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Efficiency of labor in winter pruning of apple trees using technological innovations

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Abstract: The increase of new technologies in fruit-growing crops has increased productivity in cultural practices and helped farmers expand their production areas. This work aimed to quantify labor performance in winter pruning of apple trees, using manual and electronic pruning shears associated with a pruning platform and ladders. The treatments consisted of two types of pruning shears and two support systems. A pruner carried out pruning for 16 days, with a journey of 10 h per day. The average yield in manual pruning with a ladder was 21.35 plants pruned per hour per man. Using a platform increased the yield to 46.25 plants pruned per hour per man. Pruning with electronic pruning shears with a ladder showed an average yield of 33.47 plants pruned per hour per man. With platform support, yield increased to 128.5 plants pruned per hour per man. Using electronic pruning shears reduced the time for carrying out the activity. Pruning performed with platform support was more efficient, regardless of the type of tool used. This way, the technologies available for apple tree pruning reduce costs, increasing operational profitability.

Key words: electronic pruning shear, fruit growing, pruning platform.

Učinkovitost dela pri zimskem obrezovanju jablan z uporabo tehnoloških inovacij

Izvleček: Povečanje novih tehnologij gojenja sadnih rastlin je povečalo učinkovitost načinov gojenja in pomagalo pridelovalcem pri razširitvi njihovih pridelovalnih območij. Namen raziskave je bil ovrednotiti učinkovitost dela pri zimski rezi jablan pri uporabi ročnih in električnih škarij s samohodnimi platformami in lestvami. Obravnavanja so obsegala dve vrsti škarij za rez (ročne in električne) in dva podporna sistema (samohodna platforma in lestev). Rezač je opravil delo v 16 dneh, če je rezal 10 ur na dan. Pri uporabi ročnih škarij in lestve je en rezač porezal 21,35 dreves na uro. Pri uporabi platforme in ročnih škarij se je učinkovitost rezi enega rezača povečala na 46,25 dreves na uro. Pri rezi z električnimi škarjami in lestvijo je en rezač v poprečju porezal 33,47 dreves na uro. Z uporabo električnih škarij in platforme se je učinkovitost rezi povečala na 128,5 dreves na uro. Uporaba električnih škarij je zmanjšala čas rezi. Rez z uporabo platforme je bila učinkovitejša ne glede na uporabo vrste škarij. Na takšen način dostopne tehnologije za rez jablan zmanjšujejo stroške rezi in povečajo donosnost.

Ključne besede: električne škarje za rez, sadjarstvo, samohodne platforme

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1 INTRODUCTION

Family farming is, in general, known as a backward sector from an economic, technological, and social point of view, fundamentally focused on producing primary food products with a logic of subsistence production (Souza et al., 2019). This image is far from reality since the universe of family farming in Brazil is highly heterogeneous and includes impoverished and wealthy families (Vieira et al., 2019). Family farmers differ not only in terms of property size and production capacity but also in access to technology, infrastructure, and level of organization (Souza Filho et al., 2011).

Technology is one of the most influential factors in the development and growth of various sectors of the economy at a national level. Specifically in agriculture, one of the most critical activities in the Brazilian economy, technology allows the use of innovations in rural properties. It contributes to raising the productivity of crops and labor income, creating differentiated opportunities for farmers. Furthermore, specifically in family farming, according to Souza Filho et al. (2011), adopting technology can contribute to supplying the lack of labor. It may be an alternative to family succession since one of the problems in the rural environment is the aging of farmers and, consequently, the aging process. of the workforce available on the properties due to the emigration of young people due to lack of opportunities in rural areas (Ribeiro Filho & Tahim, 2022).

The limitation on the size of the property, many times, ends up compromising the financial viability of the family establishments since the scale of production becomes a structural problem. The modernization of the property, which includes training family members, the use of quality inputs, machinery, and equipment appropriate to the segment and the conditions of family farmers, is a way of allowing sustainability and significant gains in productivity in the face of systems which are less technified (Bittencourt, 2018).

Fruit-growing crops play a vital role in Brazilian income distribution, expanding job opportunities and substantially improving the quality of life in communities. This activity often demonstrates remarkable profitability, enabling economic sustainability even for small properties. Given that it demands a considerable amount of highly specialized labor, fruit growing promotes a significant increase in the availability of jobs, conferring valuable benefits to the regions where it finds its development space (Klesener, 2020).

Among the various fruit species cultivated in Brazil, the apple tree (*Malus domestica* Borkh.) is one of the most important in production numbers. According to Beling (2022), the revenue of the productive sector was around US$ 360 million (R$ 1.73 billion) in the 2020/2021 harvest, while the total financial transaction in the area was US$ 1.24 billion (R$ 6.0 billion) in addition to offering job opportunities for 175,000 people in southern Brazil and 52,000 direct jobs in the region. The apple tree has great economic importance worldwide, being the fifth most produced fruit in the world (FAO, 2023) and the third most consumed in Brazil, behind only bananas and oranges (Beling, 2022).

In Brazil, the total apple area in general is estimated at around 32.90 thousand hectares, according to the IBGE (2022), with a production of about 1.30 million tons, with Santa Catarina contributing with 635,000 t per year, followed by Rio Grande do Sul with 628,000 t, Paraná with 30 t (Revista da Fruta, 2022), and the Southern region of the country was responsible for 98 % of the national production of this crop (IBGE, 2022). Adverse weather events, mainly frost and hail in the central producing regions of Rio Grande do Sul and Santa Catarina, may be responsible for significant production losses (CEPEA, 2018).

According to information from the Brazilian Institute of Geography and Statistics (IBGE, 2022), the State of Rio Grande do Sul is currently the most prominent national apple producer, followed by the State of Santa Catarina. Average production in the 2013/2021 period accounted for about 50 % of the Brazilian output, with the leading producers located in the northeast of the state, with emphasis on the municipalities of Vacaria, Caxias do Sul, and Bom Jesus, followed by the municipalities of Meus Capões, Monte Alegre dos Campos, Ipê, São Francisco de Paula, and São José dos Ausentes.

There is a great demand for labor in apple orchards, which requires optimization to carry out cultural practices and evaluate the possibility of mechanization. Machines that reduce manual labor, such as harvesting platforms, bin transport carts, seedling planters, shredders, and electric pruning shears, can increase the efficiency of management activities in orchards, such as pruning, thinning, and harvesting, reducing activities manuals (Petri et al., 2018).

The popularity of the apple means that its cultivation remains promising for small farmers since the number of properties dedicated to this activity in southern Brazil exceeds 4,500. Most of these properties are small, although larger crops account for at least 40 % of production (Anuário Brasileiro da Maçã, 2018). Apple cultivation is an excellent opportunity for less extensive, family-owned properties, which have this fruit as their main product and source of income in a diversified fruit culture. Incorporating new production technologies in apple tree cultivation has significantly increased the

quality and harvested volume of the fruit (Mathias & Rufato, 2017).

During the apple tree pruning period, an activity essentially carried out by family members, the demand for labor is greater than that available. This causes the action to be prolonged if temporary workers are not hired. In addition, the available workforce is often poorly qualified to carry out the activity, which is considered exhausting, making the family farmer's challenge even greater. The delay in completing this agricultural practice can be detrimental to the profitability of the crop if it is considered the high investment required to produce with quality, not to mention economic fluctuations and climatic factors (Souza Filho et al., 2011).

Fruiting or production pruning is carried out during the winter. It aims to eliminate old branches, promote the formation of new shoots, and establish a balance between the production and vegetative growth of the orchard. Its intensity will determine the plant's growth and fruiting as needed (Duarte et al., 1992).

According to Bittencourt (2017), access to innovation allows the maintenance of family farmers in the countryside, creating conditions for the economic viability of family properties and their ability to develop as a family social unit, contributing to the sector's modernization. Due to the limited size of these properties, production capacity and sustainability may be impaired. One of the main benefits that the incorporation of innovations and technologies can offer is to improve the performance of the workforce, with economic return, as well as better ergonomics for the family farmer. Souza Filho et al. (2011) point out that technology plays a vital role in determining the economic performance of the property, as it allows for increased productivity and has an important effect on the sustainability of the activity. Thus, the workforce available on the property can be better used throughout the year.

Given the above, the present work aimed to quantify labor performance in winter pruning of apple trees, using manual and electronic pruning shears associated with a pruning platform and ladders.

2 MATERIALS AND METHODS

The study was carried out in an apple orchard on a family farm located in the Capela São Gotardo community, Vila Seca District, in Caxias do Sul, RS (geographical coordinates: 29°03' S and 51°03' W), at an altitude of 680 m above sea level. The production of apples was intended for fresh consumption.

The orchard was implanted in 2008 in a total area of 9.0 ha, conducted in a high-density system, with 4.0 m spacing between rows and 1.0 m between plants, totaling approximately 2,500 plants per hectare. The composition of the orchard was 75 % 'Maxxigala' plants and 25 % 'Fuji Suprema' cultivar plants, both on 'Marubakaido' rootstock.

The treatments consisted of two types of pruning shears (manual and electronic) and two support systems (ladder and platform). The pruning of the apple trees was carried out by a pruner, an employee of the property, between August 03 and 23, 2018, totaling 16 days, for 10 h daily, divided into two shifts, corresponding to 5:00 am and 5:00 pm. The correct use of the tools was demonstrated one day before data collection to verify the pruner's understanding of how the experiment would be carried out.

Initially, pruning was conducted with manual pruning shears supported by a ladder on August 03 and 04 and August 06 and 07, 2018. Then, manual pruning shears were used with platform support from 08 to August 11, 2018. Then, electronic pruning shears with ladder support were used from August 13 to 16, 2018. Afterward, pruning was performed with electronic pruning shears with platform support from August 20 to 23, 2018. During this period, 160 h of pruning was conducted, 40 h with each tool and support system. For each repetition, 5 h of pruning time were considered, totaling eight repetitions for each treatment.

The tools used were the Felco 621 pruning saw, the Felco 31 manual pruning shears, and the Felco 820 electronic pruning shears 420 mm, with a non-slip handle and steel blade. Felco 31 manual pruning shears were used to cut branches up to 25 mm, with a mass of 225 g and a length of 210 mm; the blade was made of tempered steel and the anvil of brass, and the handle was also made of non-slip material. Felco 820 electronic pruning shears were used to cut branches up to 45 mm, with a mass of 980 g and a length of 290 mm. It was controlled and powered by a battery, and its ergonomics sought to relieve the pressure on the arms' and shoulders' muscles during the entire pruning process, the blade being made of tempered steel.

A ladder and a pruning platform were used in the experiment in support of the tools. The ladder had a height of 3 m and a mass of 12 kg, consisting of six steps, and was made of aluminum. The pruning platform had a capacity for up to five people, requiring an operator. It was hitched to the third point of the tractor, and its structure was coupled to the bin transport carts. The platform had a height of 2.8 m and a length of 4.0 m, and its advancement system was pneumatic.

The number of plants pruned per hour per man was measured for the four treatments. A completely randomized, bifactorial design followed, considering the

pruning shear (manual and electronic) and the support system (ladder and platform) as factors. The results were submitted to analysis of variance (ANOVA), and the means were compared using the Tukey test at a 5 % error probability using the AgroEstat software. Subsequently, based on the average number of plants pruned per hour per man for each pruning tool and each support system, the number of days needed to prune one hectare of apple orchards was calculated.

3 RESULTS AND DISCUSSION

Table 1 compiles the results of the average number of apple trees pruned per hour per man. The data indicate that when the activity was carried out using technological innovations (electronic pruning shears and platform), there was an increase in the number of plants pruned for the same period and the same operator.

The yield of using manual pruning shears with a ladder was 21.35 plants per hour per man. With platform support for pruning, an increase in the average number of plants pruned was observed, corresponding to 46.25 plants per hour per man, a rise of 116.63 % when compared to pruning with ladder support.

As for the number of plants pruned using electronic pruning shears and ladder support, an average of 33.47 plants were pruned per hour per man. With the pruning carried out with the platform's help, there was an increase of 283.93 % compared to the pruning with a ladder, with an average of 128.50 plants pruned per hour per man.

According to Batalha et al. (2005), family farmers' use of new technologies provides conditions for exploring new opportunities and practices that require a more sophisticated production management level. This significant difference between the support systems, ladders, and pruning platforms, even using the same tool type, is due to the ease of pruning using platforms. When using the platform, the pruner does not need to descend from the ladder and reposition it several times throughout the day, causing a loss of efficiency and worker fatigue.

The average yields obtained with the manual and electronic tools and using the ladder support system were 21.35 and 33.47 plants per hour per man, respectively (Table 1). This corresponds to a variation of 56.77 % between the two types of tools. For the results of plants pruned per hour per man using manual and electronic pruning shears, the highest average yields were obtained with platform support compared to the ladder support system. The average number of plants pruned per hour with manual pruning shears was 46.25, while with electronic pruning shears, the average was 128.50 plants, corresponding to a variation of 177.84 % between support systems.

Using the orchard in which the present study was carried out as a parameter, with an average of 2,500 plants per hectare and considering that the worker in charge of pruning works 10 h a day, it would take about 12 days to prune one hectare with the use of manual pruning shears and ladder support. On the other hand, using electronic pruning shears, pruning time would be reduced to approximately 5.5 days, an efficiency gain of roughly 6.5 days per hectare using an electronic tool (Figure 1).

ors (2023).

Figure 1 shows that in the support system that uses a pruning platform, it would take approximately 7.5 days to prune 1.0 ha using manual pruning shears and 1.9 days to prune the same area using electronic pruning shears. With this, there is an efficiency gain of approximately 5.6 days per hectare using an electronic tool. In percentage terms, this corresponds to a reduction in pruning time per hectare of 74.66 %.

Considering the four treatments used in this ex-

Table 1: Number of apple trees pruned per hour per man using manual pruning shears and electronic pruning shears, with ladder support and platform for pruning.

	Support system	
Pruning shears	Ladder	Platform
Manual	21.35 Bb	46.25 Ab
Electronic	33.47 Ba	128.50 Aa
Coefficient of variation (%)	2.5495	

Means followed by the same letter, lowercase in the column (pruning shear type) and uppercase in the line (support system type), do not differ by the Tukey's Test at a 5 % error probability.

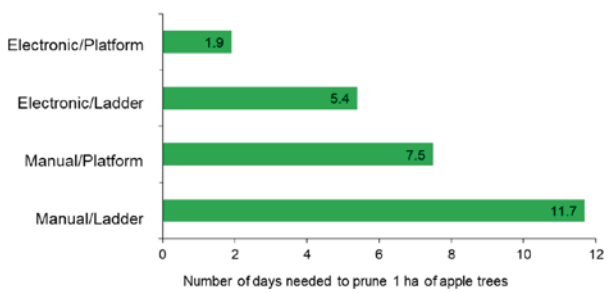

Figure 1: Number of days required to prune one hectare of apple trees considering the performance of an operator performing the pruning with manual pruning shears and electronic pruning shears, with a support ladder and platform for pruning. Source: Auth

periment, it can be noted that the highest yield gain occurred with electronic pruning shears associated with the platform, followed by the use of a manual tool and platform. The lowest yield was observed when using a combination of manual pruning shears and a ladder, a system traditionally used in orchards in the Serra Gaúcha for winter apple and other fruit tree pruning. These results demonstrate that, currently, the producer must be concerned with the planting density and conducting the narrow crown, which facilitates pruning and harvesting, improving the fruit quality and allowing mechanization in the orchard (Petri et al., 2018).

Managing a family farm is no longer based solely on mastering knowledge and traditional farming practices. Investing in education and training increases the ability to allocate resources better and make more effective decisions regarding adopting new technologies (Souza Filho et al., 2011). For the authors, the organization of the property is essential to sustainably incorporate innovations because innovation can create conditions for maintaining the economic viability of family properties and their ability to reproduce as a family social unit, contributing to their modernization.

The apple tree culture has recently undergone major transformations in Brazil, leading to important productivity increases. In addition to the rise in the number of technologies used in the crop, the planting density was of great importance for the rise in production, which went from 550 to 600 plants per hectare in the 1970s to 2,500 to 3,500 plants per hectare today. Despite this, the apple tree crop has seen its profit margin reduced (Petri et al., 2018).

Brazilian production also grew, leading to a greater supply of apples on the market. According to Petri et al. (2018), three points are essential to maintain the economic activity of the producer: production cost, productivity, and selling price. These three aspects could be improved depending on the technologies used, as the selling price is directly linked to the quality of the fruit. Furthermore, according to Souza Filho et al. (2011), the probability of investment in technology is greater when the orchard is managed by the owner, which is the reality in family farming.

Electronic pruning shears are currently one of the innovations available to facilitate the work of family farmers, who are the biggest consumers of this type of technology. Large apple-producing companies often end up not making this tool available to workers due to the low qualification of the hired labor. However, in family farming, family members are responsible for cultural practices in the orchards, including pruning. Therefore, they are more careful using and maintaining this tool.

For the production systems practiced by family farming, which are increasingly faced with the shortage and aging of the present workforce, the generation of information on the use of technologies available on the market is essential. Considering that this is the case of apple production orchards in Serra Gaúcha so that the acceptance and use of available technological innovations increase according to the farmers' resources, cultural barriers must be overcome with the generation and dissemination of information, improving the quality of life of farming families. In addition, using technologies can be an attraction for the continuity of young people in agricultural production, making them remain in rural areas.

4 CONCLUSIONS

Electronic pruning shears increased the number of plants pruned per hour per man, reducing the number of days for carrying out the activity in apple orchards. Apple tree pruning, performed with electronic pruning shears, was more efficient when compared to manual tools, regardless of the type of support used. Pruning performed with platform support was more efficient, even with manual pruning shears. Thus, the technologies available for apple tree pruning increase the efficiency of the process, reducing costs and enhancing farmer gains.

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