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CUTTING PROPERTIES OF WINE GRAPE CULTIVARS

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Abstract

This study was carried out to determine the cutting properties of different wine grape canes as a function of moisture content, canes' diameter and variety. 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 mean 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 variety were 1397.60 N, 21.68 MPa and 3.68 J, respectively. The minimum cutting force, cutting strength and cutting energy were obtained at 'Tannat' grape variety and it was 981.65 N, 13.94 MPa, and 2.39 J, respectively. Whereas, the maximum specific cutting energy obtained at 'Chardonnay' was 0.256 Jmm-2, while the minimum specific cutting energy obtained at 'Tannat' grape variety was 0.219 Jmm^{-2}. In conclusion, findings demonstrated that the cutting properties were related to the physiological, physical and mechanical properties of the grape branches. Therefore, the grape variety should be taken into account for the design of a suitable pruner machine.

Key words: *Grapevine, Cutting, Energy, Force, Strength.*

INTRODUCTION

Winter pruning is one of the critical points in the management of a vineyard especially, in small farms, where the winter pruning is predominantly performed manually. Pruning with hand-powered pruning shears increases the risk of musculoskeletal disorders of hand and wrist disorders (Roquelaure, et al., 2004). However, with the increasing scarcity of manual labor for vineyard pruning operations, mechanized vine pruning has received much attention. In the late 1960s, grape producers indicated that once mechanical harvesting was totally implemented, the most time-consuming manual operations remained in the vineyard were pruning and tying. Grape producers complained for decreasing availability of qualified labor for pruning and tying and indicated that these should be the next operations mechanized. Utilization of a mechanical pruner could lower the manual labor necessary for the operation (Morris, 2000).

Vineyard mechanization greatly reduces manual labor in the vineyard. Today, pruner machines are used in vineyards in certain countries dominant in grape production. However, in our country, the pruning operations are completely accomplished via manual labor and also, there is no reliable information on grape cutting properties, a prerequisite for appropriate machine designs. But we know that the physical and mechanical properties of products depend on the species, variety, stalk diameter, maturity, moisture content, and cellular structure of the grape (Persson, 1987; Nazari Galedar, et al., 2008). The variation in the physical properties of plant stalks and the resistance of cutting equipment have to be identified in order to understand the behavior of material with respect to different operational conditions. Several plant factors influence the cutting force and energy, such as the fiber ultimate tensile strength, the fiber stiffness, and stem structure (Persson, 1987; Ghahraei, et al., 2011). Knowing those properties will be useful for both manufacturers and consumers of food processing equipment. Especially, information on plant properties and the power or energy requirements of an equipment would be very valuable for selecting design and operational parameters (Persson, 1987; Emadi, et al., 2004; Voicu, et all., 2011; Ghahraei, et al. 2011; Hoseinzadeh and Shirneshan, 2012). Perhaps, the stem of plants' cutting energy is one of the main parameters for optimizing the design of cutting elements in harvesting and pruning machines. Therefore, comparative performance of cutting elements applied in harvester and pruning machine designs could be judged by their cutting energy requirements, cutting force and stress applied (Alizadeh, et al., 2011).

A review of the literature revealed no information on direct cutting properties of cutting grape canes. However, many researchers have studied on energy consumption during the cutting process of different plants and have collected invaluable data, which might provide valuable aid for agricultural machinery manufacturers.

Chen, et al. (2004) performed a study about power requirements of hemp stem cutting properties and conditioning. The maximum hemp cutting force requirement was found to be 243 N and its energy requirement was obtained as 2.1 J. Some studies about cutting energy requirements have been conducted on soybean stalks (Mesquita and Hanna, 1995). Romano, et al. (2010) determined cutting force for certain vine branches such as Cabernet, Sauvignon and Chardonnay in different regions in Italy. The tests were conducted in the laboratory and the results were processed to show if the manual forces dispensed during cutting were a function of diameters and cultivated varieties. Heidari and Chegini, (2011) conducted studies on rose flower. They found that the average values of shear strength and energy per unit were estimated at 1.63 MPa and 5.16 $mJmm^{-2}$, respectively. Tekin, et al. (2012) evaluated the performances of two different machines used for pruning in viticulture in the Aegean region of Turkey. They found that local pruning machines provided higher performance as compared to imported machinery.

Also, similar studies have been conducted on sunflower stalk (Ince, et al., 2005), alfalfa (Nazari Galedar, et al., 2008), wheat (Hoseinzadeh, et al., 2009; Esehaghbeygi, et al., 2009; Tavakoli, et al., (2009a), barley straw (Tavakoli, et al., 2009b), rice straw (Zareiforoush, et al., 2010), cumin stem (Mahmoodi, et al., 2010), hemp (Kronbergs, et al., 2011; Kakitis, et al., 2012), sugar cane (Taghijarah, et al., 2011), kenaf stems (Ghahraei, et al., 2011).

These studies showed that the cutting energy is related to cutting force, cutting strength, stem diameter and moisture content. Therefore, this information is very important for suitable design of grape pruning knifes, pruning machines and harvesters for efficient energy use.

The main objectives of this study were to determine certain engineering properties such as cutting force, cutting strength, cutting power, and specific cutting energy requirements for eight different wine grape canes.

MATERIALS AND METHODS

Sample preparation and measuring apparatus

The study was carried out in the Agricultural Machinery Department, Faculty of Agriculture, Dicle University in Diyarbakir province, southeastern Turkey. Eight different wine grape varieties, namely Tannat, Merlot, Cot, Chardonnay, Viognier, Cabernet Sauvignon, Shiraz, and Cabernet Franc were selected to determine cutting properties in the experiment. To conduct the cutting test, the samples were collected from Mesopotamia (commercial farm) Vineyard (Figure 1) in Diyarbakır province and experiment tests were performed during the grape pruning season of the year 2012.

Figure 1. Experimental vineyard.

In order to determine the initial moisture content of grape canes, three samples of 30 g were weighed and dried in an oven of 105°C for 24 hours, and then reweighed to measure the moisture content using the gravimetrical method. The weights were measured using electronic scales with a capacity of 1.2 kg and with a precision of 0.01 g. The moisture content levels were determined at 35.4%, 42.4% and 46.0 % w.b. The results were evaluated according to these moisture content values.

Determination of cutting properties

The Lloyd LRX Plus biological materials testing instrument (Figure 2.) was used to measure the cutting force and the cutting energy. The cutting speed was constant at 100 mm*min^{-1}, for all tests.

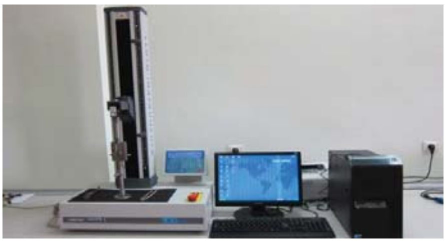

Figure 2. Instron universal test instrument.

The cutting force was measured by a double shearing apparatus (Mohsenin, 1982) (Figure 3). The shearing device was fabricated from steel. A series of holes with different diameters ranging from 4 mm to 10 mm were drilled. Before the experiment, the grape samples were divided into four different groups based on their diameter tanging from 4 mm to 10 mm (4, 6, 8, 10 mm) (Figure 4). The branch cutting diameters were measured before the test using a caliper. Testing was completed as rapidly as possible in order to reduce the effects of drying. All the required measurements for each variety were performed on the same day.

Figure 3. Shearing apparatus.

Figure 4. The grape samples.

Maximum shearing strength, obtained from the cutting force findings, was determined by the following equation (Mohsenin, 1980; Beyhan, 1998; Sessiz, 2005; Amer Eissa, et al., 2008; Tavakoli, et al., 2009b; Zareiforoush, et al., 2010):

$$S\sigma = \frac{\mathrm{Fma}}{2\mathrm{A}}$$

Where: σs is the maximum cutting strength in (MPa), F_{max} 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 cutting force-deformation curve (Chen, et al., 2004; Nazari Galedar, et al., 2008; Zareiforoush, et al., 2010; Heidar and Chegini, 2011). The cutting energy and displacement was calculated by Instron universal testing instrument. A computer data acquisition system recorded all the force-displacement curves during the cutting process. A typical force-deformation curve is given in Fig. 5.

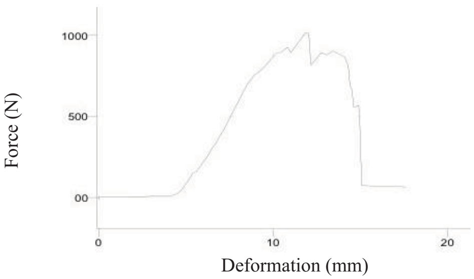

Figure 5. Typical force-deformation curve.

Using the cutting energy data, a specific cutting energy was determined using the following equation (Taghijarah, et al., 2011; Heidar and Chegini, 2011):

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

Esc: Specific cutting energy, J/mm^2
Ec: Cutting energy, J
A: Cross-section area, mm^2

Statistical analysis

The experimental results were tested using standard variance analysis (ANOVA) for the randomized complete block design. Cutting properties were determined with 3 replications in each treatment of the branches. Mean separations were made for significant relations using LSD and the means were compared at the 1% and 5% levels of significance using the Tukey multiple range tests in JAMP software.

RESULTS AND DISCUSSIONS

The relationship between grape variety and cutting properties are presented in Figures 6,7,8,9. The results displayed in the Figures indicated that there is a significant difference between Cabernet Franc and the rest of the varieties in terms of cutting force, cutting strength, cutting energy and specific cutting energy requirements at a probability level of % 5. The cutting force and energy requirement varied from variety to variety. The maximum cutting force, cutting strength and cutting energy obtained at Cabernet Franc grape variety were 1397.60 N, 21.68 MPa and 3.68 J, respectively. Followed by the varieties Shiraz, Cabernet Sauvignon, Viognar, Chardonnay, Cot, Merlot and Tannat, respectively. The minimum cutting force, cutting strength and cutting energy obtained for Tannat grape variety were 981.65 N, 13.94 MPa, and 2.39 J, respectively. The maximum specific cutting energy obtained for Chardonnay was 0.256 Jmm^{-2}, while the minimum specific cutting energy obtained for Tannat grape variety was 0.219 Jmm^{-2} (Fig. 9). There were big differences among varieties in terms of cutting force, cutting strength and cutting energy.
This variance was due to different physiological, physical and mechanical properties of grape varieties (Esehaghbeygi, et al., 2009; Hoseinzadeh and Shirneshan, 2012). However, there were no significant differences between

varieties in terms of the specific energy requirement. All varieties showed similar properties, except for Tannat, Merlot and Viognier grape varieties, where there was no significant difference between those and the rest of the varieties statistically.

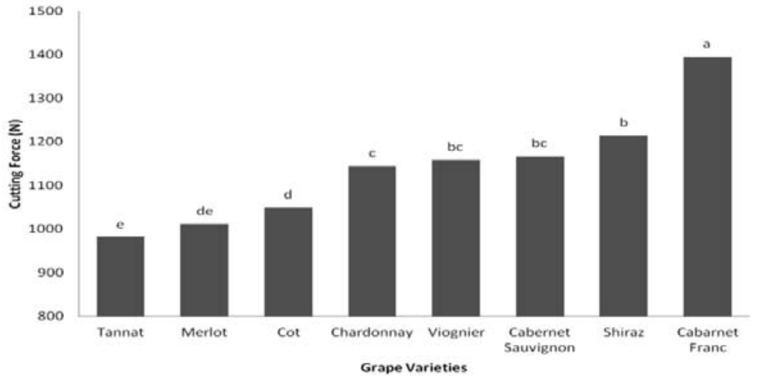

Figure 6. The relationship between grape varieties and cutting force.

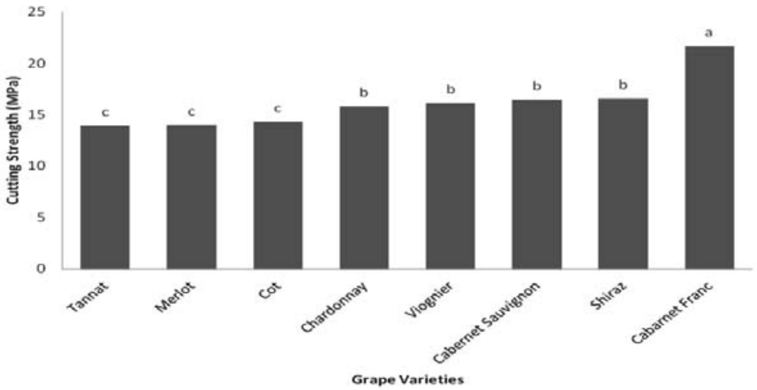

Figure 7. The relationship between grape varieties and cutting strength.

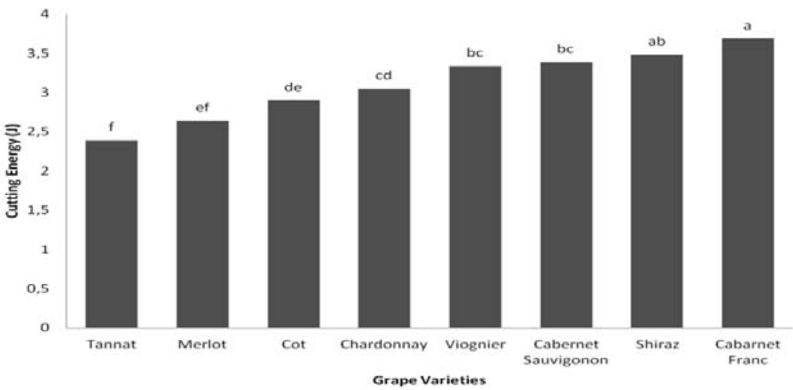

Figure 8. The relationship between grape varieties and cutting energy.

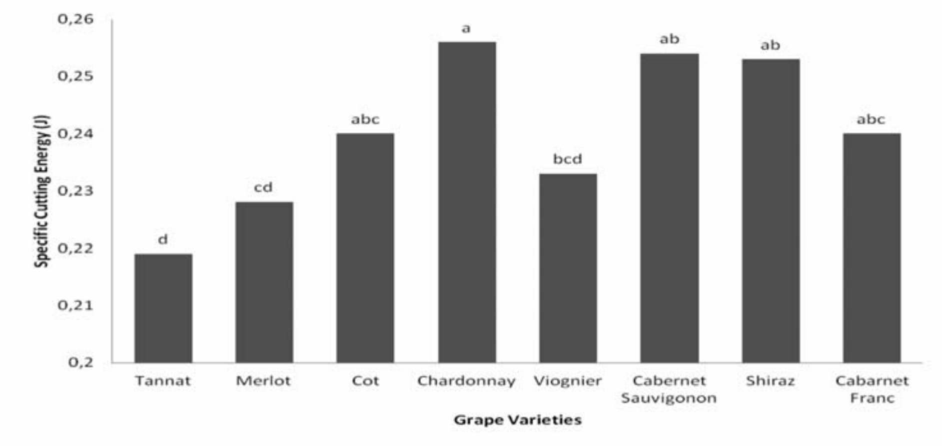

Figure 9. The relationship between grape varieties and specific cutting energy.

Selection of suitable cutting apparatus and equipment plays an important role on economizing on cutting force requirements. Based on our results, the cutting properties of grape branches varied as a function of the variety. So, a separate grape harvester or pruning machine for each variety is recommended. Study results could be considered in designing a prototype for cutting or pruning machines.
According to Skubisz (2001) mechanical properties are correlated with the structure of plant stems. Similar trends were reported by Nazari Galedar, et al. (2008) for alfalfa stem, by Tavakoli, et al. (2009 b) for barely stem, by Ince, et al. (2005) for sunflower stalk, by Esehaghbeygi, et al. (2009) for wheat, by Zareiforoush, et al. (2010) for rice straw and by Kronbergs, et al. (2001) for different hemp varieties.
Study findings showed that there is a significant difference between mean values of cutting properties based on the variety. The grape variety Cabernet Franc was found to be the strongest, while the variety Tannat, Merlot and Cot were found to be the weakest based on the shear cutting and energy requirement findings.

CONCLUSIONS

In conclusion, study findings clearly demonstrated that the mechanical properties depended on the variety to a great extend. The maximum shear force, shear strength and shear energy were obtained at Cabernet Franc grape variety at 1397.60 N, 21.68 MPa and 3.68 J respectively, followed by varieties Shiraz, Cabernet sauvignon, Viognar, Chardonnay, Cot, Merlot and Tannat. These findings show that the cutting force, cutting strength and cutting energy are related to grape branches' physical and mechanical properties. Thus, it was demonstrated that the cutting strength and energy requirements depend on the variety. Therefore, we should consider cutting properties of grape varieties for suitable designs for pruner machines.

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