Lathyrus* species, mainly *L. sativus, L. cicera, L. ochrus, L. clymenum*, L-2, 4 Diamino-butyric acid (DABA) was determined in *L. sylvestris* and *L. latifolius*, beta-aminopropionitrile (BAPN) was determined in *L. odoratus, L. hirsutus, L. pusillus* and *L. roseus* species (Barrow et al., 1974; Roy and Spencer, 1989). Diseases related to these chemical substances are seen in humans and animals that consume *Lathyrus* species, and these diseases are generally called lathyrism. The most important toxic substance determined in *Lathyrus* species is ODAP. The ODAP is found in some other leguminous genera as well as *Lathyrus* species.

In order to be protected from the toxic effects of *Lathyrus*, species with low ODAP content should be grown first. Although *L. sativus* is on the list of plants that are free to grow in Australia, its production is subject to special permission due to the neurotoxic ODAP it contains. Ceora is a free-growing variety in Australia, with not much ODAP (0.5-1.5%), and other varieties are not allowed to be introduced into *Lathyrus* planting areas. Because there are changes in the characteristics of *L. sativus* in a very short time due to foreign fertilization. The ODAP detected in this variety in 1997-98 and 99 years under controlled field conditions was 0.04%, 0.09% and 0.05%, respectively (Hanbury et al., 2005).

When people cook with ripe seeds, they soak the seeds in water overnight and the water is filtered and then the seeds are boiled. With these processes, there is a 90% decrease in the ODAP level in the seeds. The risk of Lathyrism is very low when fresh leaves, immature pods and seeds are used. Apart from that, foods rich in vitamin C are said to reduce the toxic effect of *Lathyrus* species (Kumar, 1997). ODAP is a water-soluble amino acid, and some ODAP can be reduced by leaving the seeds in water. When the grains are left in cold water for 3 minutes, the ODAP contents decrease by 30%, and the reduction rate is higher when this process is applied with hot water (Tekele-Haimanot et al., 1993). Similarly, it was observed that the rate of decrease in ODAP was 70-80% in grains cooked after being kept in hot water for a few hours (Mohan et al., 1966).

The most important factor limiting the cultivation of grass pea in general is the neurotoxic ODAP found in its seeds. The first priority in the breeding of grass pea, which is of great importance as both animal feed and human food, is the development of low or no ODAP-free varieties. It is known that the inheritance of the ODAP concentration in the plant is controlled quantitatively (Tiwari, 1994). Selection based on molecular markers will provide great convenience in breeding plum varieties with low concentration or no ODAP.

Recent Studies

According to the results of the research conducted by Özdemir et al. (2020) in Elazig ecological conditions in 2014-2015; In 31 different grass pea genotypes, the biological yield is 188.72-271.18 kg/da, the grain yield is 75.10-117.72 kg/da, the number of full pods is 7.16-16.15, the number of empty pods is 0.06-1.00, the pod length is 2.78-3.45 cm, the pod width is 0.83-1.23. cm, the number of grains per plant varies between 16.73 and 45.08 and the weight of grains per plant varies between 2.03-4.23 g.

Kosev and Vasileva (2018), in their study on grass pea in Bulgaria in 2014-2016; they determined the protein rate as 28.40%, the calcium content as 1.90% and the phosphorus content as 0.29% in the herbage.

Öten et al. (2017), carried out their study, in which they tried to determine the relationships between traits that affect herbage and seed yield in grass pea genotypes by correlation and path analysis, in the province of Antalya for 2 years in 2014-2015 planting seasons. Researchers examined plant height, herbage and grain yield, number of pods per plant, number of seeds per pod, seed yield, biological yield, harvest index, straw yield and 1000 grain weight. In the experiment, the average plant height was 100.00 cm, the herbage yield was 1622.50 kg/da, the grain yield was 409.10 kg/da, the number of pods per plant was 20.40, the number of seeds in the pod was 4.23, the seed yield was

355.00 kg/da, the biological yield was 851.10 kg/da. According to the results of the correlation analysis, a positive relationship was determined between hay yield and green forage yield, straw yield, biological yield and seed yield at 0.01 probability level. According to the path analysis, they explained that the characteristics that have an effect on grain yield are herbage yield and straw yield.

Sabancı et al. (2016), in their study conducted in Kırşehir ecological conditions in 2013-2014, cultivated some grass pea genotypes in different row spacings (20, 40 and 60 cm) and determined the forage yield and quality. According to the average results of 2 years; plant height was changed between 28.30-32.90 cm, herbage yield between 303.50-482.80 kg/da, dry matter rate between 17.60-34.20%, dry matter yield between 35.50-190.00 kg/da, crude protein rate between 20.03-28.64 and crude protein yield between 17.70-31.50 kg/da.

Özdemir (2016), in the study that aimed to determine the yield and quality characteristics of grass pea genotypes in the ecological conditions of Elazig in the 2014-2015 production season; The natural plant height of the genotypes is determined 23.00-29.67 cm, the number of main stems is 2.55-4.00, the main stem thickness is 1.46-2.19 mm, the number of pods per plant is 6.00-16.00, the number of seeds per pod is 1.84-3.54, the green herbage yield is 297.20-814.63 kg/da, dry matter yield 86.83-265.83 kg/da, biological yield 146.33-278.90 kg/da, seed yield 44.53-105.37 kg/da, harvest index 27.27-40.87%, 1000 grain weight 99.83-172.07 g, crude protein rate 11.73-21.11%, crude protein yield 16.47-45.23 kg/da, ADF ratio 25.96-32.23% and NDF ratio 33.67-42.05%.

Cengiz (2016), carried out a study to determine the agricultural characteristics of the grasspea plant, Gürbüz variety, with 4 lines, in the years 2012-2013, in Kahramanmaraş conditions. As a result of the researcher experiment; plant height is determined 37.67-38.67 cm, green herbage yield 2659.30-3106.00 kg/da, number of pods per plant 15.67-27.67, number of seeds per pod 3.00-3.67, weight of 1000 seeds 140.77-152.60 g, seed yield 256.70-390.00 kg/da, biological yield 1235.00-1391.70 kg/da and the harvest index 19.30-37.80%.

Seydoşoğlu et al. (2015), investigated some yield and yield characteristics of grasspea genotypes in Diyarbakır in 2012-2014. According to the results of the research; plant height of genotypes ranged between 39.25-59.17 cm, main stem length ranged between 74.42-98.78 cm, main stem number ranged between 1.87-2.53, number of pods per plant ranged between 33.83-67.00, number of seeds per pod ranged between 2.95-3.72, green herbage yield ranged between 1379.50-3154.17 kg/da, dry matter yield between 330.67-767.38 kg/da, seed yield ranged between 181.00-269.83 kg/da and 1000 grain weight ranged between 99.88-141.71 g.

Sayar and Han (2015), aimed to determine the seed yield and yield components of grasspea cultivars and lines that they obtained from ICARDA in winter in Diyarbakır ecological conditions in 2008-2011. According to 3-year averages, the number of pods per plant is 20.00-34.00, the number of seeds per pod is 3.08-3.72, the seed yield is

188.30-309.20 kg/da, the biological yield is 528.20-847.10 kg/da, the harvest index is 32.00-42.80% and the weight of 1000 grains is 89.30-136.50 g.

Sayar et al. (2013), in their study conducted in Diyarbakır conditions in 2008-2011, investigated the forage yield of some grasspea lines and some yield factors that are effective on forage yield. As a result of the study, they stated that the natural plant height is 48.17-60.39 cm, the main stem length is 70.07-92.33 cm, the number of main stems is 2.76-3.68, the green herbage yield is 2140.00-371100 kg/da and the dry matter yield is 463.00-711.70 kg/da.

Karadağ et al. (2012), investigated the yield and yield characteristics of grasspea lines in Tokat-Kazova conditions in 2009-2010 and 2010-2011. According to the results obtained in the research, green herbage yield varied between 2175.20-2585.50 kg/da, dry matter yield between 600.70-743.30 kg/da, seed yield between 173.30-202.80 kg/da, biological yield between 565.00-693.70 kg/da, 1000 grain weight between 93.70-141.30 g and harvest index between 27.66-31.70%.

Gündüz (2012), aimed to determine the seed yield and some vegetative characteristics of some grasspea cultivars grown in Afyon Province in 2011. In the study, the plant height was 23.00-70.00 cm, the number of main branches was 4.00-8.00, the number of seeds per pod was 2.30-3.00, the weight of 1000 seeds was 108.90-143.40 g, the number of seeds per plant was 13.00-134.00, the seed yield per plant was 1.98-17.06 g, biological yield was 628.40 kg/da and seed yield was 278.11 kg/da.

Başaran et al. (2011), in the study they carried out in the years 2007-2008, 2008-2009 in Samsun with the aim of determining the agricultural characteristics of grasspea; The protein rate was determined as 20.35-26.31%, the ADF rate as 28.80-34.40%, and the NDF rate as 33.42%-45.01%.

Karadağ and Yavuz (2010), in their study on the seed yield and chemical composition of grasspea under Tokat-Kazova conditions in 2004-2005 and 2005-2006; they determined the seed yield as 107.90-158.30 kg/da, crude protein rate as 24.19-27.44%, ADF rate as 5.24-7.35% and NDF rate as 10.18-13.55%.

Başaran et al (2010), investigated the basic situation and agronomic characteristics of grasspea cultivation in Turkey in 2008. They collected grass pea genotypes from 12 different regions in Anatolia and as a result of the research; they determined that crude protein rate in seed is 24.07-31.68%, crude protein rate in herbage is 19.03-26.00%, and 1000 grain weight is 72.20-140.80 g.

Başaran (2010), in his study; the aim of this study was to determine the agricultural characteristics and protein content of the grasspea populations collected from different regions of Turkey in the vegetation period of 2007-2008 and 2008-2009 in Samsun conditions. At the end of two years, he stated that the plant height was 30.14-56.00 cm, the number of pods per plant was 14.40-45.00, the seed yield per plant was 4.58-15.59 g, the weight of 1000 seeds was 79.93-152.13 g, and the crude protein ratio in the seed was 21.96-25.04%.

Karadağ et al. (2008), in their study in 2005-2006, aimed to determine the grasspea cultivar candidates compatible with Tokat and Amasya Provinces. According to the 2-year average results in the trial carried out as a summer trial; they stated that biological yield 356.47-638.90 kg/da, seed yield 71.00-150.23 kg/da, harvest index 3.90-25.80%, 1000 grain weight 81.67-173.90 g, crude protein ratio in herbage 17.89-26.70%.

Alay (2008), aimed to determine the effect of different seed amounts on the yield and some agronomic characteristics of grasspea lines in the study he conducted in Tokat-Kazova conditions in the 2006-2007 production season. As a result of the study he stated that, herbage yield was ranged 1006.30-1038.20 kg/da, dry matter rate was between 26.00-30.10%, dry matter yield was between 263.60-301.90 kg/da, biological yield was between 272.20-442.20 kg/da, seed yield was between 70.90-114.80 kg/da, weight of 1000 grains was between 114.00-167.80 g and the harvest index was between 23.50-28.70%. As a result of the data obtained; It was determined that the 1000 seed weight decreased with the increase in the seed amount, while the herbage and grain yield, biological yield and seed yield increased.

Gedik (2007), in his study, aimed to determine some characteristics between 5 varieties, 4 lines and a grasspea cultivar in the 2006-2007 growing season. In the results of working; the plant height was 51.80-85.00 cm, the number of main branches was 13.50-20.10, the number of seeds per pod was 3.00-3.83, and the weight of 1000 seeds was 85.30-154.00 g.

Urga et al. (2005), stated that the plum plant is one of the most important legumes in countries such as Ethiopia, Bangladesh and India. They stated that the protein ratio varies between 28.00-32.00% and the nutritional value is high.

Çeçen et al. (2005), in their research between 2000 and 2002, aimed to evaluate 6 different annual legume forage plants (common vetch, Persian clover, narbon bean, hairy vetch, fodder pea and grass pea) in Antalya as a secondary crop in terms of herbage and seed yield. They stated that the highest grain and herbage yield was obtained from Persian clover, and the seed yield was obtained from narbon bean and grasspea. As a result of the study, the researchers; they reported that the green herbage yield is 3144.00 kg/da, the dry matter yield is 505.00 kg/da, the dry matter rate is 16.30% and the seed yield is 513.00 kg/da.

Bayram et al. (2004), in their research conducted in Bursa between 2001-2002, aimed to determine the adaptation abilities and yield status of some grasspea lines. According to the results obtained from the averages of two years; plant height 66.30-100.83 cm, the number of branches 10.10-15.68, the number of pods per plant 36.18-78.37, the number of seeds per pod 2.17-3.61, the number of seeds per plant 100.17-202.73 and biological yield between 289.23-689.37 kg/da.

Tadesse and Bekele (2003), in the study they carried out with 50 different grasspea genotypes obtained from different regions of Ethiopia in 1998-1999; They determined the number of main branches per plant as 8.80-10.00, plant height as 94.10-120.90 cm, the number of pods per plant as 317.30-505.70 and the weight of 1000 seeds as 78.00-9100 g.

Balabanlı and Kara (2003), investigated some characteristics of 15 different grasspea lines in their study under the ecological conditions of Isparta in 2000-2001. According to the data obtained from the study; plant height 51.70-61.50 cm, green herbage yield 467.30-816.70 kg/da, seed yield 49.80-105.30 kg/da, dry matter yield between 100.70-168.20 kg/da and biological yield between 146.20-402.20 kg/da.

Sabancı and Özpınar (2000), in Menemen conditions, 15 grasspea lines in 1994/1995-1995/1996 growing season; 1000 grain weight, seed yield and biological yield were examined in terms of properties. On average, 1000 grain weight was determined as 63.00 g, seed yield as 250.00 kg/da and biological yield as 1188.00 kg/da.

Kendir (1999), determined that in Ankara ecological conditions, in the 1997-1998 growing period, about 16 grasspea lines; plant height was 90.83-132.83 cm, number of branches was 5.50-7.50, number of pods per plant was 12.17-20.83, biological yield was 529.42-891.52 kg/da, harvest index was 23.27-32.93%, seed yield was 153.87-277.77 kg/da and 1000 grain weight was 105.42-170.69 g.

Bucak (1999), in the study that he planted in the conditions of the Harran plain in winter and continued for 3 years (1995-1998); Average plant height of grasspea lines is 64.01-83.32 cm, green herbage yield is 2345.73-3995.52 kg/da, dry matter yield is 354.95-567.67 kg/da, seed yield is 62.52-292.93 kg/da, 1000 grain weight is 82.08-199.27 g and the number of branches per plant is 4.21-8.67 pieces.

Andiç et al. (1996), investigated the green and grain yields and plant heights of grasspea lines in Van arid conditions. The herbage yields of the grasspea lines varied between 488.90-868.10 kg/da, grain yields between 117.20-190.30 kg/da and plant heights between 34.90-38.70 cm in 3-year averages.

Campbell et al. (1994), in their research with grasspea; the plant height was 71.00 cm, the number of pods per plant was 36.00, the number of seeds per plant was 4.00, and the weight of 1000 seeds was 42.00 g.

Abd El-Moneim and Cocks (1993), in the experiment they conducted in Syria in 1985-1989 on 16 different grasspea genotypes; they stated that the herbage yield per decare ranged between 237.70-280.60 kg and the seed yield varied between 37.30-76.50 kg.

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CHAPTER 11

HAIRY VETCH (*Vicia villosa* Roth.)

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INTRODUCTION

Despite all efforts, the forage crop cultivation area in Turkey has not reached the expected level. Roughage, which is the most important input of animal production, cannot be produced in sufficient quantity and quality in our country. The fact that the feed input needed in animal production can be met with the own resources of the enterprise should not be ignored in reducing the costs and eliminating a possible nutritional problem. Arrangement of forage crop production areas in a way to include leguminous+wheat crops within the scope of agricultural activity can ensure the sustainability of the agricultural areas in question and the transfer of feed with different characteristics to the livestock enterprise (Kavut and Geren, 2018).

Considering the supply of feed, the development of very productive varieties and their presence in different areas of the agricultural system will contribute to the increase of forage production. The initial step in the development of very productive varieties is to increase the genetic variation available. This can only be achieved by collecting and evaluating wild populations in different forage crop species. Hairy vetch (*Vicia villosa* Roth.) is one of the alternative legume forage crops that can be used in this direction (Ozpinar and Sabanci, 2014).

Hairy vetch (*Vicia villosa* Roth.) originates from Asia Minor and the West, and is a winter-hardy, mostly annual legume fodder plant native to the Mediterranean region (Genckan, 1983). It is from the vetch-like tribe and has a diploid structure and 12 chromosomes (2n=12) (Yeater et al., 2004). Among the vetch species, it is the most common type of agriculture and the most resistant to winter and drought (Soya et al., 2004).

Figure 1. A general view of the hairy vetch (*Vicia villosa* Roth.). (Photograph; Kristian Peters, publisher Wikimedia Commons (GFDL License), 2004).

The root system of the hairy vetch (*Vicia villosa* Roth) can branch and go deep. Since the trunk is both thin and weak, it leans easily and is said to be grown with grains for grass production. The leaves are mutually united and consist of 4-10 leaflets. All the organs of the plant are surrounded by fine hairs, and there are also some hairless varieties. The flowers are on the stem emerging from the leaf axil. The colors of the flowers are different from each other. The fruits are flat bean-shaped, 2-3 cm long, and there are 2-8 seeds in one fruit. The colors of the seeds are different from each other and there are seeds that change color from yellow to black (Karadag, 2019).

Figure 2. A general view of the leaves, flowers, fruits and seeds of the common hairy vetch (*Vicia villosa* Roth.).

The most distinctive feature of hairy vetch in terms of climate needs is that it is resistant to winter cold and drought (Manga et al., 2003). Since it is resistant to cold, it can be planted in winter in climatic regions with harsh winters. Considering the harvest of plants grown as summer cottages, they can be planted starting from the end of summer until the first half of autumn (Cakmakci and Aydinoglu, 2009).

Hairy vetch (*Vicia villosa* Roth.) is a legume cover crop mostly used as green manure to maintain soil health in arable land. It does not have much selectivity in terms of soil demand. However, it can develop better in light and sandy soils. It cannot grow well in moist, heavy and water-retaining soils (Manga et al., 2003). The pH suitable for cultivation varies between 4.8-9.2. Hairy vetch, which is resistant to erosion (Verhallen et al., 2003), enriches the soil with nitrogen through nitrogen fixation (Smith et al., 1987).

Recent Studies

Ucar et al. (2021), used two different hairy vetch varieties (Efes-79, Menemen-79) in their study to calculate the seed yield, straw yield and straw quality of hairy vetch. Seed yield, straw yield, thousand grain weight, crude ash ratio, crude protein ratio, crude protein yield, NDF ratio, ADF ratio, digestible dry matter ratio and relative feed value were examined. As a result of the study, average seed yield 82.2 kg/da, straw yield 592 kg/da, thousand grain weight 33.8 g, crude ash rate 9.1%, crude protein rate 11.8%, crude protein yield 69.2 kg/da, NDF rate 56.3%, ADF rate 42.0%, digestible dry matter rate 56.2% and relative feed value 93.2. In the study; They determined that Efes-79 cultivar showed superior characteristics in terms of yield characteristics, while Menemen-79 cultivar showed superior characteristics in terms of quality characteristics.

Ozdemir et al. (2021), they used 2 hairy vetch varieties (Efes-79, Menemen-79) as material in their study on the determination of herbage yield and quality of some hairy vetch varieties grown in Bingöl ecological conditions. As a result of the work carried out; plant height 102.8-194.3 cm, green herbage yield 1841-2591 kg/da, dry herbage yield 280-559 kg/da, crude protein rate 17.1-18.7%, crude protein yield 47.8-103.8 kg/da, crude ash rate 8.9-9.9%, ADF ratio 35.4-39.5%, NDF ratio 47.5-49.8%, DDM ratio 58.1-61.3%, DMI ratio 2.41-2.53% and relative feed value between 112-120. As a result of this study, which they continued for three years, it was determined that both cultivars used in the study adapted to Bingol ecological conditions and Efes-79 cultivar provided higher forage yield than Menemen-79 cultivar.

Ertekin et al. (2020), stated that in the study they carried out to determine the effect of different organic fertilizer sources on the forage yield and quality of some vetch species grown for organic roughage production, they obtained results that can help organic vetch farmers and future research. They also reported that studies should be done to determine the dose of the fertilizers used.

Ova and Uslu (2020), tried to determine the yield and forage quality of some vetch (*Vicia* sp.) species harvested at different maturation periods. Vetch (*Vicia* sp.) species (common vetch-Zemheri 08, Hungarian vetch-Kansur and hairy vetch-Selçuklu 2002) were used as research material. In the experiment, an effort was made to determine the most appropriate harvest time by calculating and examining the yield and weed quality of the vetch harvested in 4 different development periods (flowering beginning, 50% blooming, full blooming and bean maturity period). According to the research data, It was revealed that the highest hay yield was obtained from Selçuklu 2002 with 887.47 kg/da, Kansur with 21% crude protein, Selçuklu 2002 with 162.6 kg/da crude protein yield, Zemheri 08 with 15.79% crude ash, Kansur with 57% NDF rate, Selcuklu 2002 with ADF ratio of 39% and Zemheri 08 varieties with 145.10 relative feed value (NYD). When considered in terms of relative feed value in Kahramanmaraş under Mediterranean ecological conditions, it was determined that the most suitable vetch variety was

Zemheri 08 variety (common vetch) and it would be appropriate to mow at the beginning of flowering.

Coskun and Cacan (2019), investigated the effect of planting times on some yield and quality characteristics of hairy vetch. It was determined that there were statistically significant differences between sowing times in terms of green herbage yield, hay yield, crude protein ratio, crude protein yield, crude ash ratio, NDF ratio, dry matter intake and relative feed value. There was no statistical difference between the rates of ADF, TDN, DDM of sowing times. The highest green fodder yield, hay yield, crude protein yield and crude ash ratio were statistically obtained from the first and second sowing times, while the highest crude protein ratio, dry matter consumption and relative feed value were obtained from the first, second and third sowing times. It was determined that the yield decreased after the second planting time and the quality decreased after the third planting time.

Erdurmus et al. (2018), collected seed samples from common vetch (*Vicia sativa* L.) determined their values. In total, 41 common vetch, 15 hairy vetch and 7 large vetch populations were collected from 63 locations, and it was said that an observation garden was created by making seed reproduction in all species. The number of flowering days (days), physiological death days (days), first pod days (days), plant height (cm), thousand grain weight (g) and number of seeds per pod (pieces) of the species were taken as morphological observations by the researchers, It has been reported that there is a wide variation among the populations of vetch species according to the observation values taken.

Akdeniz et al. (2018), compared the cultivar performance of the quality parameters of four hairy vetch cultivars (Aday-Ceylan, Efes-79, Menemen-79 and Selcuklu-2002). It was determined that all quality parameters of four winter hairy vetch cultivars were significantly ($p \leq 0.05$) affected by environmental conditions. As a result of the analyzes, it has been revealed that the Aday-Ceylan variety may be the most suitable variety for the Mediterranean environments of Turkey, as a promising variety in terms of nutritional content and nutritional value for animal nutrition.

Kavut and Geren (2018), Italian ryegrass (*Lolium multiflorum* L.) mixed with hairy vetch (*Vicia villosa* L.) in different ratios (Italian ryegrass+hairy vetch; 100%+0, 80+20%, 60+40%, 40+60%, 20+80% and 0+100%), in different form times [I. Early spring (last week of March), II. Mid-spring (second week of April) and III. Some yield and quality traits were investigated in late spring (last week of April)]. Considering the two-year average results, it was understood that plant height, dry matter yield, ADF and NDF ratios increased with the delay of the harvest date, and crude protein ratios decreased with the increase in the wheat grain ratio in the mixture. In addition, as the legume ratio in the mixtures increased, it was determined that the dry matter yield and crude protein ratio increased. It has been reported that the plots in which the hairy vetch is handled as pure have the highest yield and quality characteristics for Mediterranean conditions.

Renzi et al. (2017), aimed to develop a mechanical model to predict the natural reseeding of hairy vetch in the pasture stage of field rotation and to develop control strategies that consider hairy vetch as useful weed in the fields. The developed field output model was validated with independent field output data in 2013, 2014 and 2015. The presented model has been reported to greatly predict the timing and size of field emergence (RMSE<10.1) despite the environmental variability between years. The total effect of each submodel was found to improve the explanatory capacity of the field emergence models.

Turna and Ertus (2017), investigated the effect of different planting times on the yield of hairy vetch (*Vicia villosa* Roth.) and Hungarian vetch (*Vicia pannonica* Crantz.) in dry conditions and in Van province. The research was carried out with three replications in four different vetch varieties (Segmen, Efes, Altınova, Ege Beyazı) and in three sowing times (20 September, 10 October and 30 October). Researchers examining plant height, number of plants per square meter, green herbage yield, dry matter ratio and dry matter yields reported that they obtained the highest and least number of plants per square meter from different varieties from the third planting. The highest plant height and green herbage yield were determined at 91.70 cm and 2292.33 kg/da, respectively, after 20 September planting of Segmen (*Vicia villosa*). It has been reported that as the planting time is delayed, the yield decreases and it would be appropriate to plant in September in Van in terms of herbage yield.

Guzelogullari and Albayrak (2016), three different sowing times of common vetch (*Vicia sativa* L.), Hungarian vetch (*Vicia pannonica* Crantz.) and hairy vetch (*Vicia villosa* L.) in Isparta ecological conditions (5 October, 20 October and 5 November) and three different harvest times (10 May, 20 May and 30 May) in their study to determine the yield and some quality characteristics of the grass; The highest hay yield was obtained at the first sowing time and the last harvest time (589.00 and 568.00 kg/da, respectively) in hairy vetch and Hungarian vetch. It was reported that the highest crude protein yield was obtained at the first sowing time in vetch species, while the highest crude protein yield was determined at the third harvest time in common vetch and Hungarian vetch (60.08 and 91.37 kg/da, respectively). It was reported that harvest time had no effect on crude protein yield of hairy vetch. While the researchers determined the lowest ADF and NDF values at the first harvest time (27.80% and 32.83%, respectively), they found that planting times had no effect on ADF and NDF rates. Considering the results obtained from the research; reported that hairy vetch and Hungarian vetch should be preferred to common vetch, vetch species should be planted in the earliest period after the summer main crop harvest, and the harvest should be done on 20 May or 30 May in a way that does not harm the summer crop planting.

Alam et al. (2015), applied various doses of Molybdenum (Mo) to the soil to evaluate its effects on nodulation, nodule properties and biomass production in hairy vetch. It was determined that this application increased the number and size of nodules, nitrogenase (NA) and nitrate reductase (NR) enzyme activity in hairy vetch. The increase in enzyme activity also increased nitrogen (N) assimilation and higher biomass yield was obtained. It has been determined that high molybdenum doses (1.0 mg kg^{-1}) cause the nodule structure to deteriorate and thus to decrease the enzymatic activity in plants. It was determined that the application of 0.63 mg kg^{-1} to molybdenum soil as the optimum value maximized the biomass yield of hairy vetch.

Ozpinar and Sabanci (2014), in order to determine the agronomic characteristics of hairy vetch (*Vicia villosa* Roth.) populations collected from different regions of Turkey and preserved in the Aegean Agricultural Research Institute National Gene Bank, in the 1997-98 and 1998-99 growing seasons in Menemen and Bozdag locations. As a result of this study, significant differences were determined between the populations in terms of dry matter, seed and biological yield, thousand grain weight, harvest index and 50% flowering days. It has been determined that the grown populations do not show cold damage even at -12.8 ^{0}C.

Aasim et al. (2011), seed explants were cultured in nutrient medium containing 0.05-1.6 mg/l TDZ+IBA (0, 0.10 mg/l IBA) for hairy vetch (*Vicia villosa* Roth.) to obtain multiple shoots. The percentage of shoot regeneration was recorded as 45.83-75.00%. Up to 28.6 shoots per explant are shown in media containing 0.20 mg/l TDZ-0.10 mg/l IBA. Despite the presence of IBA in the medium, a decrease in shoot length was observed with the increase in TDZ ratio. In general, longer shoots were detected in the medium containing IBA than in the medium without IBA. The resulting shoots were treated with 50 mg/l IBA for 5, 10 and 20 minutes for rooting.

Turk et al. (2009), in their study, on the yield and quality of hairy vetch (*Vicia villosa* Roth.) five phosphorus ratios (0, 30, 60, 90 and 120 kg/ha) and three harvest periods (flowering beginning, full flowering and seed filling). investigated the effects. Within the scope of the study, dry matter (DM) yield, N, P, K, Mn, Cu, Fe, Zn, Ca, Mg, acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined in hairy vetch samples. Phosphorus rates and harvesting stages were found to significantly affect most of the components identified in hairy vetch. It was determined that phosphorus applications increased DM yield, N, P, Ca and Mg content, decreased ADF and NDF and did not have any effect on Mn, Cu, Fe and Zn. In addition, researchers reported that the late harvest period causes a decrease in feed quality.

Turgut et al. (2006), common vetch (*Vicia sativa* L.) and Hungarian vetch (*Vicia pannonica* Crantz.) harvested at the beginning of flowering under the ecological conditions of the Eastern Anatolia Region; common vetch and hairy vetch (*Vicia villosa* Roth.) obtained at the beginning of pod formation. They tried to determine the degradability levels of dry matter (DM), organic matter (OM), crude protein (CP) and neutral detergent fiber (NDF) in the rumen with nylon bag technique of common vetch, hairy vetch and Hungarian vetch harvested at the time of the lower pods. Harvested vetch samples were incubated in the rumen for 24, 48 and 72 hours. The degradability values of DM, OM and CP of these vetch groups are very important ($P<0.01$) during the incubation periods of 24, 48 and 72 hours, the degradability of NDF at 24 hours is significant (P<0.05), and the NDF degradability values at 48 and 72 hours are very important. It was determined that there were differences in the level of (P<0.01). When compared at different maturity stages, it was determined that common vetch had the highest fragmentation value. Common vetch, Hungarian vetch and hairy vetch followed in terms of DM, CP, OM and NDF degradability. In addition, it has been reported that rumen DM, CP, OM and NDF degradability values decrease with the advancing maturity period in all vetch species, and the harvest of vetch at the beginning of flowering will be the most appropriate in terms of animal nutrition.

Hakyemez et al. (2005), in their study with false hairy vetch lines of different origin in Canakkale conditions, they found that the number of maturation days was 224-275 days, the biological yield was 407-1475 kg/da, the grain yield was 59-183 kg/da, the harvest index was 6-22% and the thousand grain weight was 27-48 g.

Sparrow and Masiak (2004), reported that the CP and NDF contents of common vetch and hairy vetch grown in Alaska varied between 18.2-21.1% and 17.4-21.4%, 34.6-37.1% and 42.2-44.3%, respectively.

Aasen et al. (2004), reported that NDF and ADF ratios increased with the progression of harvest time, while crude protein ratio values decreased in legume-wheat mixtures.

Altinok and Hakyemez (2001), investigated the effects of different mixing ratios on feed yields in mixtures of hairy vetch (*Vicia villosa* L.) and vetch (*Vicia narbonensis* L.) with barley (*Hordeum vulgare* L.) in

Ankara conditions. Except for the second year dry matter and crude protein yield, it was reported that there were no significant differences between the vetch species in terms of green herbage, dry matter and crude protein yield and crude protein ratios in both years. On the other hand, in both years, significant differences at the level of 1% were determined between the forage yields and protein ratio and amount of vetch species+barley mixtures in both years.

Haj-Ayed et al. (2001), reported that the cell wall content increased and the CP content decreased with the progress of the harvesting period in common vetch and hairy vetch, the nutrient composition of the common vetch harvested during the flowering period was higher than that of the hairy vetch, in both vetches CP was highly degradable in the rumen, DM degradability was found to be higher. They determined that it decreased during the seed setting period.

Ozpinar et al. (2000), showed that the yield of green herbage was 193-2458 kg/da, the dry matter yield was 38-320 kg/da, and the seed yield was 7-63 kg/da, which included 56 hairy vetch populations collected from different regions of Turkey, and Efes and Menemen cultivars.

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