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Study on the growth and spatial distribution of the root system of different european pear cultivars on quince rootstock combinations

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Abstract- Information on root development is an essential tool capable of identifying, among plants of a species, the one that has the greatest capacity to potentiate growth and development characteristics in its aerial part. The aim of this study was to characterize the distribution of the root system throughout the soil profile of different European pear cultivars and quince rootstock combinations on medium plant density systems (2500 plants ha^{-1}). The combinations evaluated were: Abbè Fetel/Adams, Clapp´s Favourite/EMA, Santa Maria/Adams, Rocha/Adams, Decana du Comice/Adams, Packham´s Triumph/EMA, Packham´s Triumph/Adams and Conference/Adams. In relation to effective depth, it was observed that up to 40 cm deep, 80% of the total root length and 83% of root concentration were found for all combinations. For the effective distance, it was observed that 80% of the total root length is distributed in up to 80 cm for all combinations, except for Clapp's Favourite/EMA, whose actual distance was 100 cm. It was observed that the average of six combinations, 86% of root growth in the horizontal distance is located up to 80 cm.
Index terms: *Pyrus communis* L., *Cydonia oblonga* L., root.

Estudo do crescimento e distribuição espacial do sistema radicular de diferentes combinações de cultivares de pereiras europeias sobre porta-enxertos de marmeleiros

Resumo - Informações sobre desenvolvimento das raízes constituem ferramenta essencial capaz de identificar, dentre as plantas de uma espécie, a que tenha maior capacidade de potencializar características de crescimento e desenvolvimento em sua parte aérea. Assim sendo, o objetivo do trabalho foi caracterizar a distribuição do sistema radicular ao longo do perfil do solo das diferentes combinações de cultivares de pereiras europeias sobre porta-enxertos de marmeleiro em sistemas de média densidade (2.500 plantas ha^{-1}). As combinações avaliadas foram: Abbè Fetel/Adams, Clapp´s Favourite/EMA, Santa Maria/Adams, Rocha/Adams, Decana du Comice/Adams, Packham´s Triumph/EMA, Packham´s Triumph/Adams e Conference/Adams. Em relação à profundidade efetiva, observou-se que até 40 cm de profundidade se concentram 80% do comprimento total de raízes e 83% da concentração radicular para todas as combinações. Para a distância efetiva, observou-se 80% do comprimento total de raízes distribuídos até 80 cm para todas as combinações, com exceção da Clapp´s Favourite/EMA, cuja distância efetiva foi 100 cm. Foi possível observar que, na média das seis combinações, 86% da concentração radicular na distância horizontal localizam-se até 80 cm.
Termos para indexação: *Pyrus communis* L., *Cydonia oblonga* L., raiz.

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Introduction

In Brazil, pear trees (*Pyrus communis* L.) do not stand out among the most cultivated fruit trees due to the small cultivated area (1900 ha) and low productivity (11 t ha^{-1}) (FAO, 2013). As a result, there is a need for imports to meet the demand of the domestic market, becoming today the second largest importer of the fruit. Thus, it is possible to observe that pear tree cultivation is an important market opportunity for brazilian producers, despite the existence of limiting production factors, such as the lack of definition of cultivars and rootstocks adapted to the different potential producing regions, especially in southern Brazil.

As described by Francescatto et al., (2010), good rootstock should have the following characteristics: control of plant vigor, production precocity, resistance to nematodes and diseases, productivity, water and nutrient absorption, adaptation to different types of soil, physical and nutritional quality of fruits. The choice of the rootstock is directly linked to the condition of the region where the orchard will be installed, type of plant management and cultural practices adopted.

In most studies involving experiments with rootstocks, the main focus has been the aerial part, whether in experiments of productivity, quality or even of graft incompatibility. However, studies on the root system of plants are of great importance due to their role in sustaining and absorbing water and nutrients. Information on the distribution and extension of the root system of the different rootstocks are fundamental for decision making on cultural practices, especially those related to planting spacing, soil management, fertilization, irrigation and even the selection of materials adapted to a given region (Neves et al., 2008).

In this way, knowledge of the crop root system is of extreme importance for the management of the orchard, because in association with edaphoclimatic factors, well-developed roots will have greater root growth per area or soil volume, allowing the plant root system to have larger access to water and nutrients, which can directly influence orchard productivity and tolerance to water deficit and other stresses (ANDRADE JR., 2013).

Despite the importance of the root system and its direct effect on the productive efficiency of plants, studies on root systems are scarce in Brazil, especially regarding woody fruit plant rootstocks (NEVES et al., 2004).

For the study of roots, one of the methods used is the profile, which is based on the opening of trenches for better visualization and evaluation of the root distribution of the plant under study. The evaluation of *in situ* root distribution consists of digging a trench next to the plant and removing a thin layer of the profile wall in order to expose the roots, which are then counted and recorded in drawings or tables (BOHM, 1979).

In this context, the aim of the study was to characterize the root system distribution along the soil profile of the different European pear cultivars on quince rootstock combinations in medium plant density system (2500 plants ha^{-1}).

Material And Methods

The experiment was carried out in a commercial pear orchard in the region of Urupema, state of Santa Catarina, with different european pear cultivars on quince rootstock combinations. The root system characterization was carried out in the 2013/14 crop cycle in plants with approximately six years of age.

The orchard is located at 1425 m altitude above sea level, with geographic coordinates (28º17'38 ''S, 49º55'54''W), in a clay loamy Nitosol with high organic matter, phosphorus and potassium contents. The degree of saturation by aluminum is low and by bases is very high. The climate of the region is humid mesothermal Cfb-a type, with no dry season with mild summer and precipitation distributed throughout the year, with an average annual rainfall of 1789 mm and an average annual temperature of 14ºC (EPAGRI, 2013). There was no irrigation system installed in the orchard.

The experimental area was implanted in august 2008, with planting density of 2500 plants ha^{-1}. Planting was carried out with preformed seedlings and the adopted planting system was the central leader. The following graft / rootstock combinations were evaluated: Abbè Fetel/Adams, Clapp´s Favourite/EMA, Santa Maria/Adams, Rocha/Adams, Decana du Comice/Adams, Packham´s Triumph/EMA, Packham´s Triumph/Adams and Conference/Adams.

Two plants for each graft / rootstock combination were selected, where trenches were opened for further evaluation of the root distribution. The low number of experimental units is characteristic of studies on roots due to the enormous effort at field level, and to the fact that the processing is very laborious, as described by Souza et al. (2008), in a study with root distribution in citrus. In this sense, the study generated information in an exploratory character in order to characterize the vertical and horizontal distribution of the root system of the different combinations.

To evaluate the root system of the different combinations, the following procedure was performed: during the vegetative rest period, the trench method was used, manually opened, with a 50 cm in depth from the soil surface and 1.00 m in length, in the direction of the planting line, distant 0.5 m from the plant trunk. After the opening of trenches, the following steps were carried out:

a) Profile leveling: which became as vertical as possible, being executed with the aid of a straight shovel. This practice facilitated the fixation of the reticulated screen used in the capture of images, avoiding evaluation errors. In this operation, all roots exposed in the trench opening were cut close to the profile;

b) Root exposure: performed using a chiseling roller, removing a small soil layer, about 0.01 m, in an attempt to expose the roots present in the profile, in such a way that the trench wall remains vertically leveled. As the image to be acquired represents a known soil volume (100 cm in length x 50 cm in depth), it was possible to acquire the image with the amount of roots present in the desired soil volume;

c) Root painting: performed with white-color spray paint aiming at increasing the contrast in relation to the soil to facilitate the acquisition of images (with the aid of a spatula, removing the paint surplus from the soil profile);

d) Division of soil profile: for the acquisition of images, a frame of 1.00 m in length and 0.5 m in height was made. The soil profile was divided with green-painted strings to avoid reflection when photographing in of 10 x 10 cm squares (500 cm^2);

e) Image capture: images were taken with a common digital camera at a distance of one meter from the profile. For image processing, the SIARCS / EMBRAPA software (CRESTANA et al., 1994; JORGE et al, 1996) was used, with root length results in each frame. For root length calculations, images were submitted to the skeletonization process, which consists of thinning them to the thickness of a line.

The final result was expressed as total root length (cm) per trench present in 500 cm^2 of soil, percentage distribution of root length, depth and effective distance, representing the limit that up to 80% of roots are found (KLAR, 1991) .

The spatial distribution of the total root density was also performed for each graft / rootstock combination, using the Surfer application, version 7.

Results and Discussion

Abbè Fetel cultivar grafted on the Adams quince tree induced higher root growth and explored higher soil volume. On the other hand, the Clapp's Favorite / EMA combination obtained the lowest root concentration, exploiting lower soil volume. In the comparison of the root distribution along the profile of the six combinations, it is important to high light that Santa Maria and Rocha cultivars, both grafted on Adams quince, showed root growth considered intermediate when compared to the other combinations (Table 1).

By analyzing the six combinations of european pear tree cultivars by spatial distribution of root length in depth, average root density value of 83% in the first 40 cm was observed. This volume decreased in the next layer (40-50 cm), around 66% in the planting line (Table 1).

In relation to effective depth (Figures 1 and 3), it was observed that up to 40 cm, 80% of the total root length were concentrated in all combinations evaluated and that, in the average of the six combinations, 83% of the root concentration were located in that depth, which is similar to result of Santana et al. (2006) in citrus root distribution studies, who found 86% of the root concentration ($cm.cm^{-3}$of soil) located at depths of 0.0 to 38.0 cm and Neves et al., (2008), in a study on lime and lemon, who observed most of the roots at an effective depth of 36 cm and 41 cm, respectively.

The availability of nutrients in the soil to plants influences the reduction of root density in depth (BAKKER et al., 2006). According to Witschoreck et al., (2003), the concentration of fine roots in the upper soil layer is correlated with higher concentrations of organic matter and nutrients and with the favorable physical conditions of this layer. These data confirm that root reduction in depth is related to the low fertility in the deeper soil layers, which according to literature can be a limiting factor for the root system development (PARTELLI et al., 2014).

Table 1- Root length profile measured in the soil profile in soil volume of 500 cm^2 for the different european pear trees and quince rootstock combinations at planting density of 2500 plants ha^{-1}. (1) Abbè Fetel / Adams; (2) Decana du Comice / Adams; (3) Packham's Triumph / EMA; (4) Clapp's Favorite / EMA; (5) Santa Maria / Adams; (6) Rocha / Adams; (7) Packham's Triumph / Adams; (8) Conference / Adams. Lages-SC, 2014.

Combination	Cultivar Rootstock	1	2	3	4	5	6	7	8
				Root length (cm)					
Depth (cm)	0-10	623,95	496,08	695,74	199,48	613,53	484,96	536,32	812,92
	10-20	924,94	504,65	757,83	294,33	655,89	587,80	529,49	683.34
	20-30	553,27	550,29	549,33	257,26	352,38	460,26	392,93	293,04
	30-40	437,56	424,04	498,00	161,53	249,75	441,85	99,51	194,49
	40-50	417,78	368,61	267,07	121,96	185,57	175,74	53,46	311,41
Total length (cm)		2.957,50	2.343,67	2.767,97	1.034,56	2.057,12	2.150,61	1.611,71	2.295,20

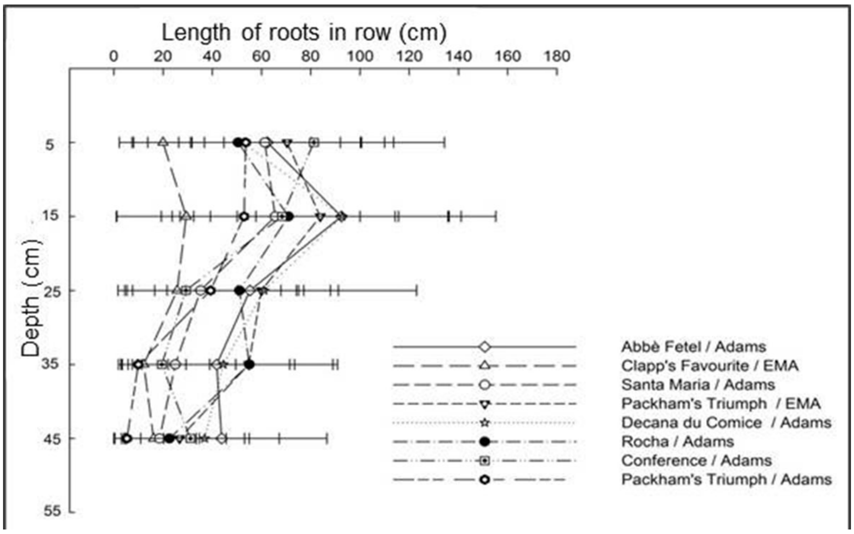

Figure 1- Mean root length by depth of different european pear trees and quince rootstock combinations in the planting line at planting density of 2500 plants ha^{-1}. Lages, 2014.

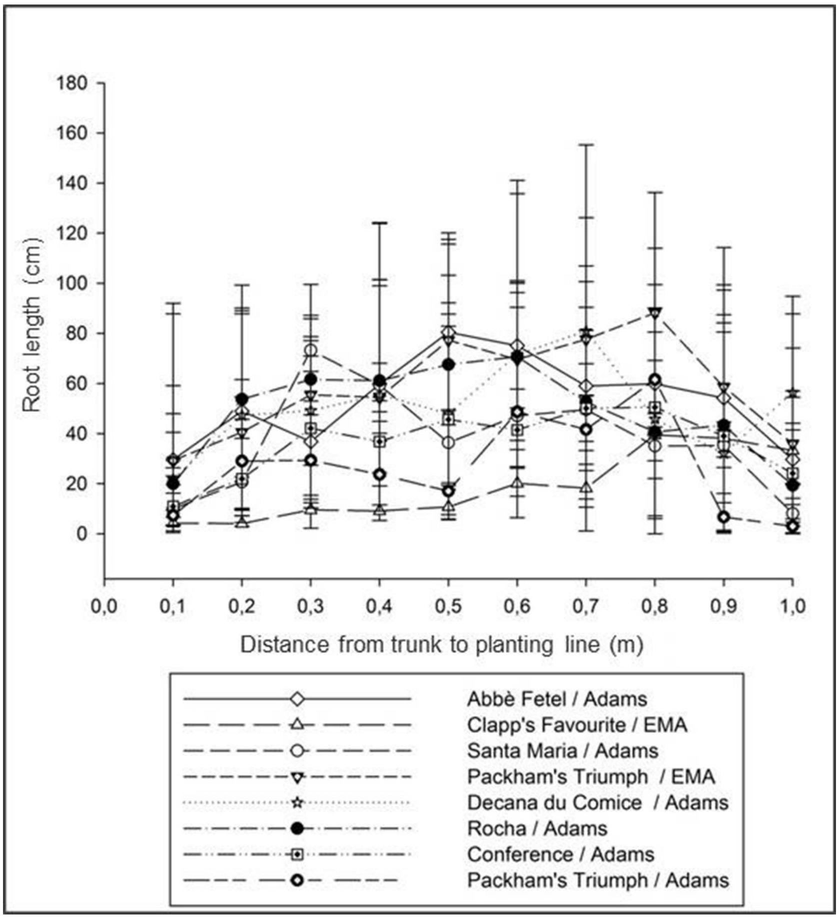

Figure 2 - Mean root length by distance in the planting line of the different european pear trees and quince rootstock combinations at planting density of 2500 plants ha^{-1}. Lages, 2014.

In relation to the effective distance of roots in relation to plant trunk, it was observed that 80% of their total length is located 80 cm away, for all combinations, except for Clapp's Favorite on EMA, whose distance was 100 cm. In the mean of the six combinations, 86% of the root concentration in the horizontal distance is located at 80 cm (Figures 2 and 3).

It is important to emphasize that greater root length was concentrated in the region of greater amount of water and nutrients available to roots, which should assure the plant greater soil exploration capacity and, consequently, greater absorption of water and nutrients, as observed by Ronchi et al., (2015), when evaluating the root system of adult *C. canephora* and arabica coffee growing plants, respectively. In addition, the authors found that, in the surface area, root length and volume reduced with depth in the soil profile, as well as the mean root diameter due to the low soil fertility in deeper zones. This decrease in root density in depth was also described by Santana et al., (2006), attributing this factor to the increase in the clay and organic material contents.

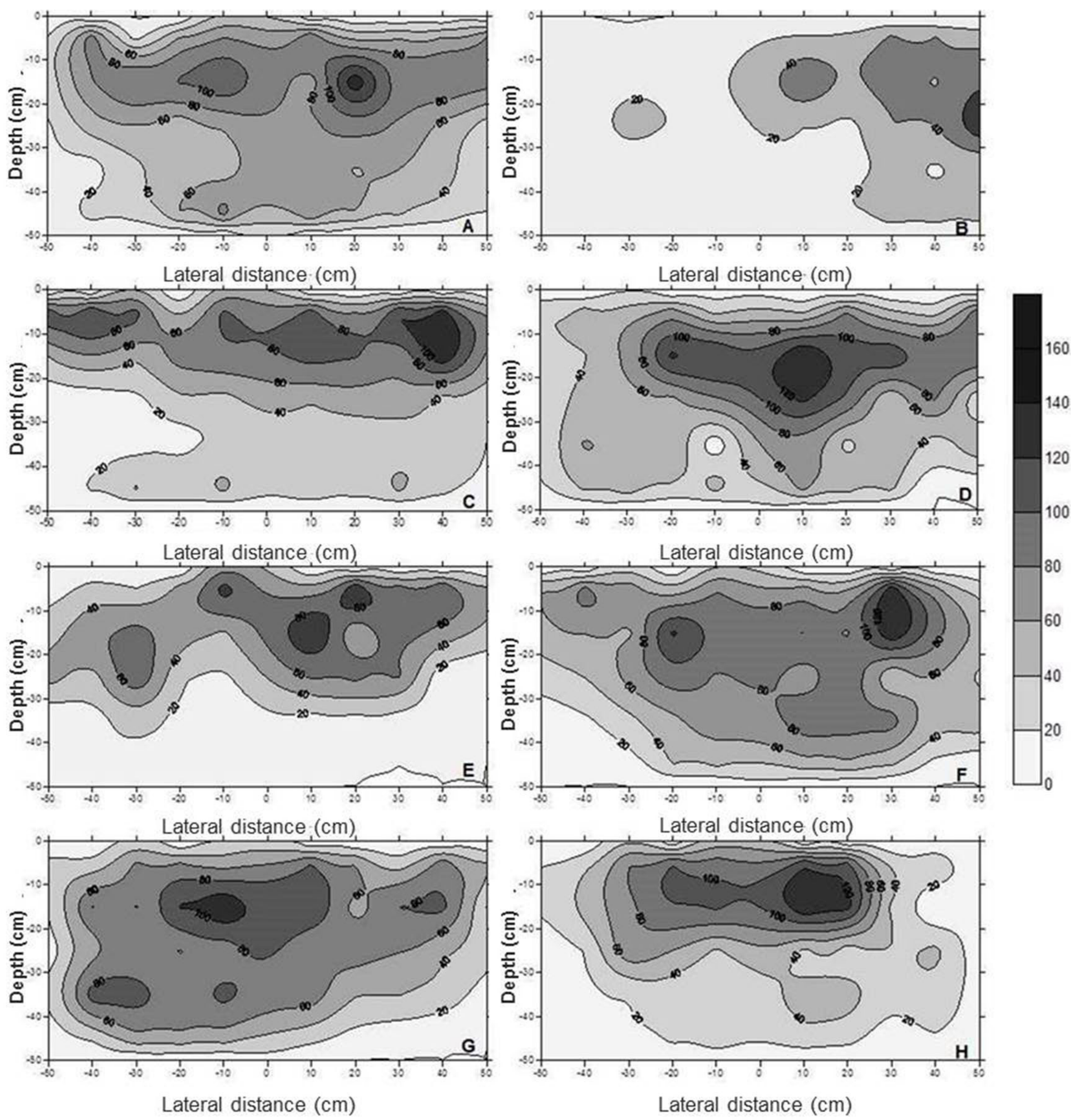

Figure 3 - Root length isolines in cm of root / 500 cm^3 of soil of the different european pear trees and quince rootstock combinations at planting density of 2500 plants ha^{-1} obtained by the trench method. Abbè Fetel / Adams (A), Clapp's Favorite / EMA (B), Conference / Adams (C), Decana du Comice/Adams (D), Packham's Triumph / Adams (E), Packham's Triumph / EMA (F), Rocha / Adams (G), Santa Maria / Adams (H).

Conclusion

- The root system distribution of combinations evaluated is concentrated in the first 40 cm of depth and in the 80 cm of effective distance of plants in the planting line, with the exception of Clapp's Favorite on EMA, whose effective distance was of 100 cm;

- Abbè Fetel/Adams combination has the highest root density. The lowest root density was observed for Clapp's Favorite/EMA combination;

- The depth of 80% of the total root length is 40 cm for all combinations evaluated.

- The highest root length was also concentrated in the region with the highest amount of water and nutrients available to roots.

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