Scientia Horticulturae 242 (2018) 30–35

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

A method for evaluating the size of damages to fruit trees during pruning using different devices

Tomasz Nowakowski, Magdalena Dąbrowska*, Michał Sypuła, Adam Strużyk

Department of Agricultural and Forestry Engineering, Faculty of Production Engineering, Warsaw University of Life Sciences, Warsaw, Poland

ARTICLE INFO

Keywords:
Fractal dimension
Fruit trees
Pruners
Size of damages

ABSTRACT

New methods of pruning are nowadays studied to optimize forming the canopy of fruit trees, as well as maintain an appropriate canopy size and density over time. The most widespread method is traditional pruning by using manual or pneumatic shears or loppers. Mechanical pruning using circular saws, mulching discs, and chain saws is also commonly used, however, there are concerns among some fruit growers to the effects of mechanical pruning. The assessment of size of damages reported in the literature is ambiguous as it depends on a number of factors, such as geographic area, plant species, and pruning technique. Therefore, this paper proposes a method for evaluating the size of damages to fruit tree shoots made by various pruning devices based on fractal dimension analysis of the cut shoots images. The study involved pear, apple, plum, and cherry shoots and four devices: a chain saw, circular saw, anvil lopper, and bypass lopper. It was found that the type of pruning device and tree species had a significant effect on the obtained fractal dimensions. The lowest dimensions, indicating low shoot damage were found for apple and pear trees (in contrast to cherry and plum trees). The damages caused by circular and chain saws were more extensive than that effected by anvil and bypass loppers. Fractal dimension analysis of pruning quality enabled quantitative assessment of each pruning device and species susceptibility to damages. The obtained results contribute to filling a lack of knowledge concerning important aspects of manual and mechanical pruning as well as susceptibility to damage the shoots.

1. Introduction

Fruit tree pruning is a fundamental horticultural practice used to regulate tree growth and fruit yield, and ensure optimum tree size and canopy density. In fast-growing orchards, pruning is applied to limit a canopy height and width to prevent the production of small fruits and enable the majority of fruits reaching the size expected for particular variety. Maintaining the right balance between crop yield and vegetative growth, as well as cost reduction are the main aims of mechanical pruning (Intrigliolo and Roccuzzo, 2011; Sgroi et al., 2014; Dorigoni, 2015). Because cutting with secateurs or garden loppers is very time-intensive, mechanical pruners have been developed as an alternative to manual labor (Giametta and Zimbalatti, 1997). Particularly, the most suitable for mechanical pruning are trees that do not require selective shoots pruning in the canopy (e.g., citruses and olives). Mechanization of pruning is continuously developing as attempts to find alternatives to manual methods. Studies of Dias et al. (2012) showed that mechanical pruning by using a cutting bar with circular saws did not decrease crop yields compared to hand pruning. Some studies on mechanical pruning have reported that it leads to obtain smaller fruits, but without affecting the overall fruit productivity (Krueger et al., 2013). Selective pruning using i.e. chainsaws, is not employed often with fruit crops because its high price and the work capacity does not increase significantly, although in other countries it is widely used in citrus pruning (Intrigliolo and Roccuzzo, 2011; Martin-Gorriz et al., 2014).

Mechanical pruning of mandarin trees shortened work time by 13% compared to manual pruning. However, mechanical pruning without follow-up manual pruning diminished fruit yield by 22% (Martin-Gorriz et al., 2014). Pérez-Bermúdez et al. (2015) evaluated the effects of traditional and mechanical pruning on grapevines, including grape yield and quality. They found that the application of mechanical pruning increased yield by 30%, thus improving economic effectiveness. While it led to smaller fruits, the quality of the obtained wine was unaffected. Also Caprara and Pezzi (2013) reported smaller grapes, decreased labor intensity, and lower costs for mechanical vs. hand pruning. The tests of mechanical pruning showed a considerable reduction in manpower as compared to hand methods. The cuts done by pruning machines in all cases did not cause damages as compared to the

* Corresponding author at: Department of Agricultural and Forestry Engineering, Faculty of Production Engineering, Warsaw University of Life Sciences, Nowoursynowska Street 164, 07-287 Warsaw, Poland.
E-mail address: magdalena_dabrowska@sggw.pl (M. Dąbrowska).

https://doi.org/10.1016/j.scienta.2018.07.006
Received 20 April 2018; Received in revised form 3 July 2018; Accepted 10 July 2018

hand pruning (Tombesi et al., 2012.)

Mechanical pruning of citrus trees was the most successful in high-density hedgerow orchards (Bordas et al., 2012). In the study of citrus orchards by Velázquez and Fernández (2010), mechanical pruning combined with manual pruning improved yield and costs were similar to those in traditional pruning. Different varieties have been observed to respond differently to mechanical pruning. In an olive grove, Vivaldi et al. (2015) found that the yields of the cultivars Arbequina, Arbosana, Nociara, and Peranzana were unaffected by mechanical pruning, while strong fruiting varieties exhibited insufficient productivity with ambiguous reactions to mechanical pruning. This was clearly visible for varieties with thin tip-bearing shoots. In those cases, mechanical pruning led to a considerable loss of fruit producing areas (Pascuzzi and Guarella, 2010; Rosati et al., 2013). Finally, excessive pruning may reduce the yield of some fruits, such as peaches and grapes (Sabbatini et al., 2015).

Mechanical pruning of apple trees may also lead to the canopy overcrowding with dense shoots limiting illumination of the upper and middle parts of the canopy. This results in high fruit density causes low fruit size with poor blush. Therefore, these kinds of trees require additional hand pruning (Mika et al., 2016).

It is essential that pruning should be performed using state-of-the-art techniques to minimize damage the shoots. As a result in lack of manpower, pruning methods may not be given a sufficient consideration while new tools and machines are being designed to increase pruning efficiency. New technological solutions of canopy forming allow meeting the guidelines concerning orchard practices (Jimenez-Brenes et al., 2017; Poni et al., 2016; Pérez-Bermúdez et al., 2015). Thus, mechanical pruning by using circular saws, chain saws, and cutting bars has recently gained in popularity (Martin-Gorriz et al., 2014; Ferguson et al., 2012; Intrigliolo and Roccuzzo, 2011). The high efficiency of the developed mechanical pruners significantly shortens the time needed to complete a pruning procedure, which is an important advantage.

A wider propagation of the practice of mechanical pruning is hindered by an irrational approach of many growers. For instance, a number of wine growers believe that in mechanically pruned vineyards the quality of fruits and the wine made of them is of inferior quality as compared to traditionally pruned vineyards despite the absence of evidence to that effect (Poni et al., 2016).However, many growers are concerned about the risk of excessive damage to trees during mechanical pruning, which could be conducive to viral and fungal infections and possibly lead to the withering of shoots (Caprara and Pezzi, 2013). Therefore, it is important for mechanical pruners to leave a smooth and compact surface of the cut, without tissue crushing or shredding, or debarking of the shoots. Evaluation of shoots damage after cutting by using different pruning devices is extremely difficult and largely depends on the researcher's knowledge and experience, as often differences in the analyzed shapes of surface are very subtle. A method based on computer-assisted image analysis for quantitative evaluation of biological objects allows to an objective assessment, enabling more accurate inferences concerning the condition of shoots cut by different techniques. In this study, cross-section outlines of shoots by using the fractal geometry were studied, because it allows analyzing the spatial complexity of objects. Essentially, a fractal dimension is a measure of the degree of space filling and complexity of the object. Furthermore, according to Guida et al. (2017) fractal dimension analysis corresponds well with subjective assessment of spatial complexity. Therefore, the objective of this study was to use the method based on the measurement of the fractal dimension, to assess the impact of the technique used to cut the shoots of fruit trees, on the resulting damages.

2. Research methodology

Samples of shoots were collected from the following types of trees:

- seven-year-old apple trees, "Idared" cultivar on "A2″ rootstocks, average shoot diameter was 9.87 ± 1.13 mm,
- seven-year-old pear trees, "Conference" cultivar on Caucasian rootstocks, average shoot diameter was 9.51 ± 1.17 mm,
- thirteen-year-old plum trees, "Węgierka Dąbrowicka" cultivar on cherry plum rootstocks, average shoot diameter was 10.51 ± 1.32 mm,
- thirteen-year-old cherry trees, "Groniasta z Ujfehertoi" cultivar on Mahaleb cherry rootstocks, average shoot diameter was 9.84 ± 1.44 mm.

Tested shoots samples were collected on 13th of April, 2016. For each tree species, 60 primary samples were taken from 20 trees (3 samples per tree). The shoots were used for measuring pruning quality by laboratory techniques. Measurements were made 16 days after sampling. Moisture content was determined by drying-weighing method in a convection drier according to ASABE Standard S358. The mean moisture contents of the shoots upon analysis were 24.65 ± 0.49% for plum shoots, 30.98 ± 0.14% for cherry shoots, 26.52 ± 0.33% for apple shoots, and 27.75 ± 0.33% for pear shoots.

The study involved the following pruning devices:

- an anvil lopper 231 (FELCO, Switzerland) with a maximum cutting diameter of 40 mm, complete with a curved blade and an anvil,
- a bypass lopper HC-1141LA (WelKut, Taiwan) with a maximum cutting diameter of 35 mm,
- circular saw KS 216 M Lasercut (METABO, Germany) with a blade diameter of 216 mm, 40 sintered carbide teeth with a width of 2.4 mm (the saw was powered by the 230 V grid, the tangential speed of the blade was 39 $m \cdot s^{-1}$, and the rated power of the motor was 1.1 kW),
- a battery-powered chain saw 436Li (Husqvarna, Sweden) equipped with a 12 inch guide and a 3/8 pitch chain; the chain speed was 15 $m \cdot s^{-1}$.

From 60 prepared primary shoots samples for each specie six randomly chosen samples were individually mounted in an anvil and six cutting trials were performed using each of the studied pruning devices. 24 photographs were obtained for one tree species and in total 96 photographs were analyzed. Shoots cross-sections were photographed in laboratory conditions under artificial light using camera mounted on a tripod. A Sony α500 (12 M P) digital camera with image converter CMOS 24,4 × 15,6 mm and lens DT 18–55 mm f/3.5–5.6 SAM was used for tests. A cross-section of shoot was placed 0.3 m from the lens. Photographed object was illuminated by two lamps with white light (4000 K). The images were saved in JPEG format with a resolution of 4592 × 3056 pixels/inch. The images (Fig. 1) were further processed to obtain clear outlines of the cross-sections (Fig. 2). To preprocessed graphic the Adobe Photoshop CS6 was used to image framing. Then, the photograph was cleared and only image of shoot with damages in primary resolution was leaved. Next step was to delete data about color and such image was put to ImageJ 1.32 j program where binarization was made and outlines of shoot cross-section were found.

The outlines were analyzed using the "box counting. In this method, a binary image is superimposed with a grid of increasingly larger squares (from 2 to 64 pixels). The number of squares (N) needed to cover the analyzed outlines of shoot cross-sections was given as a function of the length of the side of the square (r). Subsequently, a double logarithmic diagram was plotted, where the fractal dimension (D) was determined as the absolute value of the resulting linear function (Smith et al., 1996; Jelinek et al., 2010; Ristanović et al., 2010; Nowakowski, 2012; Di Ieva et al., 2013; Losa et al., 2016). Examples showing how fractal dimensions were determined for the outlines of single image of plum shoots cut using a circular saw, chain saw, anvil lopper, and bypass lopper are given in the Fig. 2. In all cases, the coefficient of fitting the straight line to the obtained nine data points