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Determination of Shearing Parameters of Stalks and Flowers of Mountain Tea *(Sideritis libanotica Labill. Ssp. Linearis)* Plant

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ABSTRACT

Turkey has an important potential in the production of medicinal plants in terms of its wide plant diversity, different climates and wide area. One of these plants is a bush plant of the genus Sideritis from the Lamiaceae family, which grows naturally in our country. Information about the growing and harvesting techniques of these wild plants is insufficient. Determination of harvest parameters of these plants is an important factor in cultivation, designing the harvesting machines, increasing the crop yield and decreasing the labor requirement. In this study cutting tests of stalk and rupture test of flower were carried out regarding to the harvest of *Sideritis libanotica Labill. ssp. Linearis* (mountain tea) species which is one of the important medicinal plants of the Turkish flora. The experiments were carried out with a height of 0-10 cm (harvest height) from the soil surface of the plant stalk, 3 different knife types (smooth, fine toothed, coarse toothed) and 3 different knife loading speeds (150, 200, 250 min^{-1}). The maximum force values were obtained in the experiments varied between 11.32±3.41 and 18.57±4.02 N, while the deformation values occurring in the plant stalk varied between 13.19±2.32 and 25.97 ± 2.11 mm.

Dağçayı Bitkisinin *(Sideritis libanotica Labill. Ssp. Linearis)* Tomurcuk ve Saplarının Dayanım Parametrelerinin Belirlenmesi

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ÖZET

Türkiye, geniş bitki çeşitliliği, farklı iklimleri ve geniş üretim alanı ile tıbbi bitki üretiminde önemli bir potansiyele sahiptir. Bu bitkilerden biri de ülkemizde doğal olarak yetişen Lamiaceae familyasından Sideritis cinsi bir çalı bitkisidir. Yabani olan bu bitkilerin yetiştirme ve hasat teknikleri hakkındaki bilgiler az olup, bu bitkilerin kültüre alınmalarında önemli bir parametre olan hasat özelliklerinin belirlenmesi, hasat makinalarının tasarımı, ürün verimi ve işgücü gereksiniminin azaltılması açısından önemlidir. Bu çalışmada, Türkiye florasında önemli tıbbi bitkilerinden biri olan Sideritis libanotica Labill. ssp. Linearis (Dağ Çayı) türünün hasadına yönelik sap kesme ve çiçek kopma denemeleri gerçekleştirilmiştir. Denemeler düz, ince dişli, kalın dişli olmak üzere 3 farklı bıçak tipi ve (150, 200, 250 min^{-1}) 3 farklı bıçak hızlarında gerçekleştirilmiştir. Denemelerde elde edilen maksimum kuvvet değerleri 11.32±3.41 ve 18.57± 4.02 N arasında değişirken bitki sapında meydana gelen deformasyon değerleri 13.19± 2.32 ve 25.97± 2.11 mm arasında değişmiştir.

1. Introduction

In parallel with the consumption of medicinal and aromatic plants in many different areas and industrial branches, the trade volume of these plants is increasing every day. As before, plants remain the primary source of medicines in the world today. Since then, plants have continued to provide people with new medicines every day. Because 50% of all clinically used drugs in the world are obtained from natural products (Van Wyk et al., 2018).

Currently, the side effects of synthetic substances and the resistance of microorganisms to antimicrobial synthetic drugs have increased the importance of medicinal plants carrying natural and herbal substances (Nakiboglu and Otan, 1994). That is why antimicrobial use of extracts from medicinal plants has been increasing in recent years (Hsieh et al., 2001). In our country, an average of 400 plant species is traded for medicinal and aromatic purposes every year, although they vary depending on the years (Şahin, 2013). The genus Sideritis (Lamiaceae), also popularly known as "balbashi grass", contains more than 150 species that grow mainly in the Mediterranean regions of Europe (Castro and Nunez, 1994; Korkmaz et al., 2017).

The genus Sideritis, a family of Lamiaceae, is a shrub 20-75 cm high that grows in subtropical regions (Figure 1). The genus Sideritis has over 150 species, the majority of which are in the Mediterranean Sea. The genus Sideritis contains 46 species in the flora of Turkey, 31 of which are endemic (Davis, 1982; 1988). These species are widely used as herbal tea and in folk medicine for the treatment of cough, bronchitis, asthma and gastrointestinal disorders. In the Balkan countries, dried in florescences of the species Sideritis are used in the preparation of drinks called "mountain tea". It has been studied in these species and stated that they have anti-ulcer, anti-inflammatory and antioxidant activity (Petreska et al., 2011).

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Figure 1. Mountain tea (Sideritis libanotica Labill. ssp. Linearis) plant.

Sideritis species have the form of one or perennial, herbaceous or shrubby plants. The trunk is erect, ascending, usually branched and woody at the base. Sideritis species are popularly used for their pain-relieving, antiromatismal, digestion-facilitating and antimicrobial effects (Piozzi, 2006). In addition, the mountain tea plant, consumed as a medicinal tea, has appetizing, stomach pain and stimulating properties (Baytop, 1999; Uçar and Turgut, 2009). In our country, the species belonging to this genus, which is more commonly known as "Island Tea" or "mountain tea", are widely used as folk medicine and herbal tea (Aytaç and Aksoy, 2000; Kirimer et al., 2001; Ayaz, 2009). Essential oils obtained from sideritis species are used as a tonic, degassing, antispasmodic, diuretic (Kaya et al., 2015). About 80% of the population in developing countries use traditional medicines because they cannot afford the high cost of medicines and healthcare (Cunningham, 1988). From a traditional and cultural point of view, these drugs are much more accepted (Maroyi, 2013; Van Wyk et al., 2018).

The plant-machine relationship in the harvesting processes of plant materials significantly affects the quality of the harvest. For this reason, knowledge of the physical and mechanical properties of plants for harvesting is of great importance in the design and development of harvesting machines. Quality harvesting aims to maximize product yield while minimizing product and quality losses. Farmers' income will increase as the harvest loss decreases (Esgici et al., 2019; Sessiz et al., 2019). The most common effects of harvesting machines on the plant during harvest (depending on the harvest process) are the effects of cutting, bending, pulling, compression and crashing (Kocabıyık, 1997).

Physical and mechanical properties related to the cutting process of the stalk are included shear force, bending force, rupture force, modulus of elasticity, coefficient of friction, etc. parameters. These parameters vary depending on the variety, maturity and humidity of the stalk (Zhenjiang Agricultural Machinery College, 1981; Shen et al., 2020).

Physical properties of materials are important in terms of shear, compression, tensile, bending, density and friction values (Shaw and Tabil, 2007; Galedar et al., 2008; Sessiz et al.,2019). These characteristics vary depending on the type of plant, stalk diameter, degree of maturity, moisture content and different harvest heights of the plant stalk. Therefore, it is necessary to know the physical and mechanical properties such as bending, shear stresses and energy requirements for operational parameters to be able to implement the appropriate design (Galedar et al., 2008).

Jia et al., (2013) compared the traditional saw blade and bionic blade for corn stalk cutting.

Yang and Li, (2019) tested cutting parameters of the hops plant, noted that in order to reduce the problems of existing harvesters, the physical-mechanical properties of plant stalks, such as cutting force, should be well known. Many studies on the mechanical properties of their stalks at home and abroad are usually conducted in wheat, feed, corn, rami, sugarcane, etc. He stated that it was aimed to determine the mechanical properties of such products.

Pekitkan et al., (2019) examined the cutting properties of vines depending on the blade type, cutting angle and cutting speed of some grape varieties.

Yilmaz et al., (2009) determined the strength and deformation parameters for closed capsule of sesame (Sesamum indicum L.) stalks according to moisture content and stalk sections.

Taghinezhad et al., (2012) studied the mechanical cutting properties of sugar cane stalks using a linear blade cutting and size reduction device to determine the effect of sample orientation.

Yilmaz et al., (2015) aimed to reduce losses, cost and yield losses during Juniper harvesting, they determined the biological and physico-mechanical properties of the product for machine Juniper harvesting. Song et al. (2015) examined the cutting performance of cotton stalks based on average speed, cutting slope and cutting speed parameters. Eliçin et al., (2019) conducted a study with grape cane. They determined cutting force and energy of grape cane used various knife types, cutting angle and speed. They found the best results with the starred-edge knife. Luo et al. (2012) conducted cutting tests on the stems of a perennial grass plant (Eulaliopsis binata) and examined the effects of cutting aperture, cutting speed, cutting knife form, number of stems and other factors on cutting effects.

Studies conducted at home and abroad on cutting systems of plant stalk have shown that harvesting and cutting dynamics are a very important element in selecting and determining the design parameters of the prototype. These dynamics in the determination of the shear test simulated on the counter or a cutting test, optimizing the parameters of the study the reproducibility of the test and significantly increase the efficiency of agricultural tools and machines of the knife to the cutting parameters and lead to the development of the dynamic stalk-cutter properties that belong to the agricultural system as well as the parameters of plant stalks on a multi-dimensional study is required (Shen et al., 2020).

In the harvest of medicinal aromatic plants, it is necessary to reduce the losses incurred in post-harvest processes such as transport, processing and storage and increase the mechanization possibilities in order to obtain quality products. In medical aromatic mechanization, it is necessary to know the biological properties of the product as well as its physical and mechanical properties. In this study, Sideritis libanotica Labill collected from Çarıksaraylar village in Şarkikarağaç District of Isparta province, which is one of the important medicinal plants of the Turkish flora, cutting tests of stalk and rupture test of the flower were carried out regarding to the harvest of Linearis (mountain tea) species. In these tests, maximum force, rupture force, deformation, elongation at maximum load, tensile strength, stress at break, work to maximum load and stiffness were determined for plant stalk cutting parameters. On the other hand, in flower rupture tests, maximum force, rupture force, deformation, stiffness, energy up to maximum load and energy spent up to break were determined. In addition, the amount of essential oil belonging to the mountain tea plant was determined.

2. Material and Method

Test material mountain tea plant was randomly harvested at the height of 5 cm from the soil surface during the harvest period after flowering from the vicinity of Çarıksaraylar village in Şarkikarağaç District of Isparta province. The harvested plants were dried in the shade and transported to the Harvesting Technologies Laboratory of the Faculty of Agriculture. In the studies conducted, the moisture values of the test materials were determined according to ASABE Standards by the oven -drying method at 103 °C for 24 hrs. (ASABE Standards, Sec. 358.2, 2008).

For rupture and shearing tests, Lloyd brand (Lloyd Instrument LRX Plus, Lloyd Instruments Ltd, An AMATEK Company) Universal Testing Machine working in the direction of pulling and compression force was used. During tests, values such as force, deformation, load speed, and test curve can be displayed instantly thanks to a connected computer and software. The maximum test load of the device is 1 kN, the application accuracy of the load cell used is less than 0.005%.

Cutting experiments were carried out with a height of 0-10 cm (harvest height) from the soil surface of the plant stalk, 3 different knife types (smooth, fine toothed, coarse toothed) and 3 different knife speeds (150, 200, 250 min^{-1}). The obtained data were transferred to a computer with NEXYGEN Plus software. The cutting process was determined by adding an apparatus prepared according to the plant (for example, a platform on which it was placed) and applying a compressing test in line with the axis of the plant handle with the help of a probe with a cutting knife on it. The types of knives used in cutting tests are shown in Figure 2.

Figure 2. Types of knives used in cutting tests (smooth, fine toothed, coarse toothed).

The rupture force of flowers was determined by pulling in line with the axis of the plant stalk with the help of Jaws designed to hold the branch where the flower is located. In the experiments, the cutting process was achieved by the linear movement of the moving upper knife to the fixed plant stalk in a vertical direction of 250 min^{-1}. In the experimental assembly, the knife is positioned perpendicular to the plant stalk. During the tests, special handle fixing apparatus was used on the assembly so that the handles could standstill in the same position. The assemblies used in rupture and shearing tests and their appearance during the cutting process are shown in Figure 3

Figure 3. Stalk cutting and flower rupture tests.

Distillation was performed with the Clevenger device to determine the amount of essential oil belonging to the mountain tea. A boiling process of 2.5 hours was applied to 100 grams of plant samples under the refrigerant. The amount of oil accumulated at the top of the Clevenger apparatus was measured with the help of a graduated tube and the amount of oil was determined (Moradi et al., 2019; Ertaş et al., 2019). This process has been repeated 3 times. The amount of essential oil is calculated as the volume of essential oil in 100 g dry matter (ml/100g).

3. Results and Discussion

The length of the materials used in the stalk cutting and flower rupture tests of the mountain tea plant varies between 180 and 320 mm. Plant moisture value was determined as 8.1% d.b The average diameter of the mountain tea plant stalk was measured as 1.45 mm. The average test results of the cutting parameters are given in Table 1 for a smooth knife.

Yang, J., Li, X. K. (2019) determined the shearing force of the hop plant varieties values between 159.55 and 258.01 N. According to the study, too high or too low velocity will increase the shearing force, and the velocity in the middle section is the most favorable for shearing. Pekitkan et al., (2019) obtained the lowest cutting force values in thin-flat blade type in the study conducted on native grape varieties. The cutting force values obtained in this blade type were changed between 234.50 and 355.8 N. Yilmaz et al., (2009) determined the maximum force values between 278 and 366 N depending on different moisture contents for cutting the sesame stalk. On the other hand the maximum force and rupture force values were determined as 14.13±5.74 and 8.47±7.37 N at the highest with 150 min^{-1} knife speed in the tests conducted at the smooth knife and different cutting speeds of the mountain tea plant, respectively. Yilmaz et al., (2009) found the bioyield deformation values of the closed capsule sesame between 6.4 and 9.1 mm according to the moisture contents. For mountain tea plant the highest deformation and elongation values were calculated as 25.97± 2.11 and 25.31± 2.09 mm, respectively, at the knife speed of 200 min^{-1}. Taghinezhad et al., (2012) determined the lowest and highest stress values of sugarcane stalks as 0.98 and 1.65 N / mm^2 in their study. Pekitkan et al., (2019) obtained the highest shear stress values for the grape plants with a coarsely toothed knife type. The fine-toothed knife and smooth knife types followed it, respectively. For the mountain tea plant, as the knife speed increased, the maximum stress that occurred on the plant stalk and the stress values at the moment of rupture decreased. The lowest values were obtained as 7.40±1.56 N/mm^2 and 2.90±2.41 N/mm^2 at the knife speed of 250 min^{-1}, respectively. The maximum work value performed at maximum load was observed at the knife speed of 150 min^{-1}, as 5.48±3.58 Ncm. Stiffness values ranged between 6.98± 3.84 and 6.89 ± 1.79 N/mm.

The cutting parameters of the plant stalk obtained as a result of experiments with a fine-toothed knife are given in Table 2.

Table 1. Mean cutting parameters of plant stalk in tests with a smooth knife

Knife speed (min^{-1})	Maximum Force	Rupture force	Deformation	Extension at maximum load	Tensile strength	Stress at break	Work to Maximum Load	Stiffness
	(N)	(N)	(mm)	(mm)	(N/mm^2)	(N/mm^2)	(Ncm)	(N/mm)
150	14.13 ± 5.74	8.47 ± 7.37	25.56 ± 1.93	24.95 ± 1.94	8.99 ± 2.70	5.03 ± 3.70	5.48 ± 3.58	6.98 ± 3.84
200	13.07 ± 4.22	5.86 ± 4.22	25.97 ± 2.11	25.31 ± 2.09	8.37 ± 4.13	3.62 ± 2.82	4.79 ± 2.45	6.63 ± 2.68
250	13.63 ± 3.14	5.48 ± 4.73	25.38 ± 1.69	24.23 ± 1.79	7.40 ± 1.56	2.90 ± 2.41	5.32 ± 1.88	6.89 ± 1.79

Table 2. Mean cutting parameters of plant stalk in tests with fine-toothed knife

Knife speed (min^{-1})	Maximum Force	Rupture force	Deformation	Extension at maximum load	Tensile strength	Stress at break	Work to Maximum Load	Stiffness
	(N)	(N)	(mm)	(mm)	(N/mm^2)	(N/mm^2)	(Ncm)	(N/mm)
150	15.97 ± 4.85	11.20 ± 6.49	20.28 ± 2.78	19.73 ± 2.80	9.89 ± 2.25	6.83 ± 3.78	3.09 ± 1.63	10.43 ± 3.86
200	17.06 ± 4.85	10.46 ± 7.24	20.01 ± 0.97	19.42 ± 0.94	12.16 ± 3.46	7.76 ± 6.05	3.61 ± 1.69	9.58 ± 3.15
250	18.57 ± 4.02	10.18 ± 7.71	20.31 ± 0.87	19.58 ± 0.88	10.99 ± 3.08	5.91 ± 4.82	4.15 ± 1.55	9.75 ± 2.74

Jia et al., (2013) found the mean maximum force value using traditional saw blade as 152.45 N for the corn stalk. For the mountain tea plant, the highest maximum force value was found as 18.57±4.02 N at the knife speed of 250 min^{-1} and the highest rupture force value was found 11.20 ±6.49 N at the knife speed of 150 min^{-1}. The lowest values deformation and elongation values occurring in the plant stalk were obtained at the knife speed of 200 min^{-1} in cutting tests with the fine-toothed knife. The deformation and elongation values were obtained at maximum load between 20.01-20.31 and 19.42-19.73 mm, respectively. The highest stress values in the plant stalk were measured at 12.16±3.46 N/mm^2 and 7.76±6.05 N/mm^2, respectively, in tests conducted at the knife speed of 200 min^{-1}. The maximum values of the work were observed at maximum load at the knife speed of 250 min^{-1} as 4.15±1.55 Ncm. The stiffness values ranged from 9.58±3.15 and 10.43±3.86 N/mm, while the highest values were measured at 150 min^{-1} knife speed.

The cutting parameters of the plant stalk obtained as a result of experiments with a coarsely toothed knife are given in Table 3.

The highest maximum force and rupture force values were determined as 14.15±4.17 and 8.55±6.66 N at 250 min^{-1} knife speed in tests with a coarsely toothed knife, respectively. The lowest deformation and elongation values were again calculated as 6.87±5.43 and 13.19±2.32 mm at the knife speed of 200 min^{-1}, respectively. The lowest stress values in the plant stalk were obtained at the knife speed of 200 min^{-1}. The highest work to maximum load and stiffness values were obtained as 3.11±1.40 Ncm and 6.51 ± 2.01 N/mm at the knife speed of 250 min^{-1}, respectively.

In flower rupture tests from the stem, the flowers were plucked at the pull rate of 250 min^{-1} with the help of a moving platform from a plant branch fixed with the help of jaws. The resulting rupture parameters are recorded in the computer. The average values of the maximum force, rupture force, deformation, stiffness, energy up to maximum load and energy spent up to break are given in Table 4.

Libanotica Labill ssp. Linearis (Mountaintea) plant collected from a height of 1.276 m in the village of Çariksaraylar, Şarkikarağaç District of Isparta province in August 2020. The essential oil color of the Linearis species was light yellow, essential oil ratio was determined as 0.15%. Erbaş and Fakir (2015) obtained 0.18% essential oil in a study they conducted. It is believed that this difference is caused by differences in the harvest time of the plant, drying conditions.

Table 3. Mean cutting parameters of plant stalk in tests with a coarsely toothed knife.

Knife speed (min^{-1})	Maximum Force	Rupture force	Deformation	Extension at maximum load	Tensile strength	Stress at break	Work to Maximum Load	Stiffness
	(N)	(N)	(mm)	(mm)	(N/mm^2)	(N/mm^2)	(Ncm)	(N/mm)
150	12.65 ± 5.35	6.89 ± 5.21	13.89 ± 2.85	13.40 ± 2.81	9.28 ± 3.10	5.05 ± 3.58	2.68 ± 1.69	6.48 ± 3.03
200	11.32 ± 3.41	6.87 ± 5.43	13.19 ± 2.32	12.67 ± 2.34	8.49 ± 2.88	4.94 ± 3.94	2.31 ± 1.02	5.69 ± 2.04
250	14.15 ± 4.17	8.55 ± 6.66	13.73 ± 2.14	13.06 ± 2.10	8.98 ± 2.70	5.23 ± 4.11	3.11 ± 1.40	6.51 ± 2.01

Table 4. Average rupture parameters of the flower of the mountain tea plant.

Knife speed (min^{-1})	Maximum Force	Rupture force	Deformation	Stiffness	Energy up to maximum load	Energy spent up to break
	(N)	(N)	(mm)	(mm)	(J)	(J)
250	0.56 ± 0.42	0.28 ± 0.39	4.86 ± 2.14	8.25 ± 13.94	0.0012 ±0.0010	0.0012 ±0.0011

4. Conclusion

According to the results, the stalk cutting and flower rupture parameters of the mountain tea (Sideritis libanotica Labill. ssp. Linearis) plant varied depending on the knife type and knife loading speed. The required force and stress values to cut the plant stalk were found higher with a fine-toothed knife, while the amount of deformation occurring in the plant stalk was higher in studies with a smooth knife. Coarse toothed harvesting knives were found to be more suitable for mountain tea plant harvesting. When examined in terms of knife speed, it was determined that the deformation and rupture values was lower in tests with knife speed of 200 min^{-1}. It is recommended to use 200 min^{-1} knife speed and coarse toothed knife type in mechanization applications that will be applied in the harvest of the mountain tea plant.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Authors' Contributions

The authors declare that they have contributed equally to the article.

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