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Hedge and central pruning in a high-density pecan orchard in southern Brazil

Cristiano Geremias Hellwig[1]*, Carlos Roberto Martins[2], Antonio Davi Vaz Lima[1], Caroline Farias Barreto[3], Julio Cesar Farias Medeiros[4], Marcelo Barbosa Malgarim[1]

[1]Federal University of Pelotas, Pelotas, Brazil
[2]Embrapa Clima Temperado, Pelotas, Brazil
[3]Alto Uruguay Educational Development Institute, Caxias do Sul, Brazil
[4]Pitol Nuts Company, Anta Gorda, Brazil
*Corresponding author, e-mail: cristiano.hellwig@gmail.com

Abstract

This study aimed at evaluating the influence of two pruning methods, as well as absence of pruning, on vegetative and productive development and in the quality of pecan fruits in a high-density orchard. The experiment was conducted with the cultivar Melhorada in a commercial pecan orchard in municipality of Santa Rosa, Rio Grande do Sul state, Brazil. The study was carried out between July 2018 (dormancy phase of plants) and June 2020 (fruit ripening stage). In a randomized block design, the following treatments were applied: no pruning, hedge pruning and central pruning. Hedge pruning increased limb growth, while central pruning decreased the number of dry branches. Fruit production oscillated in the cycles. In the first, production was higher when central pruning was conducted. In the second cycle, it was higher in unpruned trees. Even though both pruning methods decreased the number of fruit with closed epicarps, they did not affect most variables of fruit quality. Therefore, results show that pruning methods promote vegetative development of pecan trees, reducing dry branches, but they are inconclusive regarding their production and have no significant effect on the main variables of their fruit quality. The evaluation and continuity of pruning for more cycles is important to obtain the most consistent results for indicating the best alternative for producers.

Keywords: *Carya illinoinensis*, spacing, production, fruit quality

Introduction

Pecan trees [*Carya illinoinensis* (Wangenh.) K. Koch(Grauke, 1991)] are native to the United States of America and to Mexico (Sparks, 2005). However, the crop has expanded to several countries, such as China, Australia, South Africa, Brazil, Argentina, Peru and Chile, in the last decades (Zhang et al., 2015; Hilgert et al., 2020; Crosa et al., 2020).

In Brazil, the crop has grown significantly in the south, mainly in Rio Grande do Sul state, not only as the result of increase in consumption and market price, but also because of its good adaptability, different harvesting season from other crops and easy fruit storage (Lange Junior, 2020; Crosa et al., 2020).

Adult pecan trees are large, growing to 40 m in height and 20 m in crown diameter (Fronza et al., 2018). Thus, planting density is an important factor when orchards are implemented and depends on edaphoclimatic conditions, cultivars and farmers' interests (Wells, 2017). Even though dense orchards enable high yield in the early years, plant development leads to limb overlapping from the sixth to the tenth years, depending on edaphoclimatic conditions and managements with pruning.

Decrease in pecan production is related to the fact that basal branches, which are more affected by shading than others, are the ones that exhibit the highest production in orchards with ideal incident solar radiation due to the horizontalized angle of insertion. According to Núñez et al. (2001), branches may die and stop being productive when the orchard is very closed and little light penetrates through tree canopies.

Adult orchards need high levels of solar radiation to reach excellent nut growth, yield and quality (Arreola-Ávila et al., 2010). Thus, it is fundamental to carry out either plant pruning or thinning so as to minimize shading on low branches (Wood, 2009).

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Central pruning consists in removing whole branches which are strategic to enable higher incidence of solar radiation inside canopies (Lombardini, 2006), while hedge pruning is a mechanized method which prunes trees laterally. In western United States, a region with high intensity of solar radiation, hedge pruning is the standard method to increase sunlight penetration through tree canopies (Gong et al., 2020). Its objective is to refrain branches from growing, thus, enabling solar radiation to penetrate; it may also be conducted along with decrease in plant height (Lombardini, 2006; Wood, 2009; Wells, 2018). Hedge pruning also ensures better control of plant diseases (Bock, 2017).

Based on this reality and on the fact that there are few studies of the issue in the conditions found in southern Brazil, this study aimed at evaluating the influence of two pruning methods, as well as absence of pruning, on vegetative and productive development and in the quality of pecan fruits in a high-density orchard.

Material and Methods

The experiment was carried out in a commercial pecan orchard in municipalily of Santa Rosa, Rio Grande do Sul, state, Brazil. The orchard has the following geographic coordinates: latitude is 27° 55' 15" S; longitude is 54° 32' 37"W; and altitude is 330 m. In the Köppen-Geiger climate classification, the climate in the area is Cfa (Alvares et al., 2014), mean annual temperature is 20.8 °C and mean annual rainfall is 1801 mm. The soil is typic dystrophic red latosol (Santos et al., 2018). The orchard was implanted in 2009, spacing was 7m x 7m and total density was 204 plants ha^{-1}. No annual pruning management was carried out in the area from the implantation of the orchard to the beginning of the experiments (2018). The orchard has no irrigation system and annual fertilization is based on results of soil and leaf analyses and fertilization manual to Rio Grande do Sul and Santa Catarina states (Soil Fertility and Chemistry Commission-CQFS – RS/SC, 2016).

The experiment had a randomized block design with three replicates of five plants each. It consisted of the following treatments: 1) no pruning; 2) hedge pruning and; 3) central pruning. They were applied to plants of the cultivar 'Melhorada'. This cultivar registered in Brazil has vigorous growth habit and compact leaflets. The first hedge pruning, carried out on one side of the plants, and the central pruning were carried out on August 8th, 2018, in the dormant period of the plants, which is the period most commonly used by other producers as well. On the opposite side, the hedge pruning was carried out the following year, on August 13th, 2019.

Hedge pruning simulates the mechanical pruning carried out by machines and tractors with cutting discs, but, in the experiment, it was conducted by a motor pole saw for branches with large diameters and an extendable pole pruner for branches with small diameters. Pruning consisted in trimming branches exceeded 2.5m from the trunk. In order to measure this distance, every plant had a 2.5-meter bamboo tied to its base to make pruning easier and more uniform.

Central pruning, which was carried out by a motor pole saw, consisted in selecting and removing from one to three primary branches that came out of the central leader, so as to enable higher incidence of solar radiation within canopies. After central pruning, plastic emulsion paint was applied to the cuts in order to avoid activity of pathogenic agents.

Pruned branches were cut to pieces and weighed to have their pruning mass evaluated. When hedge pruning was evaluated, the sum of masses of both years was used.

The number of dry or dead branches was evaluated in January 2019 and in January 2020 by counting all branches with no leaves or the ones with dry leaves within the canopy and basal portion of plants.

Branch growth was evaluated in August 2019, a year after the pruning process. Four branches located laterally on plants were measured by a tape measure. In hedge pruning, branches which originated close to the pruning area were evaluated.

Nuts were harvested between May 26th and May 29th, 2019 and from June 2nd to June 4th, 2020 by a tractor equipped with a pecan tree shaker. After they had fallen on the ground, pecans were collected manually. Production was evaluated by weighing fruit borne by every plant on a digital scale while fruit with closed epicarps, known as shucks, were counted. Yield, production efficiency in terms of canopy volume (PECV)and production efficiency in relation to the trunk cross-sectional area (PETCSA) were calculated by the following equations: Yield (kg.ha^{-1}) was based on data on production and plant density; PECV= Production (kg)/ canopy volume (m^{-3}); PETCSA= Production (kg)/trunk cross-sectional area (cm^2) .

Regarding fruit quality, 1.4 kilogram samples were collected in order to evaluate the number of fruit per kilo after the drying process. Afterwards, both fruit and kernel length and diameter, besides shell thickness, of 25 fruit were measured by a digital caliper. Mean masses of fruit, kernels and shells were evaluated by an electronic scale. Kernel yield was evaluated by the following equation:

Kernel yield (%)= (Kernel mass (g)/fruit mass (g)) x100.

Kernels had their color (°Hue) and luminosity (L*) evaluated by a Konica Minolta CR 410 colorimeter (Konica Minolta Business solutions do Brasil Ltda., São Paulo, state, Brazil) with a D65 light source. Finally, a visual analysis led to the discard of kernels that had some defects, such as oxidation, stains caused by insects or hollowness. Percentage of edible kernels was then calculated.

Resulting data were subjected to the analysis of variance and means were compared by the Tukey's test, at 5% error probability by the SISVAR version 5.6 program (Ferreira, 2014).

Results and Discussion

As they are different pruning methods, central pruning, which removes from one to three whole branches, was found to exhibit significantly higher pruning mass than hedge pruning (Figure 1). Although the mass of hedge pruning – characterized by trimming of lateral branches – included the sum of pruning masses collected in two years, its mean was lower than the one of central pruning. The treatment with no pruning was represented by a null value. Central and hedge pruning processes exhibited decreases of 8.5% and 3.5% in total masses of aerial parts of plants, respectively. Both percentages were calculated based on the mass of a plant that was cut with a chainsaw and applying the rule of three to reach the approximate percentages that the pruning methods removed per plant.

Regarding branch growth, hedge pruning exhibited higher values than central pruning and the treatment with no pruning (Figure 2). Trimming triggers budbreak of young branches; depending on its intensity, and probably on the period, they may grow more vigorously.

Excessive growth is not beneficial, as it ends up generating unproductive branches and returning problems with shading. Ouedraogo et al. (2020) carried out a study of pruning intensity in young branches and observed that the process led to twig growth by comparison with the ones in unpruned plants.

The problem of dry branches was found in the experiment plants. It corroborates findings by Núñez et al. (2001) who reported that branches may dry and stop being productive in orchards where plant management limits solar radiation within canopies. Even though central pruning had not eliminated the problem, it decreased the number of dry branches significantly in both years under evaluation (Figure 3).

Since it consists in removing whole branches, it

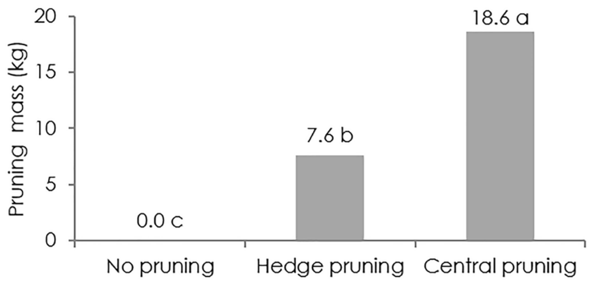

Figure 1. Pruning mass per plant of pecan trees subjected to two pruning methods
*Means followed by different letters differ by the Tukey's test at 5% probability.

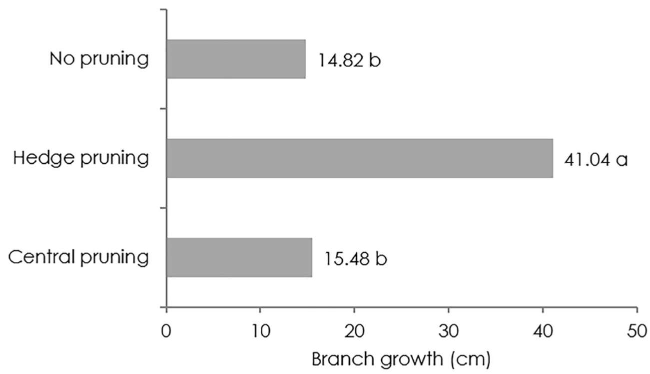

Figure 2. Branch growth of 'Melhorada' pecan trees subjected to different pruning methods after a cycle; *Means followed by different letters differ by the Tukey's test at 5% probability.

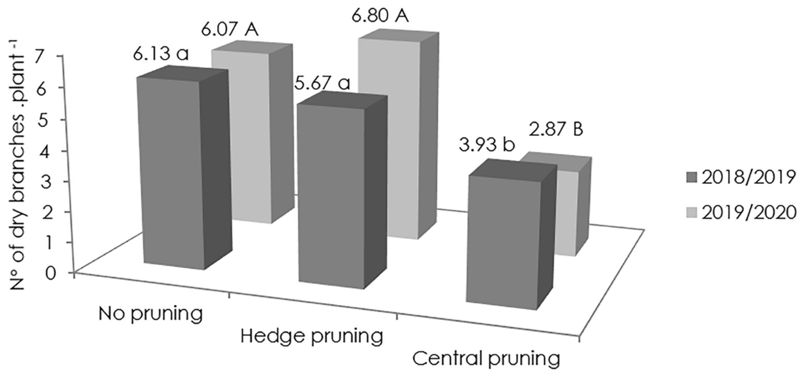

Figure 3. Number of dry branches per plant in two cycles of 'Melhorada' pecan trees subjected to two pruning methods* Means followed by different lowercase letters in the 2018/2019 cycle and uppercase in the 2019/2020 cycle differ from each other, by the Tukey's test at 5% probability.

enables more sunlight penetration through tree canopies, a fact that justifies the small number of dry branches in this treatment in both periods under evaluation. It should be highlighted that as plants develop and get larger, branch drying may seriously affect production viability. Although hedge pruning aimed at enabling sunlight penetration among rows, there was no decrease in dry branches. Since this pruning process includes trimming, which stimulates budbreak close to the pruning spot, sunlight within canopies may have been affected. Dry branches are more recurrent within canopies and in basal portions of plants because these spots are the most affected ones by shading.

In the evaluation of productive aspects, production and yield exhibited different results in the cycles (Table 1). In the 2018/2019 cycle, central pruning resulted in more production and yield, i. e., values were 26.0% higher, than the treatment with no pruning.

In the first cycle, central pruning had production and yield increased because of more sunlight within canopies, a fact that enabled higher photosynthetic efficiency, led to higher carbohydrate synthesis and, consequently, resulted in higher yields.

Table 1. Production, yield, production efficiency in terms of canopy volume (PECV), production efficiency in relation to the trunk cross-sectional area (PETCSA) and number of fruit with closed epicarps per plant (FCPP) of 'Melhorada' pecan trees subjected to different pruning methods in municipality of Santa Rosa, state of Rio Grande do Sul, Brazil, in 2018/2019 and 2019/2020 crop seasons.

Treatment	Production (kg plant^{-1})		Yield (kg ha^{-1})		PECV (kg m³)		PETCSA (kg cm²)		FCPP	
					2018/2019					
No pruning	6.55	b	1337.96	b	0.054	ns	0.031	ns	33.93	a
Hedge pruning	7.84	ab	1599.77	ab	0.066		0.036		8.33	b
Central pruning	8.85	a	1805.53	a	0.052		0.033		6.60	b
P > F	0.0405		0.0405		0.0525		0.2236		0.0001	
					2019/2020					
No pruning	3.84	a	783.36	a	0.036	a	0.015	a	22.60	a
Hedge pruning	1.52	b	310.08	b	0.013	b	0.005	b	5.67	b
Central pruning	2.05	b	418.2	b	0.014	b	0.007	b	4.67	b
P > F	0.0001		0.0001		0.0001		0.0001		0.0001	

*Means followed by different letters in a column differ by the Tukey's test at 5% probability.

ns = not significant

Hedge pruning only enabled incidence of solar radiation among plants, rather than within canopies; it may explain why production, although not different from central pruning, was not superior from the one of unpruned plants (Lombardini, 2006). However, in the 2019/2020cycle, production of both pruning methods was lower than the one of the treatment with no pruning; it was 46.6% and 60.4% lower in central and hedge pruning, respectively. In the second cycle, the best hypothesis is that, since production was higher after pruning in the first year, the alternate bearing level was higher in these treatments due to low accumulation of carbohydrate resources for the following cycle. Concerning hedge pruning, it should also be highlighted that another pruning step was carried out on the opposite side of plants; thus, branches became unproductive for some time. But the new budbreaks tend to produce over the years and lead to increase in production.

Production alternance is one of the most important problems related to pecan trees, since it is characterized by excessive load and low quality of fruit in a year, followed by low fruit loadin the next year (Khalil et al., 2016). Certain factors, such as late ripening at the end of a cycle, close to leaf drop, high energy demand due to concentration of 70% lipid in nuts and high production (number of fruit per plant) in a year, contribute to deficient production in the following year (Noperi-Mosqueda et al., 2020).

Lombardini (2006) in Texas and Wells (2018) in Georgia did not find any difference in production between unpruned plants and laterally pruned ones in the first year. However, Wood (2009) in Georgia evaluated periods and methods of hedge pruning and found low yield in all treatments with pruning, by comparison with unpruned plants in the first year. It should be noted that, in addition to using different cultivars, Lombardini (2006) carried out the experiment in Texas, a place with edaphoclimatic conditions very different from those found in the present study. In the second year, which was 'off' in experiments conducted by Wood (2009) and Wells (2018) – the same case of the experiment reported by this paper –no difference in yield was found among treatments. Lombardini (2006), in an 'on' year, only found high yield after pruning the cultivar Desirable, but found no differences in cultivars Cape Fear and Kiowa.

Regarding the number of closed epicarps, known as shucks, unpruned plants stood out, i. e., they exhibited the largest number of closed epicarps per plant. It showed that, probably as the result of little sunlight and low heat sum (degree days) in plants, there was interference in fruit development and complete ripening; thus, epicarp opening was hampered (Table 1). Considering production per plant and mean fruit mass in both 2018/2019 and 2019/2020 cycles, fruit with closed epicarp represented losses of 4.4 and 4.7% in the treatment with no pruning, 0.8% and 3.2% in hedge pruning and 0.7 and 2.0% in central pruning, respectively.

Production efficiency related to the trunk cross-sectional area and canopy volume did not differ among treatments in the first year, but both pruning methods exhibited lower values in the second year (Table 1). The negative results in the second year may be related to factors such as the alternation of production, which was higher where there was greater production in the first year, and in the case of hedge pruning, due to the removal of productive branches in the second year.

Lombardini (2006) studied three cultivars and observed that kernel yield was only higher in the treatment with hedge pruning that in the one with no pruning in the case of the cultivar Desirable, but it did not differ between cultivars Cape Fear and Kiowa. It should be highlighted that, in the second cycle, in which production load was lower than the one in all treatments carried out in the first cycle, kernel yield was 2.0% higher, on average.

Table 2. Fruit, kernel mass, shell masses, kernel yield and fruit per kilo of 'Melhorada' pecan trees subjected to different pruning methods in municipality of Santa Rosa, state of Rio Grande do Sul, Brazil, in 2018/2019 and 2019/2020 crop seasons.

Treatment	Fruit mass (g)		Kernel mass (g)		Shell mass (g)		Kernel yield (%)		Fruit kg $^{-1}$	
	2018/2019									
No pruning	8.96	ns	4.76	ns	4.19	ns	53.63	ns	113.55	ns
Hedge pruning	8.70		4.61		4.08		53.69		118.44	
Central pruning	9.10		4.80		4.24		53.04		114.00	
P > F	0.2467		0.4802		0.2945		0.6088		0.2505	
	2019/2020									
No pruning	8.42	ns	4.66	ns	3.75	ns	55.01	ns	119.90	b
Hedge pruning	8.77		4.94		3.83		55.92		125.90	ab
Central pruning	8.71		4.85		3.86		55.34		128.90	a
P > F	0.3613		0.2417		0.5874		0.3215		0.0078	

*Means followed by different letters in a column differ by the Tukey's test at 5% probability. ns = not significant.

Mean fruit masses found in the experiment are below the ones reported by Bilharva et al. (2018), who found 9.45g in the same cultivar. It may be associated with several factors, such as use of irrigation, nutrition and fruit load itself. The number of fruit in the second year was larger in plants that had been subjected to central pruning than in unpruned plants. There was a high percentage of small fruit, but it was not observed in fruit mass. Bilharva et al. (2018) also reported a small number of fruit per kilo, i. e., 107 fruit per kilo.

Concerning fruit length, fruit borne by plants subjected to central pruning were longer that the ones borne by unpruned plants in the 2018/2019 cycle. However, there was no significant difference in the second cycle (Table 3). Regarding fruit diameter and kernel length and diameter, there were no differences among treatments in both cycles under evaluation. Therefore, it is not possible to say that pruning increases the size of the fruits. Shell thickness was higher in the treatment with no pruning in the first cycle, while no difference was found in the second cycle. Shells have low commercial value; the finer they are, the easier the shelling process in the industry.

In kernel evaluation, luminosity exhibited contradictory results in both 2018/2019 and 2019/2020 cycles (Table 3). In the former, luminosity was higher in the treatment with no pruning than in hedge and central pruning, while in the latter, central pruning had higher mean that the ones of hedge pruning and treatment with no pruning. It should also be emphasized that in the second cycle, regardless of the treatment, kernels exhibited higher luminosity, a fact that may be associated with the small number of defects and low fruit production in plants.

Kernel color did not differ among treatments in the first cycle, but, in the second cycle, central pruning exhibited the highest values (Table 3). The closer the value to 90, the higher the quality and the yellower the kernels. On the other hand, the closer the value to zero, the redder the kernels. Besides, the redder the kernels, the closer to oxidation they are. Color is a criterion used by the industry to evaluate kernel quality.

The United States Department of Agriculture (USDA) (2018) classified kernels into light, light amber, amber and dark amber. When more than 25% of kernels are dark amber, are they considered defective. Some authors believe the classification is inadequate because the quality standard is extremely low and suggest the use of the simplified Munsell color system, which has six colors, rather than four, since it could be more adequate to the nut industry (Prabhakar et al., 2020).

The variable percentage of edible kernels did not exhibit any difference among treatments in both cycles. Results of preliminary studies, at least, show that most qualitative variables under evaluation did not change when the pruning methods were used.

Table 3. Fruit, kernel length, diameter, shell thickness, luminosity (L*), color (°Hue) and edible kernels of fruit borne by 'Melhorada' pecan trees subjected to different pruning methods in municipality of Santa Rosa, state of Rio Grande do Sul, Brazil, in 2018/2019 and 2019/2020 crop seasons.

Treatment	Fruit length (mm)	Fruit diameter (mm)	Kernel length (mm)	Kernel diameter (mm)	Shell thickness (mm)	Luminosity (L*)	Color (°Hue)	Edible kernels (%)
				2018/2019				
No pruning	48.21b	23.43ns	37.73ns	18.25ns	1.07a	43.09a	66.57ns	89.44ns
Hedge pruning	48.92ab	23.43	37.90	18.46	0.87b	41.26b	66.14	91.11
Central pruning	49.70a	24.01	38.91	18.52	0.90b	41.47b	66.20	91.11
P>F	0.0121	0.0615	0.0597	0.4553	0.0025	0,0112	0.5373	0.8161
				2019/2020				
No pruning	43.47ns	23.25ns	34.35ns	19.17ns	1.00ns	46.31b	71.59b	92.00ns
Hedge pruning	43.86	23.12	35.18	19.54	0.92	45.94b	70.60b	91.55
Central pruning	44.03	23.15	35.28	19.39	0.90	48.65a	73.17a	94.22
P>F	0.5306	0.6730	0.2353	0.1580	0.6696	0.0003	0.0004	0.4117

*Means followed by different letters in a column differ by the Tukey's test at 5% probability; ns = not significant.

Results showed that central pruning proved to be the most immediate option to increase fruit production in years which were considered 'on', but it did not happen in the following cycle. One of the reasons that may have led to increase in production in the first cycle is the decrease in the number of dry branches in plants. Hedge pruning, with the trimming process, did not result in productive benefits. According to Wood & Stahmann (2004), decrease in production in hedge pruning is associated with excessive canopy reduction, extreme vegetative ness and shading within the canopy. Even though fruit and kernel quality was not different in most variables evaluated in the first two cycles, continuity in the execution of pruning and evaluation throughout more cycles can represent the actual answer given by pruning methods to these aspects.

Conclusions

Central pruning in pecan trees with shading problems decreases the number of dry branches and increases fruit production in years with high production, but it is not efficient in years with low production. Hedge pruning favors vegetative growth of branches; Neither central pruning nor hedge pruning changed fruit and kernel quality significantly.

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