Effects of Knives Type, Cutting Angle and Loading Speed on Force and Energy Requirement of Grape Cane

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***Abstract*—Sire grape (*Vitis vinifera L*) variety is widely grown in Diyarbakir, Elazig and Mardin provinces, Southestern part of Turkey. In this study, cutting force and energy properties of canes of local Sire grape variety (Vitis vinifera L. cv.) was determined during the spring pruning in 2018. The canes of grapes were obtained from a commercial farm in the Diyarbakir province. Cutting properties were measured by The Lloyd LRX plus materials testing machine.**

According test results showed that the effect of knife types was found siginificiant statistically on cutting force and cutting energy. The best results were determined at serrated 1 knife type, followed by the flat knife and serrated 2. The lowest cutting force, cutting strength, cutting energy and specific cutting energy values were obtained at Serrated Type 1 (knife-edge thin) as 346.4 N and 6.887 MPa, 2.398 J and 0.04771 J mm^{-2}, respectively. The highest values of cutting force, cutting strength, cutting energy and specific cutting energy were obtained from the serrated 2 type knife. The cutting force and cutting energy gradually decreased with increase knife-cutting angle from 0° to 40° for sire varierty. The cutting force, cutting strength, cutting energy and specific cutting energy increased with increasing knife-cutting angle from 1 mm s^{-1} to 5 mm s^{-1}. The lowest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 1 mm s^{-1} loading speed as 340.8 N, 6.777 MPa, 2.430 J and 0.04831 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 5 mm s^{-1} knife loading speed as 370.8 N, 7.375 MPa, 3.712 J and 0.07384 J mm^{-2} respectively.

Keywords*—*Cutting strength, grapevine, pruning machine design

I. INTRODUCTION

Turkey is sixth largest grape producer of worldwide with an estimated production of 4 million tons in 550,000 ha production area in 2016. It is the biggest exporter of raisin grapes. Each year over 200,000 tons golden coloured raisins is exported all over the world. The grape export is 170,000 tons valued at 133 million $ [1]. Also 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. The global production of table grapes reached 22.7 million tons in 2017 [2]. Grapes are the most widely grown commercial fruit crop in the world, and also one of the most popular fruit crops for horticultural production. Grape growers constantly search the ways in order to maximize their profits all over the world [3,4]. 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. Pruning process is an important part of vineyard cultivation. Production costs and power requirement are very high and labor efficiency is lower than the other operations. Labor requirement, time-consumption and production costs can be decreased by utilizing a mechanical pruner and grape harvester [5,6]. For a suitable pruning shear, we need to determine the cutting characteristics of the grape cane is required.

The cutting properties and energy requirement depend on the species, variety, diameter, maturity, moisture content, cellular structure and the type of cutting blade used [7-9]. 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 [10].

Usually, flat-mouthed scissors are used in pruning operations in Turkey's vinyards. The same scissors are used for all types of vine. 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.

The objectives of this study were to determine the effect of the knife type, knife edge angles and cutting speed on cane cutting force, cutting strength and energy requirement for local Sire grape variety.

II. MATERIALS AND METHODS

This study was carried out using Sire (*Vitis vinifera L*) local grapes varieties canes (Fig. 1). The test amples were obtained from a commercial vineyard 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 during grape pruning season in 2018 year.

Fig. 1. *View of Sire local grapes varieties canes.*

The average diameters of the cane internodes (between two nodes of sire variety were determined as 8.00 mm. The ranges of internode diameter of the canes (mm) were converted to cross-section area in 50.24 mm^2 for Sire variety. The cane diameters were measured before the test using a caliper. The initial moisture content of canes was determined according to ASABE standard [11] by way of oven-drying 50 g of each sample at 105 °C for 24 h. The average moisture content levels of cane internodes were determined for each variety during the tests separately. The moisture content was determined as 33.8 % w.b.

Lloyd LRX Plus 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 (knife-edge flat) with five knife edge angles (0°, 10°, 20°, 30° and 40°) and five different loading speeds (1, 2, 3, 4 and 5 mm s^{-1}).

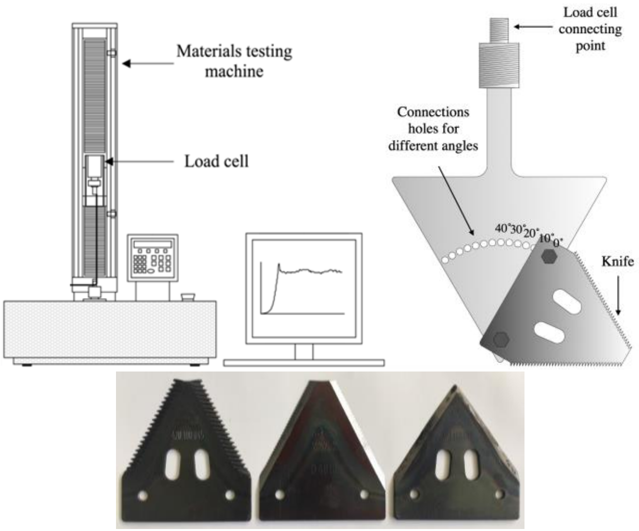

Fig. 2. *The Lloyd LRX Plus Materials Testing Machine and cutting blade.*

The peak cutting strength, obtained from the cutting force findings, was determined via the following equation [9,12-16]:

$$\sigma s = \frac{F}{A} \quad (1)$$

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 (mm^2).

The cutting energy was calculated by measuring the surface area under the force-deformation curve via material testing machine [6,8,10,15,17-27]. A computer data acquisition system recorded all force-displacement curves during the cutting process.

Specific cutting energy, E_{sc} was calculated by:

$$Esc = \frac{Ec}{A} \quad (2)$$

Where: Esc is the specific cutting energy (J mm^{-2}) and E_c 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 MSAT-C software.

III. Results and Discussion

The effect of knife type on cutting force, cutting strength, cutting energy and specific cutting energy are presented in Table 1. According to results of ANOVA tests, the effect of knife type on cutting and energy properties were found significant at 1 % probability level. As can be seen from the Table 1, Duncan test results showed that no the significant differences were found between knife types at 1 % probability level, especiallay, between the serrated knives types. However, the effect of knife types was found siginificant statistically on cutting force and cutting energy. The best results were determined at serrated 1 knife type, followed by the flat knife and serrated 2. The lowest cutting force, cutting strength, cutting energy and specific cutting energy values were obtained at Serrated Type 1 (knife-edge thin) as 346.4 N and 6.887 MPa, 2.398 J and 0.04771 J mm^{-2}, respectively. The highest values of cutting force, cutting strength, cutting energy and specific cutting energy were obtained from the serrated 2 type knife. According these results, although serrated 1 knife type is more suitable than the other knife types and we can recommend the all type knife for a new shears and pruner for Sire grape variety of cane pruning. These results are nevertheless in agreement with [7] and [28] who reported significant differences in total cutting energy for a pyrethrum stem between a smooth and serrated blade. The similar results were observed by [7]. [7] reviewed several studies on the cutting speed and concluded that cutting power is only slightly affected by cutting speed, although an increase in cutting speed will often increase the power losses caused by material acceleration. According to [7], a serrated blade edge gives a higher cutting force and requires more cutting energy than a smooth edge. In comparison to the knife with the smooth blade edge, the serrated edge had a higher value of Fmax, although these trends were not statistically significant. [29], four different types (serreted and smooth) of blades has been used in tests for hemp stalk cutting.

The best tests results showed the serrated edge blade with cutting speed of 1.17 m/s.

The effect of knife cutting angle are shown in Table 1. As shown in the Table 1, 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 and cutting energy gradually decreased with increase knife-cutting angle from 0° to 40°. Also, according to results of variance analysis, the effect of interactions of factors were found significant ($p<0.01$) on cutting force, cutting strength, cutting energy and specific cutting energy. The most significant effect was found among 0° cutting angle to other cutting angles. However, there was no significant difference among means for 20°, 30° and 40° at the probability level of 1 % and 5 %. The maximum cutting force, cutting strength, cutting energy and specific cutting energy were observed at 0° cutting angle as 449.9 N, 8.849 MPa, 3.771 N and 0.07498 Jmm^{-2} respectively. The lowest values were obtained at 20°, 30° and 40° cutting angle. There were not found significant different statistically among these cutting angle. The similar results were observed by [14]. They argued that 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 predicting the power requirements [16,25,26]. [30] reported that the optimum knife bevel angle value for cutting of corn stalk was 23°. According to [31], the knife edge angle has a significant effect on the cutting force and energy. [32] also reported that besides the cutting edge, knife edge sharpness and knife speed are effect on cutting properties of plants. Based on our results, we can prefer knife edge angle between 20° - 40° for cutting and pruning of the grape cane of Sire variety.

The change of cutting forces, cutting strength, cutting energy and specific cutting energy depend on knife loading speed are shown in Table 1. As shown in table, the effect of the knife loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant ($p<0.01$). The cutting force, cutting strength, cutting energy and specific cutting energy increased with increasing knife-cutting angle from 1 mms^{-1} to 5 mms^{-1}. The lowest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 1 mms^{-1} loading speed as 340.8 N, 6.777 MPa, 2.430 J and 0.04831 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 5 mms^{-1} knife loading speed as 370.8 N, 7.375 MPa, 3.712 J and 0.07384 J mm^{-2} respectively.

TABLE I. THE CUTTING PROPERTIES AND ENERGY VALUES OF SIRE GRAPE VARIETY

	Sire			
Knife Type	**Cutting Force (N)**	**Cutting Strength (MPa)**	**Cutting Energy (J)**	**Specific Cutting Energy (Jmm^{-2})**
Serrated type 1 (knife-edge thick)	346.4 a*	6.884 b	2.398 c	0.04771 b
Serrated type 2 (knife-edge thin)	368.5 a	7.320 a	3.678 a	0.05672 b
Flat type (knife-edge flat)	355.8 ab	7.077 ab	2.853 b	0.07311 a
Mean	**357.50**	**7.094**	**2.976**	**0.059**
LSD	**15.10**	**0.3003**	**0.2892**	**0.01020**
Knife cutting angle (◦)				
0	449.9 a	8.849 a	3.771 a	0.07498 a
10	369.0 b	7.338 b	2.974 b	0.04927 b
20	328.4 c	6.531 c	2.950 b	0.05389 b
30	323.2 c	6.429 c	2.712 bc	0.05862 b
40	317.0 c	6.322 c	2.417 c	0.05913 b
Mean	**357.50**	**7.094**	**2.976**	**0.059**
LSD	**19.49**	**0.3877**	**0.3733**	**0.01317**
Loading speed, mm/s				
1	340.8 b	6.777 b	2.430 c	0.04831 b
2	344.7 b	6.856 b	2.729 bc	0.05429 b
3	360.4 ab	7.168 ab	2.900 b	0.05762 b
4	366.6 a	7.292 a	3.111 b	0.06182 ab
5	370.8 a	7.375 a	3.712 a	0.07384 a
Mean	**357.50**	**7.094**	**2.976**	**0.059**
LSD	**19.49**	**0.3003**	**0.3733**	**0.01317**

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

IV. CONCLUSIONS

The effect of knife types was found siginificiant statistically on cutting force and cutting energy for Sire vairety. The best results were determined at serrated 1 knife type, followed by the flat knife and serrated 2. The lowest cutting force, cutting strength, cutting energy and specific cutting energy values were obtained at Serrated Type 1 (knife-edge thin) as 346.4 N and 6.887 MPa, 2.398 J and 0.04771 J mm^{-2}, respectively. The highest values of cutting force, cutting strength, cutting energy and specific cutting energy were obtained from the serrated 2 type knife. The cutting force and cutting energy gradually decreased with increase knife-cutting angle from 0° to 40° for sire varierty. The cutting force, cutting strength, cutting energy and specific cutting energy increased with increasing knife-cutting angle from 1 mm s^{-1} to 5 mm s^{-1}. The lowest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 1 mm s^{-1} loading speed as 340.8 N, 6.777 MPa, 2.430 J and 0.04831 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained 5 mm s^{-1} knife loading speed as 370.8 N, 7.375 MPa, 3.712 J and 0.07384 J mm^{-2} respectively.

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REFERENCES

[1] Anonymous, "Turkish Statistical Institute Agriculture Databases," 2016. http://www.turkstat.gov.tr/PreTabloArama.do?metod =search&araType=vt

[2] E. Anastasiou, A. Balafoutis, N. Darra, V. Psiroukis, A. Biniari, G. Xanthopoulos, S. Fountas, "Satellite and proximal sensing to estimate the yield and quality of table grapes". Agriculture, 8, 94, 2018

[3] G. Ozdemir, A. Sessiz, F.G. Pekitkan., "Precision viticulture tools to production of high quality grapes," Scientific Papers. Series B, Horticulture, Vol. LXI, 2017.

[4] G. Ozdemir, A. Sessiz, R. Esgici, "Some maturity properties of Okuzgozu (Vitis Vinifera L. CV.) grape berries," Fresenius Environmental Bulletin, Volume 28, No:10, pp 6261-6265, 2017.

[5] J.R. Morris, "Past, present, and future of vineyard mechanization," Proceeding ASEV 50 the Anniv. Ann. Mtg. Seatle, WA, 51, pp 155-164, 2000.

[6] A. Sessiz, R. Esgici, G. Ozdemir, A.K. Elicin, F.G. Pekitkan, "Cutting properties of different grape varieties," Agriculture & Forestry, 6(1), pp 211-216, 2015.

[7] S. Persson, "Mechanics of cutting plant material," ASAE Publications, 1987, St Joseph, MI, USA.

[8] A.H. Amer Eissa, A.H. Gomaa, M.H. Baiomay, A.A. Ibrahim, "Physical and mechanical characteristics for some agricultural residues," In Misr J Ag Eng, 25(1), pp 121–146, 2008.

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

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

[11] Asabe Standarts, "S358.2: 1:1 Measurement Forages," 52nd edn. American Society of Agricultural Engineers, St Joseph MI, 2006.

[12] N.N. Mohsenin, "Physical properties of plant and animals materials," 2nd edition, New York, NY: Gordon and Breach Science Publishers, 1986.

[13] C. Igathinathane, A.R. Womac, S. Sokhansanj, "Corn stalk orientation effect on mechanical cutting," Systems engineering, 107, pp 97-106, 2010.

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

[15] A. Sessiz, A.K. Elicin, R. Esgici, G. Ozdemir, L. Nozdrovický, "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), pp 80–84, 2013.

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

[17] D.M.R. Georget, A.C. Smith, K.W. Waldron, "Effect of ripening on the mechanical properties of Portuguese and Spanish varieties of olive (*Olea europaea* L)," Journal of the Science of Food and Agriculture J. Sci. Food. Agric. 81, pp 448-454, 2001.

[18] M.W. Yore, B.M. Jenkins, M.D. Summers, "Cutting properties of rice straw," Paper Number: 026154, ASAE Annual International Meeting / CIGR XVth World Congress, 2002.

[19] Y. Chen, J.L. Gratton, J. Liu, "Power requirements of hemp cutting and conditioning," Biosystems Engineering, 87(4), pp 417–424, 2004.

[20] H. Kocabiyik, B. Kayisoglu, "Determination of shearing features of sunflower stalk," In J Agric Sci, vol. 10, no. 3, pp. 263–267, 2004.

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

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

[23] A. Heidari, G.R. Chegini, "Determining the shear strength and picking force of rose flower," Agricultural Engineering. Ejpau 14(2), 13, 2011.

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

[25] G. Ozdemir, A. Sessiz, R. Esgici, A.K. Elicin, "Cutting properties of wine grape cultivars," Scientific Papers. Series B, Horticulture. Vol. LIX, pp 151-158, 2015.

[26] T. Nowakowski, "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, pp 63–70, 2016.

[27] F.G. Pekitkan, R. Esgici, A.K. Elicin, A. Sessiz, “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, pp. 360-366, 2018.

[28] J. Khazaei, H. Rabani, A. Ebadi, F. Golbabaei, “Determining the shear strength and picking force of pyrethrum flower,” AIC Paper No. 02-221, 2002.

[29] H. Jicheng, S. Cheng, L. Xianwang, T. Kunpeng, C. Qiaomin, Z. Bin, “Design and tests of hemp harvester,” International Agricultural Engineering Journal Vol. 26, No. 2 pp: 117-122, 2017.

[30] J. Prasad, C.B. Gupta, “Mechanical properties of maize stalks as related to harvesting,” J Agric Eng Res, vol. 20, no. 1, pp. 79–87, 1975.

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

[32] A. Dowgiallo, “Cutting force of fibrous materials,” Journal of Food Engineering 66(1), pp 57-61, 2005.