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CUTTING FORCE AND ENERGY REQUIREMENT OF 'BOĞAZKERE' GRAPE (*VITIS VINIFERA* L) CANE

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Abstract

In this study, cutting and energy properties of canes of 'Bogazkere' grape variety (Vitis vinifera L. cv.) were determined at spring pruning season in 2018. Cutting and energy properties were measured by the biological materials testing machine. According to test results, the best and lowest cutting force, cutting strength, cutting energy and specific cutting energy results were obtained at type of flat- edge knife as 263.50 N, 9.34 MPa, 2.70 J and 0.1056 J mm^{-2}, respectively. The highest values of cutting force, cutting strength, cutting energy and specific cutting energy were obtained from the serrated 1(knife-edge thick) type knife as 440.5 N, 15.59 MPa, 3.57 J and 0.1264 J mm^{-2}, respectively. Measured these properties gradually decreased with increase knife-cutting angle from 0° to 40°. Also, the cutting force, cutting strength, cutting energy and specific cutting energy decreased with increase knife-cutting speed from 1 mm s^{-1} to 5 mm s^{-1}. There were found significant differences between 1 m s^{-1} and the other cutting speeds. However, there were not significant different among 2, 3, 4 and 5 mm s^{-1} loading speed as statistically.

***Key words**: grape cane, cutting force, cutting energy, pruning of grape.*

INTRODUCTION

Grape is a valuable product that is consumed as both table and wine and grape juice. Table grapes have been included in the human diet since ancient times. Grapes are the most widely grown commercial fruit crop in the world, and also one of the most popular fruit crops for horticultural production. The global production of table grapes reached 22.7 million tons in 2017 (Anastasiou et al., 2018). Boğazkere grape (Vitis vinifera L) varieties is widely grown in Diyarbakır, Elazığ and Mardin provinces, Southestern part of Turkey. Even though grape has always been a valuable and important product for human diet and economy in Turkey, pruning and harvesting processes in vineyards are still mainly performed by manually. Therefore, time-consuming and production costs are very high and labor efficiency is low in the vineyard pruning operations. Grape growers constantly search the ways in order to maximize their profits all over the world. So, there is a major research effort throughout the world to modify grapevines so that viticultural practices can be economically mechanized while maintaining or improving yield and quality. To use machines successfully for shoot positioning, pruning, harvesting, and other grape production operations, trellis systems must be devised and shoots positioned to accommodate precise mechanical movement (Morris, 1993). Pruning is made by worker with scissors in viticulture. Usually, flat-mouthed scissors are used and pruning and cutting process is difficult and tiring. The same scissors are used for all types of vine. Power requirements are high. However, the cane cutting characteristics of each variety is different each other. Therefore, the mouth of the used scissors and the cutting angle are important to determine for reducing the energy requirement.

Labor requirement, time-consumption and production costs can be decreased by utilizing a mechanical pruner and grape harvester (Morris, 2000; Sessiz et al., 2018). The first stage for the design of an effective new pruner is to measure the cutting force and energy. The cutting strength and energy requirement depend on the species, variety, diameter, maturity, moisture content, cellular structure and the type of cutting blade used (Persson, 1987; Taghijarah et al. 2011; Nowakowski, 2016). Knife- edge angle, knife approach angle, shear angle, and knife rake angle are the most important knife angles that can directly influence the cutting force and energy (Ghahraei et al., 2011).

Until now, many studies have been conducted on the mechanical, physical and cutting properties of canes for differeng grape varieties. Romano et al. (2010) determined the cutting force such as Cabernet Sauvignon and Chardonnay at different regions in Italy. Sessiz et al. (2015) determined the cutting properties end energy values for some local and international grape varieties in Turkey. Some physical properties of the Rasa grape were determined by Khodaei and Akhijahani (2012). Cutting properties and energy values were determined by Ozdemir et al. (2015) depend on variety, moisture content and diameter of some local wine grape cultivars. Cutting properties of cutting force, cutting strength, cutting energy and specific cutting energy were measured in eight different wine grape varieties. Canes of Tannat, Merlot, Cot, Chardonnay, Viognier, Cabernet Sauvignon, Shiraz and Cabernet Franc were profiled for their cutting properties during the dormant season. The results of data analysis showed that there was a significant difference between averages values of cutting properties varying based on variety. The results demonstrated that the maximum cutting force, cutting strength and cutting energy for Cabernet Franc grape, the minimum cutting force, cutting strength and cutting energy were obtained at Tannat grape variety. Also, similar engineering properties of the Şire grape were determined by Esgici at al. (2017). Cutting properties of sire grape cane has been changed with harvesting time. Shearing force and energy requirement increased with increase internode diameter of canes. The maximum shearing force and energy requirement were determined the last harvesting time. Similar results were reported Pekitkan et al. (2018) for cotton stalk. Cutting parameters of some grape varieties subject to the diameter and age of canes were determined by Esgici at al. (2017). From the above literatures study, there is no information about the effect of knife type, knife edge angle and cutting speed of grape canes. So, we have felt to the need to conduct this study.

The objectives of this study were to determine the optimum the knife type, knife edge angles and cutting speed for local Boğazkere grape variety of cane (shoot). For this purpose, cutting tests were carried out with Boğazkere grape varietiy. The cutting force and energy values were measured depend on these parameters in the cutting experiments.

MATERIALS AND METHODS

This study was carried out using the canes of Boğazkere (Vitis vinifera L) local wine grape variety (Fig. 1). The test samples were obtained from the Institute of Agricultural Research of GAPUTEM at the Diyarbakir province located in south-eastern part of Turkey. The test samples were randomly cut by hand from vineyards. The cut and collected grapevine canes (Fig. 1) were transported to the laboratory at the Department of Agricultural Machinery and Technologies Engineering, University of Dicle which were preserved in a refrigerator at 5 °C until the time of the cutting tests. The experiment tests were performed spring grape pruning season in 2018 year.

Fig. 1. View of canes of Boğazkere variety

Since the diameter of the canes during the pruning is 6.00 mm, the cutting tests were conducted with 6.00 mm canes. The diameter of the canes (mm) was converted to cross-section area in 28.26 mm^2. The cane diameters were measured before the test using a caliper. The initial moisture content of canes was determined according to ASABE standard (Asabe Standarts, 2006) by way of oven-drying 50 g of each sample at 103 °C for 24 h. The average moisture content was determined as 26.00 % w.b.

An Universal Testing Machine was used to measure cutting properties of canes (Fig. 2). Cutting experiments were carried out with three various knife types (Figure 2), two of them are serrated type, Serrated 1 (knife-edge thick), Serrated 2 (knife-edge thin) and Flat-edge (knife-edge flat) with five knife edge angles (0°, 10°, 20°, 30° and 40°) and five different loading (cutting) speeds (1, 2, 3, 4 and 5 mm s^{-1}).

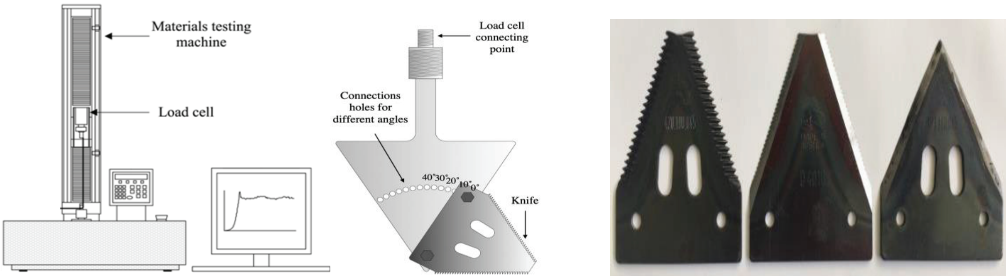

Fig. 2. Materials Testing Machine and cutting knives

The maximum cutting force, cutting strength, cutting energy and specific cutting energy were determined depend on type of knife, knife cutting angle and cutting speed. The peak cutting strength, obtained from the cutting force findings, was determined by the following equation (Mohsenin, 1986):

$$\sigma s = \frac{Fmax}{A}$$

Where: σs is the maximum cutting strength in (MPa), Fmax is the maximum cutting force in (N) and A is the cross-sectional area in (mm2).
The cutting energy was calculated by measuring the surface area under the force-deformation curve by material testing machine (Yore et al., 2002; Chen et al., 2003; Kocabiyik and Kayisoglu, 2004; Ekinci et al., 2010; Zareiforoush et al., 2010; Ghahraei et al., 2011; Voicu et al., 2011; Sessiz et al., 2018; Ozdemir et al., 2015; Nowakowski, 2016; Pekitkan et al., 2018). A computer data acquisition system recorded all force-displacement curves during the cutting process for each parameter.
Specific cutting energy, Esc was calculated by:

$$Esc = \frac{Ec}{A}$$

Where: Esc is the specific cutting energy (J mm-2) and Ec is the cutting energy (J).

The experiment was planned as a completed randomized plot design and data were determined using analysis of variance (ANOVA) method. Mean separations were made for significant effects with LSD and the means were compared at the 1% and 5% levels of significance using the Duncan multiple range tests in MSTAT-C software.

RESULTS AND DISCUSSION

As shown in the Table 1, the the effect of knives type has been found significant on the cutting force, cutting strength, cutting energy and specific cutting energy of Boğazkere grapevine canes (P<0.01). However, the results of the test showed that the significant differences were found among the knife types at 1 % probability level. As can be seen from the Table 1, while the maximum cutting force, cutting strength, cutting energy and specific cutting energy values were obtained at knife of serrated 1 (knife-edge thick) type as, 440.50 N, 15.59 MPa, 3.57 J and 0.1264 J mm^{-2} respectively, the lowest cutting force, cutting strength, cutting energy and specific cutting energy values were obtained at flat type (knife-edge flat) as 263.50 N, 9.34 MPa, 2.70 J and 0.1056 J mm^{-2} respectively. According these results, flat type knife is suitable than the serrated types and when we compared the knife types, we can recommend flat-edge type knife (shears) than serrated type knife for a new design of pruning shears for Boğazkere variety grape cane.
The effect of knife cutting angle on cutting force, cutting strength, cutting energy and specific cutting energy are shown in Table 2 for Boğazkere grape variety.

Table 1. The average cutting properties of Boğazkere grape variety

Boğazkere				
Knife Type	Cutting Force (N)	Cutting Strength (MPa)	Cutting Energy (J)	Specific Cutting Energy (Jmm^{-2})
Serrated type 1 (knife-edge thick)	440.5 a*	15.59 a	3.57 a	0.1264 a
Serrated type 2 (knife-edge thin)	311.1 b	11.01 b	2.98 b	0.0955 b
Flat type (knife-edge flat)	263.5 c	9.34 c	2.70 c	0.1056 b
Mean	**338.35**	**11.973**	**3.085**	**0.109**
LSD	**17.15**	**0.6068**	**0.2855**	**0.0102**

* Means followed by the same letter in each column are not significantly different by Duncan multiple range test at the 5% level.

As shown in the table, the cutting angle has been found significant effect on the cutting force, cutting strength, cutting energy and specific cutting energy of grapevine canes ($P<0.01$). The cutting force, cutting strength, cutting energy and specific cutting energy decreased with increasing knife-cutting angle from 0° to 40°. The maximum cutting force, cutting strength, cutting energy and specific cutting energy were observed at 0◦ cutting angle as 422.90, 14.97 MPa, 3.808 N and 0.1347 J mm-2 respectively. The lowest values were obtained at 20°, 30° and 40° cutting angle. There were not found significant different statistically among 20° and 30° cutting angle. However, the lowest values of cutting forces, cutting strength, cutting energy and specific cutting energy were obtained at 40° cutting angle as 284.6 N, 10.07 MPa, 2.637 J and 0.1020 J mm^{-2}, respectively. The similar results were observed by Kronbergs et al. (2011), according theirs results, the suitable knives bevel angle is change between 25° and 45°.The decrease of cutting force and cutting energy depend on knife edge angle allows proper design of the cutting unit and cutting machine for cotton stalk of top section and predicting the power requirements (Nowakowski 2016; Ozdemir et al., 2015; Esgici et al., 2017). Prasad and Gupta (1975) reported that the optimum knife bevel angle value for cutting of corn stalk was 23°. According to Suryanto et al. (2009), the knife edge angle has a significant effect on the cutting force and energy. Dowgiallo (2005) also reported that besides the cutting edge, knife edge sharpness and knife speed are effect on cutting properties. Based on our results, the best results were obtained at 40° cuttinge angle. As a result, we can recommend and consider these values for a new design and construct a cutting shears. This information is very valuable for selecting a suitable equipment design for reduces energy requirement and consumption. Because, the selection of suitable cutting apparatuses and equipment are plays an important role in economizing on cutting force and energy requirement.

Table 2. The average cutting and energy properties depending on cutting angle

Boğazkere				
Knife cutting angle (◦)	Cutting Force (N)	Cutting Strength (MPa)	Cutting Energy (J)	Specific Cutting Energy (Jmm^{-2})
0	422.9 a	14.97 a	3.808 a	0.1347 a
10	357.8 b	12.66 b	3.248 b	0.1149 b
20	318.5 c	11.27 c	2.880 c	0.1008 c
30	307.9 c	10.89 c	2.822 c	0.0934 c
40	284.6 d	10.07 d	2.637 bc	0.1020 bc
Mean	**338.35**	**11.973**	**3.085**	**0.109**
LSD	**22.14**	**0.7834**	**0.3686**	**0.01317**

* Means followed by the same letter in each column are not significantly different by Duncan multiple range test at the 5% level.

The effects of knife loading speed are shown in Table 3. As shown in table, the main effect of the knife loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant statistically ($p<0.01$). Measured all cutting and energy values slight decreased with an increase knife-cutting speed. While the highest values were observed at 1 ms^{-1} loading speeds, the lowest values were found at 4 and 5 mms^{-1} loading speed. However, there were not significant different among 2, 3, 4 and 5 mms^{-1} loading speed. Similar results were observed by Yiljep and Mohammed (2005). They investigated that the effect of knife velocity on cutting energy and efficiency for sorghum stalk. The results showed that there was high correlation between knife velocity, cutting energy requirement and cutting efficiency. The minimum cutting energy requirements were obtained at knife velocities of 2.91 and 3.54 ms^{-1}.

Table 3. The change of cutting and energy properties depending on cutting speed

Bogazkere				
Loading speed, mm/s	Cutting Force (N)	Cutting Strength (MPa)	Cutting Energy (J)	Specific Cutting Energy (Jmm^{-2})
1	356.3 a	12.62 a	3.631 a	0.1284 a
2	346.5 ab	12.26 ab	3.269 ab	0.1157 ab
3	330.0 b	11.68 b	3.004 bc	0.1063 bc
4	329.3 b	11.65 b	2.799 c	0.0991 c
5	329.3 b	11.65 b	2.721 c	0.0963 c
Mean	338.35	11.973	3.085	0.109
LSD	2214	0.7834	0.3686	0.01317

* Means followed by the same letter in each column are not significantly different by Duncan multiple range test at the 5% level.

CONCLUSIONS

Test results indicated that the cutting forces and energy requirement were changed depend on independent parameters. The best results were obtained at type of flat knife. The highest values of cutting force, cutting strength, cutting energy and specific cutting energy were obtained from the serrated 1 type (knife-edge thick) knife as 440.5 N,15.59 MPa, 3.57 J and 0.1264 J mm^{-2} , respectively. The cutting force, cutting strength, cutting energy and specific cutting energy gradually decreased with increase knife-cutting angle from 0° to 40°. The effect of the knife cutting speed on the cutting properties were found significant statistically ($p<0.01$). The cutting force, cutting strength, cutting energy and specific cutting energy decreased with increase knife-cutting speed from 1 mms^{-1} to 5 mms^{-1}. However, there were found significant differences between 1 m s^{-1} and the other loading speeds and there were not significant different among 2, 3, 4 and 5 mms^{-1} loading speed as statistically.

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REFERENCES

Anastasiou, E., Balafoutis, A., Darra, N., Psiroukis, V., Biniari, A., Xanthopoulos, G., Fountas, S. (2018). Satellite and proximal sensing to estimate the yield and quality of table grapes. *Agriculture,* doi:10.3390/agriculture8070094

Asabe S., (2006). S358.2: 1:1 Measurement forages. 52nd edn. *American Society of Agricultural Engineers*, St Joseph MI.

Chen, Y., Gratton, J.L., Liu, J. (2003). Power requirements of hemp cutting and conditioning. *Biosystems Engineering.* 87(4), 417–424.

Dowgiallo, A. (2005). Cutting force of fibrous materials. *Journal of Food Engineering*. 66(1), 57-61.

Ekinci, K., Yilmaz, D., Ertekin, C. (2010). Effects of moisture content and compression positions on mechanical properties of carob pod (Ceratonia siliqua L.). *African Journal of Agricultural Research*, 5(10), 1015–1021.

Esgici, R., Ozdemir, G., Pekitkan, F.G., Elicin, A.K., Ozturk, F. and Sessiz, A. (2017). Some enginnering properties of the Sire grape (Vitis Vinifera L.). *Scientific Papers-Series B-Horticulture*, vol. 61, 195–203.

Ghahraei, O., Ahmad, D., Khalina, A., Suryanto, H., Othman, J. (2011). Cutting tests of kenaf stems. *Transactions of the ASABE*, 54(1), 51-56.

Khodaei, J., Akhijahani, H.S. (2012). Some Physical Properties of Rasa Grape (Vitis vinifera L.). World *Applied Sciences Journal,* 18(6), 818-825.

Kocabiyik, H., Kayisoglu, B. (2004). Determination of shearing features of sunflower stalk. *In J Agric Sci*, vol. 10, 2004, no. 3, 263–267.

Kronbergs, A., Širaks, E., Kronbergs, A.E. (2011). Mechanical properties of hemp (cannabis sativa) biomass. *Environment, Technology, Resources. Proceedings of the 8th International Scientific and Practical Conference*. 1, 184-190.

Mohsenin, N.N. (1986). Physical properties of plant and animals materials. 2nd edition. New York, NY: *Gordon and Breach Science Publishers*.

Morris, J.R. (1993). Effects of mechanical pruning and mechanical shoot positioning on yield and quality of grapes. *Proc. 2nd nj shaulis grape symposium*, fredonia ny, 57-66 .

Morris, J.R. (2000). Past, Present, and future of vineyard mechanization. *Proceeding ASEV 50 the Anniv*. Ann. Mtg. Seatle, WA, 51, 155-164.

Nowakowski, T. (2016). Empirical model of unit energy requirements for cutting giant miscanthus stalks depending on grinding process parameters. Annals of Warsaw University of Life Sciences – SGGW, *Agriculture (Agricultural and Forest Engineering)* 67, 63–70.

Ozdemir, G., Sessiz, A., Esgici, R., Elicin, A.K. (2015). Cutting properties of wine grape cultivars. *Scientific Papers. Series B, Horticulture. Vol. LIX*, 151-158.

Pekitkan, F.G., Esgici, R., Elicin, A.K., Sessiz, A. (2018). The change of shear force and energy of cotton stalk depend on knife type and shear angle. Scientific Papers. *Series A. Agronomy, Vol. LXI,* No. 1, 360-366.

Persson, S. (1987). Mechanics of cutting plant material. *ASAE Publications*, St Joseph, MI, USA.

Prasad, J., Gupta, C.B. (1975). Mechanical properties of maize stalks as related to harvesting. *J Agric Eng Res*, vol. 20, 1975, no. 1, 79–87.

Romano E., Bonsignore R., Camillieri D., Caruso L., Conti A., Schillaci G., (2010). Evaluation of hand forces during manual vine branches cutting. *International Conference Ragusa SHWA*, September 16-18, 2010 Ragusa Ibla Campus- Italy. Work Safety and Risk Prevention in Agro-food and Forest Systems.

Sessiz, A., Elicin, A.K., Esgici, R., Ozdemir, G., Nozdrovický, L. (2013). Cutting Properties of Olive Sucker. *Acta Technologica Agriculturae. The Scientific Journal for Agricultural Engineering*, The Journal of Slovak University of Agriculture in Nitra. 16(3), 80–84.

Sessiz, A., E. Güzel., Y. Bayhan. (2018). Bazı Yerli ve Yabancı Üzüm Çeşitlerinde Sürgünlerin Kesme Kuvveti ve Enerjisinin Belirlenmesi. *Türk Tarım ve Doğa Bilimleri Dergisi (Turkish Journal of Agricultural and Natural Sciences).* 5(4), 414–423, doi.org/10.30910/turkjans.471203.

Suryanto, H., Ahmad, D., Yahya, A., Akande, F.B., Syahrita, K., (2009). Cutting tests of oil palm empty fruit bunches. *Transactions of the ASABE (American Society of Agricultural and Biological Engineers)* 52(3), 723-726.

Taghijarah, T., Ahmadi, H., Ghahderijani, M., Tavakoli, M. (2011). Shearing characteristics of sugar cane (Saccharum officinarum L.) stalks as a function of the rate of the applied force. *AJCS* 5(6), 630-634.

Voicu, G., Moiceanu, E., Sandu, M., Poenaru, I.C., Voicu, P. (2011). Experiments regarding mechanical behaviour of energetic plant Miscanthus to crushing and shear stress. *In Engineering for Rural Development*. Jelgava, 26.

Yiljep, Y., Mohammed, U. (2005). Effect of knife velocity on cutting energy and efficiency during impact cutting of sorghum stalk. Agricultural Engineering International: *The CIGR EJournal. Manuscript PM.* 05 004. Vol. VII. December, 2005.

Yore, M.W., Jenkins, B.M., Summers, M.D. (2002). Cutting Properties of Rice Straw. Paper Number: 026154.*ASAE Annual International Meeting / CIGR XVth World Congress.*

Zareiforoush, H., Mohtasebi, S.S., Tavakoli, H., Alizadeh, M.R. (2010). Effect of loading rate on mechanical properties of rice (Oryza sativa L.) straw. *Australian Journal of Crop Science*, 4(3), 190–195.