Evaluation of Hand Forces During Manual Vine Branches Cutting

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Abstract
As we know, winter pruning is one of the critical points in the management of the vineyard. In small farms, often located in slope areas, winter pruning is mainly performed manually. From studies carried out on vineyards from Sicily and Lombardy region, pruning operated with conventional scissors remain the most widely used method. The use of pre-pruning machine is a very good solution to facilitate the subsequent manual intervention. In every case, winter pruning require manual operations carried out by secateurs or, less commonly, by long handle shears. Recent works, conducted to assess through OCRA Index the muscle – skeletal risk due to manual pruning of the vineyard, showed a variability in the forces applied on the scissors. The purpose of this work is to verify the forces exerted on the scissors by different regions of the hand during the pruning of the vineyard. So we used a conventional scissors equipped with sensors able to detect the force exerted and the duration of the effort. The tests were conducted in the laboratory and the results were processed with the aim to show if the hand forces during manual cutting are function of diameters and cultivated varieties.

Keywords: cutting force, vineyard, dynamometric scissors

Introduction
In winter pruning of vines, manual shears are the most used both in case of manual intervention and in the case of finishing after mechanic pruning (Balloni et al. 2008, Schillaci et al, 2009), although there is a progressive replacement of such equipment with electric shear with electronic control. The intervention of the vine pruning is done with cuts that follow one another quickly thanks to a constant regularity in the morphology of the plant and pruning system. This activity, carried out for 4-5 consecutive months, may result in the worker musculoskeletal disorders of the upper limbs due to physical effort required to cut wood and from repetitive actions.

Regional guidelines for the prevention of musculoskeletal disorders related to repetitive movements and efforts of the upper limbs (DG Health All.1 3958/2009) lists among workers exposed to risk of biomechanical overload even the employees working continuously to some agricultural including pruning. Pruning may be associated with musculoskeletal disorders of the hand, especially paresthesias of the hand (Roquelaure et al. 2001), and wrist, combined with static work done by the shoulder-arm system (Wakula et al. 2000). The risk factors vary according to the working arrangements (just cutting and cutting and simultaneous removal of cut branches), the type of pruning, the distribution of work and the vineyard (vine, slope, height strains) (Wakula J, K Landau). The bibliography about it does not provide sufficient information to evaluate the strain and biomechanical stress to which the worker is subjected during pruning. Studies to evaluate, through OCRA index (Colombini et al. 2005), skeletal muscle, the risk from exposure to repetitive movements of upper limbs in manual pruning of the vineyard (Schillaci et al. 2009), found a variation in the forces developed by hand trimmer. Work ergonomics and design tools for pruning (Wakula et al. 2000; Paivinen et al.

2000; Haapalainen et al., 2000) were aimed observation of the accumulation of stress operator. Recent research (Spare et al. 2009) evaluating the shear strength of the shoots in the laboratory penetrometer using texture analyzer TA-HDi with load cell, showed differences between the varieties tested.

The purpose of this study was therefore to assess, through cuts made by a scissors equipped with sensors, the forces exerted by different regions of the hand during cutting of branches of different cultivars and different diameters, from eleven vineyards cultivated in two different Italian regions.

Materials and method

With this aim was used a traditional pruning scissors on which were placed 5 sensors capable of detecting the force applied and duration of these forces.

Fig.1: Shear with sensors connected to wireless transmitters

Samples collected during the pruning were immediately tested to evaluate the resistance in terms of reaction to the penetration of a blade thickness of 2 mm, with triangular section, maximum width 6 cm and maximum length 3 cm (Stoker Profil 21), weighing 240 g and length of 21 cm, chosen as the type of shear with media interaction against muscle activity (Haapalainen et al, 2000). For the measurements have been used force sensors Flexi Force Sensors ® A201 of Tekscan based on printed circuit boards, flexible and ultra-thin substrate made of two layers of film (polyester / polyamide).

Each layer is a conductive material (silver) and a layer of pressure sensitive ink. The sensitive area is formed by a circle of silver ink overlay sensitive. These sensors have the ability to detect signals of strength from 0 to 440 N, a response time of < 5microseconds on an area of detection with a diameter of 9,53 mm. The resistance of the sensor is then transferred to a computer by wireless signal. The end of such sensors is positioned so as to coincide with the point of contact of the fingers of the operator with the handles of the pruning shears during the operation in order to investigate the efforts related to the contact point with the handle of the index, middle and ring fingers and the palm corresponding to two zones closet o the thumb. Tests were conducted in laboratory and were intended to record the forces exerted by hand of the pruner and their distributions in the regions of the hand under investigation according to the diameters of the branches and the vineyard. The cuts were made in correspondence of 4 diameters: 5, 7, 10 and 12 mm. To conduct statistical analysis were performed 2 cuts for every diameter and 3 repetitions foe each cultivar. From each cut, each sensor gave the force in N and length in seconds. The samples tested were collected in February and March 2010 during the pruning from 5 farms in Sicily, and from 3 farms in Lombardy Region in order to differentiate the area sampling. The vineyards observed and the farms from which they were taken are shown in table 1.

Table 1. Characteristics of observed vineyards

Cultivar	*Pl.year*	*Form pruning*	*Site*
Cabernet Sauvignon A	2005	Spurred cordon	Viagrande (CT)
Cabernet Sauvignon B	2003	gdc	Torre de' Roveri (BG)
Chardonnay	1992	Guyot	Castiglione di Sicilia (CT)
Franconia	2001	Spurred cordon	Almenno S.Salvatore (BG)
Frappato	2002	Spurred cordon	Vittoria (RG)
Marzemino	2002	Spurred cordon	Adro (BS)
Merlot A	2006	Guyot	Viagrande (CT)
Merlot B	2000	Spurred cordon	Torre dei Roveri (BG)
Moscato di Scanzo	1993	casarsa	Torre de' Roveri (BG)
Moscato giallo	1992	Spurred cordon	Torre de' Roveri (BG)
Nerello cappuccio	2006	Spurred cordon	Linguaglossa (CT)
Nerello mascalese	1984	Spurred cordon	Castiglione di Sicilia (CT)
Nero d'Avola	2001	Spurred cordon	Pachino (SR)

Results

The samples collected in fields during pruning operations were tested with the sensorized scissors and then placed in an oven to measure moisture percentage (table 2).

Table 2. Moisture of samples

Cultivar from Sicily	*Moisture %*	*Cultivar from Lombardy*	*Moisture %*
Cabernet Sauvignon A	42,39	Cabernet Sauvignon B	48,73
Chardonnay	47,32	Franconia	40,60
Frappato	51,50	Marzemino	45,70
Merlot A	45,17	Merlot B	40,50
Nerello cappuccio	45,34	Moscato di Scanzo	45,43
Nerello mascalese	49,78	Moscato Giallo	47,11
Nero d'Avola	46,37		

Obtained results were processed using the software R for statistical variability to distribute data and to investigate the influence of independent variables considered. Were considered the factors cultivar (CV), branch diameter (DIA), date of sampling (DATA), region of the hand (FINGER), the repetition of the cut (RIP). Were investigated response variables related to maximum force implemented for each cut (FORZA) and the length of cut (TIME). The influence of these factors has been extracted, through the analysis of variance (ANOVA). As for the forced response variable, showed significant effects by the cultivar (CV), diameter (DIA) (Fig.1) and the region of the hand (FINGER) with a p-value less than 0.001. In Fig. 2 is a clear distribution of power between the regions of the hand (0: index, 1: medium, 2: ring finger, 3: region of the palm next to the thumb, 4: region of the palm distal to the thumb). Elaborations of the first order for the response variable DURATION, showed statistical significance for the factors cultivar (CV), branch diameter (DIA), with a p-value less than 0.001. Did not show significance for the factors repetition (RIP) and region of the hand (FINGER).

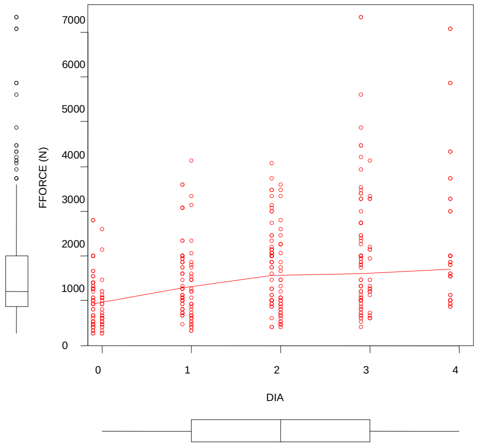

Fig. 1: Distribution of forces in the observed diameters

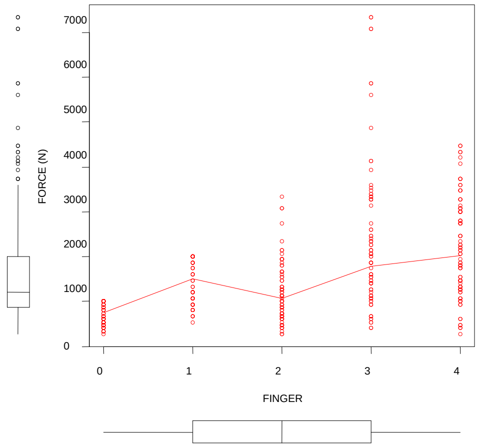

Fig. 2: Distribution of forces in the observed regions of the hand

Overall, tests gained an average strength of 14,03 N with a standard deviation of 5,50 and an average length of the cuts of 0,75 seconds with standard deviation of 0,47. Fig. 3 and fig. 4 show strengths and durations required in the cutting of branches.

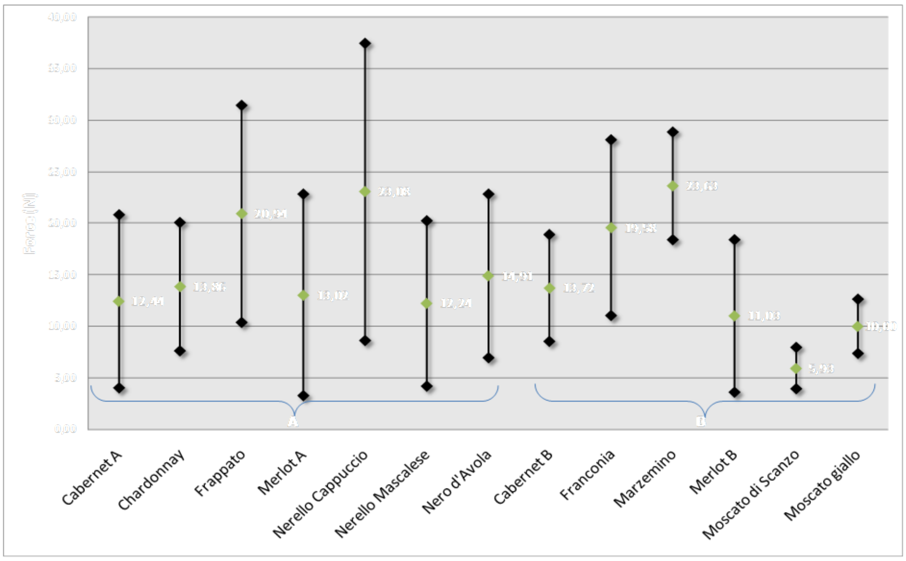

Fig.3: Mean force in studied cultivars (A= Sicily, B= Lombardy)

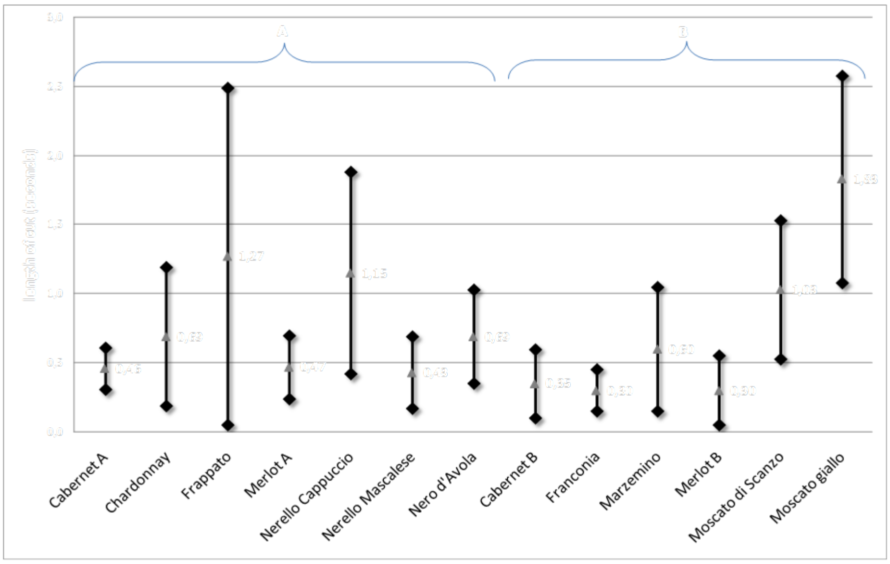

Fig.4: Mean of length of cuts (A= Sicily, B= Lombardy)

The cv that showed major forces during the cuts were Marzemino (23.63 ± 5.20) and Nerello Cappuccio (23.08 ± 14.42) while the minimum was from Moscato di Scanzo (5, 93 ± 1.99). Regarding the duration of the cut, the largest value was found for Moscato Giallo (1.83 ± 0.75) while the minimum was found for Franconia (0.3 ± 0.15) and Merlot (0.3 ± 0.25).

Conclusions and prospects

The aim of this study was to evaluate, through cuts made by scissors equipped with sensors, the forces exerted by different regions of the hand during cutting of branches from eleven cultivars during winter pruning of vines from two different region in Italy. The acquisition system has permitted to obtain values of maximum force and duration of the cut from five different regions of the hand. The statistical analysis of data has given the significance of the various factors in the study. Factors that showed influence on the force needed to make the cut were: different cultivars from the sample, the different regions of the hand, the diameters of the branches. This research suggests some considerations about the possible factors influencing repeated efforts during the operations of pruning that can be a support for studies on risks and skeletal muscle requires further confirmation by tests conducted on a larger number of cultivars and studies on optimization of the sensors on the scissors or on the hand.

References

Haapalainen M., Kivisto-Rahnasto, Mattila M. 2000. Ergonomic design of non-powered hand tools: An application of quality function deployment (QFD). Occupational Ergonomics 2(3) (1999/2000) 179–189

Paivinen M., Haapalainen M., Mattila M. 2000. Ergonomic design criteria for pruning shears. Occupational Ergonomics 2(3) (1999/2000) 163–177 163

Pezzi F., ADE G., Bordini F., Giunchi A., 2009. Evaluation of the cutting force on vine branches in winter pruning. J. of Ag. Eng. – Riv. Di Ing. Agr. (2009), 1, 33-36

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto. Atti del IX Convegno Nazionale dell'Associazione Italiana di ingegneria Agraria, Ischia Porto, 12-16 settembre 2009, mem. n.170

Wakula J., Beckmann T., Hett M., Landau K., 2000. Ergonomic analysis of grapevine pruning and wine harvesting to define work and hand tools design requirements. Occupational Ergonomics 2(3) (1999/2000) 151–161