

# Vegetative growth and productive performance of 'Abate Fetel' and 'Rocha' pear trees on quince rootstocks




**Abstract** – The objective of this work was to evaluate the vegetative growth and yield of the 'Abate Fetel' and 'Rocha' pear (*Pyrus communis*) trees grafted onto the 'Adams', 'Ba29', and 'EMC' quince (*Cydonia oblonga*) rootstocks in the climatic conditions of Southern Brazil. The plants were trained on a central leader system, at a 4.0x1.0-m spacing. Vegetative growth, yield, and fruit size were evaluated. 'Rocha' showed greater vegetative growth, but also alternate bearing, mainly due to fructification problems. 'Abate Fetel' presented high flowering intensity, but a very low fructification, which limited its yield. Among rootstocks, 'Adams' induced a higher vigor during the initial stages and an increased intensity in flowering in the sixth year. In the following seasons, there was no rootstock effect on the assessed variables. 'Rocha' has a satisfactory production, whereas 'Abate Fetel' shows a weak vegetative growth and a very low production. The 'Adams', 'Ba29', and 'EMC' rootstocks induce similar vegetative and productive behavior in the 'Abate Fetel' and 'Rocha' pear trees.

**Index terms:** *Cydonia oblonga*, *Pyrus communis*, effective fructification.

## Crescimento vegetativo e produtividade das pereiras 'Abate Fetel' e 'Rocha' em porta-enxertos de marmeleiro


**Resumo** – O objetivo deste trabalho foi avaliar o crescimento vegetativo e a produtividade das pereiras (*Pyrus communis*) 'Abate Fetel' e 'Rocha' enxertadas sobre os porta-enxertos de marmeleiro (*Cydonia oblonga*) 'Adams', 'Ba29' e 'EMC', nas condições climáticas do Sul do Brasil. As plantas foram conduzidas no sistema líder central, no espaçamento 4,0x1,0 m. Avaliaram-se crescimento vegetativo, produtividade e tamanho dos frutos. 'Rocha' apresentou maior crescimento vegetativo, mas, também, alternância de produção, principalmente em função de problemas de frutificação. 'Abate Fetel' teve alta intensidade de floração, porém frutificação muito baixa, o que limitou sua produção. Entre os porta-enxertos, o 'Adams' induziu maior vigor nas etapas iniciais e aumento na intensidade de floração no sexto ano. Nas safras seguintes, não houve efeito de porta-enxerto sobre as variáveis avaliadas. 'Rocha' exibe produção satisfatória, enquanto 'Abate Fetel' apresenta crescimento vegetativo fraco e produção muito baixa. Os porta-enxertos 'Adams', 'Ba29' e 'EMC' induzem comportamento vegetativo e produtivo similar nas pereiras 'Abate Fetel' e 'Rocha'.

**Termos para indexação:** *Cydonia oblonga*, *Pyrus communis*, frutificação efetiva.

Gustavo Klamer de Almeida<sup>(1)</sup> ,  
João Caetano Fioravanço<sup>(2)</sup>  and  
Gilmar Arduino Bettio Marodin<sup>(1)</sup> 

<sup>(1)</sup> Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Departamento de Horticultura e Silvicultura, Avenida Bento Gonçalves, nº 7.712, CEP 91540-000 Porto Alegre, RS, Brazil.  
E-mail: [gklalmeida@hotmail.com](mailto:gklalmeida@hotmail.com),  
[marodin@ufrgs.br](mailto:marodin@ufrgs.br)

<sup>(2)</sup> Embrapa Uva e Vinho, Rua Livramento, nº 515, Caixa Postal 130, CEP 95701-0008 Bento Gonçalves, RS, Brazil.  
E-mail: [joao.fioravanco@embrapa.br](mailto:joao.fioravanco@embrapa.br)

 Corresponding author

Received  
February 24, 2019

Accepted  
February 17, 2020

### How to cite

ALMEIDA, G.K. de; FIORAVANÇO, J.C.; MARODIN, G.A.B. Vegetative growth and productive performance of 'Abate Fetel' and 'Rocha' pear trees on quince rootstocks. *Pesquisa Agropecuária Brasileira*, v.55, e01306, 2020. DOI: <https://doi.org/10.1590/S1678-3921.pab2020.v55.01306>.

## Introduction

The low yield of orchards is one of the main factors that limit the expansion of pear (*Pyrus* spp.) tree crops in Southern Brazil. This low yield is attributed to a low fructification rate, related to aspects that influence pollination (Hawerth & Petri, 2011; Luz et al., 2017), such as the cultivars used in different planting regions (Rufato et al., 2012) and the excessive vegetative growth of plants due to the use of vigorous rootstocks and to climatic conditions favorable for a longer growth period (Hawerth & Petri, 2011; Rufato et al., 2012; Pasa et al., 2017).

Rootstock choice is an important strategy to modulate the vegetative growth and production of plants, and also, together with other factors, to determine planting density and orchard management (Webster, 2002). For pear tree crops, *Pyrus* and *Cydonia* spp. are generally used as rootstocks (Iglesias & Asin, 2011; North et al., 2015). However, as a rootstock, *Pyrus* sp. may cause problems related to the excessive vigor, heterogeneity, and slow production start of orchards (Massai et al., 2008). Pear trees grafted onto quinces (*Cydonia oblonga* Mill.) start producing earlier and show a higher regularity of production (North et al., 2015), besides a reduced plant size, which favors management and allows the formation of high-density orchards, with positive yield outcomes (Robinson & Dominguez, 2015). However, some of the most commercially important European pear trees (*Pyrus communis* L.), such as 'Williams', 'Abate Fetel', and 'Kaiser', have shown graft incompatibility with quinces (Maas, 2008). The incompatible plants had discontinuity of the vascular system at the grafting location, which prevented water and nutrient transport through the xylem, as well as the transport of photoassimilates through the phloem, causing reductions in vegetative growth and, in more severe cases, plant death (Darikova et al., 2011).

Regarding the influence of rootstocks on fruit quality, the results are still preliminary, possibly due to the various aspects that could affect fruit size, composition, and color, including the combination of scion and rootstock (Maas, 2008), and also the orchard site (Stern & Doron, 2009).

In Brazil, the most recent pear tree plantations mainly use quinces as rootstocks. However, due to the short time that quinces have been used for this purpose, the available information on the performance of the cultivars is still insufficient. Although the research

published about this topic is of great importance, few of them carry out harvest evaluations and they are restricted to a few regions in Southern Brazil (Pasa et al., 2011, 2012; Rufato et al., 2012; Machado et al., 2013).

The objective of this work was to evaluate the vegetative growth and yield of the 'Abate Fetel' and 'Rocha' pear trees grafted onto the 'Adams', 'Ba29', and 'EMC' quince rootstocks in the climatic conditions of Southern Brazil.

## Materials and Methods

The experiment was conducted at Embrapa Uva e Vinho, in the municipality of Vacaria, in the state of Rio Grande do Sul, Brazil (28°33'S, 50°57'W, at an approximate altitude of 955 m). The region's climate is subtropical, Cfb1, according to Köppen's classification. The number of cold hours (temperatures below 7.2°C) is above 600, and the annual average temperature is 16°C. The soil type is a Latossolo Bruno aluminico câmbico, i.e., a Rhodic Hapludox (Nachtigall et al., 2014).

The orchard was planted in 2009, with bare-root seedlings without ramification, at a spacing of 4.0 m between rows and 1.0 m between plants, totalizing 2.500 plants per hectare, trained as central leaders in the espalier system.

The experimental design was a randomized complete block, with four replicates of five plants each, with a block per row. The treatments were arranged in a 2x3 factorial arrangement: two European pear cultivars, Abate Fetel and Rocha, grafted onto three quince cultivars, Adams, Ba29, and EMC.

The evaluated variables were: trunk cross-sectional area, obtained by measuring trunk diameter at 10 cm above the grafting point during the dormancy period of each year; annual pruning fresh weight, determined by weighing the branches removed by green and winter pruning in the third, fourth, and fifth years after planting; flowering intensity, obtained by counting all flower clusters on each plant during full bloom; effective fructification, considered the relation between the number of fruits and the number of flower clusters of each plant; yield, determined by multiplying the production per plant by the number of plants per hectare; average fruit weight, measured by the relation between plant production and total number of fruits;

and fruit classification, in which the fruits with cracks on the epidermis were separated and then the other fruits were distributed in the diameter classes <50, 50–60, 60–70, and >70 mm. The frequencies of fruits in each diameter class were obtained by classifying all fruits harvested in each plot.

Data were analyzed as repeated measures using the SAS PROC MIXED procedure (SAS Institute Inc., Cary, NC, USA), with the year as an intrinsic factor. For that, the covariance structure with better model fit was selected, according to the Akaike and Bayesian information criteria. When the analysis of variance was significant, Tukey's test, at 5% probability, was applied.

Pearson's correlation analysis, through the PROC GLM procedure of SAS Enterprise Guide, version 6.1 (SAS Institute, Inc., Cary, NC, USA), was used to determine: the relationship between annual pruning fresh weight and trunk cross-sectional area in the third, fourth, and fifth years after planting; effective fructification (fruits per flower cluster) and yield; and number of flower clusters per plant and yield from the third to the eighth year.

## Results and Discussion

Significant differences were observed among the pear tree cultivars for trunk cross-sectional area (TCSA) (Figure 1 A). 'Rocha' exhibited higher TCSA growth than 'Abate Fetel' regardless of the rootstock and evaluation year. There was also a significant effect of rootstock in the first year, in which 'Adams' induced higher TCSA averages to the scion than 'Ba29' and 'EMC' (Figure 1 B). However, in the following years, no difference was observed between quinces as to plant vigor.

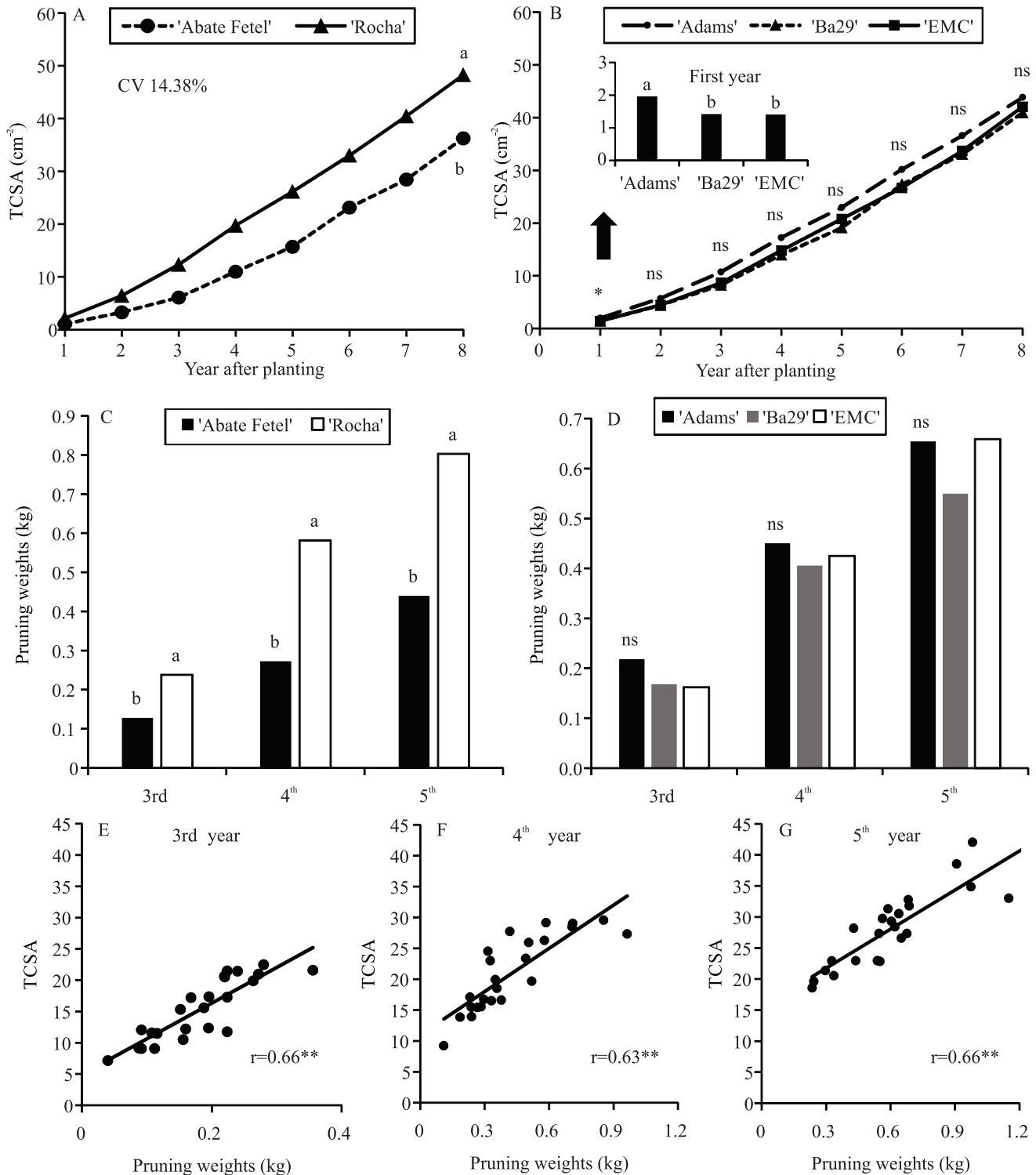
Regarding the scion cultivars, the obtained results differed from those of Machado et al. (2015), who observed a greater growth of 'Abate Fetel', compared with 'Rocha', when grafted onto 'Adams'. However, Machado et al. (2013) did not find differences between 'Rocha' and 'Abate Fetel' when grafted onto 'EMC'. Although Machado et al. (2015) observed good compatibility between 'Abate Fetel' and 'Adams', in the present study, the pear cultivar showed serious discontinuity in the bark and wood in the graft interface zone with quinces, which possibly negatively affected its growth (Almeida, 2018). These varying

results may be a consequence of the different levels of graft compatibility.

For rootstocks, the results observed in the present work are in alignment with those of other authors. Souza & Calouro (2007) and Cabrera et al. (2015), for example, also did not find differences between 'Adams' and 'Ba29', and Lepsis & Drudze (2011) and Hadad et al. (2016) between 'Ba29' and 'EMC'. In addition, Machado et al. (2013) and Cabrera et al. (2015) observed similar vigor between 'Adams' and 'EMC'. However, differences in the vigor induced by different quinces have also been reported. Machado et al. (2013) found that 'Adams' induced a higher vigor in 'Abate Fetel' than 'EMC', while Cabrera et al. (2015) concluded that 'Ba29' induced a higher vigor in 'Williams BC' than 'EMC'. Therefore, as the performance of quince rootstocks may vary due to the scion cultivar used and to differences in soil and climatic conditions, it is possible that the performance of a certain combination cannot be extrapolated to different cultivation conditions (Souza & Calouro, 2007).

It should be highlighted that some scion-rootstock combinations showed very low vegetative growth and the 1.0-m spacing between plants was very wide. For these reasons, the 'Abate Fetel'-quinces combinations did not fill the space available for each plant until the ninth year. Moreover, the 'Ba29' rootstock induced a vegetative growth below the expected in the scion.

The low vegetative growth observed in some scion-rootstock combinations can also be attributed to graft incompatibility. 'Abate Fetel', which had the lowest vegetative growth in the present work, has shown localized incompatibility, with a higher discontinuity in vascular vessels than 'Rocha' (Machado et al., 2015; Almeida, 2018). Problems in the vascular system can disturb water, nutrient, and assimilate flows, reducing plant growth (Darikova et al., 2011). As a result, the lack of plant vigor may limit yield per plant, as observed for 'Coscia' pear trees under Israel conditions (Stern & Doron, 2009; Stern et al., 2013). Another important aspect that possibly reflected negatively on vegetative growth is the absence of an irrigation system in the present work. According to Nachtigall et al. (2014), during summer in the experimental region of Vacaria, periods with water shortages occur often and may negatively affect plant physiology, mainly when associated with a superficial root system, as that of many quinces.



**Figure 1.** Effect of trunk cross-sectional area (TCSA) (A and B) and annual pruning weights (C and D) of 'Abate Felte' and 'Rocha' pear (*Pyrus communis*) trees on rootstock and canopy averages, when grafted onto the 'Adams', 'Ba29', and 'EMC' quinces (*Cydonia oblonga*), from the first to the eighth year after planting, from 2009 to 2017, and correlation between TCSA and annual pruning weights in three seasons (E, F, and G), in the municipality of Vacaria, in the state of Rio Grande do Sul, Brazil. Differences between rootstocks at the end of the first year are detailed on the bar graphic. Different letters indicate significant differences by Tukey's test, at 5% probability. \* and \*\*Significant at 5 and 1% probability, respectively. <sup>ns</sup>Nonsignificant.

Pruning fresh weights (winter + summer pruning) differed between the scion cultivars, with 'Rocha' showing higher values in the three evaluated years, independently of the quince rootstock (Figure 1 C). However, there was no effect of rootstock on this variable (Figure 1 D).

Annual pruning weights (APWs) provide information about the labor needed to conduct the orchard and, as the TCSA, are related to vegetative growth. A higher APW indicates a higher vegetative growth (Machado et al., 2013). The variables APW and TCSA showed positive correlations in the third, fourth, and fifth years after planting (Figure 1 E, F, and G); i.e., the higher the TCSA, the higher the pruning weight. Therefore, the lowest pruning demand may represent the lowest need for labor; however, low APW values, as those observed for 'Abate Fetel' in the present work, are indicative of a weak vegetative growth and difficulty in canopy formation.

Flowering intensity, quantified by the number of flower clusters per plant, differed between scions in some years, regardless of the rootstock (Table 1). 'Rocha' exhibited a higher numbers of flower clusters in the sixth year, and 'Abate Fetel', in the seventh. There were also differences in the number of flower clusters between rootstocks, but only in the sixth year, in which 'Adams' induced the highest number, when compared with 'EMC' and 'Ba29'.

The propensity to flower is affected by the scion pear tree cultivar, but also by the used rootstock (Pasa et al., 2011; Watson et al., 2012; Hadad et al., 2016), whose effect on scion vigor control possibly affects the number of floral buds (Pasa et al., 2011). According to Pasa et al. (2011), floral bud formation is hindered by the growth of vegetative organs in vigorous plants. However, Watson et al. (2012) did not observe a strong effect of the reduction of rootstock-induced vigor on flowering intensity. In the present work, the plants that

**Table 1.** Number of flower clusters per plant and number of fruits per floral cluster of the 'Abate Fetel' and 'Rocha' pear (*Pyrus communis*) trees grafted onto quinces (*Cydonia oblonga*), from the third to the eighth year after planting, from 2011 to 2017, in the conditions of the municipality of Vacaria, in the state of Rio Grande do Sul, Brazil<sup>(1)</sup>.

Scion	Rootstock	Flower cluster per plant						
		3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	
'Abate Fetel'	'Adams'	2.3 <sup>ns</sup>	47.1 <sup>ns</sup>	64.8 <sup>ns</sup>	237.5 <sup>ns</sup>	106.0 <sup>ns</sup>	107.6 <sup>ns</sup>	
	'Ba29'	0.2	23.3	35.3	156.3	64.2	90.7	
	'EMC'	1.0	13.3	30.9	148.7	75.4	106.1	
	Average	1.2 <sup>ns</sup>	27.9 <sup>ns</sup>	43.7 <sup>ns</sup>	180.8B	81.8A	101.5 <sup>ns</sup>	
'Rocha'	'Adams'	7.0 <sup>ns</sup>	49.0 <sup>ns</sup>	53.6 <sup>ns</sup>	315.5 <sup>ns</sup>	47.7 <sup>ns</sup>	137.7 <sup>ns</sup>	
	'Ba29'	5.6	35.3	75.8	252.0	68.9	137.3	
	'EMC'	5.5	32.1	56.8	271.2	27.7	103.1	
	Average	6.0	38.8	62.0	279.5A	48.1B	126.0	
		Average of the scions						
		'Adams'	4.7 <sup>ns</sup>	48.0 <sup>ns</sup>	59.2 <sup>ns</sup>	276.5a	76.8 <sup>ns</sup>	122.7 <sup>ns</sup>
		'Ba29'	2.9	29.3	55.5	204.1b	66.5	114.0
		'EMC'	3.3	22.7	43.8	210.0b	51.5	104.6
		CV (%)	28.97					
Scion	Rootstock	Fruit per flower cluster						
		3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	
'Abate Fetel'	'Adams'	0.01 <sup>ns</sup>	0.05 <sup>ns</sup>	0.00 <sup>ns</sup>	0.00 <sup>ns</sup>	0.00 <sup>ns</sup>	0.00 <sup>ns</sup>	
	'Ba29'	0.00	0.23	0.00	0.00	0.00	0.00	
	'EMC'	0.00	0.04	0.00	0.00	0.00	0.00	
	Average	0.00B	0.10B	0.00B	0.00B	0.00B	0.00B	
'Rocha'	'Adams'	0.32 <sup>ns</sup>	1.17 <sup>ns</sup>	0.24 <sup>ns</sup>	0.42 <sup>ns</sup>	0.71 <sup>ns</sup>	0.74 <sup>ns</sup>	
	'Ba29'	0.34	1.07	0.14	0.33	0.61	0.69	
	'EMC'	0.32	1.28	0.25	0.43	0.76	0.83	
	Average	0.33A	1.17A	0.21A	0.39A	0.70A	0.75A	
		CV (%)	48.32					

<sup>(1)</sup>Uppercase letters indicate significant differences between canopies for the average of the rootstocks, whereas lowercase letters compare rootstocks, both by Tukey's test, at 5% probability. <sup>ns</sup>Nonsignificant.

presented a higher vegetative growth, which were of the 'Rocha' pear tree, also showed a higher number of floral buds. This could be an indicative that the vegetative growth induced by the rootstocks was not strong enough to harm the number of floral buds per plant and that the weak vegetative growth of 'Abate Fetel' negatively impacted this variable.

Effective fructification was very low for 'Abate Fetel' in all years, while that of 'Rocha' oscillated between years (Table 1). The low fructification of 'Abate Fetel' is possibly a consequence of a lack of flowering synchrony with other cultivars, implicating in a lower pollen availability for cross-pollination. This cultivar had an earlier flowering period than the others and only showed synchrony with 'Forelle', which, in most years, presented a low flowering intensity (North et al., 2015), whereas, in the experimental conditions of the present study, 'Rocha' showed a moderate flowering synchrony with 'Packham's Triumph' (Luz et al., 2017). Therefore, the low fructification found for 'Rocha' in some years is possibly related to the low flowering intensity of 'Packham's Triumph' when used as a pollinator, which may be due to the high rate of flower abortion observed in some years and to deficiencies in pollination due to unfavorable climatic conditions during the flowering period (Luz et al., 2017).

Pollination problems were reported by Luz et al. (2017) in a 'Rocha' commercial orchard, also in the conditions of the municipality of Vacaria. The authors concluded that around 80% of the fruits were formed by self-pollination or parthenocarpy, which caused a low fructification and a yield of only 11 Mg ha<sup>-1</sup>. However, the manual pollination of 'Rocha' led to an increase in effective fructification and, consequently, increased yield to 66.7 and 72.9 Mg ha<sup>-1</sup>, when 'Packham's Triumph' and *Pyrus calleryana* L. pollen were applied, respectively (Luz et al., 2017). Therefore, the low effective fructification observed for 'Rocha' and 'Abate Fetel' pear trees in the present work may be a consequence of pollination issues. A reduction in fructification rate was also reported in pear trees with a high vegetative growth, requiring careful management especially of vigorous rootstocks (Carra et al., 2017); it should be pointed out that excess vigor was not observed in the present study.

These results show the importance of the choice of pollinator cultivars and the position of the plants in the orchard. It is recommended installing more than

one pollinator cultivar, which must have flowering synchrony and gametophytic compatibility with the producing cultivar plants (Souza & Calouro, 2014; Luz et al., 2017). Regarding the pollinator plant positions, the greater the distance for pollination, the lower fructification tends to be. According to Luz et al. (2017), the arrangement of one 'Packham's Triumph' pollinator plant row for three rows of 'Rocha', at a 4-m spacing, did not induce a fructification rate high enough to obtain a commercially satisfactory yield, as observed in the present work.

Fruit production began in the third year after planting for 'Rocha' and in the fourth for 'Abate Fetel' (Table 2). In all evaluated years, 'Rocha' produced a higher yield than 'Abate Fetel', which exhibited extremely low yields during all years, due to its very low effective fructification, although it showed an adequate flowering intensity (Table 1). 'Rocha' had alternating yields throughout the seven experimental years. During the sixth and eighth years after planting, yield averages were above 26.8 Mg ha<sup>-1</sup>, which may be considered satisfactory in relation to the Brazilian pear yield of 16.9 Mg ha<sup>-1</sup> (FAO, 2019). Yield was also high in the fourth year after planting, the time of the first production in commercial scale of 'Rocha' pear trees. However, in the other years, the low flowering intensity and low fructification rate were the main factors limiting a high yield. There was no significant difference between rootstocks for any of the scion cultivars.

Positive correlations were observed between number of flower clusters and yield per plant for 'Rocha' pear trees during the third ( $r = 0.85$ ) and seventh years ( $r = 0.86$ ), in which plants with higher flowering intensities showed the greatest productions (Table 3). However, effective fructification limited yield during the fifth ( $r = 0.92$ ) and eighth years ( $r = 0.73$ ); therefore, the plants that had a higher effective fructification were also the most productive. In the ninth year after planting, the number of flower clusters and fruits per plant were not determined for the calculation of effective fructification; however, flowering intensities were high and yield was low due to fructification problems.

Overall, in Brazil, studies evaluating the production of 'Abate Fetel' and 'Rocha' pear trees grafted onto different rootstocks are scarce. Rufato et al. (2012) reported a yield of nearly 15 Mg ha<sup>-1</sup> for 'Abate Fetel' in the conditions of Vacaria in just one experimental year. However, for the 'Rocha' pear tree grafted onto

'Adams', Pasa et al. (2015) found a maximum annual yield of only 8.65 Mg ha<sup>-1</sup> in three seasons, in the municipality of Capão do Leão, also in the state of Rio Grande do Sul. Likewise, Luz et al. (2017) observed low yields of 11 Mg ha<sup>-1</sup> for 'Rocha' in Vacaria. In the conditions of the present study, the annual average yield of 'Rocha' was 18.3 Mg ha<sup>-1</sup> on 'Adams', 16.1 Mg ha<sup>-1</sup> on 'EMC', and 14.7 Mg ha<sup>-1</sup> on 'Ba29' from the fourth year, when commercial production began, to ninth year. Therefore, productive performance may be considered satisfactory when compared with that obtained in previous studies and with the Brazilian pear average yield. The results of the present work were also considered satisfactory in relation to the average yields of 18.4, 12.5, and 10.7 Mg ha<sup>-1</sup> found for the 'Rocha' pear tree grafted onto 'Ba29', 'Adams', and 'EMC', respectively, under Portugal conditions (Souza & Calouro, 2007).

The average fruit weight of 'Rocha' did not differ between quinces (Table 2). Fruit size was small in all years, independently of the fruit load per plant, and varied from 90.3–111.1 g among the evaluated years for the rootstock averages. These values are similar to those obtained by Pasa et al. (2015). Luz et al. (2017)

found 'Rocha' fruits with average weights varying from 71–119 g in one year and from 121–150 g in another. Oliveira et al. (2007) reported a higher average of 160 g for 'Rocha' fruits; however, differently from the present work, these authors used irrigation.

The frequencies of 'Rocha' fruits in the different diameter classes was not affected by the rootstocks, and the rate of cracked fruits was high, varying from 2.07–8.10% throughout the years (Figure 2). Fruits with more than 60 mm in diameter totaled 58.8, 55.9, 26.5, and 49.7% in the fourth, fifth, sixth, and seventh years after planting, respectively. The frequency of fruits in the classes of greater diameter was lower than that obtained by other authors. Oliveira et al. (2007) and Souza & Calouro (2014), for example, found that 'Rocha' pear trees had 70.0–85.0 and 78.5–80.7%, respectively, of fruits with a diameter over 60 mm.

The obtained results show that the size of the fruits in the present study was smaller than those of the literature. The great difference in relation to the works of Oliveira et al. (2007) and Souza & Calouro (2014) is probably related to the use of an irrigation system in the orchards evaluated by these authors. In the present work, the fact that no irrigation system was used,

**Table 2.** Annual and accumulated yield of 'Abate Fetel' and 'Rocha' pear (*Pyrus communis*) trees grafted onto quinces (*Cydonia oblonga*), as well as annual fruit weight (AFW) of 'Rocha' from the third to the ninth year after planting, from 2011 to 2018, in the municipality of Vacaria, in the state of Rio Grande do Sul, Brazil<sup>(1)</sup>.

Rootstock	Yield (Mg ha <sup>-1</sup> )							Accumulated yield
	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	
'Abate Fetel'								
'Adams'	0 <sup>ns</sup>	0.8 <sup>ns</sup>	0.1 <sup>ns</sup>	0 <sup>ns</sup>	0 <sup>ns</sup>	0 <sup>ns</sup>	1.1 <sup>ns</sup>	1.9 <sup>ns</sup>
'Ba29'	0	0.7	0.0	0	0	0	1.3	2.0
'EMC'	0	0.2	0.0	0	0	0	1.0	1.3
Average	0B	0.56B	0B	0B	0B	0B	1.1B	1.7B
'Rocha'								
'Adams'	0.5 <sup>ns</sup>	17.0 <sup>ns</sup>	3.0 <sup>ns</sup>	38.2 <sup>ns</sup>	7.1 <sup>ns</sup>	31.2 <sup>ns</sup>	13.5 <sup>ns</sup>	110.7 <sup>ns</sup>
'Ba29'	0.5	10.0	2.8	31.7	9.4	24.4	9.8	88.5
'EMC'	0.6	11.3	3.7	39.9	4.8	24.9	12.3	97.5
Average	0.5A	12.8A	3.2A	36.6A	7.1A	26.8A	11.9A	98.9A
CV (%)	33.40							
RS <sup>(2)</sup>	AFW (g)							Average (g)
	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	
'Rocha'								
'Adams'	99.1 <sup>ns</sup>	100.8 <sup>ns</sup>	102.5 <sup>ns</sup>	106.9 <sup>ns</sup>	89.2 <sup>ns</sup>	104.5 <sup>ns</sup>	88.1 <sup>ns</sup>	98.7 <sup>ns</sup>
'Ba29'	94.3	108.4	111.6	125.7	94.7	116.1	95.0	106.5
'EMC'	100.4	104.1	99.3	100.8	90.5	103.8	87.7	98.1
Average	97.9	104.4	104.5	111.1	91.4	108.1	90.3	101.1
CV (%)	12.73							

<sup>(1)</sup>Uppercase letters compare cultivars in the average of the rootstocks by Tukey's test, at 5% probability. <sup>ns</sup>Nonsignificant. <sup>(2)</sup>'Adams' x 'EMC' x 'Ba29'.

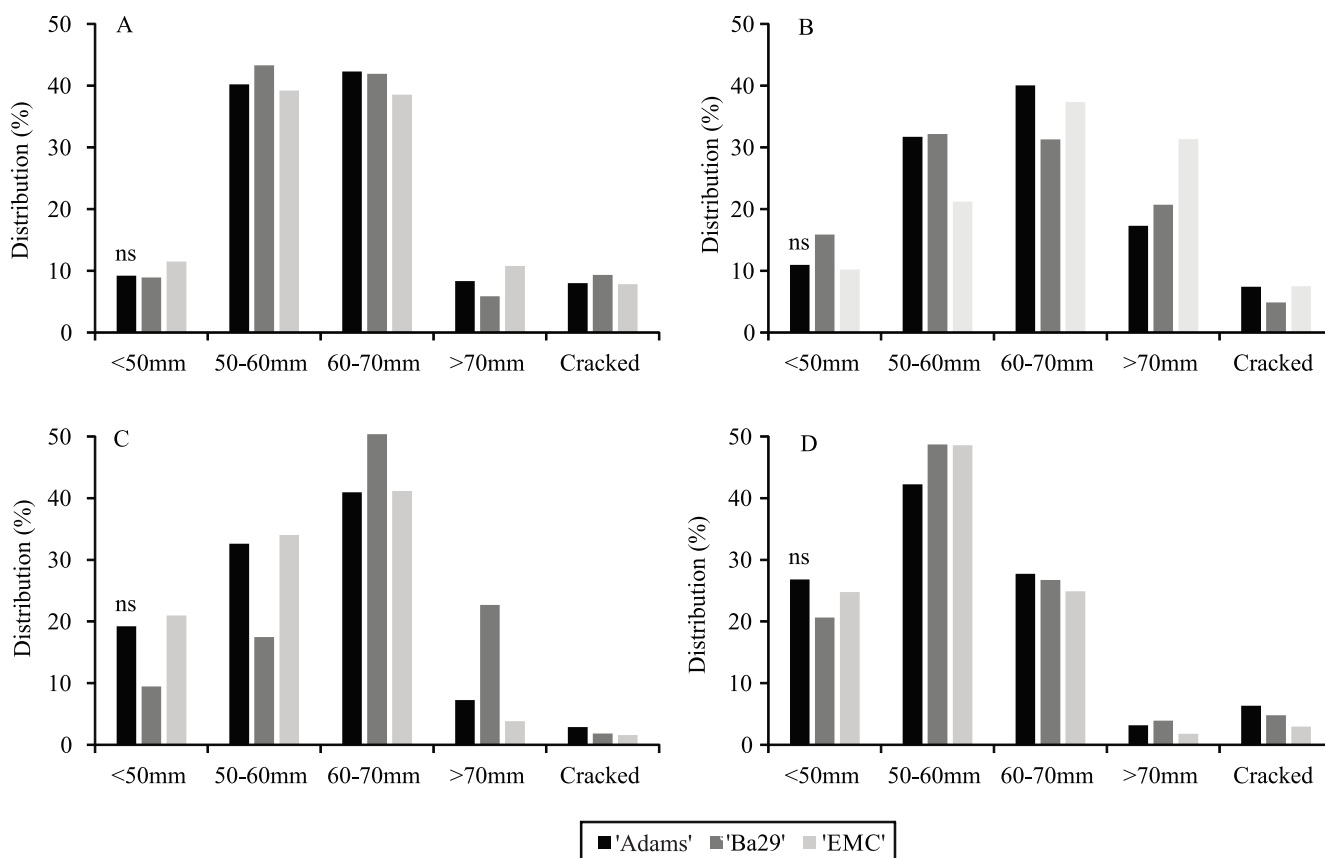
associated to the periods of water shortages that often occur in the region of Vacaria (Nachtigall et al., 2014), may have resulted in a lower fruit caliber. Another

problem related to the oscillation in soil humidity availability can be fruit cracking (Khadivi-Khub, 2015), as observed for 'Rocha' in the present work.

**Table 3.** Pearson's correlation of both number of flower clusters per plant and effective fructification (fruits per flower cluster) with yield per plant of 'Rocha' pear (*Pyrus communis*) trees grafted onto quinces (*Cydonia oblonga*), from the third to the eighth year after planting, from 2011 to 2017.

Year	Yield (kg per plant)											
	3 <sup>rd</sup> year		4 <sup>th</sup> year		5 <sup>th</sup> year		6 <sup>th</sup> year		7 <sup>th</sup> year		8 <sup>th</sup> year	
	FC	EF	FC	EF	FC	EF	FC	EF	FC	EF	FC	EF
3 <sup>rd</sup> year	0.85*	0.79**	-	-	-	-	-	-	-	-	-	-
4 <sup>th</sup> year	-	-	0.88**	-0.038 <sup>ns</sup>	-	-	-	-	-	-	-	-
5 <sup>th</sup> year	-	-	-	-	-0.35 <sup>ns</sup>	0.92**	-	-	-	-	-	-
6 <sup>th</sup> year	-	-	-	-	-	-	-0.52 <sup>ns</sup>	0.36 <sup>ns</sup>	-	-	-	-
7 <sup>th</sup> year	-	-	-	-	-	-	-	-	0.86*	-0.018 <sup>ns</sup>	-	-
8 <sup>th</sup> year	-	-	-	-	-	-	-	-	-	-	0.12 <sup>ns</sup>	0.73**

\* and \*\*Significant at 5 and 1% probability, respectively. <sup>ns</sup>Nonsignificant. FC, flower clusters; EF, effective fructification.



**Figure 2.** Distribution of the fruits of 'Rocha' pear (*Pyrus communis*) trees into diameter classes or as having cracks on the epidermis when grafted onto three different quinces (*Cydonia oblonga*) in the fourth (A), fifth (B), sixth (C), and seventh (D) years after planting, from 2012 to 2016. <sup>ns</sup>Nonsignificant.



## Conclusions

1. The 'Abate Fetel' pear (*Pyrus communis*) tree presents weak vegetative growth and fructification problems, which result in extremely low yields.

2. The 'Rocha' pear (*Pyrus communis*) tree has a satisfactory productive performance, although it shows an alternate bearing throughout the years.

3. The 'Adams', 'Ba29', and 'EMC' quinces (*Cydonia oblonga*) induce a similar effect on the vegetative and productive behavior of the 'Abate Fetel' and 'Rocha' pear trees.

## Acknowledgments

To Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for scholarship granted.

## References

- ALMEIDA, G.K. de. Crescimento, produção e compatibilidade de pereiras enxertadas sobre cultivares de marmeleiros no Rio Grande do Sul. 2018. 183p. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Porto Alegre.
- CABRERA, D.; RODRÍGUEZ, P.; ZOPPOLO, R. Evaluation of quince and selected 'Farold<sup>®</sup>' pear rootstocks for commercial 'Williams BC' production in Uruguay. *Acta Horticulturae*, v.1094, p.159-162, 2015. DOI: <https://doi.org/10.17660/ActaHortic.2015.1094.19>.
- CARRA, B.; SPAGNOL, D.; ABREU, E.S. de; PASA, M. da S.; SILVA, C.P. da; HELLWIG, C.G.; FACHINELLO, J.C. Prohexadione calcium reduces vegetative growth and increases fruit set of 'Smith' pear trees, in Southern Brazil. *Bragantia*, v.76, p.360-371, 2017. DOI: <https://doi.org/10.1590/1678-4499.298>.
- DARIKOVA, J.A.; SAVVA, Y.V.; VAGANOV, E.A.; GRACHEV, A.M.; KUZNETSOVA, G.V. Grafts of woody plants and the problem of incompatibility between scion and rootstock (a review). *Journal of the Siberian Federal University*, v.4, p.54-63, 2011.
- FAO. Food and Agriculture Organization of the United Nations. **Production of pears**. Available at: <<http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E>>. Accessed on: Oct. 20 2019.
- HADAD, M.M.; JAFARPOUR, M.; ASKARI-KHORASGANI, O. Performance of European pear 'Shahmiveh' grafted onto different rootstocks. *Revista Chapingo Serie Horticultura*, v.22, p.59-68, 2016. DOI: <https://doi.org/10.5154/r.rchsh.2015.09.022>.
- HAWERROTH, F.J.; PETRI, J.L. **Controle do desenvolvimento vegetativo em macieira e pereira**. Fortaleza: Embrapa Agroindústria Tropical, 2011. (Embrapa Agroindústria Tropical. Documentos, 147). 36p.
- IGLESIAS, I.; ASÍN, L. Agronomical performance and fruit quality of 'Conference' pear grafted on clonal quince and pear rootstocks. *Acta Horticulturae*, v.903, p.439-442, 2011. DOI: <https://doi.org/10.17660/ActaHortic.2011.903.59>.
- KHADIVI-KHUB, A. Physiological and genetic factors influencing fruit cracking. *Acta Physiologiae Plantarum*, v.37, art. 1718, 2015. DOI: <https://doi.org/10.1007/s11738-014-1718-2>.
- LEPSIS, J.; DRUDZE, I. Evaluation of seven pear rootstocks in Latvia. *Acta Horticulturae*, v.903, p.457-461, 2011. DOI: <https://doi.org/10.17660/ActaHortic.2011.903.62>.
- LUZ, A.R.; MEYER, G. de A.; SOUZA, D.S. de, RUFATO, L.; KRETZCHMAR, A.A. Polinização e frutificação da pereira 'Rocha' em Vacaria, RS, Brasil. *Revista de Ciências Agroveterinárias*, v.16, p.357-366, 2017. DOI: <https://doi.org/10.5965/223811711642017357>.
- MAAS, F. Evaluation of *Pyrus* and quince rootstocks for high density pear orchards. *Acta Horticulturae*, v.800, p.599-610, 2008. DOI: <https://doi.org/10.17660/ActaHortic.2008.800.80>.
- MACHADO, B.D.; MAGRO, M.; RUFATO, L.; BOGO, A.; KREZTSCHMAR, A.A.; SIMÕES, F. Compatibilidade fenotípica entre cultivares de pereiras europeias e porta-enxertos de marmeleiro. *Ciência Rural*, v.45, p.1551-1556, 2015. DOI: <https://doi.org/10.1590/0103-8478cr20141128>.
- MACHADO, B.D.; RUFATO, L.; BOGO, A.; KRETZSCHMAR, A.A.; MARIO, A.E. Cultivares e portaenxertos sobre o vigor de plantas de pereira europeias. *Ciência Rural*, v.43, p.1542-1545, 2013. DOI: <https://doi.org/10.1590/S0103-84782013005000105>.
- MASSAI, R.; LORETI, F.; FEI, C. Growth and yield of 'Conference' pears grafted on quince and pear rootstocks. *Acta Horticulturae*, v.800, p.617-624, 2008. DOI: <https://doi.org/10.17660/ActaHortic.2008.800.82>.
- NACHTIGALL, G.R.; CARGNINO, C.; LIMA, C.M. de. **Irrigação e fertirrigação na cultura da macieira na região de Vacaria, RS**. Bento Gonçalves: Embrapa Uva e Vinho, 2014. 20p. (Embrapa Uva e Vinho. Documentos, 89).
- NORTH, M.; DE KOCK, K.; BOOYSE, M. Effect of rootstock on 'Forelle' pear (*Pyrus communis* L.) growth and production. *South African Journal of Plant and Soil*, v.32, p.65-70, 2015. DOI: <https://doi.org/10.1080/02571862.2014.981881>.
- OLIVEIRA, I.; GUERREIRO, C.; BOTETA, L.; CATRONGA, H.; SILVA, O.; REGATO, M.; TOMÁS, S.; VARELA, M.; MORENO, N. Estudo sobre a adaptação da pera Rocha no baixo Alentejo. Avaliação da resposta a diferentes estratégias de rega. In: CONGRESSO NACIONAL DE REGA E DRENAGEM, 2., 2007, Fundão. *Anais*. Lisboa: COTR, 2007. CD-ROM.
- PASA, M. da S.; FACHINELLO, J.C.; ROSA JÚNIOR, H.F. de; FRANCESCHI, E. de; SCHMITZ, J.D.; SOUZA, A.L.K. de. Performance of 'Rocha' and 'Santa Maria' pears as affected by planting density. *Pesquisa Agropecuária Brasileira*, v.50, p.126-131, 2015. DOI: <https://doi.org/10.1590/S0100-204X2015000200004>.
- PASA, M. da S.; FACHINELLO, J.C.; SCHMITZ, J.D.; SOUZA, A.L.K. de; HERTER, F.G. Hábito de frutificação e produção de pereiras sobre diferentes porta-enxertos. *Pesquisa Agropecuária*

- Brasileira**, v.46, p.998-1005, 2011. DOI: <https://doi.org/10.1590/S0100-204X2011000900005>.
- PASA, M. da S.; FACHINELLO, J.C.; SCHMITZ, J.D.; SOUZA, A.L.K. de; FRANCESCHI, E. de. Desenvolvimento, produtividade e qualidade de peras sobre porta-enxertos de marmeleiro e *Pyrus calleryana*. **Revista Brasileira de Fruticultura**, v.34, p.873-880, 2012.
- PASA, M. da S.; SCHMITZ, J.D.; SILVA, C.P. da; GIOVANAZ, M.A. Performance of 'Carrick' pear grafted on quince rootstocks. **Agropecuária Catarinense**, v.30, p.57-60, 2017.
- ROBINSON, T.L.; DOMINGUEZ, L. Yield and profitability of high-density pear production with *Pyrus* rootstocks. **Acta Horticulturae**, v.1094, p.247-256, 2015. DOI: <https://doi.org/10.17660/ActaHortic.2015.1094.31>.
- RUFATO, L.; MARCON FILHO, J.L.; MARODIN, G.A.B.; KRETZSCHMAR, A.A.; MIQUELUTI, D.J. Intensidade e épocas de poda verde em pereira 'Abate Fetel' sobre dois porta-enxertos. **Revista Brasileira de Fruticultura**, v.34, p.475-481, 2012. DOI: <https://doi.org/10.1590/S0100-29452012000200021>.
- SOUZA, R.M.; CALOURO, F. Avaliação do comportamento de quatro porta-enxertos de pereira com a cv. 'Rocha'. In: SIMPÓSIO NACIONAL DE FRUTICULTURA, 3., 2014, Vila Real. **Anais**. Lisboa: [s.n.], 2014. p.101-107.
- SOUZA, R.M.; CALOURO, F. Efeito de sete porta-enxertos no calibre, na qualidade dos frutos e nos teores foliares de nutrientes do clone 2 da pereira 'Rocha'. In: FIALHO, D.; MARTINS, J.M.S. (Ed.). **Pêra Rocha: guia técnico**. Cadaval: Agência Nacional de Produtores de Pêra Rocha, 2007. 101p.
- STERN, R.A.; DORON, I. Performance of 'Coscia' pear (*Pyrus communis*) on nine rootstocks in the north of Israel. **Scientia Horticulturae**, v.119, p.252-256, 2009. DOI: <https://doi.org/10.1016/j.scienta.2008.08.002>.
- STERN, R.A.; DORON, I.; REDEL, G.; RAZ, A.; GOLDWAY, M.; HOLLAND, D. Lavi 1 – a new *Pyrus betulifolia* rootstock for 'Coscia' pear (*Pyrus communis*) in the hot climate of Israel. **Scientia Horticulturae**, v.161, p.293-299, 2013. DOI: <https://doi.org/10.1016/j.scienta.2013.04.040>.
- WATSON, A.E.; SELEZNYOVA, A.N.; DAYATILAKE, G.A.; TUSTIN, D.S. Rootstocks affect pear (*Pyrus communis*) tree growth through extent of node neoformation and flowering with key differences to apple. **Functional Plant Biology**, v.39, p.493-502, 2012. DOI: <https://doi.org/10.1071/FP12031>.
- WEBSTER, T. Dwarfing rootstocks: past, present and future. **Compact Fruit Tree**, v.35, p.67-72, 2002.
-