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Residual effect of phosphorus sources on the presence and absence of organic compost in the production of beet and chicory in subsequent cultivation of broccoli

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ABSTRACT

The utilization of organic fertilizer for a short cycle crop may allow planting, in sequence, another short cycle crop, without the need for new fertilizers, reducing the costs of a new fertilization. The objective of this study was to evaluate the residual effect of fertilization applied to broccoli with phosphorus sources in the presence and absence of organic compost, on beet and chicory production in subsequent cultivation. In broccoli cultivation, four sources of phosphorus (thermophosphate, natural phosphate, natural reactive phosphate, and triple superphosphate) (600 kg/ha of P_2O_5) were evaluated in the presence and absence of organic compost (Visafértil®, 55 t/ha) before planting. After the removal of the cultural remains of broccoli, beet and chicory, seedlings were transplanted in the same plots of the first crop treatments. For each species eight treatments were evaluated, in a 4 x 2 factorial scheme. The first factor were the four sources of phosphorus and the second one was the application or not of organic compost before broccoli (hybrid BRO 68) planting. Treatments with organic compost showed greater production of beet and chicory, compared to the absence of compost. Fertilization with organic compost associated to the phosphorus sources provides necessary residual effect to beet and chicory production. The best P source for beet was triple superphosphate, and for chicory, in the absence of organic compost, triple superphosphate was the best source. In the presence of organic compost, the best sources were triple superphosphate and natural phosphate.

Keywords: *Beta vulgaris*, *Cichorium endivia* L., successive cultivation, phosphate fertilization, residual organic fertilizer.

RESUMO

Efeito residual de fontes de fósforo na presença e ausência de composto orgânico na produção de beterraba e chicória em cultivo sucessivo de brócolis

A utilização de adubo orgânico para uma cultura de ciclo curto pode permitir o plantio, em sequência, de outra cultura de ciclo curto, sem a necessidade de novos adubos, reduzindo os custos de nova adubação. O objetivo deste trabalho foi avaliar o efeito residual da adubação aplicada ao brócolis com fontes de fósforo na presença e ausência de composto orgânico, na produção de beterraba e chicória em cultivos após a colheita do brócolis. No cultivo de brócolis, quatro fontes de fósforo (termofosfato, fosfato natural, fosfato reativo natural e superfosfato triplo) (600 kg/ha de P_2O_5) foram avaliadas na presença e ausência de composto orgânico (Visafértil®, 55 t/ha) antes do plantio. Após a retirada dos restos culturais do brócolis, as mudas de beterraba e chicória foram transplantadas nas mesmas parcelas onde foram cultivadas as plantas de brócolis. Para cada espécie foram avaliados oito tratamentos, em esquema fatorial 4 x 2, sendo o primeiro fator as quatro fontes de fósforo e o segundo a aplicação ou não de composto antes do plantio do brócolis (hybrid BRO 68). Os tratamentos com composto orgânico apresentaram maior produção de beterraba e de chicória, comparado à ausência de composto. A adubação com composto orgânico associado às fontes de fósforo proporciona efeito residual necessário à produção de beterraba e chicória. Para a beterraba, a melhor fonte de P foi o superfosfato triplo, e para a chicória, na ausência de composto orgânico, o superfosfato triplo foi a melhor fonte. Na presença de composto orgânico as melhores fontes foram o superfosfato triplo e o fosfato natural.

Palavras-chave: *Beta vulgaris*, *Cichorium endivia* L., cultivo sucessivo, adubação fosfatada, fertilizante orgânico residual.

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The search for sustainable and pesticide-free food helped the organic market growth, mostly vegetables, which are generally consumed *in natura*. Despite this market growth, research with fertilizer sources and their residual effect are still rare for the cultivation in organic system. This information is necessary to optimize the use of phosphate fertilizers, since phosphorus is a scarce and limited natural resource.

Phosphorus presents wide variations in terms of available sources in the market. The main sources used in Brazil are the superphosphates (simple and triple) and the ammonium phosphates (MAP and DAP), which present high capacity of releasing phosphorus to the plants, but they cannot be used in organic production systems (Cardoso *et al*., 2019).

Tropical soils are generally rich in iron and aluminum oxides, in addition to being acid, conditions that favor the retention of phosphorus, reducing its availability to plants (Almeida *et al*., 2003; Novais *et al*., 2007). Therefore, it is very common to apply high doses of phosphate fertilizers to allow the established crop to absorb part of this phosphorus (Cecilio Filho *et al*., 2015). However, much of the phosphorus released by soluble phosphates is retained in the soil, without being used by plants. On the other hand, less soluble sources release phosphorus into the soil gradually, more efficiently throughout the plant cycle (Cardoso *et al*., 2019) and, probably, can also be released to plants cultivated in subsequent cycles, even more in vegetables of short cycle.

Using less soluble sources, associated with application of organic compost, it may not be necessary to apply phosphorus to each new vegetable to be planted, taking advantage of the phosphorus applied in the previous crop. The residual effect of the phosphate fertilizers varies depending on the application method, the phosphorus concentrations and sources, the iron and aluminum oxides, the management, type of soil and crop (Almeida *et al*., 2003).

The use of residual fertilizer through subsequent growing cycles is a practice that helps in the use of fertilizers remaining on soil and in the reduction of production costs (Lanna *et al*., 2018). The soil, the fertilizers, the plants' nutrient absorption and removal capacity, as well as the climate conditions, are elements that influence on the residual efficiency of nutrients over the subsequent plants' yield.

On literature there are promising results obtained with vegetables cultivation in succession. Costa *et al*. (2012), researching the residual fertilizing effect of onion on the carrot production, observed better cost-benefit with the use of residual fertilizer. Oliveira *et al*. (2015) verified that the residual effect of silk flower (*Calotropis procera* L.) incorporation to soil (55 t/ha) provided the greatest commercial radish roots yield after mixed cultivation of beet and rocket. This practice brings benefits to producers, especially on short cycle crops, not being necessary to perform a new fertilization, providing satisfactory results.

The organic compost application improves physical, chemical, and biological soil conditions and can present residual effect due to the gradual nutrients release. The use of organic compost increases the content of macro and micronutrients, reduces soil acidity and increases soil cation exchange capacity (CEC) and base saturation (V) and, therefore, increases yield of successive crops. Lanna *et al*. (2018) related the residual effect of organic compost on radish production increase after the subsequent cultivation of chicory. However, studies about the residual effect of organic compost associated to phosphorus fertilizers are not common, despite being a practice used by some producers in organic production system.

The objective of this study was to evaluate the residual effect of fertilization applied to broccoli with phosphorus sources in the presence and absence of organic compost on beet and chicory production in subsequent cultivation.

MATERIAL AND METHODS

Two experiments were carried out at São Manuel Experimental Farm, situated in São Manuel municipality, in the state of São Paulo, Brazil (22°46'S, 48°34'W, altitude 740 m). The weather, according to the criteria adopted by Köppen, is Mesothermal Temperate Climate (Cfa).

The soil from the experimental area was classified as Red Latosol Dystrophic, sandy texture, with the following chemical characteristics before broccoli cultivation: $pH_{(CaCl2)}$ = 5.4; organic matter (OM) = 7 g/m^3; P = 21 mg/dm^3; H+Al = 15 mmol$_c$/dm^3; K = 1.0 mmol$_c$/dm^3; Ca = 12 mmol$_c$/dm^3; Mg = 11 mmol$_c$/dm^3; sum of bases (SB) = 24 mmol$_c$/dm^3; CEC = 40 mmol$_c$/dm^3 and base saturation (V%) = 61.

One research was initially installed in this area, that studied the influence of phosphorus sources with and without organic compost application before planting on broccoli production (Cardoso *et al*., 2019). After broccoli harvest, the transplanting of beet and chicory seedlings was made in the same experimental plots (part of the plot with each species), aiming to evaluate the fertilization residual effect made for broccoli on the production of these subsequent crops.

On the broccoli experiment (Cardoso *et al*., 2019), the experimental design used was of randomized blocks, with four replications, in a 4 x 2 factorial scheme, with four sources of phosphorus [thermophosphate (TM), natural phosphate (NP), natural reactive phosphate (NRP), and triple superphosphate (TS)], at the dose of 600 kg/ha of P_2O_5 for all sources (dose recommended for broccoli by Raij *et al*., 1997), in the absence and presence of organic compost before planting. In treatments with organic compost, 55 t/ha was applied, which corresponds to the average dose recommended by Raij *et al*. (1997). The organic compost from Visafértil® was used. The chemical analysis of the compost presented the values of pH = 7.5; relation C/N = 4/1, organic matter = 30%; humidity = 7%; C = 17%; N = 1.4%; P_2O_5 = 1.6%; K_2O = 1.4%; Ca = 10.4%; Mg = 1.1%; S = 0.7% and 222; 5134; 324; 17345; 910 and 177 mg/kg of B, Na, Cu, Fe, Mn and Zn, respectively.

The phosphorus sources used were analyzed and presented the following results: thermophosphate Yoorin® (TM): 16% of P_2O_5, soluble in 2% citric acid on the relation 1:100, 17.5% of total P_2O_5, 18% of calcium, 7% of magnesium, 0.1% of boron, 0.05% of copper, 0.15% of manganese, 0.55% of zinc and 10% of Si; natural phosphate Biorin Nutrisafra® (NP): 13% of OM, 40% of filter cake, 1.8% of N, 13.2% of P_2O_5, 0.8% of K_2O, 12.4% of Ca, 0.3% of Mg, 1.4% of S and 93, 3128, 826, 46963, 4208, and 5313 mg/kg of B, Na, Cu, Fe, Mn, and Zn, respectively; natural reactive phosphate Djebel Onk. Algeria (NRP): 10% of P_2O_5 soluble in 2% citric acid in a ratio 1:100 and 29% total P_2O_5 and 35% Ca; triple superphosphate (TS): 41% P_2O_5 soluble in ammonium citrate (CNA) + water, 36% water-soluble P_2O_5 and 10% Ca.

For the broccoli crop, liming was carried out 77 days before seedlings transplanting to elevate the base saturation value to 80%. Planting fertilization was hold on May 18th, 2016. On treatments with organic phosphate sources, the nitrogen fertilization was perfomed before planting with castor bean cake and the potassium with potassium sulphate, that are allowed in the organic system (Brasil, 2014), applying 1.3 t/ha and 480 kg/ha, respectively. On treatments with inorganic phosphorus source (TS), 280 kg/ha of ammonium sulphate and 400 kg/ha of potassium chloride were used. All fertilizers were spread over bedding surface (as well as the organic compost on the plots in which it was used). The fertilizers were incorporated with a rotating hoe. In broccoli top dressing we applied 2.4 t/ha of castor bean cake and 180 kg/ha of potassium sulphate on treatments with organic phosphate sources. On treatment with inorganic phosphorus source (ST), urea and potassium chloride were used. Fertilization in top dressing was divided into four steps, on 15, 30, 45 and 60 days after broccoli transplanting (DAT).

The implantation of simultaneous experiments with beet and chicory crops was carried out 26 days after the last broccoli harvest (September 19, 2016), to evaluate the residual effect of phosphorus sources in the presence and absence of the organic compost, applied before broccoli seedlings transplant. Results of soil analyses in each treatment after broccoli harvest are described in Table 1 (Cardoso *et al*., 2019).

Table 1. Soil chemical characteristics at the end of the experiment with broccoli, in relation to phosphorus sources in presence (P) and absence (A) of organic compost. São Manuel, UNESP, 2016.

P sources	pH		MO (g/dm³)		P_{resin} (mg/dm³)		H + Al (mmolc/dm³)		K (mmolc/dm³)	
	P	A	P	A	P	A	P	A	P	A
TM	6.16Aa	5.92Ba	9Aab	9Aa	89Aab	67Bb	9Ba	11Ab	3Ab	2.2Bab
NP	6.17Aa	5.70Bb	11Aa	7Bb	82Ac	71Bab	9Ba	13Aa	4.1Aa	2.5Ba
RNP	6.20Aa	75Bab	8Ab	8Aab	85Abc	56Bc	10Ba	12Aab	3.2Ab	2.1Bab
TSP	6.20Aa	5.58Bb	8Ab	7Ab	93Aa	74Ba	10Ba	14Aa	3.3Ab	1.7Bb
CV (%)	1.77		9.26		4.58		7.46		11.28	

	Ca		Mg		SB		CTC		V (%)	
	P	A	P	A	P	A	P	A	P	A
TM	32Aab	19Ba	9aA	7Ba	45Aa	29Ba	54Aa	40Ba	82Aa	74Ba
NP	30Ab	17Bb	6bA	5Bb	41Ab	24Bbc	50Ab	38Ba	82Aa	64Bb
RNP	27Ac	19Bab	5bA	5Ab	36Ac	27Bab	46Ac	40Ba	77Ab	71Ba
TSP	34Aa	16Bb	5bA	5Ab	43Aab	23Bc	53Aab	38Ba	81Aa	63Bb
CV (%)	5.48		10.34		4.92		3.79		2.51	

Averages followed by same letters, uppercase in lines and lowercase in columns, do not differ from each other, by Tukey test, 5%. TM = thermophosphate; NP = natural phosphate, RNP = reactive natural phosphate; TSP = triple superphosphate. Source: Cardoso *et al.* (2019).

New fertilization was not carried out before beet (‘Early Wonder’) and chicory (‘Amazonas Gigante’) implantation. Beet and chicory seedlings were transplanted on September 19th, 2016, to beds, 1.0 m wide, in four lines on longitudinal direction, where beet was spaced out at 0.25 m between lines and 0.10 m between plants; and chicory 0.30 m between lines and 0.25 m between plants. Seedlings were allocated at the same plots of the first crop treatments (broccoli). Forty beet plants were used per plot of 1 m², in which only eight plants from the central rows formed the useful plot. For chicory, 24 plants were used in plots of 1.5 m², being considered as useful the six plants from the central rows.

Irrigation was performed by sprinkler system, and weeds were controlled through manual weeding during the crop cycle. There was no need for pathogens and pests’ control.

Top dressing fertilization in beet was conducted with application of 450 kg/ha of castor bean cake and 20 kg/ha of potassium sulphate, on treatments with organic phosphate sources. For the treatment with triple superphosphate (inorganic fertilization), 100 kg/ha was applied of ammonium sulphate and 20 kg/ha of potassium chloride, divided into three times, on October 03, 17 and 31, 2016, corresponding to 14, 28 and 42 DAT, respectively. On chicory, top dressing fertilization was divided into two times, on October 03 and 17, 2016, corresponding to 14 and 28 DAT, respectively, being applied 120 kg/ha of ammonium sulphate and 570 kg/ha of castor bean cake on treatments with inorganic and organic sources, respectively.

The results of chemical analysis of castor bean cake are: pH = 5.7; humidity = 0.0; organic matter = 35.3%; total N = 4.6%; P_2O_5 = 1.87%; K_2O = 1.12%; Ca = 2.59%; Mg = 0.71%; S = 0.22%; B = 14.5 mg/kg; Cu = 330 mg/kg; Mn = 230 mg/kg; Zn = 33 mg/kg; Fe = 4194 mg/kg; C/N ratio = 4.3. In Table 2, the amount of nutrients is estimated in fertilizers used in top dressing (castor bean cake, potassium sulphate, ammonium nitrate and potassium chloride) in the production of beet and chicory.

Table 2. Estimated quantity of nutrients in fertilizers used in top dressing (castor bean cake (CBC), potassium sulphate (PS), ammonium sulphate (AS) and potassium chloride (KCl)) in the production of beet and chicory. São Manuel, UNESP, 2016.

Nutrient	Beet		Chicory	
	CBC + PS	AS + KCl	CBC	AS
	(kg/ha)			
N	20.7	21.0	26.2	25.2
P_2O_5	8.4	0.0	10.7	0.0
K_2O	14.6	12.0	7.0	0.0
Ca	11.6	0.0	14.8	0.0
Mg	3.2	0.0	4.0	0.0
S	4.0	24.0	1.3	24.0
	(g/ha)			
B	6.5	0.0	8.3	0.0
Cu	148.5	0.0	188.1	0.0
Fe	1887.3	0.0	2390.6	0.0
Mn	103.5	0.0	131.1	0.0
Zn	14.8	0.0	18.8	0.0

Chicory was harvested on November 8th, 2016 (61 DAT) and beet on November 19th, 2016 (72 DAT). On chicory, the height (cm) and diameter (cm) of plants were estimated using a ruler; number of leaves per plant (all leaves) were counted, including the dry ones; fresh weight of aerial part (g/plant, being the plants harvested with all the leaves) was obtained by weighing; and dry weight of aerial part (g/plant) was obtained after drying it in forced air circulation oven at 65ºC until reaching constant weight, using an electronic digital scale. The evaluated characteristics in beet were the plants' height (cm), determined with the use of a ruler, measuring the distance between the soil surface and the highest part of the plant; roots' length (mm) and diameter (mm) were obtained using a digital caliper; fresh matter weight of the aerial part and root (g) was determined by weighing the aerial part and roots on electronic digital scale; dry matter weight of the aerial part and root (g) after drying the materials in forced air circulation oven at 65 ºC until reaching constant weight, was determined by weighing on electronic digital scale and yield obtained transforming the average weight data of the root to t/ha, according to plants' population (Silva *et al*., 2016a).

Results were submitted to analysis of variance, and the Tukey test was used at 5% probability to compare the averages using the statistics software ASSISTAT 7.7.

RESULTS AND DISCUSSION

Beet production

There was an interaction between phosphorus sources and the presence or absence of organic compost for all evaluated characteristics on beet. Regarding the residual effect of phosphorus sources, the triple superphosphate provided greater plant height in the presence of organic compost, while in its absence the greatest height was obtained with thermophosphate (Table 3). The sources did not differ in root length in the presence of the organic compost. But, in the absence of the organic compost, the residual fertilization with thermophosphate and triple superphosphate provided greater length than natural phosphate. The residual fertilization with triple superphosphate source, in relation to the other sources, resulted larger root diameter in the presence and absence of organic compost. Roots presenting diameter greater than 50 mm and smaller than 90 mm are classified as "Extra A" or "2A", having greater commercial value. These values were observed in the treatments with triple superphosphate, thermophosphate, natural phosphate and natural reactive phosphate in the presence of organic compost and, in the absence of organic compost, with triple superphosphate and thermophosphate.

Table 3. Plant height (PH), root length (RL), root diameter (RD), fresh weight of aerial part (FWAP), fresh weight of root (FWR), dry weight of aerial part (DWAP), dry weight of root (DWR) and beet yield in function of the residual effect of phosphorus sources in the presence and absence of organic compost. São Manuel, UNESP, 2016.

Phosphorus sources	PH (cm)		RL (cm)		RD (mm)		FWAP(g/plant)	
	P*	A	P	A	P	A	P	A
TM	25.71cA	25.25aA	47.38aA	42.22aB	52.83cA	50.97bA	35.00bA	36.50cA
NP	28.25bA	22.25bcB	51.16aA	35.07bB	58.70bA	42.19cB	36.00bB	42.00bA
NRP	24.86cA	21.12cB	47.44aA	37.25abB	56.63bA	37.87dB	33.00bB	46.25bA
TS	33.54aA	23.40abB	50.42aA	42.96aB	65.98aA	54.51aB	45.00aB	53.25aA
CV (%)	3.8		6.8		2.9		5.8	
	FWR (g/plant)		DWAP(g/plant)		DWR (g/plant)		Yield (t/ha)	
	P	A	P	A	P	A	P	A
TM	99.00bA	97.33bA	3.66bB	4.68bA	15.05bA	15.45bA	30.53bA	29.94bA
NP	110.50bA	96.00bB	3.69bB	4.57bA	16.69bA	13.23cB	34.00bA	29.77bB
NRP	97.50bA	76.25cB	3.57bB	5.94aA	15.23bA	12.16cB	30.00bA	23.46cB
TS	134.25aA	130.00aA	5.06aB	5.92aA	25.89aA	25.93aA	41.46aA	39.99aA
CV (%)	6.4		9.4		5.6		6.4	

* P = presence and A = absence of organic compost in planting. Averages followed by same letter, lowercase letter in column and capital letter in line, did not differ among each other, by Tukey test at 5% probability. TM= thermophosphate, NP = natural phosphate, NRP = natural reactive phosphate and TS = triple superphosphate.

The triple superphosphate source also provided higher fresh weight of aerial part, fresh and dry weight of root in the presence and absence of residual organic compost. For dry weight of aerial part, the triple superphosphate source was superior to the other sources in the presence of organic compost and triple superphosphate and natural reactive phosphate, not differing among themselves without the compost resulting in superior values compared to other sources (Table 3).

The triple superphosphate source also provided higher yield than other sources both in the presence and absence of organic compost, and application of organic compost resulted in higher yield than absence in the treatments with natural phosphate and natural reactive phosphate (Table 3).The observed values (maximum of 41.46 t/ha roots) were higher or were close to those found by Trani *et al*. (2005), Zárate *et al*. (2008), Corrêa *et al*. (2014) and Magro *et al*. (2015) obtained maximum yield which ranged from 15 to 43 t/ha. So, it can be observed that, even without new fertilization before beet planting, the residual effect of fertilizers applied before broccoli production, mainly superphosphate in the presence of organic compost, was enough to guarantee good beet yield.

The positive effect of the triple superphosphate source can be observed in most of the evaluated characteristics, in the presence or absence of organic compost, indicating high residual power. Despite being a readily soluble source, this result can be assigned to the lower fixation of P in soil, supporting Korndörfer & Sousa (2010) who verified that triple superphosphate in granule form presents lower fixation of P and high recovering in relation to the P applied. The increase in beet vegetative characteristics provided by the triple superphosphate source was also observed by Avalhaes *et al.* (2009) and Oliveira *et al*. (2016) in the same specie.

The application of organic compost resulted in higher plants and roots with larger diameter in relation to absence of organic compost for most of the sources, except thermophosphate and higher roots length for all sources (Table 3). Diameters obtained in all sources in the presence of organic compost are classified as Extra A (Ceagesp, 2023).

Organic compost application, besides the effects on physical and biological quality of the soil, also helps in the continuous macro and micronutrients releases in a balanced way, favoring plant development (Kiehl, 2010; Cardoso *et al*., 2019). After broccoli cultivation, the use of organic compost at planting provided higher pH in soil and contents of P, K, Ca, SB, CEC and V%, independent of the P source applied (Table 1; Cardoso *et al*., 2019). So, the soil after broccoli cultivation had greater fertility than before broccoli fertilization, and these nutrients were disponible for beet and chicory plants. Besides this, fertilizers were applied in top dressing that were sources of nutrients (Table 2), mainly N and K that are recommended in greater quantity for beet production, and micronutrients, also recommended but in smaller quantities, according to Raij *et al*. (1997).

Besides nutrient release, organic compost has potential to reduce P fixation (Kiehl, 2010), with the reduction of P adsorption sites due to the association of organic compounds with positively charged colloids in the soil. Furthermore, the decomposition of organic matter produces organic acids capable of solubilizing the P adsorbed in the soil. According to Fink *et al.* (2016), in highly weathered soils, organic matter is one of the constituents of the soil that most affects phosphorus desorption and adsorption. In addition, the presence of organic matter improves soil physical properties and increases microbial life (Souza & Resende, 2014), that can favor P desorption. Although P content in organic fertilizers normally being low, the use of organic compost plus a phosphorus source can improve the effect of these sources, and it is possible to reduce the need for this nutrient, reducing costs and uses of an input that is finite.

Beet roots production presented homogeneous size with residual fertilization of organic compost, a result similar to the one obtained by Silva *et al*. (2016a), who did not observe differences in the classes of beet diameter with organic compost fertilization associated to castor bean cake doses in top dressing, favoring the homogeneity of the lot.

In general, it can be noticed that residual of organic compost promoted the improvement of most characteristics on beet root (Table 3). A similar result was obtained by Magro *et al*. (2015) who observed that the application of organic compost (46 to 52 t/ha) provided higher fresh weight of roots (134 g), diameter (62 mm), length (65 mm) and yield (43 t/ha) of beet. Silva *et al*. (2016a) also obtained higher plant height (30.5 cm), fresh (59.5 g) and dry (6.78 g) weight of the aerial part, fresh (139 g) and dry (15 g) weight of root, length (5.7 cm), diameter (6.5 cm) and yield (43 t/ha) with the application of organic compost (40 t/ha). Some superior values obtained in these studies, when compared to the present study, can be concerned to the use of hybrids with high yield potential by these authors and to the fact that fertilization is not residual. According to the recommendation from the official report of the State of São Paulo, Brazil, 30 to 50 t/ha should be applied of organic compost on beet production and from 40 to 60 t/ha to broccoli (Raij *et al*., 1997). On broccoli crop 55 t/ha of organic compost was applied, a value above the recommended for beet, which resulted in residual fertilization that provided increases on vegetative characteristics of beet.

The absence of organic compost provided higher fresh weights of aerial part with natural phosphate, natural reactive phosphate and triple superphosphate sources and dry weight of aerial part (all the sources) (Table 3). That is, the absence of fertilization with organic compost before broccoli planting favored the aerial part of the beet plant in subsequent cultivation, but resulted, on average, in smaller roots and lower yield with natural phosphate and natural reactive phosphate sources.

Thus, in the conditions in which the present study was conducted, fertilization with organic compost associated to the phosphorus sources provides residual effect to beet production, cultivated after the application of these fertilizers in broccoli, resulting in roots with commercial value, with no need for new fertilization before planting.

Chicory production

There was interaction between phosphorus sources and the presence or absence of organic compost before planting for all characteristics evaluated on chicory. Greater plant height was observed with the natural phosphate source in the presence of organic compost, while in the absence of organic compost, the triple superphosphate source was superior to thermophosphate and natural reactive phosphate (Table 4). Thermophosphate source provided larger diameter in the presence of organic compost and the triple superphosphate source in its absence, although superior only to natural reactive phosphate. The highest number of leaves was obtained with natural phosphate and triple superphosphate sources in the presence of organic compost and with thermophosphate and triple superphosphate sources in the absence of organic compost. The greater fresh weight of aerial part was obtained with natural phosphate and triple superphosphate sources in the presence of organic compost and with triple superphosphate source in the absence of organic compost (Table 4).

For the dry weight of aerial part, the natural phosphate and triple superphosphate provided higher values in the presence of organic compost. On the other hand, in the absence of organic compost, the thermophosphate, natural phosphate and triple superphosphate sources resulted in greater values than natural reactive phosphate. Despite knowing that the high solubility of triple superphosphate source eases the immediate utilization of nutrients by the plant, the residual effect of this source increasing chicory production can be observed. Studies about the residual effect of phosphorus sources in chicory crops were not observed. Studies in literature are related to the immediate effect of phosphate fertilization, as observed by Silva *et al*. (2016b) and Mantovani *et al*. (2014) in lettuce, using triple superphosphate.

Table 4. Plant height (PH), diameter (D), number of leaves (NL), fresh (FWAP) and dry (DWAP) weight of aerial part of chicory in function of the residual effect of phosphorus sources in the presence and absence of organic compost. São Manuel, UNESP, 2016.

Phosphorus sources	PH (cm)		D (cm)		NL	
	P*	A	P	A	P	A
TM	15.34bA	13.62bB	27.18aA	24.46abB	44.69bA	42.75aB
NP	17.25aA	14.43abB	26.60abA	24.25abB	45.87aA	39.82bB
NRP	15.25bA	13.31bB	25.25bA	23.15bB	38.91bA	36.32cB
TS	15.54bA	15.31aA	26.85abA	25.54aB	48.33aA	44.97aB
CV (%)	5.2		3.4		3.3	

	FWAP (g/plant)		DWAP (g/plant)	
	P	A	P	A
TM	288.69bA	235.72bB	37.78bA	36.41aA
NP	377.71aA	232.65bB	44.51aA	33.67aB
NRP	234.43cA	188.63cB	36.96bA	26.96bB
TS	359.13aA	276.97aB	44.17aA	36.90aB
CV (%)	3.8		6.4	

* P = presence and A = absence of organic compost in planting. Averages followed by same letter, lowercase letter in column and capital letter in line, did not differ from each other, by Tukey test at 5% probability. TM = thermophosphate, NP = natural phosphate, NRP = natural reactive phosphate and TS = triple superphosphate.

Besides triple superphosphate, the natural phosphate source also provided increases in chicory characteristics, probably due to its composition that contains micro-organisms to help in mineralization of nutrients and filter cake, rich in organic matter. Probably these micro-organisms can release organic acids that facilitate the use of phosphorus. In relation to the thermophosphate source, the positive effect of this source was observed by Viana & Vasconcelos (2008) who obtained greater lettuce fresh and dry weight associated with poultry litter and cattle manure with thermophosphate, different from what was found in this study, where thermophosphate provided only larger diameter when associated to organic compost. Martins *et al.* (2013) obtained, in lettuce, higher number of leaves and fresh and dry weights with association to phosphorus sources (natural phosphate and thermophosphate) with organic compost.

Generally, natural reactive phosphate source was the one that resulted in the lowest values for all characteristics, although not always significantly lower. This source, natural reactive phosphate, has in its composition only P and Ca, while the other sources have other nutrientes in their composition. For example, natural phosphate presents, besides P and Ca, N, K, Mg and S, important nutrients for the chicory plants development. The same result was observed in broccoli planting in the previous harvest, better results with triple superphosphate source and minor results with natural reactive phosphate (Cardoso *et al*., 2019).

The application of organic compost in planting resulted, in general, better chicory characteristics (Table 4). Similar result was obtained by Lanna *et al*. (2017) evaluating the influence of the organic compost on chicory production in area of low (0 mg/dm^3) phosphorus and high (99 mg/dm^3) phosphorus initial fertility, obtaining increase in yield in both areas with the application of organic compost. Sobreiro *et al.* (2014) observed greater height, diameter, number of leaves and dry weight of chicory plants with the use of poultry litter composted. In lettuce, Abreu *et al.* (2010), evaluating different fertilizations (without fertilization, chemical fertilization, chicken manure, cattle manure, earthworm humus and organic compost) observed higher fresh weight with chicken manure and organic compost.

As discussed for beet, besides nutrient release, organic compost has potential to reduce P fixation (Kiehl, 2010; Fink *et al*., 2016), with the reduction of P adsorption sites due to the association of organic compounds with positively charged colloids in the soil. Furthermore, the decomposition of organic matter produces organic acids capable of solubilizing the P adsorbed in the soil. Therefore, the application of organic compost favored the absorption of applied phosphorus, with less fixation and, therefore, greater availability of this nutrient with the different sources used. Besides this, organic compost is rich in nitrogen, the nutrient that most improves production in leaf vegetables, such as chicory (Lanna *et al*., 2017).

Organic fertilization recommended for chicory crop is from 60 to 80 t/ha (Raij *et al*., 1997). However, the application on planting fertilization of broccoli experiment was 55 t/ha. But, even so, the application of organic compost resulted in better agronomic performance of chicory, which can be attributed to its composition, being rich in organic matter and macro and micronutrients. Thus, nutrients deriving from phosphate fertilizers and organic compost, besides fertilizers in top dressing, were used by chicory plants, even after exportation at the end of the first crop (broccoli), 185 days after the incorporation of organic compost.

Thus, in the conditions of the present study, fertilization with organic compost associated to the phosphorus sources provides necessary residual effect to beet and chicory production. For beet, triple superphosphate was the best P source, and for chicory in the absence of organic compost, triple superphosphate was the best source and in the presence of organic compost the best sources were triple superphosphate and the natural phosphate.

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