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VEGETATIVE DEVELOPMENT OF EUROPEAN PEAR WITH QUINCE AND DIFFERENT APPLICATION FORMS OF NUTRIENTS[1]

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ABSTRACT – The pear consumption in Brazil is significant and the country is dependent on the import of this fruit to meet the internal market. The aim of this study was to evaluate the vegetative growth of European pear trees grafted on quince with two application forms of nutrients. The study was conducted during the 2012/2013, 2013/2014 and 2014/2015 harvests, in the experimental area of the Universidade do Estado de Santa Catarina / UDESC, in Lages. The cultivars used were Rocha, Santa Maria and Abbé Fétel. The quinces were 'Adams' and 'EMA'. The application forms of the nutrients were conventional and fertigation. The experiment was carried out in a randomized block design and the arrangement of treatments was sub subdivided plots. The application form of nutrients and rootstocks of quince little influenced on the vegetative growth of the plants, being more influenced by the scion in the soil conditions of this study.
Index terms: *Pyrus communis* L., fertigation, vigor, *Cydonia oblonga* L., sectional area of the stem, solid fertilizer.

DESENVOLVIMENTO VEGETATIVO DE PEREIRAS EUROPEIAS COM MARMELEIROS E DIFERENTES FORMAS DE APLICAÇÃO DOS NUTRIENTES

RESUMO – O consumo de pera no Brasil é expressivo, e o País é dependente da importação dessa fruta para atender ao mercado interno. O objetivo deste trabalho foi avaliar o desenvolvimento vegetativo de pereiras-europeias enxertados em marmeleiros com duas formas de aplicação dos nutrientes. O estudo foi conduzido durante as safras de 2012/2013, 2013/2014 e 2014/2015, na área experimental da Universidade do Estado de Santa Catarina-UDESC, em Lages. As cultivares avaliadas foram Rocha, Santa Maria e Abbé Fétel com os portaenxertos de marmeleiros 'Adams' e 'EMA' e utilizando a aplicação sólida dos nutrientes e via fertirrigação. O experimento foi conduzido no delineamento em blocos casualizados, e o arranjo dos tratamentos foi em parcelas subsubdivididas. A forma de aplicação de nutrientes e os porta-enxertos de marmeleiro pouco influenciaram no crescimento vegetativo das plantas, sendo esse mais influenciado pela cultivar-copa nas condições edáficas do presente estudo.
Termos para indexação: *Pyrus communis* L., fertirrigação, vigor, *Cydonia oblonga* L., área de seção do tronco, adubação sólida.

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INTRODUCTION

The Brazilian fruit cultivation is recognized worldwide as one of the most diversified, however, the pear cultivation in Brazil does not stand out. The pear is, among the fruits of temperate climate, the one that has the least expression in terms of cultivated area, production and production value (FIORAVANÇO, 2007). However, its domestic consumption is significant, making it the third biggest importer of fruit in the world (USDA/FAS, 2015), which makes this crop an excellent market opportunity for domestic producers (FACHINELLO et al., 2011).

One of the limiting factors of economically satisfactory production is in the definition of cultivars and rootstocks adapted to the different potentially producing regions (MACHADO et al., 2013). Most of the pear cultivars in Brazil use the *P. calleryana* (Decne.) rootstock, which provides plants with high vigor and slow production period (GIACOBBO et. al., 2007).The emergence of different quince clones (*Cydonia oblonga*) provided lower plant vigor and rapid fruiting (MILOSEVIC; MILOSEVIC, 2011); however, the quince root system is considered superficial and poorly expanded, with about 80% of the roots concentrated in the first 40 cm of depth (MACHADO, 2014).This characteristic of their root system gives the plants weak support to the soil, needing the installation of support systems and irrigation systems due to the greater stress of the plants in periods of low precipitation (ALMEIDA, 2014).

The drip irrigation system is adapted to the production conditions of the pear tree grafted to quince in the south of Brazil, in addition to making possible the use of fertirrigation considered one of the most efficient methods in providing nutrients for fruit trees (NEILSEN; NEILSEN, 2008).

Fertigation is used in Belgium and the Netherlands in *Conference* pears to increase the efficiency of nutrient absorption and to maximize the fruit production (PIETER et al., 2013).The nitrogen fertigation in the pear crop has the potential to reduce its losses and to increase its absorption efficiency, since the N presents high mobility in the soil profile, being absorbed through mass flow (RAIJ, 2011). Research carried out with fertigation in the pear crop has shown an increase in the efficiency of N absorption, reducing the amount applied up to 23% and its losses in 45% in orchards in China (YIN et al., 2012).

The process of phosphorus absorption in the soil occurs 95% by the diffusion mechanism, in which the volumetric humidity of the soil is the most important factor to promote its absorption by the roots (NEILSEN; NEILSEN, 2008). In *Spadona* pear, the fertigation with P increased the concentration of this ion in the soil significantly when compared to the solid application of the nutrient (KLEIN et al., 1999). Higher fertigation frequencies with N and P in pear orchards may increase the efficiency of nutrient use compared to the application of solid fertilizers in the soil surface (YIN et al., 2007).

In Brazil, there is a lack of information related to the use of irrigation and/or fertigation systems for pear cultivation and its use in orchards with the use of quince (*Cydonia oblonga*). Therefore, the aim of this study was to evaluate the vegetative development of European pear cultivars grafted on quince with two forms of nutrient application in the region of Planalto Serrano, state of Santa Catarina, during the 2012/13, 2013/14 and 2014/15 harvests.

MATERIALS AND METHODS

The experiment was conducted during the 2012/13, 2013/14 and 2014/15 harvests, in the experimental area of the State University of Santa Catarina/UDESC, at the Agroveterinary Sciences Center/CAV, in the municipality of Lages, Santa Catarina, at 938 m of altitude, 27º19'44" of latitude and 50º19'44" of longitude. The climate, according to Köppen classification, is the Cfb type, temperate and humid climate with fresh summer and average annual temperature of 14.3 ºC, with average annual rainfall of 1.479 mm (CARDOSO et al., 2003).

The soil of the experimental area is classified as *Cambisol Humic Aluminum leptic* (EMBRAPA, 2013), with free texture, moderate A horizon and substrate composed of siltstones and argillites (BERTOL, 2002).The soil physico-chemical analyzes carried out in 2007 indicated the following results: pH in water of 4.8; SMP index of 5.1; 11.2 mg dm^{-3} of P; 165 mg dm^{-3} of K; 2.0 $cmol_c$ dm^{-3} of Ca; 1.1 $cmol_c$ dm^{-3} of Mg; 4.1% of organic matter and 35% of clay. In the implantation of the experiment, the initial preparation of the soil with plowing and harrowing was carried out. In order to correct the acidity, liming was carried out in soil, in order to raise the soil pH in water to 6.0. In the correction fertilization, K_2O and P_2O_5 were applied when necessary, following the recommendation of the Soil Chemistry and Fertility Committee RS/SC (2004).

The experimental area was implanted in 2008, with pre-formed seedlings consisting of the *Rocha*, *Abbé Fétel* and *Santa Maria* European pear cultivars grafted on the Adams and EMA quince rootstocks. The company *Frutirol Agrícola Ltda*, located in Vacaria, RS, supplied the seedlings. The planting spacing used was 3.0 m between rows and 1.0 m between plants, resulting in a planting density of 3,333 plants/ha. The plants were conducted in the central leader system and the cultural treatments consisted in the accomplishment of fertilization, bending of branches, crowning, pruning, control of weeds and pests, according to the technical recommendations of the crop (NAKASU et al., 2007).The irrigation system was installed in the dormancy period of the plants in 2011, using the localized system by drip. The irrigation management used was the same in both treatments (solid nutrient application and via fertirrigation) in order to maintain soil tension levels in values close to 10 kPa. The monitoring of the need for irrigation was carried out using puncture tensiometers placed in the soil, at depths corresponding to layers from 0 to 0.20 and from 0.20 to 0.40 m.

In the 2011/12 harvest, soil samples were collected again for the physical-chemical analyzes that indicated: pH in water of 5.2; SMP index of 5.8; 5.0 mg dm^{-3} of P Mehlich; 89.0 mg dm^{-3} of K; 4.0 $cmol_c$ dm^{-3} of Ca; 2.9 $cmol_c$ dm^{-3} of Mg; CEC effective of 7.6 $cmol_c$ dm^{-3}, 3.3% of organic matter and 36% of clay. The total fertilizer applied in the treatments with solid application in the surface and via fertigation was estimated based on the soil analysis carried out in the 2011/12 harvest, using 42 kg ha^{-1} of KCl - potassium chloride (60% of K_2O) and 295 kg ha^{-1} of MAP- monoammonium phosphate (10% of N and 48% of P_2O_5). In the application of the nutrients in the solid form, 44 grams of MAP and 6 grams of KCl per plant were distributed in the canopy projection area in May, and the same fertilization was repeated in October. In the fertirrigation, the same amounts of nutrients were applied, but in a piecemeal way, divided into a weekly application in the months from May to June and from October to December, totaling 20 applications. The nutritive solution applied via fertigation was balanced so that the plants submitted to the fertirrigated treatment received the same amounts of nutrients as the plants submitted to the application in the solid form of the fertilizers. The application of the nutrients in the fertigation system was carried out by direct suction through a Venturi injector, with permanent agitation directly in the fertilizer dissolution tank.

During the 2012/13, 2013/14 and 2014/15 harvests, foliar fertilization was carried out in all plants of the experimental area with boron (0.4%); two applications, calcium (0.6%); six applications and magnesium (2%); three applications carried out in the period from October 15 to January 15 at biweekly intervals.

The experiment was conducted in a randomized complete block design with three replicates and the treatment arrangement was in sub-subdivided plots. The cultivar factor constituted the main plots: *Rocha*, *Abbé Fétel* and *Santa Maria*. The rootstocks factor was allocated in the subplots: Adams and EMA quince. The form of nutrients application factor composed the sub-subplot: application in solid form on the surface and application via fertigation. Each sub-subplot was constituted by ten plants.

The evaluation of the vegetative development was carried out during the plant rest period. The sub-subplots were composed by ten plants, being the central six plants considered as useful and the following parameters being evaluated: a) cross-sectional area of the rootstock trunk (CSART), obtained by the equation CSART = $\pi d^2/4$, where d is the trunk diameter of the plants measured with a digital caliper 5.0 cm below the grafting point; b) cross-sectional area of the trunk of the cv. canopy (CATC), obtained by the CATC equation = $\pi d^2/4$, where d is the trunk diameter of the plants measured with a digital caliper, 5.0 cm above the grafting point; c) plant height (m) (PH), obtained with a measuring tape, from the neck of the plant to the apex of the main branch; d) canopy volume (m^3) (CV), obtained by considering the plant canopy as a cone, through the formula $CV = (\pi \times T \times W \times h)/3$, where T is the plant thickness (m), W is the width of the plant (m), and h is the plant height from the insertion of the first branches (m) to the apex of the central leader; e) buds index (buds number/cm $branch^{-1}$) (BI), obtained through the relation between the number of buds and the length of the branch.

The data were submitted to analysis of variance and the averages analyzed by the Tukey test at 5% probability, using the Winstat 2.0 program.

RESULTS AND DISCUSSION

The vegetative characteristics were significantly influenced by the cultivars used. The *Abbé Fétel* showed higher plant height (PH) in the first harvest and greater cross section area of the rootstock trunk (CSART) in the three harvests, comparing to *Rocha* and *Santa Maria* (Table 1).

The plant vigor is directly correlated with the cross-sectional area of the trunk of the cv. canopy (CATC) measured at 5 cm above the point of grafting (CZYNCZYK; BIELICKI, 2012), this CATC was superior in cv. *Abbé Fétel* (Table 1). Several authors report the high vigor pattern of *Abbé Fétel* (TOMAZ et al., 2009; MUSACCHI et al., 2011; GALLI et al., 2011; MACHADO et al., 2013; PETINELI, 2014).

The development of branches in the canopy of the plants differed significantly between the cv. canopies. Based on the canopy volume (CV), the cvs. *Abbé Fétel* and *Rocha* showed superior CV than the *Santa Maria* in the three harvests. The plant height (PH) was influenced by cv. canopy, being superior in *Abbé Fétel* in the first year of evaluation but not differing from *Rocha* in the two subsequent years (Table 1). As observed in the field, *Abbé Fétel* showed more vigorous plants characterized by the erect height with greater development of apical dominance, which may have caused the formation of tall canopy with long branches and with a larger number and size of leaves. The estimated productivity in *Abbé Fétel* in this study was very low (0.39 t ha^{-1}, 0.01 t ha^{-1} and 0.52 t ha^{-1} during the three harvests, respectively), and this behavior was also observed in Vacaria/RS. The coincidence of the flowering season of *Abbé Fétel* with cv. *Rocha* and *Santa Maria* and the absence of pollinators within the orchard are some of the factors that associated with its excessive plant vigor may have compromised the production of *Abbé Fétel* fruits, considering that the estimated yield of the cultivars did not differ in relation to the effect of the application of nutrients in any harvest. This vigorous growth of the *Abbé Fétel* shoot and the consequent canopy shading negatively affected the formation of vegetative and reproductive structures determined through the buds index (BI), being the lowest observed in *Abbé Fétel* in the first and third year of evaluation (Table 1).This result was already expected, since, according to Rufato et al. (2012) the bud index is inversely proportional to the vegetative growth of the plant. According to Pasa et al. (2011), the formation of buds suffers greater competition for carbohydrates in vigorous plants, because branches of high vigor have greater apical dominance, influencing the hormonal and nutritional balance; differently from the *Rocha* plants, which were characterized by the semi-erect height with greater light interception of the branches located inside the canopy, which provided a better balance in the plant vegetative/productive relation with significant additions in the bud index of this cv. in two harvests (Table 1). This adequate balance resulted in significantly higher estimated yields in the Rocha cultivar (2.39 t ha^{-1}, 1.85 t $ha^{-1}$and 5.03 t ha^{-1}, respectively in the 2012/13, 2013/14 and 2014/15 harvests), when compared to the *Abbé Fétel* and *Santa Maria* cultivars in the three harvests, although considered low for this crop.

The cross-sectional area of the rootstock trunk (CSART) and the cross-sectional area of the trunk of the cv. (CATC) were influenced by quince. The *Adams* provided superior vigor in relation to the CSART and the CATC in the three-year evaluation (Table 2). Results verified by Almeida (2014) also report greater vigor of *Adams* compared to *EMA*. However, the differences induced by rootstock in plant vigor may vary according to the climatic conditions of each site (LEPSIS; DRUZE, 2011; ALMEIDA, 2014), or due to changes in soil type, nutrient absorption and translocation to the shoot (BAKSHI; SINGH, 2010), on the compatibility of grafting due to the movement of sap in xylem and phloem (FACHINELLO; PASA, 2010; PETINELI, 2014) And also according to the cultivar used (STERN; DORON, 2009; PASA et al., 2012; IKINCI et al., 2014), and other factors. This explains why the rootstock had an influence on the CSART and the CATC and, however, did not affect the plant height (PH) and the bud index (BI) (Table 2) over the three evaluated years.

The nutritional status of the plant is a determining factor in pear growth and development. The fertigation is considered an efficient method of supplying nutrients to fruit trees (NEILSEN; NEILSEN, 2008). Regarding the nutrient application, fertigation had a negative effect on the BI in the first year, but increased PH in the second year of evaluation only (Table 3).

The application form did not change the CATC and CV in the three evaluation years (Table 3) and the differences for the PH and the BI were verified in only one of the three evaluated years, which leads to inconsistent results in relation to the influence of the nutrient application forms in pear growth and development. Similar results related to the lack of the application form effect were also verified by Yin et al. (2009) with *'D'Anjou* pear, in relation to the application of N and P in the solid form on the surface and via fertirrigation. In the following study, the authors did not verify differences regarding the use of the two application forms of N, in the growth of the plants, in the production and the size of the pear fruits (YIN et al., 2012). The application of fertilizers also did not alter the growth of *Conference* and *Lukasowka* pear on EMA (LIPA; SZOT, 2013).

TABLE 1 - Cross-sectional area of the rootstock trunk (CSART), cross-sectional area of the trunk of the cv. canopy (CATC), plant height (PH), canopy volume (CV) and bud index (BI) for the different European pear canopy cultivars in the 2012/13, 2013/14 and 2014/15 harvests.

		2012/13 Harvest			
Cultivars	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Rocha	17.45 b	11.70 b	2.06 b	1.75 a	0.49 a
Abbé Fétel	28.90 a	19.84 a	2.18 a	1.62 a	0.41 c
Santa Maria	13.54 c	10.71 b	1.73 c	0.96 b	0.46 b
Average	19.96	14.08	1.99	1.44	0.45
CV (%)	9.88	16.29	5.47	25.28	3.14
		2013/14 Harvest			
Cultivars	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Rocha	25.85 b	18.46 b	2.46 a	3.74 a	0.45 b
Abbé Fétel	37.69 a	25.88 a	2.56 a	3.70 a	0.50 a
Santa Maria	20.56 c	14.77 c	1.98 b	1.17 b	0.40 c
Average	28.03	19.70	2.33	2.87	0.45
CV (%)	7.49	6.79	6.74	25.05	9.05
		2014/15 Harvest			
Cultivars	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Rocha	36.00 b	26.54 b	3.08 a	4.38 a	0.42 a
Abbé Fétel	42.72 a	30.64 a	3.13 a	4.26 a	0.36 b
Santa Maria	27.72 c	19.99 c	2.37 b	2.20 b	0.33 b
Average	35.48	25.73	2.86	3.61	0.37
CV (%)	11.83	9.74	5.49	16.75	13.32

*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability.

TABLE 2 - Cross-sectional area of the rootstock trunk (CSART), cross-sectional area of the trunk of the cv. canopy (CATC), plant height (PH), canopy volume (CV) and bud index (BI) for the different quince rootstock in the 2012/13, 2013/14 and 2014/15 harvests.

		2012/13 Harvest			
Rootstocks	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Adams	22.11 a	15.83 a	2.02 a	1.63 a	0.45 a
EMA	17.81 b	12.34 b	1.96 a	1.26 b	0.46 a
Average	19.96	14.08	1.99	1.44	0.45
CV (%)	9.88	16.29	5.47	25.28	3.14
		2013/14 Harvest			
Rootstocks	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Adams	31.04 a	21.59 a	2.35 a	3.03 a	0.44 a
EMA	25.03 b	17.82 b	2.31 a	2.71 a	0.46 a
Average	28.03	19.70	2.33	2.87	0.45
CV (%)	7.49	6.79	6.74	25.05	9.05
		2014/15 Harvest			
Rootstocks	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Adams	38.99 a	27.92 a	2.82 a	3.53 a	0.37 a
EMA	31.97 b	23.53 b	2.90 a	3.69 a	0.37 a
Average	35.48	25.73	2.86	3.61	0.37
CV (%)	11.83	9.74	5.49	16.75	13.32

*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability.

TABLE 3 - Cross-sectional area of the rootstock trunk (CSART), cross-sectional area of the trunk of the cv. canopy (CATC), plant height (PH), canopy volume (CV) and bud index (BI) for the different application forms of nutrients in the 2012/13, 2013/14 and 2014/15 harvests.

		2012/13 Harvest			
Applications forms	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Conventional	19.5 a	14.1 a	2.0 a	1.4 a	0.4 a
Fertirrigation	20.4 a	13.9 a	1.9 a	1.4 a	0.4 b
Average	19.9	14.0	1.9	1.4	0.4
CV (%)	9.8	16.2	5.4	25.2	3.1
		2013/14 Harvest			
Applications forms	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Conventional	28.4 a	19.9 a	2.2 b	2.6 a	0.4 a
Fertirrigation	27.6 a	19.4 a	2.4 a	3.0 a	0.4 a
Average	28.0	19.7	2.3	2.8	0.4
CV (%)	7.4	6.7	6.7	25.0	9.0
		2014/15 Harvest			
Applications forms	**CSART (cm^2)**	**CATC (cm^2)**	**PH (m)**	**CV (m^3)**	**BI**
Conventional	36.4 a	25.9 a	2.9 a	3.8 a	0.3 a
Fertirrigation	34.5 a	25.4 a	2.8 a	3.3 b	0.3 a
Average	35.4	25.7	2.8	3.6	0.3
CV (%)	11.8	9.7	5.4	16.7	13.2

*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability.

CONCLUSIONS

The *Abbé Fétel* cultivar has a larger area of the cross section of the rootstock trunk and of the canopy cultivar. The cv. *Rocha* and *Abbé Fétel* have higher canopy height and volume; *Rocha* and *Abbé Fétel* produce the highest buds index in the branch.

The Adams quince has a larger cross-sectional area of the trunk and induces a larger cross-sectional area of the trunk of the canopy cultivars.

The application of nutrients has no effect on the cross-sectional area of the rootstock trunk and on the cross-sectional area of the trunk of the canopy cultivar. The plant height can be positively influenced by fertigation. With the increase of the plants age, the conventional application of nutrients induces a greater canopy volume in the edaphic conditions and with the management adopted in this study.

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