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Research Article

Effect of Various Knife Type, Cutting Angle and Speed on Cutting Force and Energy of Grape Cane

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Abstract

In this study, some cutting and energy properties of canes of local grapes varieties Okuzgozu (Vitis vinifera L. cv.) were determined depend on knife type, cutting angle and cutting speed 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 a material testing machine. According to test results, the significant differences were found between the knives types at 1 % probability level. The best results were determined at the flat knife knife type, followed by serrated 2 and serrated 1, respectively. While the lowest cutting force and cutting strength values were obtained at flat type (knife edge flat) as 234.50 N, 8.299 MPa, 1.783 J and 0.06307 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained at serrated type 1 (knife edge thin) knife as 303.8 N, 10.75 MPa, 2.136 J and 0.075610 J mm^{-2} respectively. The cutting force and energy values 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 319.3 N, 11.30 MPa, 2.393 N and 0.08464 J mm^{-2} respectively. The effect of the knife loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant statistically ($p<0.01$). The lowest cutting force, cutting strength, cutting energy and specific cutting energy were obtained at the 1 m s^{-1} as 246.1 N, 8.705 MPa, 1.273 J and 0.04502 J mm^{-1}, respectively.

Keywords: Grape cane, Cutting force, Cutting energy, Pruning.

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1. Introduction

Pruning and harvesting operations are the most critical stages in the management of the vineyards. 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 by worker with scissors in viticulture. Also, the same scissors are used for all types of vine. We konow that 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. Usually, flat-mouthed scissors are used and this method of conventional pruning process is difficult and tiring. Therefore, production costs and crop losses are very high, power requirements are high and labor efficiency is low. Moreover, Labor requirement, time-consumption and production costs can be decreased by utilizing a mechanical pruner and grape harvester (Morris, 2000; Sessiz et al. 2015).

For the design and manufacture of a new pruning shears and machines, it is necessary to know the require force and energy values of grape canes. The cutting properties and energy requirement depend on the species, variety, diameter, maturity, moisture content, cellular structure and the type of cutting blade used (Persson, 1987; Ammer Eissa et al. 2008; 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 and physical properties of agricultural products and biological materials such as fruits, grains and seeds. However, it was observed that the results of published studies were not related directly with the cutting properties of grape internodes of canes and their relations (Ozdemir et al., 2017a; Esgici et al., 2017). Romano et al. (2010) determined the cutting force for certain vine branches such as Cabernet Sauvignon and Chardonnay at different regions in Italy. Sessiz et al. (2015) determined the cutting properties for some grape varieties in Turkey. Some physical properties of the Rasa grape were determined by Khodaei and Akhijahani (2012). Cutting properties of some wine grape cultivars were determined by Ozdemir et al. (2015). Similar results were reported by Yore et al. (2002) for rice straw, by Kronsberg et al. (2011) for hemp stalk, by Alizadeh et al. (2011) for rice stem, by Ghahraei et al. (2011) for kenaf stems, by Sessiz et al. (2013) for olive sucker, by Ozdemir et al. (2015) for grape sucker, by Sessiz et al. (2015) for cane of some different grape variety, by Pekitkan et al. (2018) for cotton stalk.

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 Okuzgozu grape variety.

2. Materials and Methods

This study was carried out using Okuzgozu local grape variety canes (Figure 1). The test materilas were obtained from a commercial vineyard at the Diyarbakir province located in south-eastern part of Turkey. The cut and collected grapevine canes from vineyard (Figure 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.

Figure 1. Okuzgozu local grapes variety canes.

The canes with an average diameter of 6 mm were used as test material. The ranges of internode diameter of the canes (mm) were converted to cross-section area in 28.26 mm^2 for Okuzgozu grape variety. 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, 2008) by way of oven-drying 50 g of each sample at 105°C for 24 h. The moisture content was determined as 37.80 % w.b.

An Universal Testing Machine was used to measure cutting force and energy requiremnt of canes (Figure 2). The cane samples were placed on the machine loading table in a flat position during the tests. Loading was applied vertical direction. 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}).

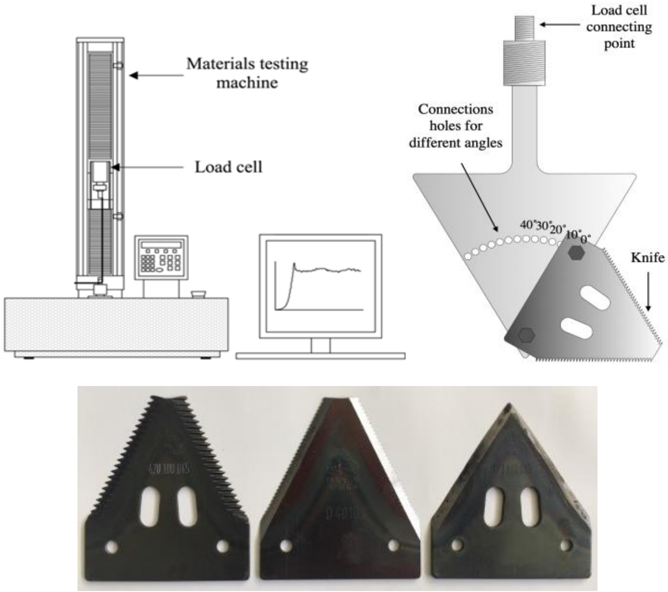

Figure 2. The Lloyd LRX Plus Materials Testing Machine and cutting blade.

The maximum cutting force, cutting strength, cutting energy and specific cutting energy were determined depend on type of knife, knife cutting angle and loading speed. The peak cutting strength, obtained from the cutting force findings, was determined by the following equation (Mohsenin, 1986; Sessiz et al., 2013):

$$\sigma s=Fmax/A \quad (1)$$

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 (Georget et al., 2001; Yore et al., 2002; Chen et al., 2004; Kocabiyik and Kayisoglu, 2004; Amer Eissa et al., 2008; Ekinci et al., 2010; Zareiforoush et al., 2010; Ghahraei et al., 2011; Heidari and Chegini, 2011; Voicu et al., 2011; Sessiz et al., 2013; Sessiz et al., 2015; Nowakowski, 2016; Ozdemir et al., 2017b; Pekitkan et al., 2018). A computer data acquisition system recorded all force-displacement curves during the cutting process.

Specific cutting energy, Esc was calculated by:

$$Esc=Ec/A \quad (2)$$

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.

3. Results and Discussion

The results of the cutting test showed that the significant differences were found between the serrated knife types and flate type at 1 % probability level (Table 1). However, there were not found significant differences between the serrated type 1 and serrated type 2 knives. As can be seen from the Table 1, the best results were determined at the flat knife knife type, followed by serrated 2 and serrated 1, respectively. While the lowest cutting force and cutting strength values were obtained at flat type (knife edge flat) as 234.50 N, 8.299 MPa, 1.783 J and 0.06307 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained at serrated type 1 (knife edge thin) knife as 303.8 N, 10.75 MPa, 2.136 J and 0.075610 J mm^{-2} respectively. According these results, the flat type knife is suitable than the serrated type knives for cutting and pruning of Okuzgozu grape cane. When we compared the knife types and we can recommend that the flat type than serrated type knife for a new design of cutting machine and pruning for the cane of Okuzgozu grape variety.

The effect of knife cutting angle on cutting force, cutting strength, cutting energy and specific cutting energy are shown in Table 1. As shown in the table, the cutting angle has been 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°. 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 between 0° and 10° cutting angle to other cutting angle (20°, 30° and 40°). 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 319.3 N, 11.30 MPa, 2.393 N and 0.08464 J mm^{-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. However, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained at 40° cutting angle as 249.0 N, 8.810 MPa, 1.677 J and 0.05940 J mm^{-2} respectively. The main values 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 main effect of the knife loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant statistically ($p<0.01$). The 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 cutting force, cutting strength, cutting energy and specific cutting energy were obtained at the 1 m s^{-1} as 246.1 N, 8.705 MPa, 1.273 J and 0.04502 J mm^{-1} respectively. However, there were not found significant differences among the 2, 3, 4 and 5 mm s^{-1}. Similar results were obtained by Chandio et al. (2013) for rice stem. According to this study, cutting force increased with increasing the load speed, and the shear energy did not change with knife loading speed. Khazaei et al. (2002) reported that by increasing the cutting speed from 20 to 500 mm min^{-1}, the shearing strength and the shearing energy decrased for flower stems. Zareiforoush et al. (2010) have been examined the effect of loading rate on mechanical properties of rice (Oryza sativa L.) straw. They reported that the effect of loading was not significant effect on cutting strength and cutting energy of rice straw. Similar results were obtained by Kusińska and Starek (2012). They have been used variable parameters such as knife sharpening angle (2.5°; 7.5°; 12.5° and 17.5°) and velocity of its movement (0.83 mm s^{-1}, 1.66 mm s^{-1}, 2.49 mm s^{-1}, 4.15 and 10 mm s^{-1}) in experiments. Their test results proved significant dependence of the maximum cutting force value on changes of mechanical properties of tissues in relation to the place of collecting samples, the knife sharpening angle and its movement. The highest value of force was obtained during cutting with a knife of the sharpening angle of 17.5° and the lowest during the use of a knife with 2.5°. Along with the increase of the knife movement velocity, the cutting force decreased. The best quality of samples was obtained with the use of the velocity which was 2.49 mm s^{-1} and 4.15 mm s^{-1} with knives with the cutting angle of 2.5° and 7.5°. According to Igathinathane et al. (2010), searing energy is depending on used knives, shear bars, and linear knife grids with ram. Dange et al. (2011) have determined cutting energy and force for Pigeon pea stems. They consider blade type, sharpened at 30° and 45° bevel angle were selected for the experiment. Mathanker et al. (2015) conducted a study that the effect of blade oblique angle and cutting speed on cutting energy for energycane stems. The results showed that the specific cutting energy increases with cutting speed. The lowest average specific energy was 0.26 J mm^{-1} for a 60° oblique cut at an average cutting speed of 7.9 m s^{-1}, whereas the highest average specific cutting energy was 1.24 J mm^{-1} for a straight cut at an average cutting speed of 16.4 m s^{-1}. The effect of cutting velocity, diameter of stalks and types of blades on cutting energy, cutting force and specific energy for chickpea stalks were studied by Sushilendra et al. (2016). Jasim et al. (2017) have been investigated that the effect of knives type on some operational characteristics for a locally assembly motorized vibration cutter used for date palm fronds pruning. Singh et al. (2016a) conducted a study on the effect of varying knife speed and contact area on peak cutting force during slicing of peeled potato (Solanum tuberosum). In terms of product type and physical and mechanical properties of stem in crops, the estimation of harvesting energy in agricultural products can be completely different (Yiljep and Mohammed, 2005). Gan et al. (2018) reported that the designs of cutting blade is effect on energy consumption during mowing-conditioning of Miscanthus Giganteus. Azadbakht et al. (2015) were conducted a study energy consumption during impact cutting of canola stalk as a function of moisture content and cutting height. The tests results showed the effect of height and moisture content on cutting energy is significant (P<1%), The minimum cutting energy was obsorved 0.76 kJ in 11.6 (w.b.%) moisture content, 30 cm cutting height and 2.64 m/s balde cutting velocity. According to Singh et al. (2016b), the effective edge angle is 15° for cutting vegetables. Similar were conducted by Allameh and Alizadeh (2016) on the specific cutting energy for rice stem. The results revealed that rice cultivar and blade velocity had significant effects (P<0.01) on the specific cutting energy. When blade velocity increased from 1.5 m s–1 to 2.5 m s–1, specific cutting energy raised about 77 %. Blade cutting and bevel angles were not solely influential on the specific cutting energy but they interacted with rice cultivar and impacted it. Nandede et al. (2017) an investigation was conducted to study the effect of blade type, moisture content (MC) and diameter of the sorghum stalk and earhead on cutting energy as required for design of critical cutting component of sorghum harvester.

Table 1. The cahnge of cutting and energy properties depend on knife type, cutting angle and cutting speed.

Okuzgozu				
Knife type	Cutting Force (N)	Cutting Strength (MPa)	Cutting Energy (J)	Specific Cutting Energy (J mm^{-2})
Serrated type 1 (knife-edge thick)	303.8 a*	10.75 a	2.136 a	0.07561 a
Serrated type 2 (knife-edge thin)	294.9 a	10.44 a	1.988 ab	0.07039 ab
Flat type (knife-edge flat)	234.50 b	8.299 b	1.783 b	0.06307 b
Mean	**277.73**	**9.83**	**1.969**	**0.06969**
LSD	**12.49**	**0.442**	**0.222**	**0.0102**
Knife cutting angle (◦)				
0	319.3 a	11.30 a	2.393 a	0.08464 a
10	311.5 a	11.07 a	2.147 a	0.07596 ab
20	256.1 b	9.063 b	1.834 b	0.06496 bc
30	252.2 b	8.913 b	1.794 b	0.06349 bc

40	249.0 b	8.810 b	1.677 b	0.05940 c
Mean	**277.73**	**9.83**	**1.969**	**0.06969**
LSD	**16.13**	**0.5706**	**0.2877**	**0.01317**
Loading speed, mm/s				
1	246.1 b	8.705 b	1.273 c	0.04502 c
2	288.8 a	10.24 a	1.884 b	0.06667 b
3	285.8 a	10.05 a	2.094 ab	0.07413 a
4	284.1 a	10.12 a	2.283 a	0.08073 a
5	283.8 a	10.22 a	2.312 a	0.08189 a
Mean	**277.73**	**9.83**	**1.969**	**0.06969**
LSD	**16.13**	**0.5706**	**0.2877**	**0.01317**

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

4. Conclusions

The significant differences were found between the knives types at 1 % probability level. The best results were determined at the flat knife knife type, followed by serrated 2 and serrated 1, respectively. While the lowest cutting force and cutting strength values were obtained at flat type (knife edge flat) as 234.50 N, 8.299 MPa, 1.783 J and 0.06307 J mm^{-2} respectively, the highest values cutting forces, cutting strength, cutting energy and specific cutting energy were obtained at serrated type 1 (knife edge thin) knife as 303.8 N, 10.75 MPa, 2.136 J and 0.075610 J mm^{-2} respectively.

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The effect of the knife loading speed on the cutting forces, cutting strength, cutting energy and specific cutting energy were found significant statistically ($p<0.01$). The lowest cutting force, cutting strength, cutting energy and specific cutting energy were obtained at the 1 m s^{-1} as 246.1 N, 8.705 MPa, 1.273 J and 0.04502 J mm^{-1} respectively.

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