Growing vegetables in succession in different soils and doses of phosphorus in an organomineral fertilizer

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ABSTRACT: The objective of this study was to evaluate the residual concentration from the application of levels of phosphorus contained in an organomineral fertilizer (OMF) in two soils cultivated with cabbage and lettuce in succession. In randomized blocks, five doses of OMF were used as a source of P in Oxisol (0, 50, 100, 200, and 300% of the P dose was recommended for cabbage crop using OMF), plus an additional treatment (100% mineral). The doses applied to the Entisol were as follows: 0, 50, 100, 200, and 300% of the recommended P dose with OMF for cabbage crop, plus an additional treatment (100% mineral), with four repetitions. The production of fresh matter (FM) and dry matter (DM), the nutritional status of the cabbage and lettuce, and the residual effect of nutrients in the soil were also evaluated. The P concentration in the soil increased ($p \leq 0.05$) with higher doses of OMF in the Oxisol in the two cycles evaluated. However, this occurred only in the first cycle in the Entisol. Using the 50% dose of OMF in the cabbage in both soils provided FM and DM production values that were at least 11% higher than those attained with mineral fertilizer.

Key words: *Brassica oleracea* var. *capitata*, *Lactuca sativa* L., organic matter

Cultivo de hortaliças em sucessão em diferentes solos e doses de fosforo via fertilizante organomineral

RESUMO: O objetivo deste estudo foi avaliar o teor residual da aplicação de doses fosforo (P) via fertilizante organomineral (FO) em dois solos cultivados com repolho e alface em sucessão. Em blocos casualizados, utilizou-se cinco doses de FO como fonte de P. No Oxisol aplicaram-se: 0; 50; 100; 200 e 300% da dose de P recomendada para o repolho com utilização de FO, mais um tratamento com 100% da dose via fertilizante mineral. No Entisol aplicaram-se: 0; 50; 100; 200 e 300% da dose de P com FO para a cultura do repolho, além de um tratamento adicional (100% mineral), com quatro repetições. Avaliaram-se a produção de massa fresca (MF) e seca (MS), estado nutricional do repolho e da alface e o efeito residual de nutrientes no solo. O teor residual do P no solo aumentou ($p \leq 0,05$) quanto maior foi à dose de FO utilizada no Oxisol nos dois ciclos avaliados, enquanto que no Entisol isto só ocorreu no primeiro ciclo. Usando 50% da dose de FO no repolho em ambos os solos proporciona produção de MF e MS no mínimo 11% superior, comparado à adubação mineral.

Palavras-chave: *Brassica oleracea* var. *capitata*, *Lactuca sativa* L., matéria orgânica

Introduction

New technologies are being developed to increase the sustainability of vegetable cultivation. The use of organomineral fertilizer (OMF) has been considered an efficient way to provide nutrients and organic matter (OM) in comparison to exclusive use of mineral sources (Magela et al., 2019; Silva et al., 2020).

OMF is a product obtained by physically mixing different sources of OM with mineral fertilizer in the same granule (Luz et al., 2010). Chavez et al. (2019) emphasized that OMF presents gradual solubilization, which allows the slow release of nutrients during the crop cycle, providing a greater residual effect from the fertilizer used and promoting sustainable production. Among OM sources, filter cake has been used most frequently in the production of OMF because it is a residue with 1.2 to 1.8% P that has been applied in the cultivation of vegetables and has increased their production (Oliveira et al., 2014; Mota et al., 2019).

The use of OMF has been considered as one of the alternatives for providing increased development and quality of production in short-cycle vegetables, such as arugula (Oliveira et al., 2018) and lettuce (Luz et al., 2010), as well as in medium- or long-cycle vegetables, salad fresh tomatoes (Rosset et al., 2016) and industrial tomatoes (Peres et al., 2020). However, the residual effect of OMF in the soil needs to be further evaluated (Aguilar et al., 2019). The objective of this study was to evaluate the residual concentration from the application of quantities of organomineral fertilizer (OMF) in two soils cultivated with cabbage and lettuce in succession.

Material and Methods

The study was conducted in a greenhouse in the municipality of Uberaba, MG, Brazil, located at coordinates 19° 39' 19" S, 47° 57' 27" W and at an altitude of approximately 800 m, between September 2017 and February 2018. Pots with a soil volume of 6 dm³ (24 × 20 × 16.5 cm) were placed on a wooden support at 15 cm above the ground in an arched greenhouse model. The climate of the region is classified as tropical hot (Aw), according to the updated Köppen classification (Beck et al., 2018).

Samples collected from the layer up to 0.20 m depth from two soils were used as substrate. One of these soils was an Oxisol, a moderate A horizon, whereas the other was an Entisol, a humic A horizon. Both soils had a medium texture (Santos et al., 2018) and presented the following physical characteristics: 220, 720, and 60 g kg^{-1} and 122, 615, and 263 g kg^{-1} of clay, sand, and silt, respectively, for Oxisol and Entisol. The chemical attributes of these soils are presented in Table 1.

The pH of both soils was corrected using dolomitic limestone (36.4% calcium oxide, 44.0% magnesium oxide,

99.87% neutralizing power (NP), and a relative total neutralizing power (RTNP) of 90.28%) to raise the V% to 70. The incubation period of the soil in the pots for the limestone reaction was 30 days.

Two successive experiments were installed in these pots. The first one was used for growing cabbage (*Brassica oleracea* var. *capitata*). Seedlings that were 30 days old were transplanted (on September 22, 2017) with the recommended fertilization for this crop, according to Ribeiro et al. (1999). The second experiment was used to grow lettuce (*Lactuca sativa* var. *Crispa*). The seedlings of the same age were transplanted (on December 19, 2017) without any complementary fertilization. The experimental design consisted of randomized blocks, with five doses of phosphorus (P) using pelletized OMF, as well as an additional treatment with 100% mineral fertilization. The design included four repetitions with five plants per plot, totaling 20 plants per treatment.

The following doses were used in the Oxisol: T1 = 0, T2 = 50% (400 mg dm^{-3} of P$_2$O$_5$), T3 = 100% (800 mg dm^{-3} of P$_2$O$_5$), T4 = 200% (1600 mg dm^{-3} of P$_2$O$_5$), and T5 = 300% (2400 mg dm^{-3} of P$_2$O$_5$), as well as an additional mineral treatment (100% mineral). The doses used in Entisol were T1 = 0, T2 = 50% (100 mg dm^{-3} of P$_2$O$_5$), T3 = 100% (200 mg dm^{-3} of P$_2$O$_5$), T4 = 200% (400 mg dm^{-3} of P$_2$O$_5$), and T5 = 300% (600 mg dm^{-3} of P$_2$O$_5$), as well as an additional mineral treatment (100% mineral). In the additional treatment, the following doses were used for the Oxisol: 75, 200, and 120 mg dm^{-3} of N, P$_2$O$_5$, and K$_2$O, respectively. The doses for the Entisol were 75, 50, and 75 mg dm^{-3} of N, P$_2$O$_5$, and K$_2$O, respectively. These fertilization recommendations were consistent with the soil analysis and the needs of the crop (Ribeiro et al., 1999).

The OMF formulation, which was based on the filter cake, was 5:17:10 (N:P:K) (0.1% boron + 3% silicon + 0.4% zinc, and 8% total organic carbon). The doses of P were fixed and the other nutrients were balanced, and therefore, all treatments received the same fertilization. The OMF and the mineral fertilizer were distributed equidistantly around the seedlings at a depth of 0.05 m and were then covered by a layer of soil. The transplanting of the cabbage and lettuce seedlings was carried out when they had four to five expanded leaves. One seedling was placed in the center of each pot.

The irrigation of the pots in both experiments was completed using drip irrigation, with water depth calculated based on the reference evapotranspiration (ETo) estimated using the data obtained in the Federal Institute of the Triângulo Mineiro weather station. To determine the depth, temperature values were collected daily and the reference evapotranspiration was generated using the equation by Hargreaves (1973) as follows:

$$\mathrm{ETo} = 0.0134 \mathrm{KtQo} (\mathrm{t\,max} - \mathrm{t\,min}) 0.5 \times (\mathrm{tmed} + 17.3) \quad (1)$$

Table 1. Chemical attributes of Oxisol and Entisol in layer up to 0.20 m

pH H$_2$O	P meh-1	K$^+$	Ca^{2+}	Mg^{2+}	H + Al	SB	OM	OC	V
1-2.5	(mg dm^{-3})				(cmol$_c$ dm^{-3})		(dag kg^{-1})		(%)
Oxisol									
6.80	0.85	27.30	2.20	0.85	1.62	3.12	1.15	0.65	65.7
Entisol									
6.45	147.50	35.10	4.78	3.65	5.07	8.39	4.92	2.80	62.3

SB - Sum of bases; OC - organic carbon; OM - Organic matter; V - Percentage of base saturation

where:

ETo - reference evapotranspiration, mm d^{-1};

Kt - dimensionless constant (0.162) for the region of Uberaba, MG, Brazil;

tmax - maximum temperature recorded during the day, °C;

tmin - minimum temperature, °C; and,

tmed - average temperature, °C.

The average temperature was 24.5 °C, the reference evapotranspiration was 7.01 mm, Kc was 1.07, and the application depth was 7.50 mm day^{-1}, for a volume (pot) of 462 mL with an irrigation time of 17.3 min, which is the time necessary to restitute 100% of the water used.

The cabbage was harvested when the head was beginning to form, which occurred 80 days after transplanting the seedlings. whereas lettuce was harvested 45 days after transplanting. The greens were cut close to the ground, and after determining fresh matter (FM), they were packed into paper bags and taken to a forced air circulation oven where they were heated at 65 °C for 72 h, or until the weight was constant, to determine dry matter (DM). To evaluate the agronomic efficiency of the OMF dose, the agronomic efficiency index (AEI), described by Goedert et al. (1986), was adopted.

To analyze the nutritional status of the plants, according to the methodology proposed by Martinez et al. (1999), samples were taken from recently matured leaves at the time of the formation of lettuce and cabbage head. The levels of total nitrogen (N) were quantified using the Kjeldahl method (Tedesco et al., 1985), whereas phosphorus (P) and potassium (K) levels were determined by nitric-perchloric acid digestion (Bataglia et al., 1983).

A process for determining the residual effects from the organomineral and mineral fertilizers remaining in the soil after the cabbage and lettuce were harvested was performed to evaluate the pH of water (pH$_{H2O}$), P by the Mehlich-1 method (P meh-1), and K by flame photometry (Tedesco et al., 1985).

The data were submitted to the analysis of variance, applying the F-test when significant. Regression analysis was used to study the doses, and Tukey's test (p ≤ 0.05) was employed for the soils, using the SISVAR program. A comparison between the means of the treatments and the additional treatment was performed using Dunnett's test (p ≤ 0.05).

RESULTS AND DISCUSSION

The production of FM and DM from both the cabbage and lettuce obtained with the organomineral and mineral fertilizers (Table 2) emphasized the need for the use of phosphate fertilization in the production of the vegetables in both soils.

For cabbage, in both the Oxisol and Entisol, there were no differences in the production of FM and DM between the doses of OMF and the mineral fertilizer; however, these were all higher in comparison with the control treatment. For lettuce, the highest yields of FM and DM occurred with the highest doses of OMF (200 and 300%) and with the mineral fertilizer (100% dose).

Even in the Entisol, which has high OM content, there was a response to P, as cabbage and lettuce are very responsive crops. P deficiency occurs naturally either due to a lack of the nutrient or its adsorption. Thus, there is a need to apply high doses of P while planting, as suggested by Hansel et al. (2014).

The AEI was used to determine the dose of OMF needed to obtain the same production of FM and DM as obtained with the mineral fertilizer (reference value). For cabbage in the Oxisol, 50% dose of OMF (400 mg dm^{-3} of P$_2$O$_5$) provided 11% more FM and DM production in comparison with 100% mineral fertilization (200 mg dm^{-3} of P$_2$O$_5$). In the Entisol, the FM and DM production values of cabbage with OMF were 25% higher and 42% higher, respectively, in comparison with mineral fertilization (Table 2).

It has been shown that both the sources of fertilizer can be used for cabbage in both the types of soil. However, notably, the production of FM and DM with the lowest dose of OMF (50%) was statistically similar to that yielded using the highest dose of OMF (300%) and the mineral fertilization (Table 2). Crops with a longer cycle allow better exploration of the controlled

Table 2. Production of fresh matter (FM) and dry matter (DM) and agronomic efficiency indices of FM (AEIFM) and DM (AEIDM) as a function of organomineral fertilizer dose in the Oxisol and Entisol

Treatment (mg dm^{-3} of P$_2$O$_5$)	Cabbage				Lettuce			
	FM	DM	AEIFM	AEIDM	FM	DM	AEIFM	AEIDM
	(g plant^{-1})		(%)		(g plant^{-1})		(%)	
Oxisol								
0	35.8 b*	14.8 b*	0	0	7.9 e*	0.8 d*	0	0
400 (50%)	308.3 a	47.5 a	111	111	18.8 d*	2.4 c*	29	31
800 (100%)	308.0 a	50.5 a	111	121	27.4 c*	2.9 c*	52	41
1600 (200%)	341.8 a	47.9 a	125	112	36.8 b	4.0 b*	78	63
2400 (300%)	327.3 a	46.1 a	119	106	37.1 b	3.8 b*	78	59
200 (100% mineral)	281.2 a	44.3 a	100	100	45.1 a	5.9 a	100	100
CV %	18.2	12.7	--	--		20. 7	21.0	--
Entisol								
0	232.5 b*	41.9 b	0	0	8.8 c*	1.7 c	0	0
100 (50%)	329.8 a	55.5 a	125	142	18.7 c*	1.8 c	59	14
200 (100%)	343.7 a	54.6 a	143	132	21.6 b	2.3 b	77	86
400 (200%)	277.5 a	50.3 a	58	88	31.2 a*	3.4 a*	134	243
600 (300%)	332.3 a	53.4 a	128	120	31.7 a	3.5 a*	137	257
50 (100% mineral)	310.5 a	51.5 a	100	100	25.5 b	2.4 b	100	100
CV %	13.0	9.8	--	--	13.3	16.8	--	--

Averages followed by same letters in the column do not differ from each other at p ≤ 0.05 by Tukey's test; CV - Coefficient of variation; *Organomineral treatment differs from mineral fertilization by Dunnett's test (p ≤ 0.05)

release of nutrients from OMF. Castoldi et al. (2009) claimed that the highest demand for nutrients by cauliflower occurs in the last 10 days of its cycle; however, Aquino et al. (2009) mentioned that this greater demand occurs in the last 20 days of the cycle of cabbage.

For the production of lettuce in the Entisol, the dose of 200% OMF (400 mg dm^{-3} of P_2O_5) resulted in a 34 and 143% increase in the production of FM and DM, respectively, in comparison with the 100% recommended for mineral fertilization (50 mg dm^{-3} of P_2O_5).

For lettuce in the Oxisol, the highest productions of FM and DM occurred with mineral fertilization. Grangeiro et al. (2006) quantitatively demonstrated a high demand of lettuce for P. This is because lettuce absorbs high concentrations of P in a short period of time because of its short cultivation cycle of 45 days.

The regression analysis for the OMF doses used for cabbage in the Oxisol showed an exponential increase of FM and DM production up to the dose of 400 mg dm^{-3} of P_2O_5 (50% dose) ($p \leq 0.05$; F = 14.90) (Figure 1A).

For lettuce grown in the Oxisol, the curves presented quadratic adjustments, confirming that the increase in the OMF dose positively influenced the production of FM and DM up to the value of 2000 mg dm^{-3} of P_2O_5 ($p \leq 0.05$, F = 24.30) and a slow decrease in the production of FM and DM occurred from this point onward (Figure 1B).

It is possible that the application of higher doses of OMF provided greater crop development due to the increases in the levels of exchangeable bases and P in the soil and the availability of N retained in the OM.

For cabbage in the Entisol, the production of FM and DM remained constant, irrespective of the fertilization level (Figure 1C). For lettuce, the regression curve showed a quadratic adjustment for FM, with a significant increase in production up to the estimated maximum dose of 538 mg dm^{-3} of P_2O_5 ($p \leq 0.05$, F =13.12) followed by diminishing values (Figure 1D).

OM, when associated with mineral fertilizer, facilitates the absorption of nutrients and aids the transport of photoassimilates produced by the plant (Chavez et al., 2019). However, the release of nutrients from OMFs is slower (Hansel et al., 2014). In the lettuce crop, exclusive mineral fertilization yielded a higher production of FM and DM, irrespective of the soil used. This can be explained by the short cycle of the plant and its tendency to demand phosphate fertilization to yield higher production.

For the contents of N, P, and K in the leaves of the cabbage grown in the Oxisol, the regression curve showed a linear adjustment for N and K, indicating that the availability of nutrients in the plant increased with the increase in organomineral dose (Figure 2A, 2C). For the contents of P in the plant, a quadratic adjustment by which the levels of P decreased with dose up to 476 mg dm^{-3} of P_2O_5 was observed. However, from this dosage onward, there was a significant increase ($p \leq 0.05$, F = 17.61) up to the dose of 2400 mg dm^{-3} of P_2O_5 (300% of the dose) (Figure 2B).

The N content of the lettuce leaves averaged 13.8 g kg^{-1} (Figure 2A). The P regression curve presented a quadratic
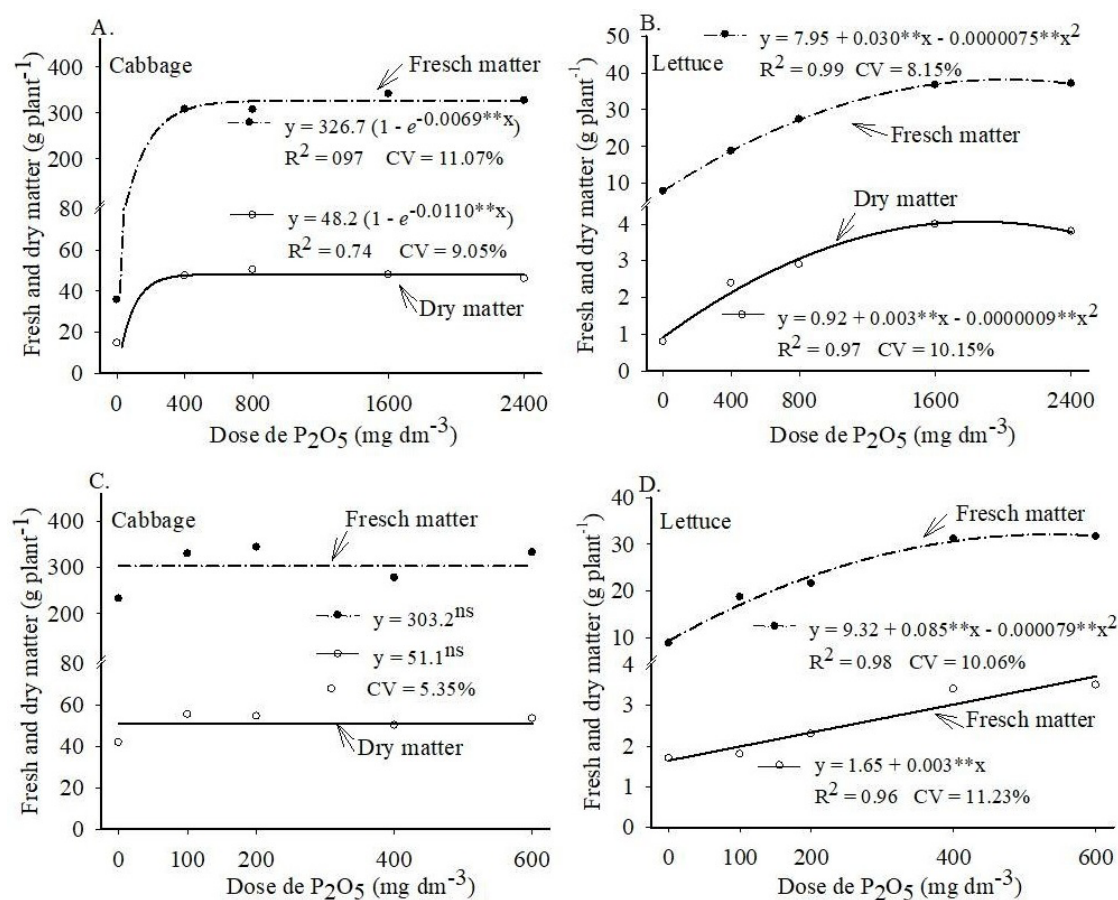
ns and ** - Not significant and significant at p ≤ 0.01 by Tukey's test, respectively

Figure 1. Production of fresh matter and dry matter in function of doses of phosphorus in the Oxisol for cabbage (——●——) (A) and lettuce (····◇····) (B) and in the Entisol for cabbage (C) and lettuce (D)
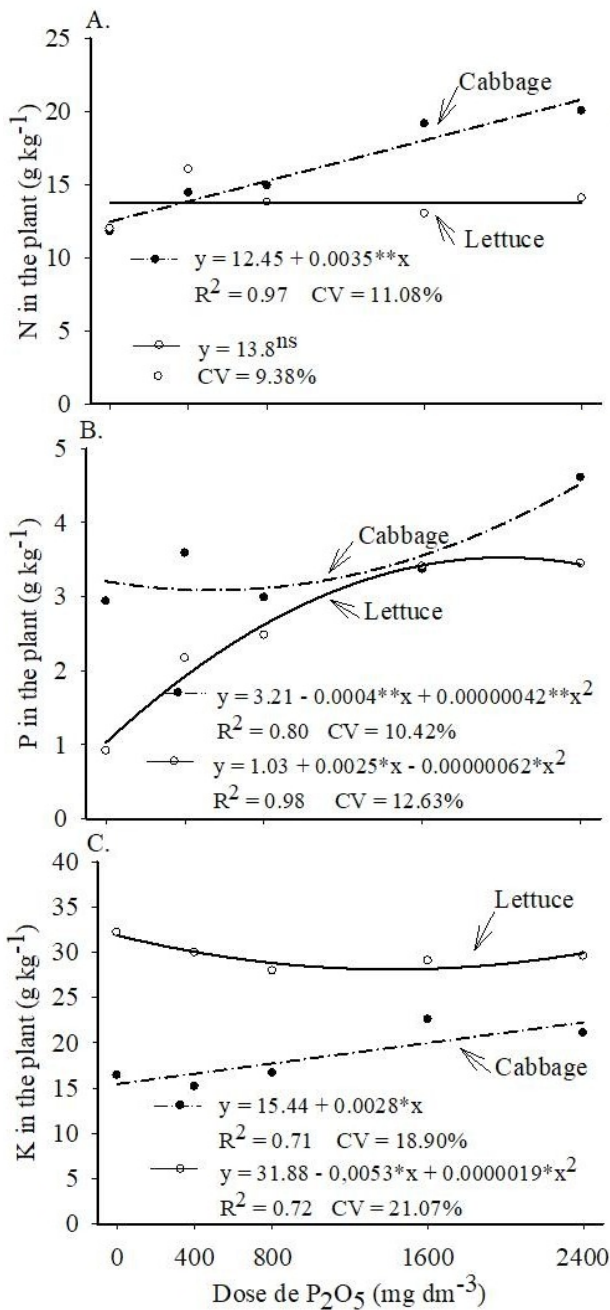
ns, *, and ** - Not significant, significant at $p \leq 0.05$, and significant at $p \leq 0.01$ by F test

Figure 2. Contents of (A) nitrogen, (B) phosphorus, and (C) potassium in the residues of cabbage (——●——) and lettuce (·····◇·····) grown in function of doses of phosphorus in Oxisol

adjustment, with an increase in plant P content up to the estimated dose of 2016 mg dm^{-3} of P_2O_5 (Figure 2B). This behavior can be explained by the physiology of the plant, which accumulates the maximum amount of P when it is close to harvest.

The accumulation of P tends to decrease when the plant begins its flowering period. Kano et al. (2011) noticed that the amounts of P accumulated in lettuce at the end of a cycle of 112 days after transplanting (DAT) were 6, 25, 28, and 81% at 20, 34, 49, and 69 DAT, with only 19% being accumulated between the beginning of flowering (DAT 69) and the end of the plant cycle for seed production (DAT 112).

The K levels in the lettuce were adjusted as shown by the quadratic regression; however, as the dose of OMF increased,

the K contents in the plant decreased up to a dose of 1374 mg dm^{-3} of P_2O_5. From this dose onward, there was an increase in foliar K content (Figure 2C), which can be explained by an increase in absorption of K by the plant at the end of the cycle, as already demonstrated in other studies (Grangeiro et al., 2006; Kano et al., 2011).

The absorption of nutrients in cabbage and lettuce leaves occurred in the order of K > N > P, which confirmed the results obtained by Aquino et al. (2009) and Silva (2016) in studies with cabbage and by Grangeiro et al. (2006) in studies with curly lettuce.

For both vegetables in the Entisol, a quadratic adjustment in foliar N contents was observed (Figure 3A), with the minimum
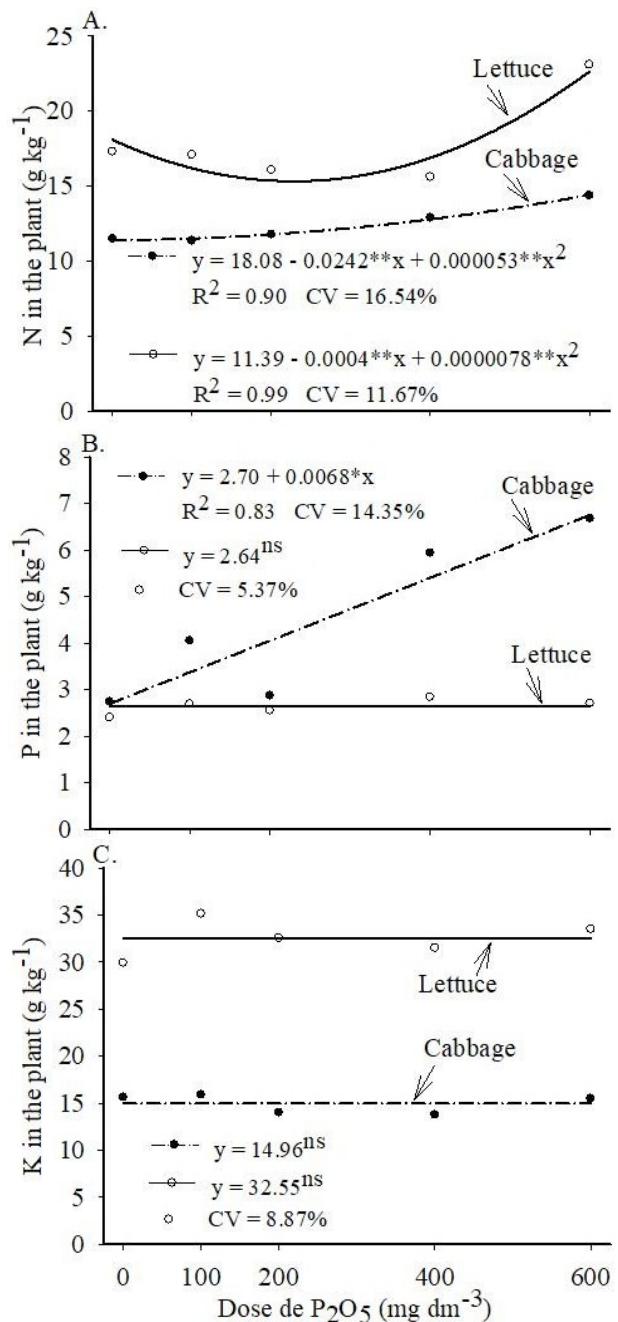
ns, *, and ** - Not significant, significant at $p \leq 0.05$, and significant at $p \leq 0.01$ by F test

Figure 3. Regression curves for contents of (A) nitrogen, (B) phosphorus, and (C) potassium in the residues of cabbage (——●——) and lettuce (·····◇·····) in function of doses of phosphorus in Entisol

reached at the dose of 228 mg dm^{-3} of P_2O_5 for lettuce and the dose of 256 mg dm^{-3} of P_2O_5 for cabbage (Figure 3A). This behavior is possibly due to the slower initial development of the plant, which results in an increase in the absorption of N over the plant development period until harvest, as highlighted by Kano et al. (2011).

There was a linear adjustment for P in the cabbage crop, in which the concentration of P increased ($p \leq 0.05$) to its maximum at the dose of 600 mg dm^{-3} of P_2O_5 (300% of the dose) (Figure 3B). The K contents in the plant were close to 14.96 g kg^{-1} for cabbage and 32.55 g kg^{-1} for lettuce (Figure 3C). In general, when the dose of P applied through OMF in both soils (Oxisol and Entisol) was higher, there were higher levels of N and K in the plant residue in comparison with the control treatment.

The OMF doses changed the availability of N, P, and K in the soil solution because the nutrients were released slowly, allowing for greater absorption by the plant and a greater residual effect. Menezes Júnior et al. (2013) pointed out that it is possible to obtain a greater residual effect for each fertilizer used.

Regarding the pH in the Oxisol, the pH of the soil decreased significantly ($p \leq 0.05$) from 6.45 to 6.10 for cabbage and from 6.45 to 5.85 for lettuce with an increase in OMF dose (Figure 4A).

With respect to P, a quadratic adjustment of the regression curves was observed. For cabbage, the P content in the soil increased significantly ($p \leq 0.05$, F = 1.94) for doses equal to or greater than 16 mg dm^{-3} of P_2O_5; similar response was observed for lettuce for doses equal to or greater than 332 mg dm^{-3} of P_2O_5 (Figure 4B). This confirms that the availability of P in the soil for both plants increased as the amount of applied OMF increased.

The availability of P in the Oxisol after the cultivation of cabbage increased significantly ($p \leq 0.05$) with an increase in the dose of OMF. With the 0, 50, 100, 200, and 300% doses, the values in the soil increased by 5.37, 12.40, 36.60, 58.62, and 152.50 mg dm^{-3}, respectively. However, these numbers were lower than those attained by mineral fertilization (266.65 mg dm^{-3}).

Similar behavior was observed after the cultivation of lettuce, which suggests the marked residual effect provided by the OMF, given that there was no reapplication of phosphate fertilizer for the lettuce crop.

Following the growing of cabbage, the K content in the soil increased with the application of OMF for doses equal to and exceeding 372 mg dm^{-3} of P_2O_5. In contrast, for the soil used to grow lettuce, the increase in soil K content was significant ($p \leq 0.05$, F = 8.41) for doses equal to and exceeding 836 mg dm^{-3} of P_2O_5 (Figure 4C).

The availability of K in the soil after cabbage cultivation increased significantly ($p \leq 0.05$) as the dose of OMF increased, beginning with the dose of 50%. For the 0, 50, 100, 200, and 300% doses, the values in the soil increased by 134.75, 77.50, 100.25, 183.00, and 215.25 mg dm^{-3}, respectively. However, these values were higher in comparison to those provided by mineral fertilization (65.00 mg dm^{-3}). Similar behavior was
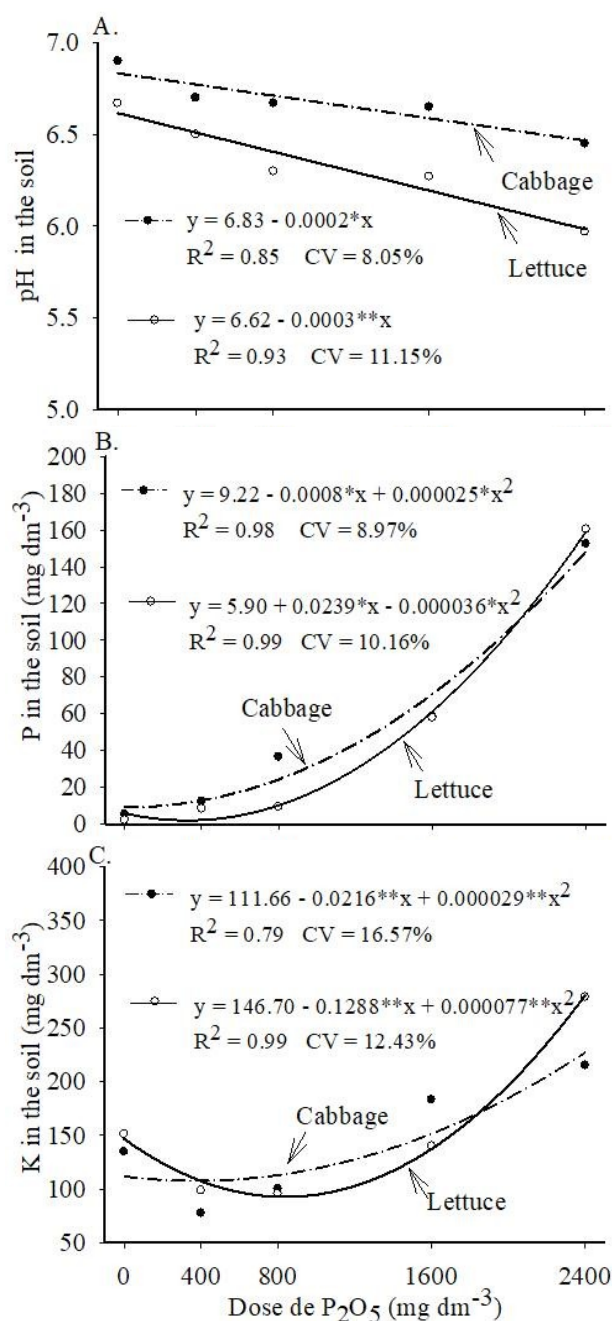
ns, *, and ** - Not significant, significant at $p \leq 0.05$, and significant at $p \leq 0.01$ by F test

Figure 4. (A) pH value, (B) phosphorus, and (C) potassium in Oxisol in the early stage and following harvest of cabbage (—●—) and lettuce (····◇····) in function of doses of phosphorus

observed after the cultivation of lettuce. For the 0, 50, 100, 200, and 300% doses, the values in the soil increased by 151.25, 95.50, 98.75, 140.00, and 278.75 mg dm^{-3}, respectively, which were also higher in comparison to those by mineral fertilization (75.25 mg dm^{-3}).

After growing cabbage and lettuce, the K content in the soil at zero dose of OMF was higher than that at the 100% dose, which may be related to the high mobility of this element in the soil. However, as OM was added to the soil via the OMF, this mobility decreased. This is attributable to the fact that the mobility of K, similar to other cations, decreases as the density of negative charges increases, as proven by Neves et al. (2009). Menezes Júnior et al. (2013) demonstrated a decrease in pH and increase in OM, P, K, Ca, and V% in soil after harvesting

onions in treatments that received manure and a biofertilizer based on cattle manure in comparison with the conventional treatment of mineral fertilizers.

In the Entisol soil, pH remained constant in both crops, with the values of 6.20 for cabbage and 6.00 for lettuce (Figure 5A). This behavior can be explained by the elevated natural content of OM, given that even mineral fertilization yielded no detectable change in pH value.

The P content in the Entisol in the lettuce area was constant at approximately 151.75 mg dm^{-3} of P_2O_5; however, in the cabbage area, a quadratic adjustment was observed, in which the content of P in the soil increased for doses equal to and exceeding 111 mg dm^{-3} of P_2O_5 (Figure 5B).
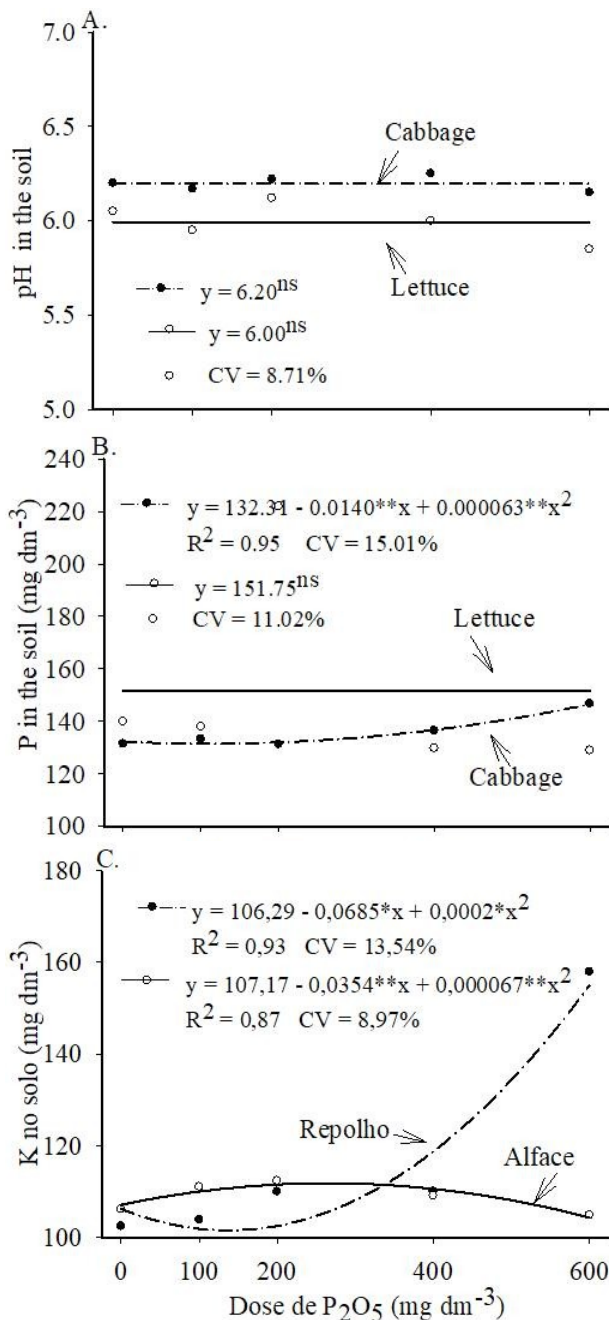
ns, * and ** - Not significant, significant at $p \leq 0.05$, and significant at $p \leq 0.01$ by F test

Figure 5. (A) pH, (B) phosphorus, and (C) potassium in Entisol in the early stage after correcting the acidity and harvesting the cabbage (—●—) and lettuce (┄┄◇┄┄) in function of doses of phosphorus

The availability of P in the Entisol increased significantly ($p \leq 0.05$) with the increase in the dose of OMF. However, this was not the case after the cultivation of lettuce, as there were no differences between the 0, 50, 100, 200 and 300% doses of OMF, which yielded the values of 2.40, 2.69, 2.55, 2.84, and 2.70 g kg^{-1}, respectively. These values were also equal ($p \leq 0.05$) to those provided by mineral fertilization (2.37 g kg^{-1}), respectively.

The K content in the soil after the cultivation of cabbage increased significantly ($p \leq 0.05$) for doses equal to and exceeding 171 mg dm^{-3} of K_2O. With lettuce, the K content in the soil increased to 264 mg dm^{-3} of K_2O (Figure 5C).

Regarding the availability of K in the Entisol, there were no differences ($p \leq 0.05$) among the 0, 50, 100, 200, and 300% doses of OMF and the mineral fertilizer (100%) following the cultivation of cabbage. The values were 15.63, 15.89, 13.99, 13.77, 15.50, and 14.42 g kg^{-1}, respectively. However, the same did not occur after the cultivation of lettuce, because all the K values in the soil at the 0, 50, 100, 200, and 300% doses of OMF were significantly similar ($p \leq 0.05$), with the values of 29.92, 35.15, 32.57, 31.52, and 33.50 g kg^{-1}. These values were higher than the value yielded by mineral fertilization (24.62 g kg^{-1}).

The gradual release of nutrients that occurs as organic waste which is broken down by microorganisms in the soil is one of the great advantages of OMFs because it prevents the nutrients from leaching, thereby increasing the residual contents of nutrients in the soil (Chavez et al., 2019).

By correlating the soil chemical characteristics and the production of lettuce biomass fertilized with organic compounds, Oliveira et al. (2014) observed that the addition of organic compounds increased the DM production of lettuce and the OM content in the soil. In addition, according to them, higher doses of organic compounds provided greater availability of P and K, reduced soil acidity, and promoted an increase in productivity, which is similar to the results in this study.

Conclusions

1. In the Oxisol, the residual soil phosphorus content increased with the increase in the dose of OMF in both the cycles evaluated. In the Entisol, this occurred only in the first cycle.

2. The use of the 50% dose of OMF for the cultivation of cabbage provided an index of agronomic efficiency of FM and DM that was at least 11% higher than that of mineral fertilization (100%) in both soils.

3. The highest rates of agronomic efficiency in lettuce occurred with 100% mineral fertilization in the Oxisol and 200% organomineral fertilization in the Entisol.

4. In both soils, P and K contents were significantly higher when using the 300% dose of OMF and 100% mineral fertilizer.

Acknowledgements

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