Comunicata Scientiae
Horticultural Journal

REVIEW
published: 31 December 2021
https://doi.org/10.14295/CS.v12.3865

Pear production in Brazil: a review

Leo Rufato[1]*, Alberto Ramos Luz[1], Deivid Silva de Souza[1], Janaína Muniz[2], Bruno Dalazen Machado[2], Augusto Schütz Ferreira[1]

[1]Santa Catarina State University, Lages, Brazil
[2]Federal Institute of Santa Catarina, Lages, Brazil
*Corresponding author, e-mail: leoruffato@yahoo.com.br

Abstract

The cultivation of pear trees in Brazil started with a larger harvested area than apple trees, however, it did not have the same development. The production of pears has not been as promising as expected, being considered one of the temperate-climate fruits of less commercial interest in Brazil, due to several factors that are discussed in this paper. However, the pear has great economic importance in Brazil as it is the main item in the Brazilian fresh fruit import agenda. Aspects related to the main scientific advances and applied technologies are also described in this paper, mainly regarding rootstocks, cultivars, management techniques and, finally, some considerations about what is missing to produce more pears in Brazil.

Pear introduction in Brazil

The first pear cultivars were introduced in Brazil around 1850 and 1900 by European immigrants, mainly Italians, Germans, and Poles. Some years later, the Japanese immigrants introduced the Asian pears. There were several commercial pear production attempts, mainly between 1950 and 1990, but few producers were successful (Luz et al., 2021).

In 1909, at the Fazenda Santa Elisa in São Paulo, currently Instituto Agronômico (IAC) - Centro Experimental de Campinas, the German pomologist João Hermann was hired to work on the introduction, multiplication, and cultivation of many fruit species, among them, pears. The beginning of experimental cultivations and tests with pear trees in Brazil is believed to have been in 1926, in the city of Valinhos, state of São Paulo, by the fruit grower Batista Bigneti (Bleicher, 2006).

The 1930s was the peak of the planting and cultivation of European pear trees, mainly in the municipalities of São Roque and Guarulhos, São Paulo. In the 1950s, the first Japanese and Chinese cultivars were introduced in the state. Due to low productivity and quality, as well as little economic return with European cultivars, there was a decline in crop planting. Between the 60s and 70s, cultivars developed by IAC were planted in some areas, grafted on quince rootstocks. Thanks to the experimental results of research consolidated between the 1930s and 1950s, in the states of São Paulo and Rio Grande do Sul, the culture of the pear tree began to gain prominence in Brazilian agriculture, as well as other fruit crops (Faoro, 2001; Bleicher, 2006; Bonetti et al., 2006).

Between the years 1965 and 1975, the Sociedade Agrícola Fraiburgo, in Santa Catarina, imported from Europe varieties of all temperate fruit trees, including pear species that could best be adapted to the edaphoclimatic conditions of the Santa Catarina state

Received: 17 November 2021
Accepted: 24 November 2021

(Bonetti et al., 2006).

However, over the years, its cultivation and production has not been as promising as expected, due to several problems with its vegetative and reproductive development, considering one of the least planted and studied temperate fruit crop in Brazil.

Production

The cultivation of pear trees in Brazil started with a larger harvested area than apple tree, on the other hand, did not have the same development. In 1961, the country had 3,553 hectares (ha) of pears harvested area, producing 45,092 tons (t), resulting in an average yield of 12.7 t ha^{-1} (FAO, 2019).

Both total pear production and harvested area increased to 60,676 t over 4,703 ha in 1970. However, in 1973 production began to fall to 32,899 t annually, a reduction of 46% (FAO, 2019).

From 1973, a linear reduction in pears production started until the 2000s, mainly due to the yield reduction, which produced on average of 8 t ha^{-1}. In 1977 there was a peak in cultivated area with pear trees, 5,528 ha, but the low productivity, as well as the positive advances in apple tree cultivation, were determinant factors for the reduction of the cultivated area with pear trees, which started in 1978 and continues to occur nowadays (Figure 1) (FAO, 2019).

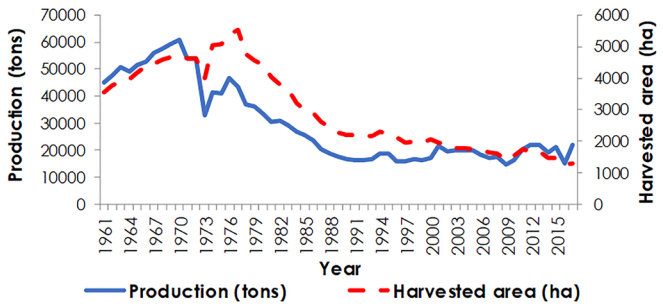

Figure 1. Cultivated area (ha) and pear production (tons) in Brazil from 1961 to 2017.
Source: FAO (2019).

During this period of cultivated area reduction, there was a small increase in the years 2010 and 2011, with the planting of 356 ha. That increase is believed to be due to the growth in the number of scientific studies on pear culture conducted at universities and research institutions. The scientific knowledge generated, besides bringing back this deficiency in Brazilian production, stimulated the fruit growers to implement new orchards due to the better technical knowledge about the culture when compared to previous years. However, in 2012, eradication of old orchards continued, which were the responsible for reducing harvested area to 1,249 ha in 2016. The most current data on harvested area is 1284 ha in 2018 (IBGE, 2019). The continuous eradication of pear orchards in Brazil comes because of the lack of research that are not providing technologies to the growers to make it a profitable activity and mainly stable over the years.

Since 1988 national production did not exceed 20 thousand tons until the early 2000s, where the national productivity average went from 8 to 11 t ha^{-1}. The national average productivity remained for a little over 10 years between 10 and 11 t ha^{-1}, so production decreased as the cultivated area reduced.

In contrast to the linear reduction in pear cultivated area in Brazil, production has stabilized in recent years due to increased productivity. Although still with little expression of production, it can be said that from 2011 there was a more pronounced positive change in the Brazilian pear orchards. From this year, it began to reap Brazilian pear culture research results, with the publication of more than 130 scientific articles, various technical events and training carried out to update the growers (Luz et al., 2021). This reflected the increase in technology employed in orchards, increasing yields to 16.9 t ha^{-1} in 2017 and 15,4 in 2018, keeping production at 20-22 thousand tons, around ten percent of national consumption.

Historically, even though fruit demand was high, low productivity encouraged the growers to migrate to more profitable activities. Besides the increase of more than 60 percent in less than ten years, the yields obtained from pear cultivation in Brazil are considered low compared to the countries around Brazil, such as Argentina and Chile, which in 2017 produced an average of 36.2 t ha^{-1} and 35.6 t ha^{-1}, respectively. The apple tree crop, which is consolidated in Brazil, obtained an average yield of 39.3 t ha^{-1} in 2017 (FAO, 2019).

The limitation of pear cultivation has not been due to lack of market, but due to factors that interfere in the production process, and these can be divided into two distinct situations: a) when there is no fruit production and no flowering. This situation is more complex, and several factors may be related to low productivity, such as cultivars not adapted to the cultivation conditions (Silva et al., 2008), use of inadequate rootstocks (Giacobbo, 2006; Machado, 2014; Souza, 2016), excessive vegetative growth, either due to improper management or inadequate choice of combining canopy and rootstock cultivars and planting density, leading to early plant sprouting or complete vegetative imbalance in the orchard, which has a negative effect on the formation

of floral buds, mainly by shading the inner and lower parts of the canopy, among others; and b) when there is no fruit production but there is flowering, and in this case the problem occurs mainly in the pollination and fertilization phase, causing low fruit set (Luz, 2016). This another situation often occurs in Brazilian pear orchards, and it may be related to the lack of pollinating cultivars, use of incompatible or non-coincident flowering cultivars, improper weather conditions (low temperatures, rainfall, and high winds) during flowering period, absence of pollinating insects, among others (Luz et al., 2017; Almeida et al., 2020).

Regarding national production, Rio Grande do Sul state remains the largest Brazilian state producing pears (67.5%), followed by the states of Santa Catarina (26.7%) and Paraná (4.7%). According to Fioravanço & Oliveira (2014), São Paulo and Minas Gerais states were among the main producing states, but with the production growth in Santa Catarina and Paraná, besides the decrease in production in São Paulo and Minas Gerais, South-eastern states have reduced their share of national pears production (IBGE, 2019).

Currently, irrigated areas in the Brazilian semiarid region, mainly in the São Francisco Valley region, have shown that there is the possibility of cultivating pear with economic potential, contrary to most of the existing literature, which states that the highest production and quality of pear trees can be acquired in temperate regions of southern Brazil. In this region, cultivars with low chilling requirements predominate, the trees do not enter the dormancy phase, and through the control of irrigation, management of fertilizers and the use of plant growth regulators, the floral induction of pear trees is promoted, obtaining two productive cycles in twelve months. It is still a recent exploration and research has been intensified, but it is proven the pears production viability in these regions.

According to data from FAO (2019), there was a 63% decrease in harvested area from 1961 until 2017. In terms of production, there was a decrease of 51% in the same period, however, productivity increased by 33.5%, showing the culture had increased yield efficiency, although still needs further studies to make the pear culture self-sufficient.

Importation and exportation of pears

Pear is the main item in Brazilian fruit import agenda, both in volume and value, far surpassing other fresh fruits, such as grapes, apples, peaches, plums, among others, generating a cost that represents more than 40 percent of all investment in fresh fruit imports across the country (Souza, 2016). Imported amount of fruit is significant, due to the deficit of national production, which could soften the amount spent to supply the consumption of pears in the country.

According to data from the Brazilian Ministry of Industry, Foreign Trade and Services (Comex Stat, 2020), the behaviour of pear imports into the Brazilian market can be divided into three moments, from 1997 to 2019 (Figure 2). From 1997 to 2003, there was a growing reduction in the quantity of imported pears, representing a reduction of 59 percent. From 2003, the behaviour was reversed and presented an annual increase until 2012, the year of largest importation of pears ever recorded in Brazilian history, with a volume above 217 thousand tons, representing an increase of 245 percent compared to 2003, which coincidentally was the year with the lowest volume imported in the last twenty years. From 2012 the volume decreased again until the amount of 153 thousand tons in 2019.

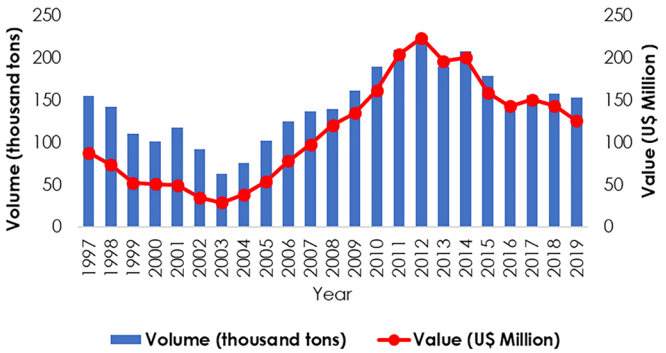

Figure 2. Volume (thousand tons) and costs (U$) of pear imports from Brazil between 1997 and 2019.
Source: Comex Stat, (2020).

Although there have been fluctuations in the quantities imported into Brazil, pear has always been at the top of the import list of fresh fruits both in volume and spent values, and in recent years have been the largest and most expensive fruit to import. Amounts spent importing pears ranged from $ 29 million with an average price of 0.46 U$ Kg^{-1} in 2003 to $ 223 million with an average price of 1.03 U$ Kg^{-1} in 2012. In 2017, $ 151 million was spent with an average price of 0.97 U$ Kg^{-1}. On average, over the past ten years, imports of approximately 180,000 tons have been imported at a cost of $ 170 million and an average price of 0.94 U$ Kg^{-1} (Comex Stat, 2020).

According to Viana et al. (2013) around ten pears cultivars have been sold in Brazil, especially from Argentina and Portugal, which provides diversity of supply, attracting consumption. The most common are 'William's', 'D'anjou' and 'Rocha' pears.

Argentina has always been the leading supplier of pears to Brazil, but local production has been hampered by the country's economic crisis (Viana et al., 2013). Given this, Portugal has been favoured, and has increased its shipments to Brazil. According to Portugal's National Association of Pear Producers (Anp, 2019), which represents over 80 percent of Portuguese fruit producers, Brazil is already the largest destination for Portuguese pears. Argentina and Portugal are the most important pear suppliers to Brazil followed by Spain, Chile, and the United States. In recent years there has been a change in the representativeness of each of these countries to supply pears to Brazil, where there has been a considerable reduction in the amount supplied by Argentina and the United States, and an increase in the representativeness of Portuguese, Spanish and Chilean pears. From 2014 to 2019, Argentina accounted for between 58 and 67% of pears imported by Brazil, followed by Portugal (21 to 27%), Spain (4 to 9%), Chile (1.5 to 2.8%) and the United States (1.5%) (Comex Stat, 2020).

Despite the production deficit when compared to consumption, a small part of Brazilian production was destined for foreign trade in some specific years. The pear exports earnings are tiny compared to the amounts spent to supply domestic consumption.

In 1997, 9.6 t worth 0.58 U$ Kg^{-1} were exported, generating income of 5,589 U$ (Figure 3). The volume exported again has a slight volume between 2001 and 2004. The largest volume exported in this period is in 2003, with the quantity of 7.7 t, as the main destination of the African countries Angola and Cape Verde. Between 2006 and 2008 there is a growing demand for selling pears to the foreign market, reaching 66.2 t in 2008. Most of the pear exported during this period went to Italy. From 2010 to 2012, pear exports also occur in a significant but lower volume compared to 2006 to 2008, peaking at 22.7 t, with most of the fruit being exported to Argentina and France (Comex Stat, 2020).

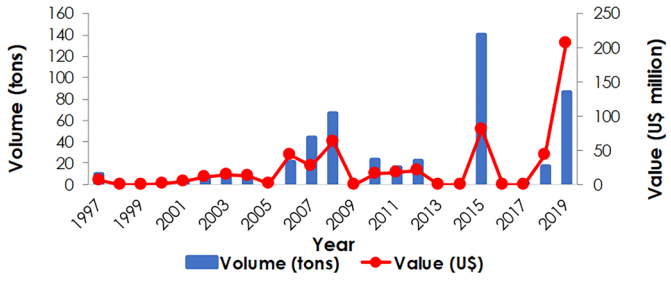

Figure 3. Volume (tons) and value (U$) of pear exported by Brazil between 1997 and 2019.
Source: Comex Stat (2020).

The exportation of pears in some specific years occurred because it was more profitable international trade due to currency differences and the national pear be undervalued in the Brazilian market. According to Bueno & Baccarin (2012), Brazil has presented in recent years an export evolution of fresh fruits, mainly for adding value to the product.

In 2015, the largest export of Brazilian pears in history was recorded, 140.3 t to Portugal, an exception when compared to the volumes exported so far. According to Silva (2016), in that same year there was a 53 percent increase in exports from Portugal to Germany, which shows that the European country needed Brazilian fruit to supply its own market or even to resell it in Europe.

Brazil had an average pear export value of 21.7 t, sold at an average price of 1.5 U$ Kg^{-1}, with an average value of 18543.3 U$ sold. In 2000 the fruit was sold at the highest price, being 3.35 U$ Kg^{-1}, while the lowest price recorded was 0.57 U$ Kg^{-1} in 2015. That year there was also the biggest gain, of 80182 U$, already despite the low price, the quantity exported was significantly higher than in previous years (Comex Stat, 2020).

Brazilian pears exportation is not significant, occurring only in some specific years, but it exists and can be explored with the increase of national production, since the harvest occurs in the opposed period to harvest of the producing countries in the northern hemisphere. Brazil exported pears mainly to Argentina, Italy, and Portugal, which are also the main pear suppliers to Brazil (Comex Stat, 2020). At this moment, with a large difference in the value of the Brazilian currency in relation to the Dollar and the Euro, exports can be much more profitable than selling the pears to the domestic market.

Consumption of peras in Brazil

The consumption of pears in Brazil is the sum of the national production with the imported volume, less the exported volume. Pears were reduced from 171,348 t in 1997, with per capita consumption of 1.07 Kg $person^{-1}$ $year^{-1}$ to 82,657 t in 2003, equivalent to 0.47 Kg $person^{-1}$ $year^{-1}$ (Figure 4). From 2004, the consumption of the fruit increased until 2012, when it decreased again. The consumed volume of the fruit in 2012 was 239,099 t, being the largest consumed volume of the fruit by the Brazilian consumers, equivalent to 1.23 Kg $person^{-1}$ $year^{-1}$ (IBGE, 2019; Comex Stat, 2020; FAO 2019).

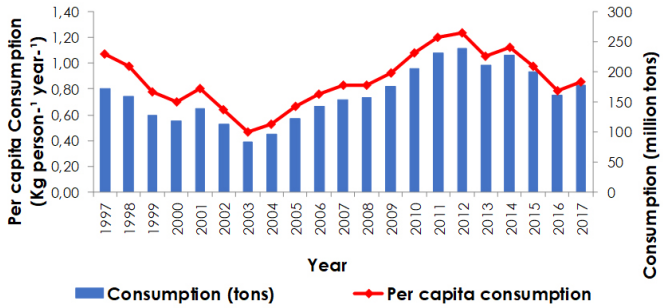

Figure 4. Total consumption (million tons) and per capita consumption (Kg person^{-1} year^{-1}) of pear in Brazil, between 1997 and 2017.
Source: Adapted from IBGE (2019), Comex Stat, (2020) and FAO (2019).

Economic factors may be linked to the behaviour of consumption, and when there is a decrease in prices and an increase in population income, the consumption of more expensive products, such as pear, may increase. According to Fioravanço & Oliveira (2014), the increase in consumption is usually related to the increase of the purchasing power of people, diversity of cultivars supplies and possibility of more regular supply of the market due to the origin of the fruit from countries of both hemispheres.

From 1997 to 2017 the average consumption in the Brazilian market was 162,615 t, with an average per capita consumption of 1 Kg person^{-1} year^{-1}. Comparing 1997 with 2017, the volume consumed increased by only 4.05%, but with a decrease of 19.75% in per capita consumption. When comparing the per capita consumption of the pear with the apple, which in Brazil has a consumption of 5.94 Kg person^{-1} year^{-1}, or with the banana, estimated at 24 Kg person^{-1} year^{-1}, it is noted that the individual consumption of pear fruit in Brazil is low.

The commercialization price of pears is the main factor in low per capita consumption, being consumed only by the highest income earners, from the upper to upper-middle class, a minority of the Brazilian population. The rest of the population prefers cheaper fruits such as apples and bananas. According to the São Paulo State Warehouse and Warehouses Company, the third largest wholesale food centre in the world and the first in Latin America, prices traded in October 2020 in Brazil, ranges from 0.87 to 2.01 U$ Kg^{-1} of pears, from 0.88 to 1.58 U$ Kg^{-1} of apples and 0.34 to 0.84 U$ Kg^{-1} of bananas, the latter being marketed for up to 0.15 U$ Kg^{-1} in certain Brazilian regions and times of the year, while pears can be found in some specific markets for over 2.5 U$ Kg^{-1} (Ceagesp, 2020).

Depending on the time of harvesting and the origin of the fruit, its price difference may increase, as national production of apples and bananas is practically enough to meet demand, while most of the pears consumed come from foreign markets. The low supply of national pears, as well as the rising cost of imports, discourages the consumption of most of the Brazilian population. Among some possible factors, a greater supply of national fruit and a decrease in the price of commercialization could increase the per capita consumption of pears.

The fact most of pears consumed in the country are imported are a clear indicator of the need for investment in research that can provide enough information to be interested in the establishment of new orchards, and consequent increase in national production (Ribeiro et al., 2018).

The participation of national pears in Brazilian consumption had a constant behaviour between 1997 and 2017, representing approximately 10% of consumed. Only in 2003 was there an exception due to the low imported volume, where the national pear represented 24% of the total consumed (Figure 5). The apple tree was introduced in Brazil in the same period as the pear tree, but had a better adaptation and faster evolution, where it went from importer to exporter of apples, and today the Brazilian apple represents 91% of the apples consumed in the country, comportment extremely opposite to pears (FAO, 2019; Comex Stat, 2020).

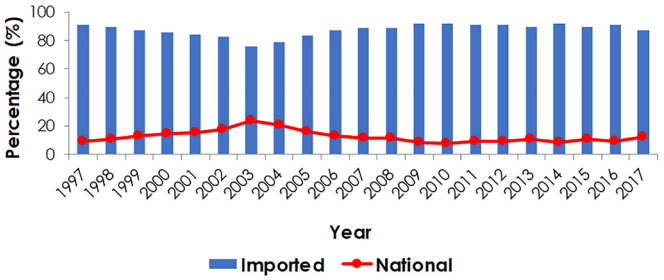

Figure 5. Consumption percentage of national and imported pear in Brazil, between 1997 and 2017.
Source: Adapted from Comex Stat (2020) and FAO (2019).

Main scientific advances and applied technology

According to Luz et al. (2021), there have been around 40 years of research on the culture of the pear tree in Brazil, studying the most varied subjects, mainly in the southern region of the country, totalling 222 scientific papers published in Brazilian and international journals. Results generated were and still are important, serving as knowledge for fruit growers, extension workers and researchers.

The main results of applied research will be highlighted below, as well as what has worked in practice in pear orchards in Brazil and some topics that are being studied with good prospects.

Rootstocks

The combination of rootstocks and cultivars were studied for their vegetative and productive behavior, incompatibility, and propagation. The most studied rootstocks were the Belgian quince Adams, the British quince EMC (East Mailing C) and selections of *Pyrus calleryana* (Luz et al., 2021).

The main results found do not indicate the use of EMC as a rootstock for pear trees due to incompatibility problems. Low vigor rootstocks such as Adams can be used with some cultivars in high density orchards and mandatorily with irrigation systems (Silveira et al., 2017; Machado et al., 2017). Ba-29 is the better rootstock option today for providing the best vegetative and productive balance, specially for Rocha cultivar. The use of *Pyrus calleryana* as rootstock for pear trees is possible, however, with the use of numerous techniques to control the excessive vegetative growth, even early productions are possible from the third year, but the high demand for labor to perform the tree management is the main difficulty (Almeida et al., 2019). This last rootstock is predominantly used for hybrid and Asian pear orchards (Nakasu & Leite, 1990; Leite & Denardi, 1992; Leite, 1992).

Some genotypes of the Old Home Farmingdale series are being studied, together with selections of rootstocks obtained by the CAV UDESC fruit crops group, such as CAV 3.

The selections Old Home x Farmingdale (OHxF) were developed in Oregon in the United States of America, in 1960, resulting from crosses between two pear cultivars belonging to the genus Pyrus communis 'Old Home' and 'Farmingdale' (Machado et al., 2012). The OHxF series enjoys great success at a commercial level in the world, being the same constituted by countless clones with diverse levels of vigor being: OHxF 18, 34, 40, 51, 69, 87, 97, 112, 130, 198, 217, 226, 230, 266, 267, 282, 288, 333, 361 and 515 (Sansavini, 2007).

Among the positive characteristics of these rootstocks stand out their adaptability to soils with a tendency to water deficit, high tolerance to active limestone (superior to all known quince rootstocks), to heavy soils, to chlorosis, excellent affinity of grafting with the most cultivated pear varieties, medium vigor, and early production (Campbell, 2003; Colombo, 2003). Other positive characteristics are that it does not present incompatibility with the cultivars of *Pyrus communis*, maintaining greater regularity in productivity over the years, reducing the problem of early sprouting observed in quince trees.

According to Reil et al. (2007) and Westwood (1982) this whole series is resistant or at least little susceptible to fire blight (*Erwinia amylovora*) and crown gall (*Agrobacterium tumefaciens*). However, most rootstocks in this series have difficulty rooting via woody cuttings (Reil et al., 2007; Machado et al., 2012).

OHxF 69 is of moderate vigor and productive efficiency from moderate to high and has constant production with great anchoring of the roots (Reil et al., 2007). After 10 years of evaluations of the pear cultivar Starkrimson grafted on different rootstocks from the OHxF series, the best results of accumulated productivity were obtained in the trees grafted on OHxF 69 and OHxF 87 (Ing, 2002). In initial studies by Nedilha (2019) in Brazil, it was found that the OHxF 69 rootstock showed great adaptation and compatibility with the cultivars Santa Maria and Rocha in the region of Guarapuava in the state of Paraná.

According to Ing (2002) and Loreti et al. (2002), OHxF 87 is the most promising among all tested rootstocks in the OHxF series. In studies by Robinson (2015), this rootstock proved to be one of the best options for high density pear orchards in the northeastern United States of America.

The CAV UDESC Fruit Crops Group in 2012 started to select new genotypes of rootstocks originating from a population of *Pyrus communis* established in 2008, containing 320 seedlings, to develop a micropropagation protocol for these genotypes with objective of configuring less vigor to the trees, compatible with the European cultivars of interest, and adaptable to the edaphoclimatic conditions of the southern region of Brazil. Four advanced selections were selected, CAV 3, CAV 121, CAV 217 and CAV 54. The CAV 3 genotype was more prominent and maintained its characteristics over the years (Grimaldi, 2014).

Experimental areas were implanted in 2017, with the cultivars Rocha, Santa Maria and Carmen grafted on CAV 3, OHxF 69 and OHxF 87 in São Joaquim - SC and Caxias do Sul - RS. Soon we will have the first results on the behavior of these rootstocks in Brazilian conditions.

Cultivars

The definition of the canopy cultivar is one of the main factors in the success of the production system (Machado et al., 2012). The chilling requirement of each cultivar must be considered (Brighenti, 2012), mainly for the purpose of selecting cultivars with potentially coincident flowering, with good budding and minimal risks of late frosts, in addition to other management and consumer market aspects, which will depend on each region.

The European most studied cultivars in Brazil were Packham's Triumph, Abate Fetel, William's, Rocha, and Santa Maria. The most studied Asian's cultivars were Hosui, Nijisseiki, and Kosui and the most studied hybrids pears were Kieffer, Carrick, Seleta, and Tenra (Luz et al., 2021).

'Rocha' is the Portuguese pear, one of the cultivars that stands out for its regular production when well managed, and for the interest of consumers, who already knows this cultivar from Portugal, second most pear's suppliers to Brazil. On the other hand, it has medium to small size fruits, a fact that makes it difficult to achieve high yields. There are considered good yields for this cultivar between 25 and 35 t ha^{-1}. The chilling requirement during the winter period is at least 550 hours below 7.2 ºC (Couto, 1979). Rocha is an inter-fertile and partially self-fertile cultivar, that for high yields, it is necessary to have pollinators and 5 to 8 hives per hectare (Sousa, 2010). Among the cultivars recommended as pollinators for 'Rocha' are 'Carapinheira', 'Packham's Triumph', 'Tosca®', 'Angelys®', 'Carmen®' (Sousa, 2010), and 'Santa Maria' (Wrege et al., 2016; Epagri, 2016). It is a pear with good storage potential, with a recommended harvest point between 54 and 64 Newtons of flesh firmness and between 11 and 13% ºBrix of soluble solids (Alexandre, 2001).

Packham's Triumph and Santa Maria are also among the most productive European pears under Brazilian conditions (Machado et al., 2015). 'Santa Maria' has medium chilling requirement (Chabchoub et al., 2010), it is indicated for some regions of Rio Grande do Sul and Santa Catarina that has more than 500 hours below 7.2 ºC (Wrege et al., 2016). Arouses interest in its precocity and quality of the fruits, which are harvested in mid-January, early February, with flesh firmness between 57 and 48 N (Antoniolli et al., 2016). The cultivars Passa Crassane, Precoce Morettini, Rocha and Packham's Triumph are indicated as pollinators. (Morettini et al., 1967; EPAGRI, 2016). As limitations, it has a low storage period and is considered susceptible to the main diseases that occur in Brazil, such as Entomosporium leaf spot (*Entomosporium mespili*) (Gonçalves et al., 2013) pear scab (*Venturia pirina*) and European canker (*Neonectria ditíssima*).

'Packham's Triumph' pear trees present medium to large size fruits 270 g (Morettini, 1967) which facilitates reaching productivity of 50 t ha^{-1}. The fruit skin is thin, green in color when immature and light yellowish green when ripe and may show little prominent russeting. Its fruits have good resistance to handling and high potential for quality conservation after harvest. The following cultivars can be used as pollinators: Rocha, Santa Maria, Hosui, William's or Max Red Bartlett, with greater or lesser coincidence of flowering, depending on the growing region (Faoro et al., 2016).

Among the Asian ones, 'Hosui' and 'Ya-li' stand out, while the hybrid 'Kieffer' is the most productive pear in Brazil, reaching yields of around 80 t, without serious problems of alternate bearing. 'Kieffer' pears, botanically classified as a cross between the European 'Bartlett' pear (*Pyrus communis*) and the Asian 'Sand' pear (*Pyrus pyrifolia*). Because it is classified as a hard pear, it is considered by many people to be a low-quality pear and has not aroused interest in national research. On the other hand, it is the growers' favorite for its high and constant production, being marketed by growers between 0.18 and 0.45 U$ Kg^{-1}, a good income compared to apple trees that are normally marketed between 0.14 to 0.27 U$ Kg^{-1}. Due to the low supply of national pears, or cheaper pears, there is a demand for this pear and associated with high productivity it becomes a profitable activity.

In Brazil, there are pear trees genotypes of low chilling requirement, developed in Brazilian breeding programs, by the Campinas Agronomic Institute (IAC) and Brazilian Agricultural Research Corporation (EMBRAPA), such as the cultivars Tenra, Primorosa, Princesinha, Seleta, Teen, Centenária, Le Conte, Cascatense, among others registered or others that still under selection. Some of these are pears produced in the tropical climate of the Brazilian semi-arid region. These pear trees have high productive potential, since the trees have good flowering and fruit set. As a negative point, they are early cultivars with a risk of damage by late frosts during flowering, and in general, the fruits do have a short period of storage.

These cultivars are often judged to be inferior to traditional European pears, but 'Kieffer' is proof that "low-quality" pears are accepted by the Brazilian consumers. These cultivars should gain more attention through research, as they produce fruits more easily than European pear trees, but information is lacking to ensure the profitability to the growers. It is also a way of valuing the technologies and findings of national research with potential for economic cultivation.

A paper was published by Wrege et al. (2016) indicating the agroclimatic zoning for European and Asian pears to Southern Brazil, the authors describe the cultivars Carrick, Ya-li and Packham's Triumph as indicated for practically all the southern regions of the country, followed by the cultivars Cascatense, Forelle, Housui, and Kousui, indicated for most areas, and third,

the cultivars Tenra, Seleta, Santa Maria, Kieffer, Nijisseiki, Rocha, and Le Conte (among others), indicated for only half of the regions zoned by the work.

In addition to choosing the cultivar according to their chilling requirement, attention should be paid to the choice of pollinating cultivars, which coincide with the flowering period and are genetically compatible. Good results have been obtained in orchards with 'Rocha' (Figure 6 and 7), 'Packham's Triumph' (Figure 7) and 'Santa Maria' (Figure 8) pear trees, however in some years when the flowering period is short, around 10 days, pollination may not be efficient because the flowering does not completely overlap. Differences in phenology also occur according to the cultivation climate, being indicated the presence of more cultivars to ensure efficient pollination in all years. It is believed that the cultivars Carmen, Coscia, Carapinheira, Precoce Morettini and Passe Crassane may be alternatives for pollinating 'Rocha', 'Santa Maria' and 'Packham's Triumph' pear trees, as well as their fruits have potential for commercialization in Brazil.

The arrangement of cultivars on orchard is an important factor due to the difficulties of pollination and fruit set. Almeida et al. (2020) and Luz et al. (2017) describes that the arrangement in blocks of one row of 'Packhams Triumph' by three rows of 'Rocha' does not provide efficiency in pollination, indicating the distribution of pollinator cultivars in the line, with a maximum distance of 20 meters from each other, and at least one more pollinating cultivar, where in the case studied it could be 'Santa Maria' pear.

Figure 6. Production of 'Rocha' pear grafted on 'BA 29' on São Joaquim, SC, during the 2019/20 season.
Photo: Alberto Ramos Luz

Figure 7. Production of 'Packham's Triumph' (left) and 'Rocha' (right) pear grafted on 'BA 29' on Lages, SC, during the 2019/20 season, reaching estimated yields of 40 ton ha^{-1} on 'Packham's' and 30 ton ha^{-1} on 'Rocha'.
Photo: Alberto Ramos Luz

Figure 8. Production of 'Santa Maria' pear grafted on 'BA 29' on São Joaquim, SC, during the 2019/20 season, reaching estimated yield of 45 ton ha^{-1}.
Photo: Alberto Ramos Luz

Management techniques

The use of plant growth regulators (PGRs) in pear tree culture was a very studied topic, focusing on their use in dormancy, reducing the vegetative growth and increasing yield of pear trees. The PGRs in the dormancy studied hydrogen cyanamide associated or not to thidiazuron (TDZ) and mineral oil, lime sulphur (calcium polysulphide) and garlic extract for the budbreak of pear trees. Several alternatives help to stimulate budbreak of pear trees, with variable results for dose, cultivar, and cultivation area (Oliveira et al., 2008; Oliveira et al., 2009a; Oliveira et al., 2009b).

For vegetative growth control, papers were published on the use of PGRs, all of them discussing results of the use of prohexadione calcium to reduce vegetative growth of European and Asian pear trees, concluding that the prohexadione calcium is efficient (in different percentages) for the reduction of vegetative growth and even reducing winter pruning in pear trees (Carra et al., 2016; Carra et al., 2017a; Carra et al., 2017b; Hawerroth et al., 2012). Also, girdling high-vigor pear trees helps the floral formation and the partition of carbohydrates for the reproductive organs (Luz et al., 2018; Rufato et al., 2015a).

Gibberellin and cytokinin PGR's as well as ethylene synthesis inhibitors have been studied to increase fruit set of pear trees in Brazil. Products based on gibberellins and cytokinins action during the bloom period, as Thidiazuron, Promalin®, gibberellic acid, among others, combined or not with AVG (Retain®) around 7 to 14 days after full bloom demonstrated the best results increasing the fruit set of several pear cultivars, however it is a complementary tool and cross-pollination with the use of different compatible cultivars and management of hives during the flowering period should be used (Carra et al., 2018; Pasa et al., 2018; Luz et al., 2017; Pasa et al., 2017; Rufato et al., 2015b; Luz et al., 2014; Rufato et al., 2012; Rufato et al., 2011; Bianchi et al., 2000).

What is missing to produce more pears in Brazil?

In Brazil the pear trees cultivation is carried out the same or in a very similar way to the cultivation of apple trees, becoming a problem, since the pear tree is less efficient photosynthetically than the apple tree, with that it becomes more difficult the floral formation; the flowering period is shorter, where climatic conditions play a fundamental role in pollination and fertilization of flowers, as well as pear blossoms are less attractive to pollinating insects than apple blossoms, among other factors. Therefore, with countless differences between these crops, the management must be different to achieve high yield efficiency in pear orchards.

There is a difficulty for pear grower to receive knowledge through existing information and technologies, whether generated by national research or through international publications, due to the lack of professionals involved in research and the production of pears in Brazil. As a result, there are few professionals who dominate the pear tree management and are up to date on scientific and technological advances. As a result, many basic problems regarding tree management and pollination, for example, which begin to be solved as soon as the orchard is correctly established, could be avoided if the extension programs were more efficient.

The lack of interest in research with pear trees in Brazil is another aggravating factor in the development

of pear production. The understanding of some problems, mainly due to the cultivation in a sub tropical climate, could be understood and solved through research. As well as the study of new cultivars, rootstocks, training systems, and other important topics that would make the activity more technological and competitive.

There is already enough knowledge to produce pears profitably in Brazil. The exploration of hybrid cultivars with low chilling requirements could be a viable alternative, due to the greater adaptation of these cultivars to the edaphoclimatic conditions, but they need to be better studied in the different cultivation areas. 'Kieffer' is already successfully exploited, but through research, more efficient ways of production could be developed, with higher density orchards and lower labor costs.

Among European pears, Rocha pear also has viable production technologies, however many orchards do not use these technologies, thus not achieving profitable yields. Among the technologies, the use of the rootstock Ba-29 stands out until now, preferably with irrigation system, at least two compatible pollinating cultivars (Packham's Triumph and Santa Maria), but in addition to these, the use of other pollinators such as 'Carmen', 'Coscia', 'Carapinheira', 'Precoce Morettini' and 'Passe Crassane' could help to increase the fruit set, one of the biggest difficulties in the production of pears in Brazil. The use of six to ten beehives per hectare during the flowering period, as well as the use of plant growth regulators can ensure enough fruit set.

Although many factors are unfavorable to pear production in Brazil, there are other factors that are favorable and help to make pear production viable. Among these factors, we highlight the use of transportation logistics, sales network, and storage structure available from the apple production; the high price of imported pears and low national competition, means that the national pear has a value of two to four times more than the value of the apple, allowing the same profit with smaller productions since the production cost is similar.

Therefore, the production of pears in Brazil is possible and the expansion of the crop depends on several factors that enable the productive system, among them, the use of existing technologies and greater involvement of researchers, technicians and extension workers with the crop stands out, and greater investments in research, which has been drastically reduced in recent years, either financially or through research actions.

References

Alexandre, J. 2001. Colheita da pera Rocha. In: Soares, J., Silva, A., Alexandre, J. (ed.) *O livro da pera Rocha, volume primeiro*. Grafilipe, Cadaval, Portugal. p. 169-183.

Almeida, G.K., Fioravanço, J.C., Marodin, G.A.B. 2020. Vegetative growth and productive performance of 'Abate Fetel' and 'Rocha' pear trees on quince rootstocks. *Pesquisa Agropecuária Brasileira* 55: e01306.

Almeida, G.K., Marodin, G.A.B., Luz, A.R. 2019. Precocity production of pear trees grafted on high-vigor rootstocks. In: Luz, A.R. (ed.) *Pears: cultivars, production and harvesting*. Nova Science Publishers, Hauppauge, USA. p. 111-140.

ANP. Associação Nacional de Produtores de Pera Rocha. 2019. Produtores de pera 'Rocha' querem chegar aos 100 milhões de euros de exportações em 2019. https://perarocha.pt/anp/noticias/<Access on 20 Jan. 2020>

Antoniolli, L.R., Schild, P.M., Marco, D., Hoffmann, J.F. 2016. *Pera 'Santa Maria' – estádio de maturação e condicionamento por baixa temperatura na indução do amadurecimento*. Embrapa Uva e Vinho, Bento Gonçalves, Brazil. 4 p. (Circular Técnica 127).

Bianchi, V.J., Silveira, C.A.P., Faria, J.L.C., Fachinello, J.C., Silva, J.B. 2000. Aumento da frutificação efetiva em pereiras cultivar Garber com uso de AG3 e TDZ. *Revista Brasileira de Agrociência* 6: 191-193.

Bleicher, J. 2006. História da macieira. In: Epagri (ed.) *A cultura da macieira*. EPAGRI, Florianópolis, Brazil. p. 29-36.

Bonetti, J.I.S., Cesa, J.D., Petri, J.L., Bleicher, J. 2006. Evolução da cultura da macieira. In: Epagri (ed.) *A cultura da macieira.* EPAGRI, Florianópolis, Brazil. p. 37-57.

Brighenti, L.M. 2012. Dormência da Pereira. In: Rufato, L., Kretzschmar, A.A., Bogo, A. (ed.) *A Cultura da Pereira*. DIOESC, Florianópolis, Brazil. 214 p.

Bueno, G., Baccarin, J.G. 2012. Participação das principais frutas brasileiras no comércio internacional: 1997 a 2008. *Revista Brasileira de Fruticultura* 34: 424-434.

Campbell, J. 2003. *Pear Rootstocks*. Agfact, NSW Agriculture, Australia. H4.1.15.

Carra, B., Fachinello, J.C., Abreu, E.S., Pasa, M.S., Spagnol, D., Giovanaz, M.A., Silva, C.P. 2017b. Control of the vegetative growth of 'Shinseiki' pear trees by prohexadione calcium and root pruning. *Pesquisa Agropecuária Brasileira* 52: 177-185.

Carra, B., Pasa, M.S., Fachinello, J.C., Spagnol, D., Abreu, E.S., Giovanaz, M.A. 2016. Prohexadione calcium affects shoot growth, but not yield components, of 'Le Conte' pear in warm-winter climate conditions. *Scientia Horticulturae* 209: 241-248.

Carra, B., Spagnol, D., Abreu, E.S., Pasa, M.S., Silva, C.P., Hellwig, C.G., Fachinello, J.C. 2017a. Prohexadione calcium reduces vegetative growth and increases fruit set of -Smith? pear trees, in Southern Brazil. *Bragantia* 76: 360-371.

Ceagesp. Companhia de Entrepostos e Armazéns Gerais de São Paulo. 2020. http://www.ceagesp.gov.br/entrepostos/servicos/cotacoes/#cotacao/<Access on 26 Oct. 2020>

Chabchoub, M.A., Aounallah, M.K., Sahli, A. 2010. Effect of hydrogen cyanamide on bud break, flowering and fruit growth of two pear cultivars (*Pyrus communis*) under Tunisian condition. *Acta Horticulturae* 884: 427-432.

Colombo, R. 2003. *Portinnesti del PERO, un modello vincente*. http://www.ermesagricoltura.it/rivista/2003/settembre/RA030972s.pdf<Access on 20 Feb. 2020>

Comex Stat. Ministério da indústria, comércio exterior e serviços. 2020. http://comexstat.mdic.gov.br/<Access on 15 Jul. 2020>

Couto, A.A. 1979. *Aspectos pomológicos da pereira Rocha*. Ministério da Agricultura, Lisboa, Portugal.

EPAGRI. 2016. *Avaliação de cultivares para o estado de Santa Catarina 2016-2017*. EPAGRI, Florianópolis, Brazil. 74 p. (Boletim Técnico 172). http://docweb.epagri.sc.gov.br/website_epagri/BT/BT-172_Avaliacao-de-cultivares-2016-17.pdf<Access on 15 Mar. 2020>

FAO. Food and Agriculture Organization of the United Nations. 2019. http://apps.fao.org/<Access on 10 Aug. 2020>

Faoro, I.D. 2001. História e produção. In: EPAGRI (ed.) *Nashi, a pêra japonesa*. EPAGRI/JICA, Florianópolis, Brazil. p. 15-65.

Faoro, I.D., Pasa, M.S., Sezerino, A.A., Souza, Z.S., Katsurayama, J.M., Kvitschal, M.V. 2016. Pera. In: EPAGRI (ed.) *Avaliação de cultivares para o estado de Santa Catarina 2016-2017*. EPAGRI, Florianópolis, Brazil. (Boletim Técnico 172). http://docweb.epagri.sc.gov.br/website_epagri/BT/BT-172_Avaliacao-de-cultivares-2016-17.pdf<Access on 15 Mar. 2020>

Fioravanço, J.C., Oliveira, P.R.D. 2014 Produção e importação brasileira de pera no período de 2001 a 2012. *Informações Econômicas* 44: 16-22.

Giacobbo, C.L. 2006. *Porta-enxertos para a cultura da pereira tipo Europeia*. 77p. (Ph.D. Thesis on Agronomy) - Federal University of Pelotas, Pelotas, Brazil.

Gonçalves, M.J., Bogo, A., Rufato, L., Jesus, W.C., Casa, R.T., Weber, G.C., Correa, D. 2013. Behavior of European pear cultivars under different quince rootstocks to 'Entomosporium' leaf spot in southern Brazil. *Crop Protection* 49: 26-30.

Grimaldi, F. 2014. *Seleção de genótipos de Pyrus communis L. com potencial para porta-enxerto e desenvolvimento de protocolo de micropropagação*. 128p. (Ph.D. Thesis on Plant Production) - Santa Catarina State University, Lages, Brazil.

Hawerroth, F.J., Petri, J.L., Fachinello, J.C., Herter, F.G., Prezotto, M.E., Hass, L.B., Pretto, A. 2012. Reduction of winter pruning and fruit production increase in 'Hosui' pears by prohexadione calcium use. *Pesquisa Agropecuária Brasileira* 47: 939–947.

IBGE. Instituto Brasileiro de Geografia e Estatistica. 2019. *Produção Agrícola Municipal*. http://www.sidra.ibge.gov.br/<Access on 10 Dec. 2019>

Ing, G. 2002. Ten years of pear production and precocity data from a commercial pear orchard comparing eight Old Home by Farmingdale clonal rootstocks. *Acta Horticulturae* 596: 369-372.

Leite, G.B. 1992. O uso do marmeleiro como porta-enxerto da pereira. *Hortisul*, 2: 28-32.

Leite, G.B., Denardi, F. 1992. Porta-enxertos para pereira: adaptação a algumas condições ambientais. *Agropecuária Catarinense* 5: 47-49.

Loreti, F., Massai, R., Fei, C., Cinelli, F. 2002. Performance of 'Conference' cultivar on several quince and pear rootstocks: preliminary results. *Acta Horticulturae* 596: 311-318.

Luz, A.R. 2016. *Técnicas de redução de vigor e aumento da frutificação de pereiras Europeias*. 163p. (Ph.D. Thesis on Plant Production) - Santa Catarina State University, Lages, Brazil.

Luz, A.R., Meyer, G.A., Souza, D.S., Rufato, L., Kretzschmar, A.A. 2017 Pollination and fruit set of 'Rocha' pears tree grown in Vacaria, RS, Brazil. *Journal of Agroveterinary Sciences* 16: 357-366.

Luz, A.R., Souza, D.S., Mario, A.E., Posser, A.J., Fagherazzi, A.F., Fagherazzi, M.M. 2021. The scientific history of pear research in Brazil. *Acta Horticulturae* 1303: 545-553.

Luz, A.R., Souza, D.S., Petineli, R., Hipólito, J.S., Rufato, L., Kretzschmar, A.A. 2018. Redução de vigor em pereiras europeias utilizando métodos físicos e químicos. *Revista de Ciências Agroveterinárias* 17: 226-234.

Luz, A.R., Souza, D.S., Petineli, R., Meyer, G.A., Rufato, L., Kretzschmar, A.A. 2014. Plant growth regulators increase yield of *Pyrus communis* L. 'Williams' pear in southern Brazil. *Acta Horticulturae* 1042: 325-330.

Machado, B.D. 2014. *Standards of growth and production of cultivars of European pear trees on quince rootstocks*. 148p. (Ph.D. Thesis) - Santa Catarina State University, Lages, Brazil.

Machado, B.D., Magro, M., Rufato, L., Bogo, A., Kretzschmar, A.A. 2017. Graft compatibility between European pear cultivars and East Malling "C" rootstock. *Revista Brasileira de Fruticultura* 39: e-063.

Machado, B.D., Magro, M., Rufato, L., Bogo, A., Kreztschmar, A.A., Simões, F. 2015. Compatibilidade fenotípica entre cultivares de pereiras europeias em porta-enxertos de marmeleiro. *Ciência Rural* 45: 1551-1556.

Machado, B.D., Rufato, A.R., Marcon Filho, J.L. 2012. Cultivares de pereiras europeias. In: Rufato, L., Kretzschmar, A.A., Bogo, A. (ed.) *A cultura da Pereira*. DIOESC, Florianópolis, Brazil. p. 150-171.

Morettini, A., Baldini, E., Scaramuzzi, F., Mittempergher, L. 1967. *Monografia dele principali Cultivar di Pero*. Firenze, Itália. 412 p.

Nakasu, B.H., Leite, D.L. 1990. Indicação de porta-enxertos e cultivares de pereira para o sul do Brasil. *Hortisul* 1: 20-24.

Nedilha, M.B.C.L. 2019. *Características biométricas, fisiológicas e bioquímicas de pereiras europeias sobre diferentes porta-enxertos*. 107p. (M.Sc. Thesis) - State University of the Midwest, Guarapuava, Brazil.

Oliveira, O.R., Biasi, L.A., Skalitz, R., Poltronieri, A.S. 2009b. Quebra de dormência de pereira 'Hosui' com calda sulfocálcica em dois sistemas de condução. *Revista Brasileira de Ciências Agrárias* 4: 383-387.

Oliveira, O.R., Lipski, B., Silva, E.D.B., Biasi, L.A., Coelho, S.S. 2009a. Extrato de alho na superação da dormência de pereira 'Housui'. *Scientia Agrária* 10: 283-288.

Oliveira, O.R., Peressuti, R.A., Skalitz, R., Antunes, M.C., Biasi, L.A., Zanette, F. 2008. Quebra de dormência de pereira 'Hosui' com uso de óleo mineral em dois tipos de condução. *Revista Brasileira de Fruticultura* 30: 4409-4413.

Pasa, M.S., Carra, B., Silva, C.P., Ciotta, M.N., Brighenti, A.F., Pereira, A.J. 2017. Early spring application of aminoethoxyvinilglycine (AVG) increases fruit set and yield of 'Rocha' pears. *Revista Brasileira de Fruticultura* 39: 1-8.

Pasa, M.S., Silva, C.P., Carra, B., Brighenti, A.F., Souza, A.L.K., Schmitz, J.D., Katsurayama, J.M., Ciotta, M.N. 2018. A frutificação efetiva e produtividade de pereiras 'Santa Maria' e 'Abate Fetel' são incrementadas pela aplicação de aminoetoxivinilglicina (AVG) no início da primavera. *Revista de Ciências Agroveterinárias* 16: 487-491.

Reil, W.O., Ireland, J., Elkins, R.B. 2007. Propagation and rootstock seletion. In: Mitcham, E.J., Elkins, R.B. *Pear Production and Handling Manual*. University of California, Agriculture and Natural Resources, California, USA. p.33-44.

Ribeiro, T.D., Savian, T.V., Fernandes, T.J., Muniz, J.A. 2018. The use of the nonlinear models in the growth of pears of 'Shinseiki' cultivar. *Ciência Rural* 48: e20161097.

Robinson, T.L., Dominguez, L. 2015. Yield and profitability of high-density pear production with *Pyrus* rootstocks. *Acta Horticulturae* 1094: 247-256.

Rufato, L., Kretzschmar, A.A., Brighenti, A.F., Machado, B.D., Luz, A.R., Marcon Filho, J.L. 2011. Plant growth regulators increase productivity of 'Packham's Triumph' pear in southern brazil. *Acta Horticulturae* 909: 429-434.

Rufato, L., Kretzschmar, A.A., Brighenti, A.F., Machado, B.D., Marchi, T. 2012. Increasing fruit set of European pears in Southern Brazil. *Acta Horticulturae* 932: 477-482.

Rufato, L., Machado, B.D., Luz, A.R., Marcon Filho, J.L., Hipólito, J.S., Kretzschmar, A.A. 2015a. Effect of trunk girdling on growth and crop yield of 'Packham's Triumph' pear. *Acta Horticulturae* 1094: 265-268.

Rufato, L., Muniz, J., Kretzschmar, A.A., Luz, A.R., Hipolito, J.S., Silveira, F.N., Sander, G.F. 2015b. The use of PGR and fertiliser on the 'Rocha' pear to increase the productivity. *Acta Horticulturae* 1094: 367-372.

Sansavini, S. Portinnesti 2007. In: Fideghelli, C., Ponti, I. (ed.) *Il Pero*. Art Servizi, Bologna, Italy. p. 270-281.

Silva, L., Herrero, M., Oliveira, C.M. 2008 Effects of gibberellic acid and pollination on fruit set and fruit quality in Rocha pear. *Acta Horticulturae* 800: 199-204.

Silveira, F.N., Kretzschmar, A.A., Machado, B.D., Corrêa, D., Rufato, L. 2017 Vegetative development of European pear with quince and different application forms of nutrients. *Revista Brasileira de Fruticultura* 39: e-594.

Sousa, R.M. 2010. Alguns conceitos a atender na poda da pereira cultivar 'Rocha'. *Revista Voz do Campo* 139: 28-31.

Souza, D.S. 2016. *Características produtivas e vegetativas de pereira europeia.* 130p. (M.Sc. Thesis) - Santa Catarina State University, Lages, Brazil.

Viana, M.M., Julião, L., Lorenzi, C.O., Gomes, F.G., Scatena, H.S., Silva, A.J., Nascimento, F.N. 2013. Importação. *Hortifruti Brasil* 129: 8-23.

Westwood, M.N. 1982. *Fruticultura de Zonas Templadas*. Ediciones Mundi-Prensa, Madri, Spain. 464 p.

Wrege, M.S., Faoro, I.D., Herter, F.G., Pandolfo, C., Almeida, I.R., Alba, J.M.F., Pereira, J.F.M. 2016. Agroclimatic zoning of European and Asian pear cultivars with potential for commercial planting in southern Brazil. *Revista Brasileira de Fruticultura* 39: e-312.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.