

CHAPTER 4

HOPS (*Humulus lupulus* L.)

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1.INTRODUCTION

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

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

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

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

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

2. SYSTEMATIC AND MORPHOLOGY

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

Team: Urticales

Family: Cannabaceae

Genus: *Humulus* T.

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

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



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

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

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

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

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



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

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



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

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

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

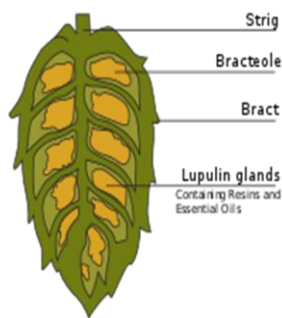


Figure 2.4. Flower of hop (Anonym, 2023h)

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

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

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



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

3. ADAPTATION

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

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

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

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

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

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



Figure 2.6. Growing of hop (İbrik, 2020)

4. YIELD AND QUALITY

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

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

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

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

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

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

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

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



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

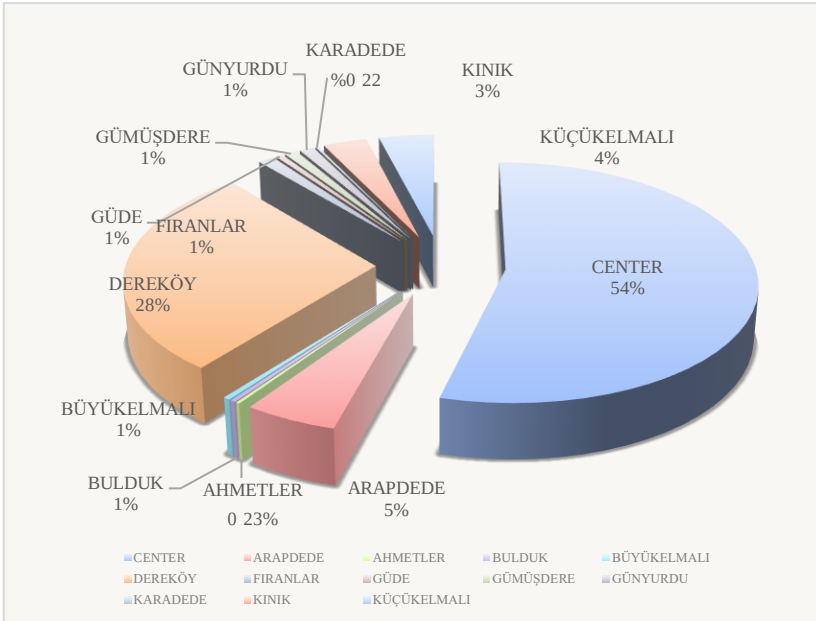


Figure 2.8. Pazaryeri villages hops area distribution (%) (İbrık, 2020)

The cultivation of the hop plant has spread over a wide area in Europe. In Turkey, it is cultivated only in the Pazaryeri district of Bilecik province. Bilecik is located at the intersection points of the Marmara, Black Sea, Central Anatolia, and Aegean Regions. Bilecik is one of the small provinces of Turkey, with an area of 4.307 km². It consists of 8 districts, 3 towns, and 245 villages, including the central district (Anonymous, 2018). Pazaryeri is among the smallest districts in the province.

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

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

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

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

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

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

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

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

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

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

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

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

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

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



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

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

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