THE PEAR TREE RESPONSE TO PHOSPHORUS AND POTASSIUM FERTILIZATION[1]

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ABSTRACT – The aim of this study was to evaluate the response to phosphorus (P) and potassium (K) fertilization and to establish the critical levels of P and K in the soil and in the plant tissue in pear trees. Two experiments were conducted in São Joaquim (SC), Brazil. In experiment 1, the plants received annually the application of increasing rates of phosphate fertilizer (0, 40, 80, 120 and 160 kg P_2O_5 ha^{-1}), while in experiment 2, increasing rates of potassium fertilizer (0, 40, 80, 120 and 160 kg K_2O ha^{-1}) were applied annually. In the two experiments, soil was collected annually from the 0-10, 10-20 and 0-20 cm layers, and the available P (experiment 1) and exchangeable K (experiment 2) content was analyzed. Whole leaves were collected annually, which were subjected to analysis of total P (experiment 1) and total K (experiment 2) content. The number and weight of the fruits per plant and fruit yield were evaluated. Application of P on the soil planted with pear trees increased the nutrient content in the soil and, in most crop seasons, in the whole leaf, but it did not affect the yield components and fruit yield. The application of K on the soil with pear trees increased the nutrient content in the soil and, in most of the crop seasons, in the whole leaf, but the potassium content in the whole leaf decreased in the crop season with greater fruit yield. The yield components and fruit yield were not affected by K fertilization.

Index terms: *Pyrus communis* L., sufficiency level, phosphate fertilization, potassium fertilization, yield.

RESPOSTA DA PEREIRA À APLICAÇÃO DE FÓSFORO E POTÁSSIO

RESUMO - O trabalho objetivou avaliar a resposta à adubação com fósforo (P) e potássio (K) e estabelecer o nível crítico no solo e no tecido de P e K em pereira. Dois experimentos foram conduzidos em São Joaquim (SC). No experimento 1 as plantas receberam anualmente a aplicação de doses crescentes de fertilizante fosfatado (0; 40; 80; 120 e 160 kg de P_2O_5 ha^{-1}), enquanto no experimento 2 foram aplicadas anualmente doses crescentes de fertilizante potássico (0; 40; 80; 120 e 160 kg de K_2O ha^{-1}). Nos dois experimentos foi coletado anualmente solo nas camadas de 0-10; 10-20 e 0-20 cm, onde foi analisado o teor de P disponível (experimento 1) e K trocável (experimento 2). Anualmente foram coletadas folhas completas que foram submetidas à análise do teor total de P (experimento 1) e K (experimento 2). Avaliaram-se o número e a massa dos frutos por planta e a produção de frutos. A aplicação de P no solo cultivado com pereira incrementou o teor do nutriente no solo e, na maioria das safras, na folha completa. Porém, o incremento do teor de P disponível no solo e na folha não foi acompanhado de aumentos nos componentes de produção e na produção de frutos, impossibilitando o estabelecimento do nível crítico de P no solo e no tecido. A aplicação de K no solo aumentou o teor do nutriente no solo e, na maioria das safras, na folha completa da pereira, mas o teor de K na folha completa diminuiu na safra com maior produção de frutos. O incremento de K trocável no solo e na folha não foi acompanhado de aumentos nos componentes de produção e na produção de frutos, não permitindo o estabelecimento do nível crítico de K no solo e no tecido.

Termos de indexação: *Pyrus communis* L., nível de suficiência, adubação fosfatada, adubação potássica, produção.

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INTRODUCTION

Definition of the need for fertilization and the nutrient rate in pear (*Pyrus communis* L.) tree in the states of Rio Grande do Sul (RS) and Santa Catarina (SC), Brazil, is based on combined analysis of nutrient contents in the whole leaves and in the soil, and also on the age of the plants, plant growth, planting and training system, previous fertilizations, on the yield, crop treatments and symptoms of nutritional disorders (CQFS-RS/SC, 2004). Nevertheless, for the nutrient contents in the soil and in the plant tissue, the critical contents used for establishment of classes of interpretation are the same as those of annual plants. This occurs because information is scarce regarding the response of the pear tree to the addition of nutrients even in soils with low availability. Thus, the critical levels of phosphorus (P) and potassium (K) in the soil and in the plant tissue for the crop are still an open question, which justifies carrying out medium and/or long-term experiments in traditional fruit producing regions, such as the Planalto Serrano of Santa Catarina.

Soils in the South of Brazil, like those of the Planalto Serrano of SC, in general are acidic, have low available P content and the small quantity of exchangeable K (KAMINSKI et al., 2007). This may cause low pear yield, and for that reason, phosphate and potassium fertilization is recommended as a safety measure to ensure greater yields (NAVA et al., 2008; NAVA; DECHEN, 2009; SOUZA et al., 2013).

The application of P sources in the soil promotes phosphate sorption in the functional groups of inorganic reactive particles of the soil, but as successive applications occur, the binding energy between the phosphate and the functional groups decreases, and there may also be P migration in the soil profile (SCHMITT et al., 2013). In the same way, but in a readier manner, K migration occurs, as long as the quantity added is greater than that used by the crops, because its adsorption to the functional groups of inorganic and organic reactive particles takes place with low binding energy, facilitating its migration in the soil profile (KAMINSKI et al., 2007). With the accumulation of available P and exchangeable K in soil surface layers and even in deeper layers, it is expected that part of these nutrients draws near the outside surface of the roots, especially through diffusion and, if taken up, contents of the nutrients will increase within the plant, and this may be diagnosed by the total content in the whole leaves (MELO et al., 2012; CURETTI et al., 2013). Therefore, an increase may be expected in the values of yield components, such as fruit weight, which may be reflected in an increase in fruit yield per plant and per area (NEILSEN et al., 2008; NAVA; DECHEN, 2009). The aim of this study was to evaluate the response to phosphorus (P) and potassium (K) fertilization and to establish the critical levels of P and K in the soil and in the plant tissue in pear trees.

MATERIALS AND METHODS

Two experiments were conducted in a commercial pear (*Pyrus communis* L.) orchard in the municipality of São Joaquim, in the Planalto Serrano region of SC, Brazil (28° 17' 38" S, 49° 55' 54" W, and mean altitude of 1,353 m). Climate in the region is classified, according to Köppen, as Cfb with mild summers and cold winters. Mean temperature is 13°C and mean annual rainfall is 1,360 to 1,600 mm a year, and there may be 20 to 29 frosts throughout the year. The soil was classified as Humic Cambisol (Soil Survey Staff, 1999), with A horizon from 0-30 cm and incipient B horizon from 60-80 cm, derived from acidic extrusive rock. Soil in the 0-20 cm layer before setting up the experiments exhibited the characteristics described in Table 1.

The pear cultivar was 'Rocha', grafted onto the rootstock *Pyrus caleriana*, with a density of 1,250 plants ha^{-1} (4 m between rows x 2 m between plants). A central leader plant training system was used and winter pruning was performed annually seeking to eliminate branches with few fructification structures, as well as to avoid crossing of branches between neighboring plants. The orchard of the two experiments was established in 2004 in an area previously used as native pasture. Before the transplanting of seedlings, limestone was applied to raise pH in water up to 6.0.

The treatments in the two experiments were implemented in October 2010, using a randomized block experimental design with four replications. The plot was composed of five plants arranged sequentially in the plant row, with only the three central plants being used for purposes of evaluation. In experiment 1, the treatments consisted of annual applications of 0, 40, 80, 120 and 160 kg P_2O_5 ha^{-1} as simple superphosphate and, in experiment 2, the treatments were annual applications of 0, 40, 80, 120 and 160 kg K_2O ha^{-1} as potassium chloride. The fertilizers were applied on the soil surface, without incorporation, in a 2.0 m wide strip in the plant rows, up to 50 cm beyond the line of projection of the canopies. The soil surface that received the application of the fertilizers was kept free of weeds through application of non-residual herbicide. Applications of fungicides and insecticides, when

necessary, were carried out following the technical recommendations for the crop.

In February 2011, 2012 and 2013, which coincided with fruit maturation and proximity to harvest, soil was collected from the 0-10, 10-20 and 0-20 cm layers in the plant row using a soil auger, and the samples were set aside. In the period from January 15th to February 15th of each year, 20 whole leaves were collected in the middle third of the branches from opposite sides of each plant and set aside. The soil samples were dried in a forced air laboratory oven at 45°C until constant weight, ground, passed through a sieve with a 2 mm screen and analyzed for available P (experiment 1) and exchangeable K (experiment 2), both extracted by the Mehlich 1 method. The leaves were dried, ground and prepared for analysis of P content (experiment 1) and of K content (experiment 2) (MELO et al., 2012).

In March 2011, 2012 and 2013, in the two experiments, the number of fruits per plant was counted, which were later collected and weighed. The results obtained were subjected to analysis of variance and, when the effects were significant, polynomial regression equations were fitted (P<0.05). Relative yield (*ry*) was calculated using the equation *ry=(ty/my)*100*, where *ty* is the treatment yield and *my* is the maximum yield of the three crop seasons. The results of the *ry* were related to the available P content (experiment 1) and exchangeable K content (experiment 2) in the soil, and related to the total P and K contents in the whole leaves so as to obtain the sufficiency level in reference to an *ry* of 90%. Mathematical adjustment among the variables was carried out using the Mitscherlich model *ŷ=a(1-b^x),* where *ŷ* represents the *ry*, *a* and *b* are coefficients from the adjusted model and *x* is the nutrient content in the soil or in the whole leaf.

RESULTS AND DISCUSSION

Experiment 1

Greater available P content was observed in the 0-10 cm layer, in comparison with the 10-20 cm layer, especially in the second (2011/2012) and third (2012/2013) crop season and at the higher rates of phosphate fertilizer, such as 80, 120 and 160 kg P_2O_5 ha^{-1} (Table 3). Accumulation of available P in the uppermost soil layer, especially at greater application rates, occurred because the phosphate fertilizer was applied on the soil surface over the years, without incorporation, to avoid mechanical damage to the roots, which may reduce nutrient uptake capacity (GRANATSTEIN; SÁNCHEZ, 2009). In addition, accumulation of P on the soil

surface may be attributed to its high energy in binding to the surface of the mineral fraction of the soil. Adsorption occurs mainly through the ligand exchange mechanism, through giving up OH$^-$ or H_2O and taking in the phosphate ion ($H_2PO_4^-$ or HPO_4^{-2}) and, depending on the soil pH value, this may happen in the functional groups of the oxides and of kaolinite. The interaction between the oxygen of the phosphate and the cation of the functional group, especially the aluminol of the clay minerals, and the Fe-OH and Al-OH groups of the oxide surface, leads to the occurrence of binding with different degrees of energy (BARROW et al., 1998). However, over the years, continued applications of P on the soil surface may cause occupation of the adsorption sites, leading to a decrease in their adsorption energy, which may increase desorption and, consequently, migration in the profile of soils planted to fruit-bearing plants (SCHMITT et al., 2013), increasing content of the nutrient in deeper layers, as observed in the 10-20 cm layer, where there was an increase in available P with the increase in the rate of phosphate fertilizer in all the crop seasons.

The available P content, in general, increased in the 0-10, 10-20 and 0-20 cm layers along with the rate of phosphate fertilizer applied in all the crop seasons evaluated (Table 3). Thus, there was a trend toward increase in the total P content in the whole leaves of the pear trees in the second and third crop seasons evaluated, which shows that the organ, the whole leaf, the collection position in the plant and the collection period described by NETO et al. (2011) are sensitive in diagnosing the increase in the P content within the plant. In addition, it was seen that in the 2010/2011 crop season, even though increase in the total P content in the whole leaves was not observed with the increase in the soil nutrient content, the content in the leaves, at all the different rates of phosphate fertilizer application, was interpreted as normal (1.5-3.0 g kg^{-1}) (BOTELHO et al., 2010), which was also observed in the 2011/2012 crop season. However, in the 2012/2013 crop season, in both non fertilized and fertilized plants with 40 kg P_2O_5 ha^{-1}, the total P content in the whole leaves was interpreted as below normal (1.0-1.4 g kg^{-1}) (BOTELHO et al., 2010). This occurred in the crop season where the greatest production of fruits in all the treatments was observed, indicating that in soils with lower content of available P, for example, the soil of the treatment without application of the nutrient, the P reserves within the plant may decrease because part of the nutrient of annual organs, such as leaves, may be redistributed to the fruit (NEILSEN et al., 2008), which represents export of the nutrient from

the orchard. In addition, it is fitting to mention that in the 2010/2011 and 2011/2012 crop seasons, where fruit yield in all treatments was lower comparing to the 2012/2013 crop season, the total P content in the whole leaf was greater, which shows that a smaller quantity of the nutrient was redistributed to the fruit and, consequently, probably remained accumulated in annual or perennial plant organs, increasing reserves of the nutrient, a common phenomenon in fruit-bearing plants (ZAMBROSI et al., 2012).

The application of increasing doses of the phosphate fertilizer in the plant row in the three crop seasons, which led to an increase in the available P content in the three soil layers, did not affect the number of fruits per plant, the weight of the fruit, nor fruit yield (Table 3). However, increase in the fruit yield components was expected, which could be reflected in yield in the plants under the application of phosphate fertilizer, because the available P content in the 0-20 cm soil layer before application of the fertilizer was interpreted as low (Table 2) (Texture class 2 = 60 to 41% clay, with available P content from 3.1 to 6.0). The lack of response of the pear trees to application of the phosphate fertilizer may have occurred especially because the finest and youngest plant roots, responsible for uptake of water and nutrients in the entire orchard, may have taken up P in layers deeper than the layers sampled and also in the unfertilized region (MAYER et al., 2007). In addition, the lack of climatic adaptation of the European pear trees in the South of Brazil, e.g., the Rocha cultivar used in the present study, poor pollination of flowers and variations of P reserves between plants, when the experiment was established, were probably other limiting factors in expression of maximum yield. Because fruit yield was not affected by the increase in the phosphate fertilizer rate, it was not possible to establish the critical level of the nutrient between the relative yield of fruit obtained in the three crop seasons and the P content in the 0-10 cm layer (Figure 1a) and 0-20 cm layer (Figure 1b), which is the layer used for diagnosis of the available P content in the soil for fruit-bearing plants in the states of RS and SC, nor between the relative yield of fruit with the total P content in the whole leaves (Figure 1e). The lack of establishment of the critical level between relative yield of fruit and the available P content in the soil may be explained in part by the soil collection having been made in the plant row, which coincides with the projection of the tree canopy, where fertilizer was applied and probably where most of the roots are located. However, part of the roots, which may also take up available P not derived from the fertilizer,

are present between the plant rows, where the soil was not sampled.

Experiment 2

The exchangeable K content in the 0-10 cm layer in the soil, especially in the soil under the application of different rates of potassium fertilizer and in all the crop seasons, was greater than the content observed in the 10-20 cm layer (Table 4). This may be attributed to the application of the fertilizer on the soil surface, without turnover, and to the adsorption of part of the K in the functional groups of organic and inorganic particles (DUARTE et al., 2013). However, part of the K content of the fertilizer migrated in depth, especially at the greater rates of fertilizer applied, for example, 120 and 160 kg K_2O ha^{-1} in the 2010/2011 crop season, and practically at all the different rates of the fertilizer applied in the other crop seasons, 2011/2012 and 2012/2013.

The application of increasing rates of K fertilizer increased the exchangeable K content in the 0-10, 10-20 and 0-20 cm layers (Table 4). In the 2011/2012 and 2012/2013 crop seasons, an increase was observed in the total K content in the whole leaves of the pear trees subjected to the application of increasing rates of potassium fertilizer. In the 2010/2011 crop season, the total K content in the leaves of the pear trees in most of the treatments was interpreted as below normal (8.00-11.9 g kg^{-1}) (BOTELHO et al., 2010), which was repeated in the 2011/2012 crop season in the whole leaves of the plants grown in the soil without application of the potassium fertilizer and with the application of 40 kg K_2O ha^{-1}. However, in this same crop season, the total K content in the whole leaves of the pear trees under the application of the other treatments was interpreted as normal (12.0-15.0 g kg^{-1}) (BOTELHO et al., 2010). In contrast, in the 2012/2013 crop season, the total K content in the whole leaves of both plants without and with the addition of most of the different rates of potassium fertilizers was interpreted as insufficient (<8.0 g kg^{-1}) (BOTELHO et al., 2010). The lower total K content in the leaves in this crop season may have occurred especially because it was seen in the plants of most of the treatments that yield was greater than that observed in the 2010/2011 and 2011/2012 crop seasons, which is in agreement with the yield data obtained in the plants under the application of phosphate fertilizer (Table 2). The greater yield obtained in this crop season may be associated with the greater temperatures that occurred in the period from August to September 2012 (Table 1), favoring the development and fertilization of the flowers, as well as effective fructification (LUZ et al., 2012).

Therefore, since K has high mobility within the plants, part of the K residing in the leaves may have been redistributed to the fruit, as is normally observed in some fruit-bearing plants (ZAMBROSI et al., 2012). If redistribution of K has also occurred from other plant organs to the fruit, this may represent a reduction in internal reserves of the nutrient in the plant (NAVA; DECHEN, 2009) and also may negatively affect fruit yield in ensuing years. In addition, based on the results of K analysis in the whole leaf, especially in the 2012/2013 crop season, an estimate of the need for application, or even of the K application rate only by the total content of this nutrient in the leaf, is not adequate because, in some cases where the nutrient was interpreted as insufficient (Table 4), especially because of the greater yield of fruit, the K content in the soil was interpreted as very high (>120 mg of K in soil with $CEC_{pH\,7.0}$ from 5 to 15 $cmol_c$ kg^{-1}).

The application of potassium did not affect the number of fruits per plant, weight of the fruit nor yield (Table 4), in agreement with the data obtained with the application of different rates of phosphate fertilizers (Table 3). This may have occurred in part because the exchangeable K content in the soil at the beginning of the experiment was interpreted as high (61 to 120 mg of K, in soil with $CEC_{pH\,7.0}$ from 5 to 15 $cmol_c$ kg^{-1}) and, for that reason, the natural contents in the soil may have supplied demand of the plant for the nutrient. However, already in the third crop season,

for example, under the treatment without addition of potassium fertilizer, reduction in the exchangeable K content in the soil was noticed, possibly because higher plants are efficient in uptake of the nutrient, especially with the decrease in the K concentration in the soil solution and, for that reason, a strong chemical gradient is created in the direction of the rhizosphere (GOMMERS et al., 2005). Thus, if the soil in the present study does not have high contents of non-exchangeable K forms, due to the high ability of the plants in uptake of K and to export K when there are high yields (KAMINSKI et al., 2007), it is probable that in the near future the response of the pear tree to the addition of the nutrient or even of the different rate applied will be observed. Establishing the relationship between the relative yield of fruit obtained in the three evaluated crop seasons and the exchangeable K content in the 0-10 cm layer (Figure 1c) and 0-20 cm layer (Figure 1d) did not allow to establish the critical level of the nutrient. This may have occurred because, throughout the crop seasons, the exchangeable K contents in the soil were similar among the treatments and, in most of them, interpreted as high or very high, which may actually have increased (as in the 2010/2011 and 2011/2012 crop seasons) the total K content in the leaves, which also were similar among the treatments, making impossible the establishment of the critical level of the nutrient in the tissue (Figure 1f).

TABLE 1- Average temperature and rainfall in 2010/2011, 2011/2012 and 2012/2013 crop seasons.

Month	2010/2011 crop season		2011/2012 crop season		2012/2013 crop season	
	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)
January	18.3	205.3	16.5	147.8	16.1	66.5
February	17.6	354.0	18.6	198.1	16.3	247.1
March	15.5	188.8	16.0	180.0	16.1	167.2
April	13.4	233.7	14.2	118.8	13.7	88.8
May	10.7	179.6	10.0	100.1	11.2	31.9
June	9.9	140.7	8.5	143.3	10.1	154.3
July	10.1	187.5	9.8	239.6	8.6	168.3
August	9.9	83.4	9.8	368.8	12.8	19.1
September	11.9	246.4	11.2	145.2	12.3	146.4
October	11.6	121.3	13.7	168.4	14.9	181.2
November	14.1	180.4	14.1	76.3	15.1	50.7
December	16.3	166.0	15.4	167.8	18.6	178.0

TABLE 2- Physical and chemical characteristics of the soil of the experiments 1 and 2.

Soil characteristics	Experiment 1	Experiment 2
Clay (g kg^{-1})	440	360
Organic matter (g kg^{-1})	37.0	48.0
pH in water	5.5	5.5
Available P (mg kg^{-1})	4.5	6.2
Exchangeable K (mg kg^{-1})	62.0	76.0
Exchangeable Ca (cmol$_c$ kg^{-1})	5.7	6.6
Exchangeable Mg (cmol$_c$ kg^{-1})	2.3	2.8
Exchangeable Al (cmol$_c$ kg^{-1})	0.0	0.0
CEC$_{pH7.0}$ (cmol$_c$ kg^{-1})	13.0	13.5
CEC$_{Effective}$ (cmol$_c$ kg^{-1})	8.6	9.6
Base saturation (%)	62.5	71.2

TABLE 3- Available P content in the soil, total P content in the leaves, number of fruits per plant, mean weight of fruit and yield in pear trees subjected to the application of different rates of phosphate fertilizer.

Rate	Available P			Total P in leaves	Number of fruits plant^{-1}	Mean weight of fruit	Fruit yield
	0-10 cm	10-20 cm	0-20 cm				
kg P$_2$O$_5$ ha^{-1}	--------------mg kg^{-1}-------------			g kg^{-1}		kg	Mg ha^{-1}
--- 2010/2011 crop season ---							
0	8.35a[1]	6.61a[2]	7.01[3]	1.59^{ns}	20^{ns}	0.207^{ns}	5.1^{ns}
40	9.07a	7.45a	7.88	1.88	27	0.209	7.2
80	10.80a	10.62a	10.72	2.02	33	0.212	8.0
120	10.90a	11.25a	11.05	2.00	7	0.209	1.8
160	21.86a	13.43b	18.91	2.08	9	0.223	2.6
-- 2011/2012 crop season --							
0	2.01a[4]	1.91a[5]	1.93[6]	1.76[7]	23^{ns}	0.182^{ns}	5.2^{ns}
40	2.74a	2.64a	2.69	2.47	13	0.181	3.0
80	15.58a	3.65b	10.45	2.55	26	0.195	6.3
120	37.84a	5.80b	18.54	2.45	27	0.182	6.1
160	51.03a	11.87b	20.25	2.86	27	0.174	5.9
-- 2012/2013 crop season --							
0	5.47a[8]	2.85a[9]	4.77[10]	1.34[11]	68^{ns}	0.185^{ns}	15.6^{ns}
40	8.32a	3.87b	6.38	1.40	74	0.197	18.0
80	8.65a	4.42b	8.11	1.55	74	0.195	18.3
120	21.42a	6.63b	18.75	1.64	125	0.18	28.0
160	31.09a	9.17b	19.56	1.48	63	0.182	14.4

[1] $y = 9.1176 - 0.0625x + 0.0008x^2$ ($R^2 = 0.73^{**}$); [2] $y = 6.381 + 0.0436x$ ($R^2 = 0.76^{**}$); [3] $y = 7.3599 - 0.0145x + 0.0005x^2$ ($R^2 = 0.90^{**}$); [4] $y = 0.1201 + 0.0874x + 0.0015x^2$ ($R^2 = 0.91^{**}$); [5] $y = 2.2454 - 0.0267x + 0.0005x^2$ ($R^2 = 0.84^{**}$); [6] $y = 0.2734 + 0.1312x$ ($R^2 = 0.88^{**}$); [7] $y = 1.8704 + 0.0109x - 0.00003x^2$ ($R^2 = 0.53^{**}$); [8] $y = 5.8504 - 0.0255x + 0.0012x^2$ ($R^2 = 0.90^{**}$); [9] $y = 2.9807 + 0.0049x + 0.0002x^2$ ($R^2 = 0.89^{**}$); [10] $y = 4.1713 + 0.0526x + 0.0003x^2$ ($R^2 = 0.85^{**}$); [11] $y = 1.3194 + 0.0051x - 0.00002x^2$ ($R^2 = 0.42^{*}$); ^{ns} = not significant; * = significant at 5% probability of error; ** = significant at 1% probability of error.

TABLE 4- Exchangeable potassium in the soil, total K content in the leaves, number of fruits per plant, mean weight of fruit and yield in pear trees subjected to the application of different rates of potassium fertilizer.

Rate	Exchangeable K			Total K in the leaves	Number of fruits plant[-1]	Mean weight of fruit	Fruit yield
	0-10 cm	10-20 cm	0-20 cm				
kg K_2Oha[-1]	---------mg kg^{-1}-----------			g kg^{-1}		kg	Mg ha^{-1}
--------------------------------------- 2010/2011 crop season ---							
0	101.33a[1]	71.33a[2]	77.69[3]	12.65[ns]	15[ns]	0.219[ns]	4.6[ns]
40	179.00a	73.25b	95.61	10.53	23	0.225	6.3
80	230.33a	89.00b	130.25	11.14	26	0.209	7
120	361.50a	124.00b	236.77	11.41	31	0.215	8.3
160	403.33a	164.67b	245.97	12.31	18	0.247	5.2
--------------------------------------- 2011/2012 crop season ---							
0	60.30a[4]	38.57a[5]	59.08[6]	10.00[7]	30[ns]	0.170[ns]	6.4[ns]
40	101.16a	69.42a	71.57	11.21	37	0.18	8.4
80	185.71a	86.92b	171.26	13.02	28	0.166	5.9
120	238.22a	91.71b	197.42	13.58	34	0.192	8.1
160	373.13a	218.05b	333.17	13.65	35	0.191	8.4
--------------------------------------- 2012/2013 crop season ---							
0	76.17a[6]	55.03a[9]	57.90[10]	5.50[11]	72[ns]	0.193[ns]	17.3[ns]
40	220.73a	86.15b	117.29	5.81	144	0.193	34.3
80	293.05a	118.54b	207.79	7.08	40	0.187	9.3
120	374.49a	170.00b	269.3	7.47	82	0.189	19.3
160	460.96a	259.41b	353.76	9.26	76	0.212	20

[1] $y = 97.7995 + 1.9663x$ ($R^2 = 0.85^{**}$); [2] $y = 70.7874 - 0.00975x + 0.0043x^2$ ($R^2 = 0.86^{**}$); [3] $y = 69.4927 + 0.8054x + 0.0024x^2$ ($R^2 = 0.87^{**}$); [4] $y = 61.4524 + 0.7922x + 0.007x^2$ ($R^2 = 0.95^{**}$); [5] $y = 50.1491 - 0.3202x - 0.008x^2$ ($R^2 = 0.84^{**}$); [6] $y = 56.4026 + 0.4495x + 0.0077x^2$ ($R^2 = 0.94^{**}$); [7] $y = 9.852 + 0.0494x - 0.0002x^2$ ($R^2 = 0.53^*$); [8] $y = 85.1193 + 3.0731x - 0.0048x^2$ ($R^2 = 0.81^{**}$); [9] $y = 58.6801 + 0.2627x + 0.0061x^2$ ($R^2 = 0.96^{**}$); [10] $y = 52.459 + 1.8593x$ ($R^2 = 0.98^{**}$); [11] $y = 5.4856 + 0.0081x - 0.00009x^2$ ($R^2 = 0.82^{**}$); [ns] = not significant; [*] = significant at 5% probability of error; [**] = significant at 1% probability of error.
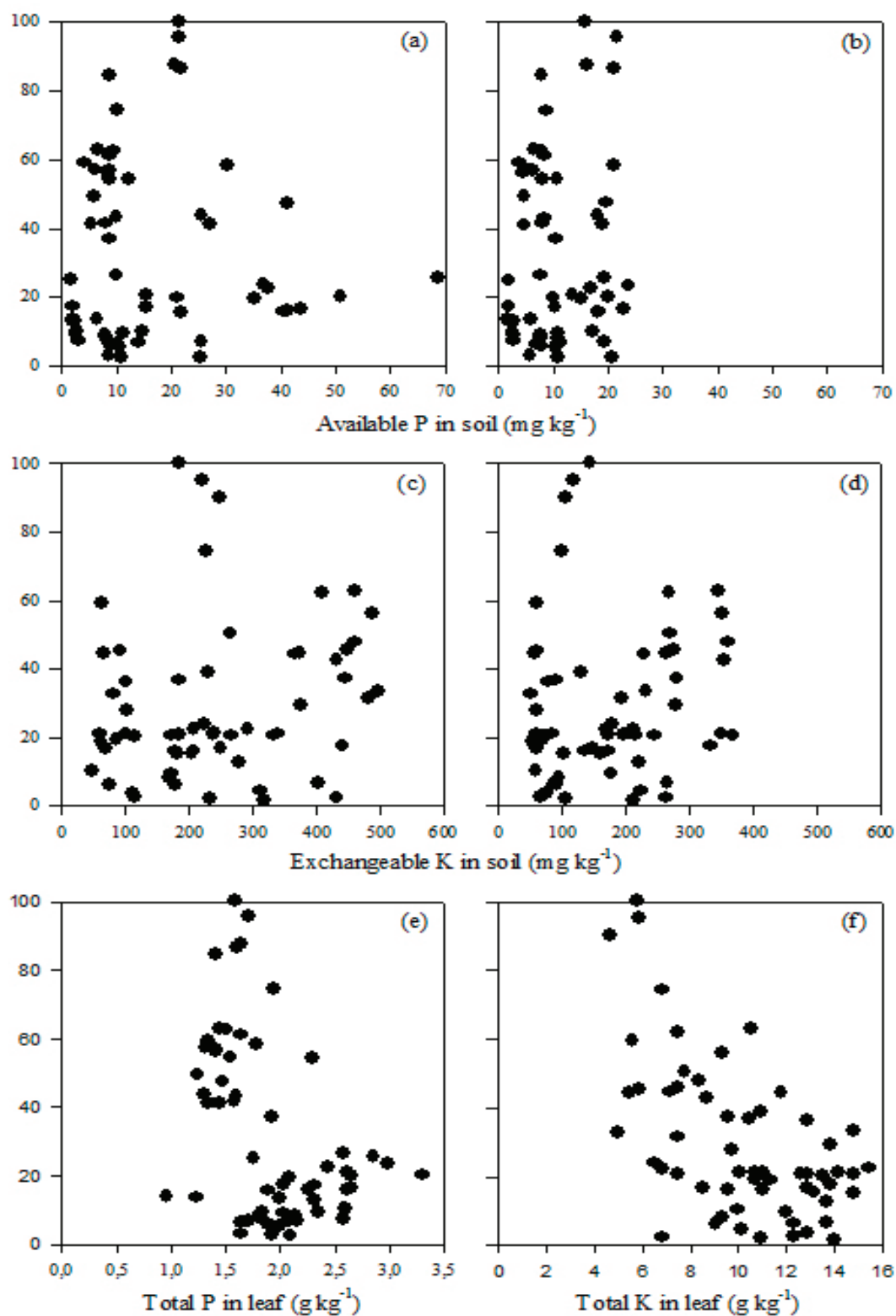
FIGURE 1- Relation between the relative yield of the trees and the available P content in the 0-10 cm soil layer (a), the available P content in the 0-20 cm soil layer (b), the exchangeable K content in the 0-10 cm soil layer (c), the exchangeable K content in the 0-20 cm soil layer (d), the total P content in the leaf (e) the total K content in the leaf (f).

CONCLUSIONS

Application of phosphorus on the soil planted with pear trees increased the nutrient content in the soil and, in most crop seasons, in the whole leaf, but did not affect the yield components and fruit yield.

2. The application of potassium on the soil of pear trees increased the nutrient content in the soil and, in most crop seasons, in the whole leaf, but the potassium content in the whole leaf decreased in the crop season with greater fruit yield. The potassium fertilizer did not affect the yield components and fruit yield.

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