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ASSESSMENT OF TREE SPROUTS PRUNING WITH VARIOUS TYPES OF CUTTING UNITS

Tomasz Nowakowski*, Maciej Nowakowski

Department of Agricultural and Forestry Machines, Warsaw University of Life Sciences

*Corresponding author: e-mail: tomasz_nowakowski@sggw.pl

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ABSTRACT

Changes in horticulture induce fruit producers to introduce more efficient tree pruning systems. The increase of efficiency is related to application of various cutting devices, the effect of which on cultivated fruit trees has not been completely recognized yet. Therefore, the objective of the paper was to compare and assess the fruit tree sprouts cut with various types of cutting units. Four cutting units were applied in the study: pruning shears, anvil secateur, circular saw and chain saw and four cultivars of fruit trees: apple, pear, plum and cherry tree. A fractal dimension was used for assessment of the cutting quality that allows assessment of the spatial complexity of the image of the cut sprout. The obtained results allowed determination that the least sprout damaging cutting system is in case of the use of the anvil secateur and pruning shears (the best cutting quality) then circular and chain saw. It was also proved that susceptibility to damage is characteristic for the investigated fruit trees. Pear trees proved the lowest susceptibility to damages regardless the cutting unit.

Introduction

Fruit trees cutting is one of the most important treatments in an orchard during annual agrotechnical works like fruit trees pruning. This treatment affects considerably the yield, condition of trees as well as growth and correct development of plants (Pieniążek, 2000; Mika, 2012; Romański et al., 2014; Kuklewski, 2017). It is important to ensure that cutting is performed with suitable tools which cause the least possible damage to sprouts, in a relevant time and with the use of the best cutting methods. Manual pruning is very laborious and tiresome since it is carried out in various weather conditions (Rabcewicz, 2007). Deficit in labour force causes that less attention is paid to the technique of fruit tree cutting with simultaneous introduction of even new tools, devices and machines which aim at the increase of the efficiency of this treatment. Thus, there are many new technical solutions for fruit tree cutting available on the market, new recommendations are introduced for cutting methods and maintaining of an orchard. Thus, mechanical orchard cutting with circular and chain saws and shears has become very popular in the recent years (Strużyk, 2013; Wilczyńska, 2013; Gorriz et al. 2014; Okła, 2017). A need to reduce the costs related to orchard treatment also induces introduction of new solutions (Łukawska, 2014; Sgroi et al.

2014; Gościło, 2015; 2017). However, application of this method is related to the risk of occurrence of tree wounds during cutting which open the door for bacteria and increase the risk of infection with viruses and fungi. It is important that the cutting unit cuts sprouts without crushing, tearing them and without any damage to bark (Strużyk, 2011). The aim is to obtain after cutting a smooth and consistent surface of the sprout which causes that pathogenic microorganisms have the smallest surface to penetrate inside the plants. This problem also occurred during harvesting of energy plants where minimization of the stock damage by cutting units allows correct regrowth in the following agrotechnical season (Lisowski et al., 2010a; 2010b; Nowakowski, 2012b). The surface which is made after cutting is very difficult to assess. However, the obtained information becomes useful in the processes of concluding on the condition of the surface and the applied cutting system. Thus, even more often for analysis of biological objects and their quality assessment the methods based on the computer image analysis are applied (Frączek and Mudryk, 2008; Koszela, 2015; Koszela et al., 2015; Szwedziak and Wojtkiewicz, 2015; Wąsik and Michalec, 2016). An example of the approach to the surface image analysis is the application of the fractal geometry. It enables analysis of the complexity of the spatial surface (Nowakowski, 2012a). Differences in the analysed shapes are sometimes small, thus the application of the quantity analysis method becomes a precious tool which enables the description of the interesting phenomena. The applied fractal dimension should be understood simply as a measure of the degree of the space filling by the investigated object and the degree of its spatial complexity. On the surface it is within 1 to 2 and is dimensionless. The more complicated is the outline of the object the more the value approaches 2 (Martyn, 1996).

The objective of the paper was to assess and describe the impact of the cutting unit: circular, chain saw, anvil secateur and pruning shears and susceptibility of fruit tree sprouts on the damage of the cutting sprouts surface. The obtained results will enable evaluation of the cutting system which is the most favourable for the investigated plants.

Methodology of research

The investigated fruit trees sprouts were collected from the orchard on 13 April 2016. 60 samples were collected for each cultivar (sprout fragments) from twenty trees, 3 from each tree. The cut sprouts were used for making measurements of cutting with various methods in laboratory conditions. The investigated sprouts were placed in the vice and six cutting attempts were made with various cutting units. The measurements were made eight days after harvesting; the average moisture during the research was 31.87±0.49% for the plum tree 35.10±0.35% for the cherry tree, 31.92±0.86% for the apple tree and 35.62±0.53% for the pear tree. The moisture was determined with the oven-dry method as the average from three measurements according to the ASABE Standard S358.

Samples of apple tree sprouts were collected from Idared cultivar which was growing on the rootstock 'A2'. The plum sprouts used in the investigation were collected from 'Węgierka Dąbrowicka' cultivar which was growing on 'Ałycza' rootstock. Cherry tree sprouts were collected from 'Groniasta from Ujfehertoi' cultivar which was growing on 'Antypka' rootstock. Samples of pear were collected from 'Konferencja' cultivar cultivated on the rootstock of seedlings of Caucasian pear. Apple and pear trees were seven years old and

plum and cherry trees were three years old. Basic parameters of the investigated samples were presented in table 1.

Table 1.
The list of parameters of investigated sprouts

Parameters of investigated sprouts	Unit	Apple tree	Plum tree	Cherry tree	Pear tree
Average diameter of sprouts	(mm)	9.87	10.51	9.84	9.51
Median	(mm)	9.85	10.35	9.91	9.55
Standard deviation	(mm)	1.13	1.32	1.44	1.17
Coefficient of variability (%)	(%)	11.42	12.58	14.68	12.27
Length	(mm)	350-600	360-640	330-590	300-580

Three cutting units were applied in investigations. The first one is an anvil secateurs – this unit is equipped with curved blades with an anvil (fig. 1). The admissible maximum cutting diameter of the secateur was 40 mm. The next unit consisted of the double hand pruning shear; maximum admissible cutting diameter was 35 mm. Another unit was a circular saw supplied from the electric network with the voltage of 230 V, power 1.1 kW. A plate with the diameter of 126 mm was equipped with 40 tines made of self-bonded carbide with the width of 2.4 mm, the rotational speed of 39 $m \cdot s^{-1}$. The fourth cutting device used in the study was a battery supplied chain saw HUSGWARNA 436Li. The chain saw was equipped with a 12- inch guidebar and a chain with a scale of 3/8 inches. The maximum shearing speed was 15 $m \cdot s^{-1}$.

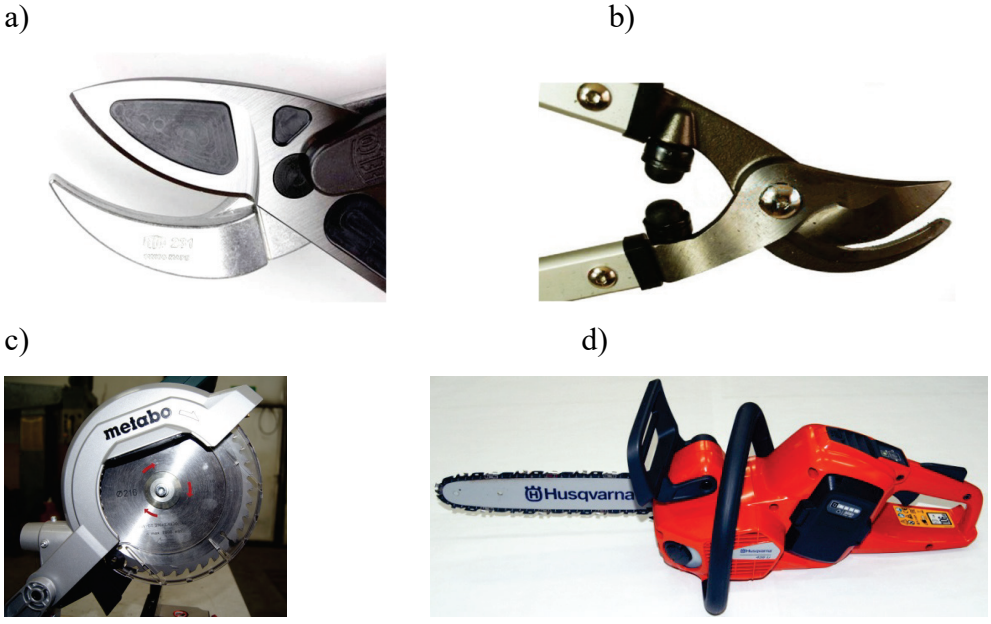

Figure 1. Cutting units used in the research: a) cutting head of the anvil secateur, b) cutting head of the pruning shears, c) circular saw, d) chain saw HUSGWARNA 436Li

Sprouts were cut with the analysed units. Then, the obtained surface from the part of the sprout remaining on the plant was photographed. Pictures were taken in laboratory conditions by artificial light with a digital camera Sony α500 (12 MP) placed on the tripod stand. Pictures were saved in the JPG format with the resolution of 4592×3056 pixels/inch. The obtained picture was initially cleaned and cropped in the graphic program with maintaining the initial resolution. The image prepared so was the initial image for further graphical processing which in the final result enabled obtaining the image of the sprout edge outline (fig. 2). After the outline of the surface was obtained, determination of the fractal dimension was carried out with the use of the box counting method in the ImageJ 1.32j program. In the box counting method, the image is covered with networks with bigger boxes from 2 to 64 pixels. Then, the number of boxes which cover the object is counted and a double logarithmic diagram is drawn. The gradient of the obtained line is a fractional part of the fractal dimension (Gawlik et al 2011, Jelinek et al., 2010). The exemplary result of estimation of the fractal dimension for the cherry sprout outline cut with the circular saw was presented in figure 3. The obtained research results of the fractal dimension (D) were developed with the statistical analysis methods with the use of Statistica v. 13 program with the use of analysis of variance ANOVA and the multiple comparison Scheffe's test.

a) b)

Figure 2. Cross-section of cherry sprout cut with circular saw: a) sprout view, b) view of the outline of the sprout edge

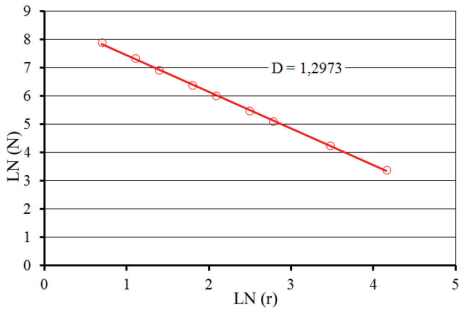

Figure 3. Determination of the fractal dimension with the box-counting method for the cherry sprout cut with the circular saw: D – fractal dimension, N – number of boxes covering the sprout edge, r – length of the box side

Research results

The obtained results make us conclude that the intensity of damage differed in relation to the applied cutting unit and the fruit tree cultivar (table 2). An anvil secateur and pruning shears proved to be the best cutting units for the apple tree and a chain saw was the worst. The lowest discrepancies in measurements were obtained for pear sprouts and the highest for plum sprouts.

Table 2.
Fractal dimensions (D) for the investigated tree cultivars (PL – chain saw, PT – circular saw, SK – anvil secateur, SN – pruning shears)

Cultivar	Cutting unit	Average	Minimum	Maximum	Standard deviation	Coefficient of variability
Pear tree	PL	1.167	1.141	1.187	0.017	1.491
	PT	1.150	1.128	1.180	0.019	1.660
	SK	1.145	1.128	1.151	0.009	0.760
	SN	1.161	1.149	1.176	0.010	0.862
Apple tree	PL	1.205	1.185	1.242	0.023	1.946
	PT	1.178	1.141	1.217	0.030	2.511
	SK	1.150	1.119	1.178	0.024	2.042
	SN	1.153	1.122	1.173	0.019	1.670
Plum tree	PL	1.186	1.157	1.222	0.023	1.948
	PT	1.174	1.117	1.224	0.044	3.785
	SK	1.169	1.142	1.201	0.022	1.840
	SN	1.188	1.148	1.269	0.046	3.866
Cherry tree	PL	1.201	1.179	1.238	0.023	1.881
	PT	1.225	1.179	1.278	0.040	3.264
	SK	1.166	1.130	1.196	0.026	2.250
	SN	1.156	1.126	1.170	0.016	1.390

The relation of the fractal dimension with the applied cutting unit and the plant cultivar was presented in figure 4. The lowest number of damages was reported in case of pear sprouts cut with the anvil secateur (D=1.145). For cherry sprouts the biggest damages during sprout cutting were reported in case of cutting with a circular saw. In this case the fractal dimension was 1.225. The anvil secateur proved to be the cutting unit for which the lowest sprout damage was reported, except for cherry sprouts. In this case the prunning shear caused less damage with a fractal dimension of 1.156. In the cross section of sprouts cut with the anvil secateur the spot where the shear touched to the sprout is noticeable as the slight crushing of the phloem and the skin. Sometimes the phloem tearing and skin breaking occurs. The wooden surface in the cut sprout stays smooth. Depending on the size of damages, the quality of cutting was assessed as: very good, good, sufficient and insufficient. The process of sprout cutting with the anvil secateur may be assessed as very good i.e. which causes the least damage to the sprouts. In case when sprouts are cut with pruning shears, breaking of the skin and separation of the phloem with the skin from the wood is

noticeable. Sometimes the place where the blade touches the counter-blade it is noticeable in cross sections. Sometimes the surface is smooth there. In the place where the counter-blade affects the sprout we can notice damaged phloem with skin. Cutting a sprout with the pruning shear may be considered as good.

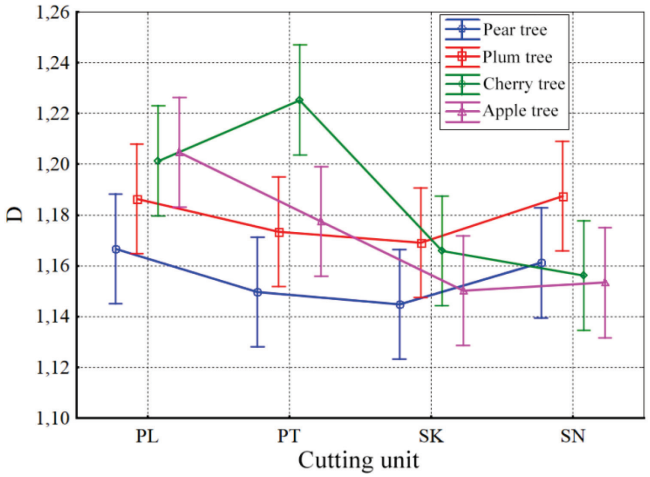

Figure 4. Values of fractal dimension (D) in relation to applied cutting unit during cutting of four fruit tree species (PL – chain saw, PT – circular saw, SK – anvil secateur, CN – pruning shears)

The chain saw was the worst cutting unit since regardless the tree species it usually achieved the highest values of the fractal dimension (except for the cherry and plum tree). The surface of cut sprouts was uneven. Skin was often torn from the wood. The wooden surface was cracked in many cases; wood fibres were torn.

For cherry sprouts the highest values of the fractal dimension occurred during circular saw cutting (D=1.225), chain saw was the second with the result of D=1.201. Cutting sprouts with the circular saw leaves the woody surface of the cut sprout usually smooth with small protruding strands of wood structures. Sometimes, it was noticeable that the skin was torn from the phloem and on the edges of the sprout in the direction of saw operation; noticeable layering of the fibres torn from the wood with the skin which was not clearly cut. Depending on the size of damage, the quality of cutting was assessed as correct.

For the plum tree, the worst unit were pruning shears D= 1.188, chain saw was the second from the end with the result of C=1.186. However, one may notice that the differences in average values between the cutting units are slight. Thus, it may be stated that for the plum, the applied cutting units do not affect the quality of the left sprout. The anvil secateur was the best cutting unit, except for the cherry tree, for which the pruning shears proved to be the best. We may conclude from the research that the circular straw cannot be used for cutting cherry sprouts. For cutting sprouts of the investigated species, the best are secateurs,

in particular for cherry and apple sprouts. For cutting pears and plums we may use circular saws which proved to be better cutting units than the pruning shears.

The assessment of the cutting quality was statistically confirmed. Based on the results of the two-way analysis of variance, one may state that the investigated factors had a highly statistically significant impact on the varied values of the fractal dimension values: since for the tree type, the F-Fisher-Snedecor test values were $F_{v1=3,v2=80}=6.1$ with the critical level of significance p=0.0008 and for the cutting unit $F_{v1=3,v2=80}=7.5$ (p=0.0002). Moreover, significant interactions for the investigated factors were reported: tree type and the cutting unit type ($F_{v1=9,v2=80}=2.7$ at p=0.0079).

Based on the Scheffe's test one may conclude that the use of anvil secateurs and pruning shears for cutting fruit trees allows obtaining the smallest sprout damage but the smallest values of the fractal dimension were obtained for the anvil sector (table 3). Application of the cutting units in the form of circular and chain straw considerably increases damage of sprouts, those units form a uniform group. The least susceptible to damage of wood proved to be the pear tree. The quality of cutting the pear is significantly different than the plum and cherry and the quality of cutting apple tree does not differ significantly from any of the investigated species (table 4). Cherry tree proved to be the most sensitive species to the cutting technique.

Table 3.
Division of the fractal dimension value (D) into uniform groups with Scheffe's test according to the cutting unit

Specification	Average fractal dimension (D)
Anvil secateur	1.157^{a}
Pruning shears	$1.164^{a,b}$
Circular saw	$1.182^{b,c}$
Chain saw	1.190^{c}

^{a,b,c} – average values in columns marked with the same letter do not differ significantly at the level of significance 0.05

Table 4.
Division of the fractal dimension value (D) into uniform groups with Scheffe's test according to the tree species

Specification	Average fractal dimension (D)
Pear tree	1.156^{a}
Apple tree	$1.171^{a,b}$
Plum tree	1.179^{b}
Cherry tree	1.187^{b}

^{a,b,c} – average values in columns marked with the same letter do not differ significantly at the level of significance 0.05

Conclusions

1. The investigations proved that the cutting quality differs in relation to the fruit tree species and the applied cutting unit.
2. The anvil secateur was the least damaging, then the pruning shears and the circular saw and the most damaging was the chain saw. The statistical analysis enabled separation of two uniform groups of cutting units: anvil secateur and pruning shears as well as the circular saw and chain saw.
3. The order: pear tree, then apple tree, plum tree and cherry tree indicates the species which are the least susceptible to damage during cutting. Significant differences in the size of damage of sprouts were reported between the pear and plum tree and cherry tree, while for the apple tree there no significant differences in any of the investigated species.

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OCENA JAKOŚCI CIECIA PĘDÓW DRZEW OWOCOWYCH RÓŻNYMI RODZAJAMI ZESPOŁÓW TNĄCYCH

Streszczenie. Zmiany zachodzące w sadownictwie, skłaniają producentów owoców do wprowadzania coraz wydajniejszych systemów cięcia drzew. Zwiększenie wydajności wiąże się ze stosowaniem różnych zespołów tnących, których oddziaływanie na uprawiane drzewa owocowe nie jest do końca poznane. Dlatego celem pracy było porównanie i ocena pędów drzew owocowych przecinanych różnymi rodzajami zespołów tnących. W badaniach wykorzystano cztery zespoły tnące: sekator nożycowy, sekator kowadełkowy, piłę tarczową i piłę łańcuchową oraz cztery gatunki drzew owocowych: jabłoń, grusza, śliwa i wiśnia. Do oceny jakości cięcia wykorzystano wymiar fraktalny, który pozwala na ocenę złożoności przestrzennej obrazu przeciętego pędu. Otrzymane wyniki pozwoliły stwierdzić, że najmniej uszkadzający pędy system cięcia to zastosowanie sekatora kowadełkowego i nożycowego (jakość cięcia najlepsza), następnie piły tarczowej i piły łańcuchowej. Również wykazano, że podatność na uszkodzenia jest cechą charakterystyczną dla badanych drzew owocowych. Pędy gruszy okazały się być najmniej podatne na uszkodzenia niezależnie od stosowanego zespołu tnącego.

Słowa kluczowe: drzewa owocowe, zespoły tnące, jakość cięcia, wymiar fraktalny