

FERTILITY PROPERTIES AND LEAFY VEGETABLE PRODUCTION IN SOILS FERTILIZED WITH CATTLE MANURE¹

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ABSTRACT - The effect of organic fertilization with cattle manure on fertility properties of soils with different clay contents was evaluated; as well as the influence of cattle manure fertilization on the production of lettuce, and on subsequent arugula and common chicory grown in these soils. The experiment with pot plants was arranged in randomized blocks and analyzed in a 3x6 factorial design with four replications. The treatments consisted of three soil types with different clay contents (166; 362; 565 g kg⁻¹) and six cattle manure rates (0; 10; 20; 40; 80, and 160 t ha⁻¹). Batches of each soil were manured, limed, filled in pots, moistened, and incubated for 30 days. Then, mineral base fertilization was applied and one lettuce seedling per each pot was grown. After lettuce harvest, the residual effect of organic fertilization was assessed in two subsequent crops, first arugula and then common chicory. The application of up to 160 t ha⁻¹ cattle manure reduces soil acidity and increases nutrient contents, particularly of P, K and Zn, in soils with 165 to 565 g kg⁻¹ clay content. Fertilization with cattle manure at rates of up to 160 t ha⁻¹ increases electrical conductivity of soils, without affecting growth and yield of the leafy vegetables. Cattle manuring increases the yield of lettuce, as well as of arugula and common chicory grown afterwards.

Keywords: *Lactuca sativa*. *Cichorium intybus*. *Eruca sativa*. Organic fertilization. Successive crop.

ATRIBUTOS DE FERTILIDADE E PRODUÇÃO DE HORTALIÇAS FOLHOSAS EM SOLOS ADUBADOS COM ESTERCO BOVINO

RESUMO - O presente trabalho teve como objetivos avaliar o efeito da adubação com esterco bovino em atributos de fertilidade de solos com diferentes teores de argila e, verificar a influência da adubação com esterco bovino na produção de alface americana, e da rúcula e almeirão, cultivados de forma sucessiva a alface. O experimento foi realizado em vasos, em delineamento em blocos ao acaso, com os tratamentos arranjados em esquema fatorial 3x6 com quatro repetições. Os tratamentos foram constituídos por três solos com diferentes teores de argila (166; 362; 565 g kg⁻¹) e seis doses de esterco bovino (0; 10; 20; 40; 80 e 160 t ha⁻¹). Porções de cada solo receberam esterco bovino e calcário, foram transferidas para vasos, umedecidas e incubadas por 30 dias. A seguir, efetuou-se adubação mineral de plantio e cada vaso recebeu uma muda de alface. Após a colheita da alface, para avaliar o efeito residual da adubação orgânica foram realizados dois cultivos sucessivos, um de rúcula e outro de almeirão. A aplicação de até 160 t ha⁻¹ de esterco bovino diminui a acidez e, aumenta os teores de nutrientes, particularmente P, K e Zn em solos com teores de argila de 165 a 565 g kg⁻¹. A adubação com esterco bovino em doses de até 160 t ha⁻¹ aumenta a condutividade elétrica dos solos, e esse acréscimo não prejudica o crescimento e a produção de hortaliças folhosas. A adubação com esterco bovino aumenta a produção de alface, como também a de rúcula e almeirão, cultivados de forma sucessiva.

Palavras-chave: *Lactuca sativa*. *Cichorium intybus*. *Eruca sativa*. Adubação orgânica. Cultivo sucessivo.

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INTRODUCTION

Leafy vegetables, as well as other vegetables, are considered nutrient-demanding because they require relatively large amounts in a relatively short period of time (GRANGEIRO et al., 2006). Thus, applications of high rates of organic and mineral fertilizers are common in the cultivation of leafy vegetables (PÔRTO et al., 2008; SANTI et al., 2010).

Among the leafy vegetables, lettuce (*Lactuca sativa*) is the most widely cultivated and most consumed in Brazil, and the consumption and planted acreage of crisphead lettuce (Iceberg group) in particular has increased considerably in the last years (SALA; COSTA, 2012). Apart from lettuce, common chicory (*Cichorium intybus*) and arugula (*Eruca sativa*) are important leafy vegetables from the economic point of view, and have gained more space in the market (SANTOS et al., 2013; CECÍLIO FILHO et al., 2014).

Organic fertilization is frequently used by vegetable producers, and the applied rates depend, among other factors, on the type and chemical composition of the organic fertilizer and on the soil texture and initial fertility (SILVA, 2008).

Among the organic fertilizers used for vegetable cultivation, cattle manure is the most common. For the State of São Paulo, rates of 60 to 80 t ha⁻¹ are recommended for lettuce, common chicory, chicory, endive, arugula, and watercress, regardless of the soil texture (TRANI; RAIJ, 1997). In the States of Santa Catarina and Rio Grande do Sul, cattle manure rates of 40 to 80 t ha⁻¹ are recommended for vegetables (CQFS, 2004) and in Minas Gerais, 50 t ha⁻¹ for lettuce cultivation (CFSEMG, 1999). However, there are reports of increased lettuce yields after applications of up to 150 t ha⁻¹ cattle manure (PÔRTO et al., 2008).

Organic fertilizers improve the soil chemical, physical and biological properties, contributing to raise crop yields (MELO; SILVA; DIAS., 2008).

From the chemical point of view, the use of organic fertilizers such as cattle manure, maintains or increases soil organic matter contents and provides plants with nutrients (BATISTA et al., 2012). However, very high rates may disturb the balance between nutrients and increase salt contents in the soil, which can hamper vegetable yields. This problem is usually greater in sandy soils, where organic fertilizers decompose faster and salt contents in the soil solution are higher (FIOREZE et al., 2012).

In the production of leafy vegetables, crops are grown subsequently in several seasons throughout the year in the same area, usually with applications of organic fertilizer prior to the planting of each crop, without taking residual effects into account. In addition, studies that evaluate the residual effect of organic fertilization on leafy vegetable cultivation in Brazil are scarce (PEIXOTO FILHO et al., 2013).

In this context, we evaluated the effect of organic fertilization with cattle manure on fertility properties of soils with different clay contents and assessed the influence of cattle manuring on the production of crisphead lettuce as well as on the subsequent cultivation of arugula and common chicory.

MATERIAL AND METHODS

This experiment with pot plants was carried out in a greenhouse, from September 2013 to August 2014, in Alfenas, Minas Gerais. About 200 dm³ of the surface layer (0 - 20 cm) of three soils with different clay contents (Table 1) were collected. After removal, each soil was separately air-dried in the shade, crumbled, sieved (4 mm mesh) and sampled for particle-size analysis (CAMARGO et al., 2009) and routine chemical analyses (SILVA, 2009) (results see Tables 1 and Table 2).

Table 1. Particle-size analysis of the soils used in the experiment.

Soil	Coarse sand	Fine sand	Total sand	Silt	Clay	Textural class
	----- g kg ⁻¹ -----					
S1	373	357	730	104	166	Medium
S2	295	111	406	232	362	Clayey
S3	237	90	327	108	565	Clayey

Table 2. Chemical analyses of the soils at the start of the experiment.

Soil	P	O.M.	pH	K	Ca	Mg	H+Al	Al	SB	CEC	V
	Mehlich		CaCl ₂								
	mg dm ⁻³	g dm ⁻³		----- mmol _c dm ⁻³ -----							%
S1	2	19	5.1	3.1	13	6	23	1	22	45	49
S2	4	27	4.6	3.4	12	8	47	4	23	70	33
S3	2	35	5.4	2.3	37	9	33	0	48	81	59

A randomized block design was used, with treatments arranged in a 3x6 factorial design, with four replications, i.e., a total of 72 experimental units (pots). The treatments consisted of a combination of three soils (S1, S2 and S3) and six manure rates (0; 10; 20; 40; 80, and 160 t ha⁻¹), based on the soil volume of each pot and the soil volume of the 0-20 cm layer of an area of 1 ha. The treatment

without organic fertilization (0 t ha⁻¹ manure) was used as control. The tanned cattle manure used was from a dairy farm in the county of Alfenas-MG, air-dried in the shade, sieved, homogenized, and sampled to determine the chemical composition, dry basis, pH, and moisture, as described by Tedesco et al. (1995) (Table 3).

Table 3. Chemical composition, dry basis, pH, and moisture of cattle manure used in the experiment.

Water content	pH	C-org.	N	C/N ratio	P	K
%		----- g kg ⁻¹ -----			----- g kg ⁻¹ -----	
8	8.2	200.4	19.3	10	5.2	9
Ca	Mg	S	B	Cu	Mn	Zn
----- g kg ⁻¹ -----				----- mg kg ⁻¹ -----		
12.1	5.3	3.0	157	71	384	262

Batches of 6.5 dm³ of each soil were mixed dry with the cattle manure rates, according to the treatments, and with dolomitic limestone, to raise the initial base saturation (V%) of each soil to 70%. After mixing, the treated soils were transferred to 7-dm³ pots, moistened with distilled water to about 70% of the water-holding capacity, and incubated for 30 days. During incubation, soil moisture was controlled every two days by weighing the pots and water was replaced to maintain the soil moisture content at approximately the initial water-retention level.

At the end of the incubation period, the soil batches were removed from the pots, air-dried, and 0.3 dm³ soil per pot was sampled for chemical analyses of pH in CaCl₂, H+Al, organic matter, P extracted by Mehlich, K⁺, Ca²⁺, and Mg²⁺ (SILVA, 2009), of S-SO₄²⁻, and of the micronutrients Cu, Fe, Mn, and Zn, and to determine the electrical conductivity, in 1:5 soil : distilled water (RAIJ et al., 2001).

After sampling, 6.2 dm³ of soil were returned to the pots, remoistened to 70% of the water-holding capacity, and mineral base fertilization was applied equally in all treatments including the control, to raise the contents of most soil nutrients to medium levels. Mineral fertilization was applied, since the combined use of organic and mineral fertilizers is common in vegetable cultivation. The mineral fertilizers were applied in solution, containing 80 mg dm⁻³ P; 20 mg dm⁻³ N; 30 mg dm⁻³ K; 10 mg dm⁻³ S; 2 mg dm⁻³ Zn, and 0.5 mg dm⁻³ B, as recommended by Novais, Neves and Barros (1991) for pot experiments. An amount of 7,200 mL of solution was prepared using the reagents (PA) NH₄H₂PO₄; KH₂PO₄; K₂SO₄; ZnSO₄.7H₂O; H₃BO₃. Of this solution, 100 mL per pot was applied to the soil surface in a testtube. Afterwards, one crisphead lettuce seedling, cultivar Tainá, previously grown for 27 days after sowing in polystyrene trays, was planted per pot.

At 10, 20 and 30 days after transplanting the lettuce seedlings, sidedressing was applied in all

treatments, using a solution of, respectively, 20; 20 and 30 mg dm⁻³ urea N. At each sidedressing, 100 mL of solution per pot was applied. Lettuce was harvested on April 10, 2014, at 45 days after transplanting. The height and largest diameter of the shoot of each plant were evaluated. Afterwards, the plants were cut at the ground level, weighed to obtain the fresh matter yield of the shoot, washed, as recommended by Tedesco et al. (1995), and dried to constant weight in a forced air circulation oven, at around 65°C.

After lettuce harvest, to evaluate the residual effect of cattle manure fertilization, arugula was cultivated and subsequently common chicory.

The arugula cultivar Cultivada was planted, and 40 mg dm⁻³ P and 17 mg dm⁻³ N in form of NH₄H₂PO₄ were applied in solution at sowing, to all treatments. The arugula seedlings were thinned to 6 plants per pot, 10 days after sowing. Ten days after thinning, sidedressing was performed in all pots by means of a solution, applying 20 mg dm⁻³ urea N. At the time of arugula harvest, 25 days after thinning, plant height and fresh and dry matter yield of the shoot were evaluated, as described for lettuce.

After arugula was harvested, fertilization was applied in all pots by means of a solution containing 40 mg dm⁻³ P and 50 mg dm⁻³ K, in form of KH₂PO₄. The common chicory cultivar Folha Larga was planted, and 12 days after sowing, thinned to one plant per pot. Sidedressing was carried out 10, 20 and 30 days after thinning, respectively, applying 20; 20 and 30 mg dm⁻³ urea N in solution to all pots. The crop was harvested 45 days after thinning, and plant height and fresh and dry matter yield of the shoot were evaluated.

The results of the soil chemical properties, of the samples collected before transplanting crisphead lettuce, and the yield of each leafy vegetable, as well as the total vegetable yield per pot (sum of lettuce, arugula and common chicory shoot yields) of the treatments were subjected to analysis of variance. The Tukey test was applied to compare the means for the qualitative factor (soils), and polynomial

regression analysis for the quantitative factor (cattle manure rates), using the statistical program AgroEstat (BARBOSA; MALDONADO JÚNIOR, 2015).

RESULTS AND DISCUSSION

Effects of cattle manure on soil fertility properties

There was a significant interaction between the tested cattle manure rates and soil types for organic matter, pH, potential acidity and for the contents of P, Zn and SO_4^{2-}S , indicating that the effect of organic fertilization on these properties depended on the soil type. Cattle manuring and soil type significantly ($P < 0.01$) affected electrical conductivity (EC), and the K^+ , Ca^{2+} and Mg^{2+} contents of the soils.

On the other hand, organic fertilization did not change ($P > 0.05$) the available levels of the soil micronutrients Cu, Mn and Fe. The Cu, Mn and Fe contents of the soils did not fit to linear or quadratic regression equations either. The mean values were, respectively, 1; 9 and 62 mg dm^{-3} in the soil with

166 g kg^{-1} clay (S1); 0.5; 3 and 11 mg dm^{-3} in the soil with 362 g kg^{-1} clay (S2); and 5; 10 and 37 mg dm^{-3} in the soil with 565 g kg^{-1} clay (S3).

The chemical composition of the cattle manure applied and the rapid oxidation of Fe^{2+} and Mn^{2+} to insoluble forms in the soil can possibly explain the results obtained for the soil micronutrients Cu, Mn and Fe. In a 6-year observation period, Menezes and Silva (2008) found no increase either in Cu and Fe contents in sand textured soil fertilized annually with 15 t ha^{-1} manure.

The electrical conductivity and the organic matter, K^+ and Ca^{2+} contents increased linearly with cattle manure rates in the three soils (Figure 1A, B, C and D). For electrical conductivity and K^+ and Ca^{2+} contents, regardless of the soil type, the values increased, respectively, about 6.5; 4.0 and 2.5 times in the treatments treated with the highest cattle manure rate in relation to the control (0 t ha^{-1} organic fertilizer). According to Melo, Silva and Dias (2008), the use of manure as organic fertilizer, depending on the application rates and frequency, may contribute to soil salinization, due to the electrical conductivity of these materials.

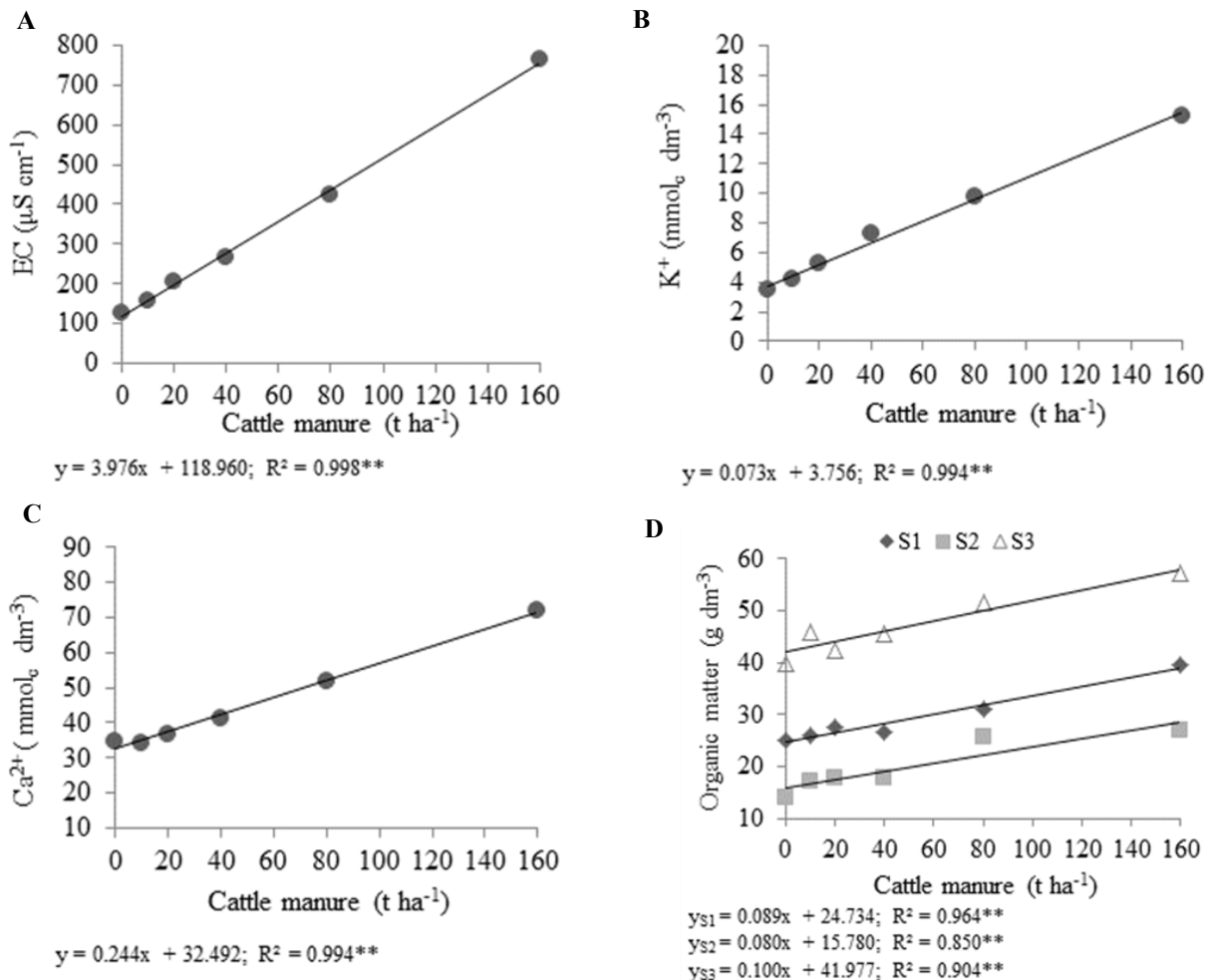


Figure 1. Effect of cattle manure fertilization on the electrical conductivity (A) and contents of K^+ (B), Ca^{2+} (C) and soil organic matter (D). S1, S2 and S3 correspond to soil containing 166; 362 and 565 g kg^{-1} clay, respectively.

In response to the highest rate of organic fertilizer (160 t ha^{-1}), the increase was about 1.7-fold in soils with lower clay content (S1 and S2) and about 1.4-fold in the soil with highest clay content (S3), in comparison with the control (Figure 1D). In laboratory studies, Yagi et al. (2003) observed an increase of 3.5 g dm^{-3} in soil organic C after application of 70 t ha^{-1} cattle manure and 180 days of incubation. Menezes and Silva (2008) also reported an increase in soil organic matter after cattle manure application.

In the soils with lower clay content (S1 and S2), about 53% of organic C added to the soil via cattle manure remained in the soil as an organic matter component, as detected by chemical analysis, while the rest was released into the atmosphere in the form of CO_2 . In S3, the amount of organic C added by cattle manure that remained in the soil was about 63%. More clayey soils are less aerated and contain

more stable aggregates, which protect organic C from the action of soil microorganisms. Thus, the microbial activity and organic residue decomposition are reduced in relation to soils with lower clay contents (FIOREZE et al., 2012).

Increases in organic matter contents of soils can mean improvements in soil physical and chemical properties. The main consequences of increased organic matter content for soil fertility are increased nitrogen pools for plants and higher CEC (GUIMARÃES et al., 2012).

The soils S1 and S3 responded with an increase in pH in CaCl_2 to cattle manure fertilization (Figure 2A). In S2, a quadratic effect was observed and, according to the regression equation, the pH values increased up to an estimated organic fertilizer rate of 114 t ha^{-1} . In addition, there was a linear decrease in the potential acidity (H+Al) of the soils fertilized with cattle manure rates (Figure 2B).

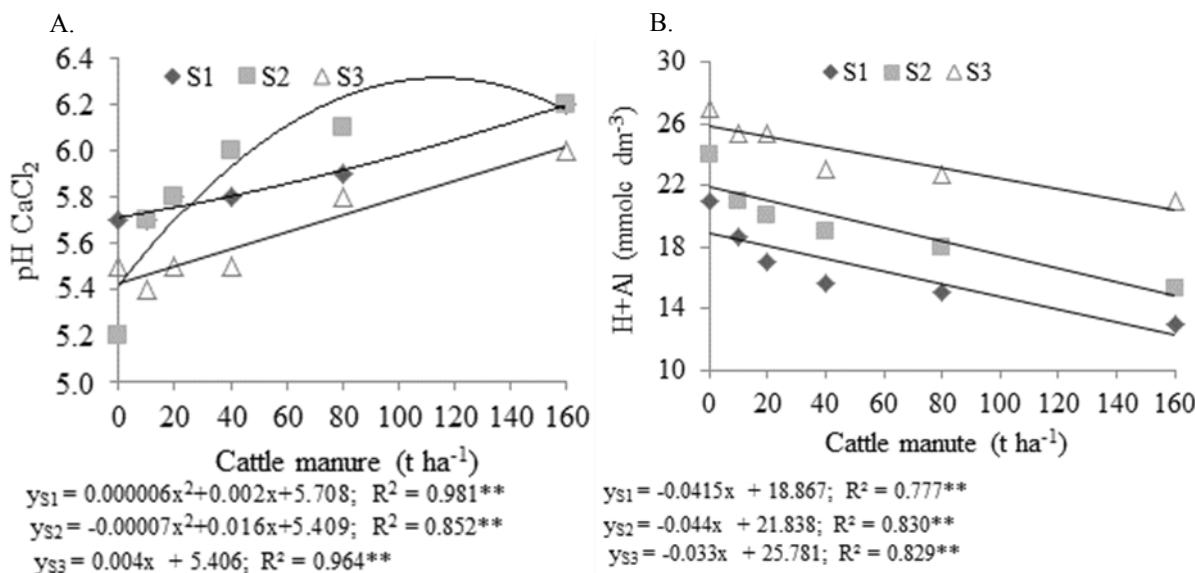


Figure 2. Effect of cattle manure fertilization on pH in CaCl_2 (A) and potential acidity (B) of the soils. S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg^{-1} , respectively.

As shown by the results of pH and H+Al, cattle manure fertilization caused a decrease in soil acidity, and this effect was higher in the soils with lower clay contents (S1 and S2), due to the lower buffering capacity of these soils.

In the S1 and S2 soils, with clay contents of 166 and 362 g kg^{-1} respectively, the pH increased in the mean 0.6 units and potential acidity decreased in the mean 7 mmolc dm^{-3} , in a comparison of the cattle manure treatment of 160 t ha^{-1} with the control. Thus, for these two soils, there was an increase of 0.1 unit in the pH in CaCl_2 for every 30 t ha^{-1} of manure applied, apart from a reduction of about 50% in the potential acidity of the soils after application of the highest cattle manure rate. In soil S3 (565 g kg^{-1} clay) the variations in these properties with organic fertilization were 0.4 units and 5 mmolc dm^{-3} , respectively, corresponding to an increase of 0.1 unit in pH for each 40 t ha^{-1} of

manure supplied to the soil, and a reduction of about 25% in potential acidity.

Similar results were obtained by Yagi et al. (2003); Guimarães et al. (2012); Braos et al. (2015) who also reported increases in soil pH with the application of organic fertilizers. After the application of 20 t kg^{-1} of cattle manure, Braos et al. (2015) observed an increase of 0.4 units in the pH in CaCl_2 of the surface layer (0-20 cm) of a soil containing 340 g kg^{-1} clay. These authors attributed this result to the buffering effect of bicarbonate (HCO_3^-) and to organic anions contained in cattle manure or generated during decomposition.

According to Narambuye and Haynes (2007), organic material contains phenolic, carboxylic and enolic groups, which can consume protons due to the association of hydrogen ions (H^+) in the soil solution with these anions, raising the soil pH.

To three soils with different clay contents and CEC potential, Guimarães et al. (2012) applied up to 500 m³ ha⁻¹ biological sludge from the gelatine industry and found that the soils with lower buffering capacity responded with a higher pH increase to the organic residues.

The Mg²⁺ contents of the three soils were adjusted to the quadratic model as a function of cattle manure rates, and the soil contents under organic fertilization varied in the mean from 13 (high) to 16 mmol_c dm⁻³ (very high) (Figure 3A), considering the criteria of CFSEMG (1999). In relation to the

SO₄²⁻ S contents, depending on the soil type, the increase with organic fertilization was higher (S3) or lower (S2) (Figure 3B). The small increase in Mg²⁺ contents of the soils under organic fertilization was possibly due to a low content of this nutrient in the cattle manure. In relation to the SO₄²⁻ S contents, the results can be explained by the differences in the initial nutrient contents between the soils, since the content was considered low in S3 and high in S2, according to the classification proposed by Rajj et al. (2001).

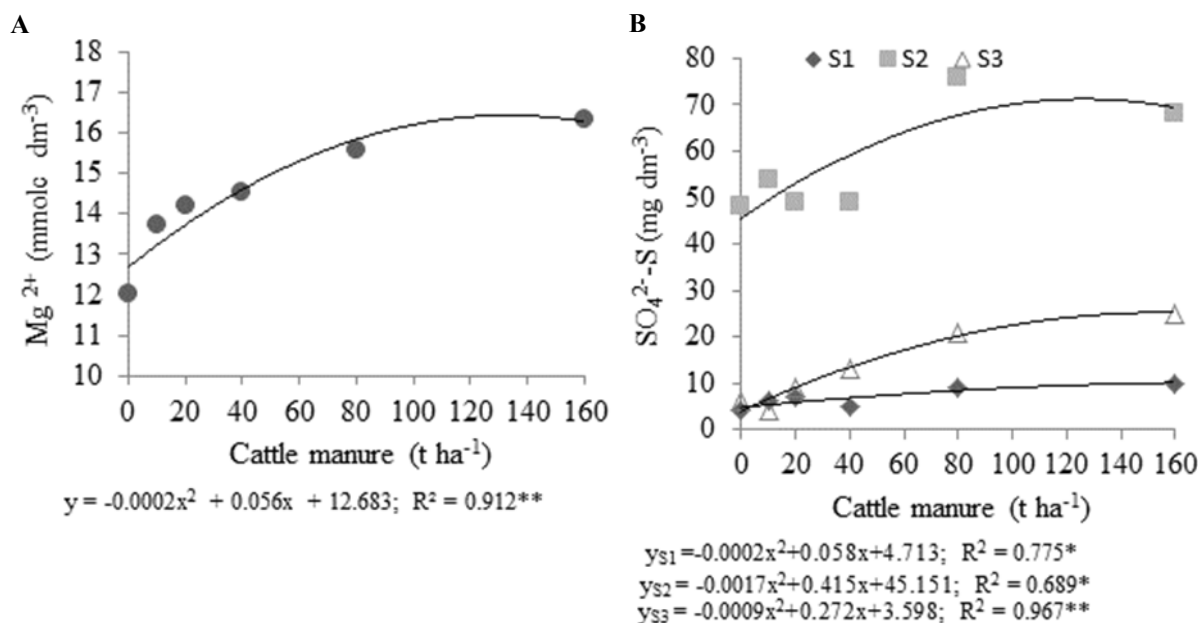


Figure 3. Effect of cattle manure fertilization on the contents of Mg²⁺ (A) and SO₄²⁻ S (B) of the soil. S1, S2 and S3 correspond to soils with clay contents of 166, 362 and 565 g kg⁻¹, respectively.

In relation to P and Zn, the contents of the three soils increased with organic fertilization (Figures 4A and 4B). In the case of P, the increases were more pronounced in the soil with lower clay content (S1), where the contents increased 41 times in the comparison of the control with the highest manure rate treatment. In the case of the soils S2 and S3, the increases in P contents were about 20 and 15-fold, respectively. This was due to the lower adsorption of the nutrient to mineral components of the solid phase, particularly Fe and Al sesquioxides, and to the greater contribution of organic and inorganic P forms of manure to the fraction available to the plants (P-Mehlich), in the soil with lower clay content (S1).

In areas with predominantly sandy soils treated with 12 to 20 t ha⁻¹ cattle manure for a period of 15 to 40 years, Galvão, Salcedo and Oliveira (2008) observed a mean increase of 20 times the available P content compared with areas not treated with organic fertilizer. Braos et al. (2015) also found

an increase in the levels of soil available P by the application of cattle manure. In the field, these authors observed that most of the P of cattle manure is in highly soluble inorganic and organic forms, which are rapidly transformed into the available form. According to these authors, the increase in soil available P by organic fertilization is due to the presence of P in manure, the increase in soil pH resulting from organic fertilization, and anion release during decomposition.

As the pH increases, the intensity of phosphate adsorption and precipitation processes decreases, which can lead to the extraction of higher amounts. Similarly, the release of organic anions can decrease P adsorption by competition or coating of the oxide surfaces and there may also be Fe and Al complexation by the simple organic compounds released from decomposition and, consequently, decrease of the phosphate precipitation reactions with these elements (SOUZA et al., 2006; BRAOS et al., 2015).

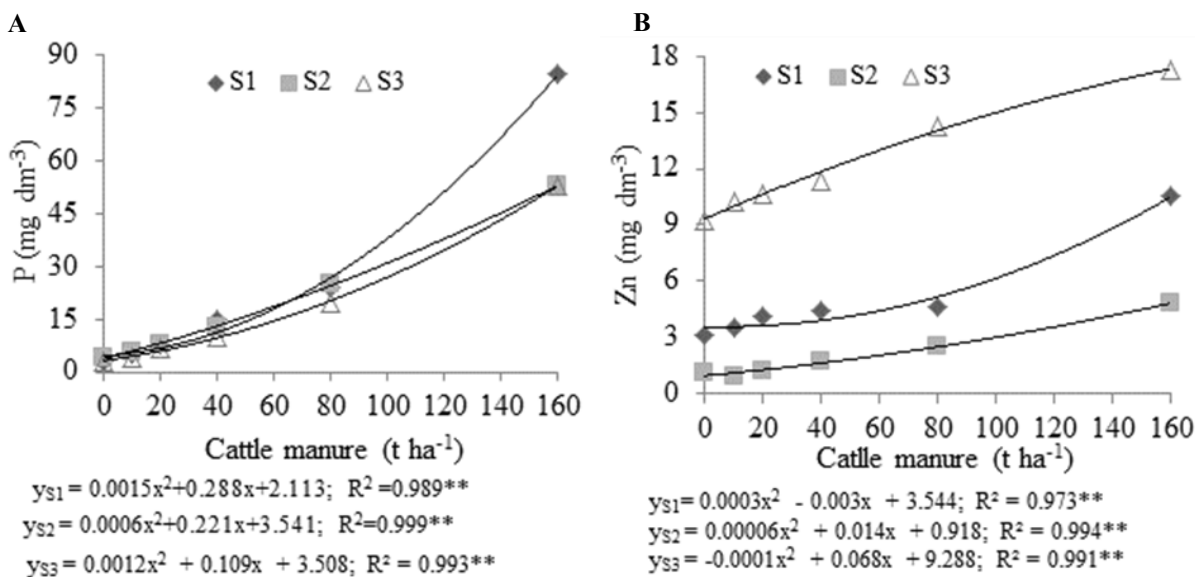


Figure 4. Effect of cattle manure fertilization on P-Mehlich (A) and Zn (B) soil contents. S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg⁻¹, respectively.

Zn levels in the soil showed increases of 2 to 4 times, depending on the soil used, with the application of the highest rate of cattle manure, with a lower increase in soil with higher clay content (S3). This result was probably due to the higher adsorption of the nutrient in solid phase components of the soil with higher clay content. Similar results were obtained by Menezes and Silva (2008), which verified that Zn levels of sandy soil doubled after annual applications of 15 t ha⁻¹ of manure for six

years.

Comparing the differences between soils in terms of chemical properties, the soils S1 and S3 had the highest levels of K⁺, Mg²⁺, Mn, and electrical conductivity than S2, regardless of the rate of cattle manure used (Table 4). In addition, in the soil with highest clay content (S3), the Ca²⁺ contents, organic matter, Cu and Zn were also higher than in the other soils.

Table 4. Fertility properties in soils with different clay contents.

Soil	EC	OM	pH	K ⁺	Ca ²⁺	Mg ²⁺	H+Al
	μS cm ⁻¹	g dm ⁻³		mmolc dm ⁻³			
S1*	351 A	29 B	5.9 A	7.8 A	47 B	15 A	17 C
S2	269 B	20 C	5.8 A	6.3 B	31 C	13 B	20 B
S3	353 A	47 A	5.6 B	8.5 A	56 A	15 A	24 A
Soil	SO ₄ ²⁻ -S	P	Zn	Cu	Mn	Fe	
	mg dm ⁻³						
S1*	7 C	23 A	5.0 B	1.0 B	9 A	62 A	
S2	57 A	18 B	2.0 C	0.5 C	3 B	11 C	
S3	13 B	16 C	12.2 A	5.4 A	10 A	37 B	

*S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg⁻¹, respectively. OM - organic matter; EC - electrical conductivity. Means followed by the same letter in the column did not differ by the Tukey test (P < 0.05).

It was also observed that the acidity of soil S3 was higher than that of the other soils, because the pH value was lower and the potential acidity higher, especially in the treatments treated with the two highest cattle manure rates. For P, the contents were lowest in S3, in response to the three highest organic fertilizer rates. In relation to SO₄²⁻-S, the contents were highest in soil S2. Aside from the clay content, the initial value of each chemical property and the CEC of the soils possibly explain these results.

Effect of cattle manure on leafy vegetable yields

There was a significant effect of interaction between cattle manure rates and soil types on plant height of lettuce, arugula and common chicory plants, on fresh matter and dry matter yield of lettuce, arugula and common chicory, and on the total yield of leafy vegetables, indicating that the effect of organic fertilization on these properties depended on the soil type. Organic fertilization with cattle manure did not alter (P > 0.05) the shoot diameter of lettuce. This parameter did not fit to the regression equations either, and the mean values were 48; 42 and 48 cm for the soils S1, S2 and S3,

respectively.

There was a linear increase in plant height of crisphead lettuce in the soils S1 and S3, of arugula in all three soils (Figures 5A and 5B), and of common chicory only in soil S3 with cattle manure fertilization (Figure 5C). For the other soil types, it was not possible to fit an equation, observing a mean

plant height of 22.8 cm for lettuce, 31 for arugula and 30 cm for common chicory. A comparison of the extreme organic fertilizer rates (0 and 160 t ha⁻¹), according to the soil type, showed plant height increases from 0 to 12% for lettuce, from 41 to 85% for arugula, and from 0 to 36% for common chicory.

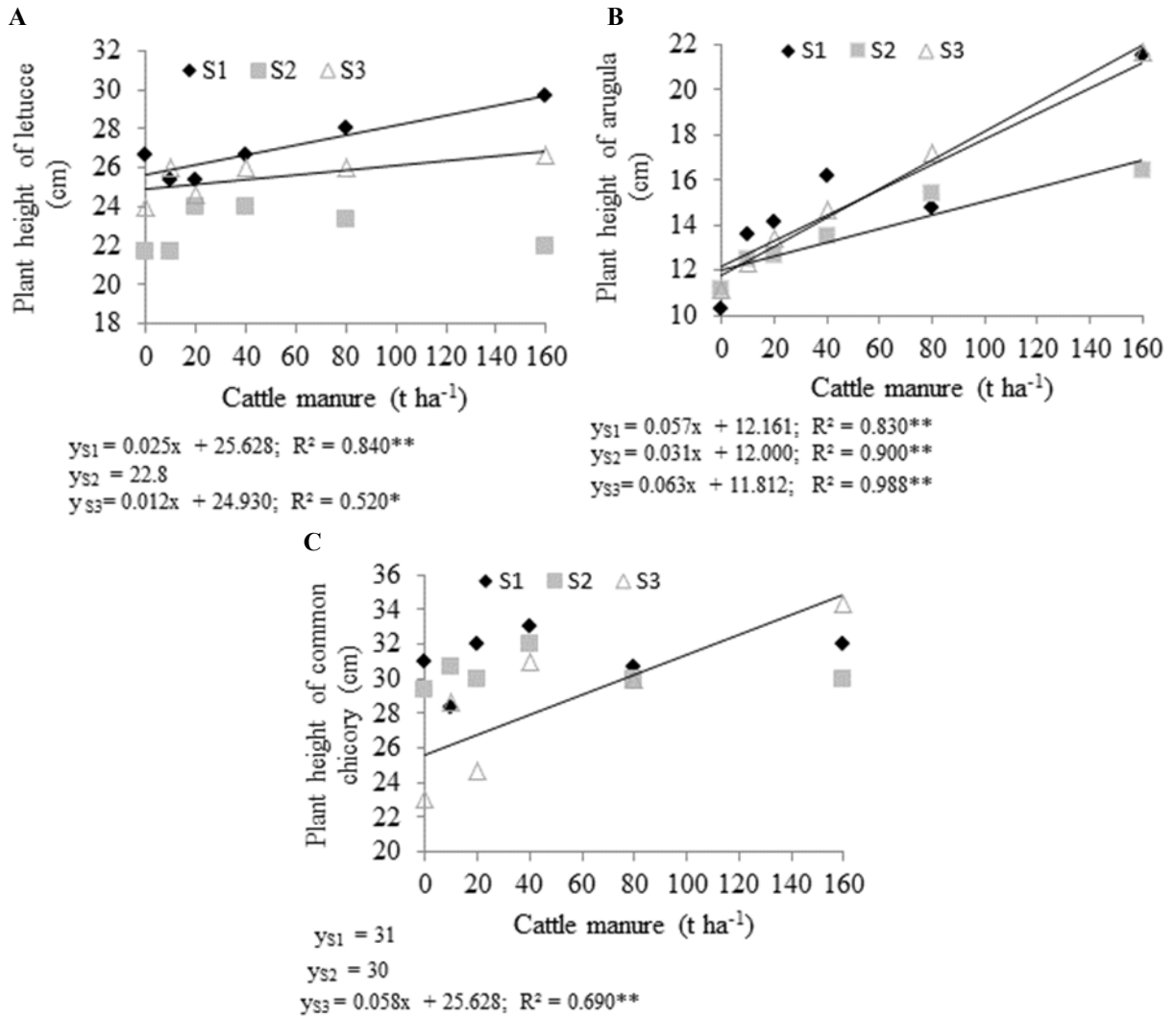


Figure 5. Effect of cattle manure fertilization on plant height of lettuce (A), arugula (B) and common chicory (C), cultivated subsequently. S1, S2 and S3 correspond to soils with contents of 166; 362 and 565 g kg⁻¹ clay, respectively.

Fresh lettuce yield increased linearly in response to cattle manure fertilization in S1 and S3 (Figure 6), and in these two soils, lettuce yield under organic fertilization ranged from 729 to 986 g plant⁻¹. In soil S2, a quadratic effect was observed, with an increase in fresh lettuce matter up to the estimated rate of 114 t ha⁻¹.

The increase in fresh dry matter yield of crisphead lettuce in response to organic fertilization was 1.4 times higher in soils S1 and S3. In S2, the estimated maximum yield of fresh dry matter of lettuce at a rate of 114 t ha⁻¹ would be 1.4 times that of the control.

In a field experiment with sandy textured soil,

Pôrto et al. (2008) obtained a linear increase in lettuce yield of the curly group, with the application of up to 150 t ha⁻¹ cattle manure. In another study, Rodrigues et al. (2008) found that rates of 60 t ha⁻¹ cattle manure increased the plant height and fresh and dry matter yields of arugula in a greenhouse pot experiment.

With regard to lettuce dry matter, a linear yield increase in response to soil manure rates was only observed in soil S3, which exceeded that of the control 1.5 times (Figure 7A). In the soils S1 and S2, the mean lettuce dry matter yield was 29.4 and 21.7 g plant⁻¹, respectively.

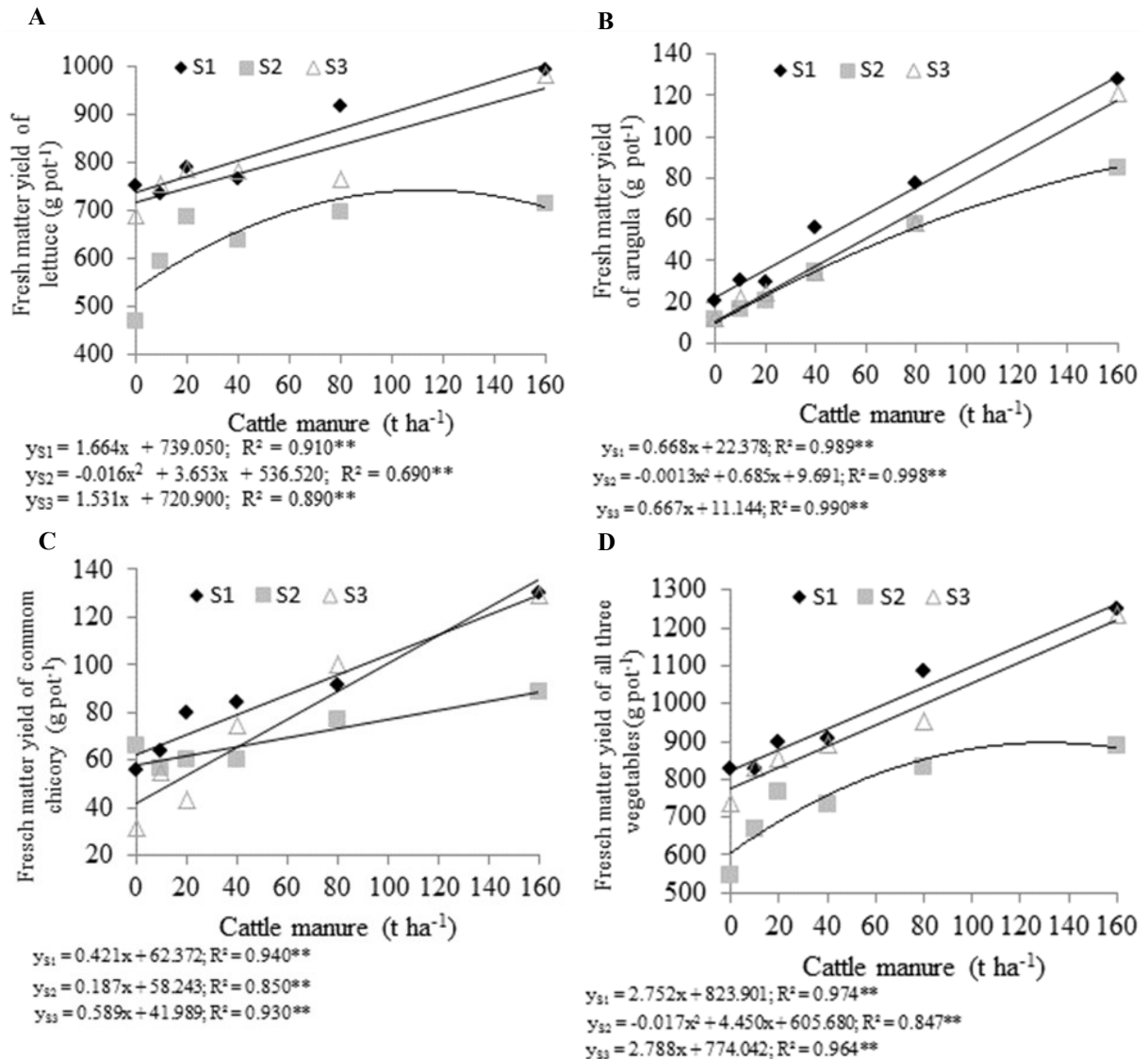


Figure 6. Effect of cattle manure fertilization on fresh matter yield of lettuce (A), arugula (B), common chicory (C) and all three vegetables (lettuce+arugula+common chicory), cultivated subsequently. S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg⁻¹, respectively.

The increase in electrical conductivity of the three soils increased to close to 800 $\mu\text{s cm}^{-1}$ in response to organic fertilization (Figure 1A), which did not affect growth and yields of crisphead lettuce or the other vegetables evaluated.

For the leafy vegetables arugula and common chicory, fresh and dry matter yields increased by cattle manure applications to the three soils (Figures 6 and 7). In the case of arugula, depending on the soil used, the application of the highest rate of cattle manure (160 t ha⁻¹) provided 5.7 to 10.3-fold increases in fresh matter yield, and 7 to 12-fold increases in dry matter yield, compared to the control. For common chicory, the observed increases in fresh and dry matter yield, respectively, were 1.5 to 3.2-fold, and 1.6 to 4-fold.

The increases in arugula and common chicory yield in response to organic fertilization were more

marked than for lettuce, indicating that the residual effect of cattle manuring on vegetable yield was higher than the effect obtained in the first cultivation after organic fertilization. This can be attributed to the slow release of N from cattle manure, and to the fact that the plants of the first crop exploited the soil N pool.

In a pot experiment with sandy soil in a greenhouse, Sampaio, Oliveira and Nascimento (2007) found that cattle manure caused immobilization of soil N in the first month after incorporation. After this period, N release increased progressively, reaching the highest amounts between three and six months after incorporation. Still, according to these authors, the effect of manure on nutrient supply for maize plants was highest in the third or fourth consecutive crop.

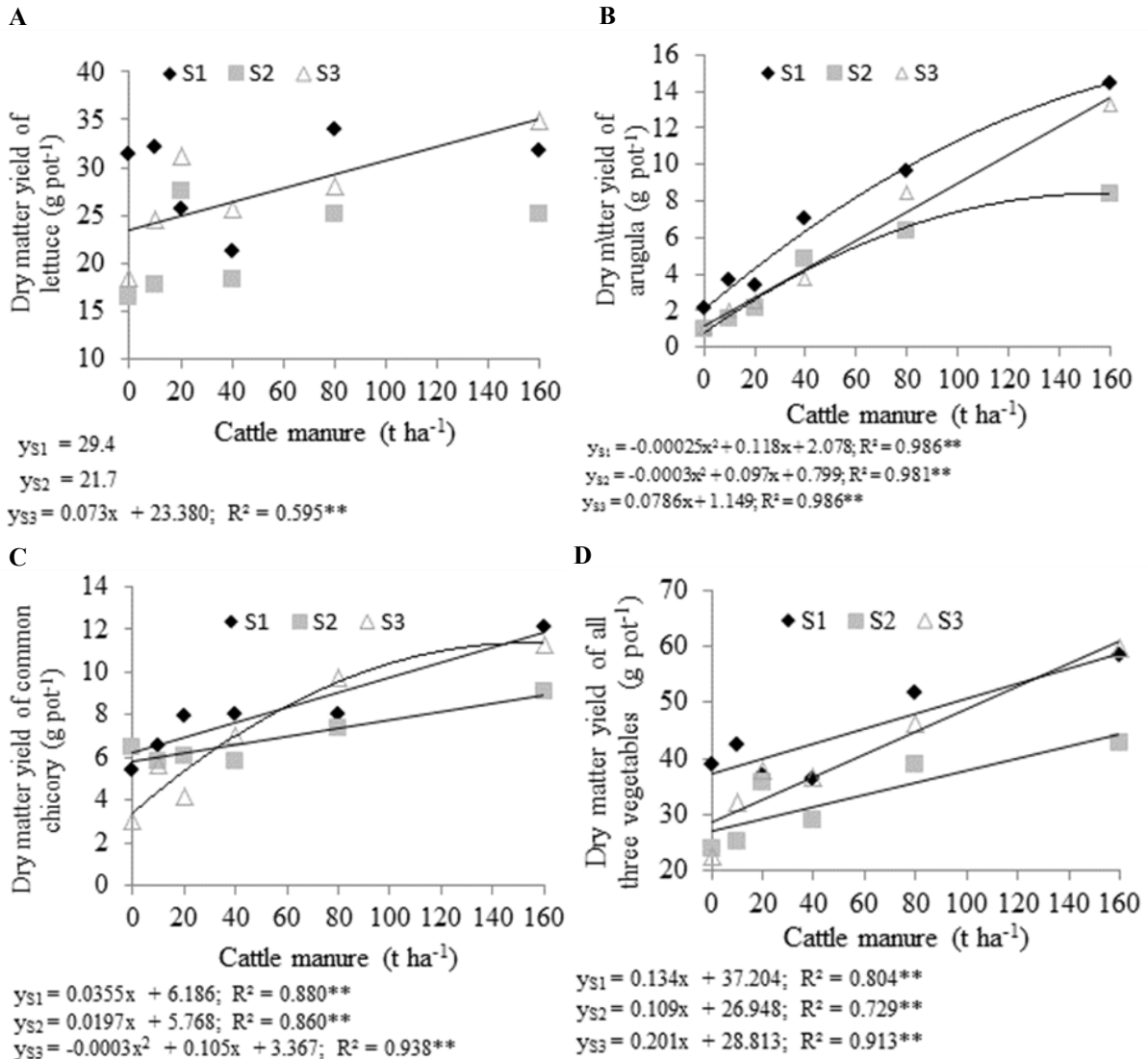


Figure 7. Effect of cattle manure fertilization on dry matter yield of lettuce (A), arugula (B), common chicory (C) and all three vegetables (lettuce+arugula+common chicory) (D), cultivated subsequently. S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg⁻¹, respectively.

In the field, Peixoto Filho et al. (2013) planted five subsequent lettuce crops, and stated an increase in the productivity of this vegetable in response to organic fertilization, as well as residual effects of animal manures, in particular of cattle manure, until the third crop. In addition, according to these authors, the mineralization of cattle manure was slower than that of chicken manure, which has a direct influence on nutrient release from organic fertilizers to plants, especially of crops with a shorter cycle, such as lettuce.

The total fresh matter yield of the vegetables (lettuce+arugula+common chicory) increased linearly with organic fertilization in soils S1 and S3. In S2, the effect was quadratic, with increases up to

the estimated manure rate of 131 t ha⁻¹ (Figure 6D). For the three soils, the total fresh matter yield of the vegetables increased about 1.5 times in relation to the control after application of the highest cattle manure rate. The improvement in soil fertility by organic fertilization possibly explains this increase in vegetable yield.

With regard to dry matter, the total yields in the three soils also increased linearly with organic fertilization and were, in the mean, 1.8 times higher in the 160 t ha⁻¹ cattle manure than the control treatment (Figure 7D).

Growth and yields of the leafy vegetables were generally higher in the soil with lowest clay content (S1) than in the others (Table 5).

Table 5. Parameters evaluated in leafy vegetables in soils with different clay contents.

Soil	LPH	APH	CCPH	LSD	LSFM	ASFM
	cm			g pot ⁻¹		
S1*	26.9 A	15.1 A	31.2 A	48 A	825.1 A	56.9 A
S2	22.8 B	13.6 B	30.3 A	42 B	797.5 A	37.6 C
S3	25.6 A	15.1 A	28.6 A	48 A	633.4 B	45.6 B
Soil	CSFM	LSDM	ASDM	CSDM	TSFM	TSDM
	g pot ⁻¹					
S1*	84.1 A	29.4 A	6.7 A	8.0 A	966.2 A	44.2 A
S2	67.9 B	21.7 B	4.1 C	6.8 B	738.9 B	32.6 C
S3	72.4 B	27.2 A	5.2 B	6.8 B	918.1 A	39.2 B

*S1, S2 and S3 correspond to soils with clay contents of 166; 362 and 565 g kg⁻¹, respectively. LPH - lettuce plant height; APH - arugula plant height; CCPH - common chicory plant height; LSD - lettuce shoot diameter; LSFM - lettuce shoot fresh matter; ASFM - arugula shoot fresh matter; CSFM - common chicory shoot fresh matter; LSDM - lettuce shoot dry matter; ASDM - arugula shoot dry matter; CSDM - common chicory shoot dry matter; TSFM - total shoot fresh matter of leafy vegetables (lettuce+arugula+common chicory); TSDM - total shoot dry matter of leafy vegetables (lettuce+arugula+common chicory). Means followed by the same letter in the column do not differ by the Tukey test (P <0.05).

The results indicated that the vegetable crops lettuce, arugula and common chicory, cultivated one after the other, respond positively to the application of high cattle manure rates in different soils, even when combined with mineral fertilization.

CONCLUSIONS

The application of up to 160 t ha⁻¹ cattle manure reduces soil acidity and increases nutrient contents, particularly of P, K and Zn, in soils with 166 to 565 g kg⁻¹ clay content;

Fertilization with cattle manure at rates of up to 160 t ha⁻¹ increases the electrical conductivity of soils, without affecting growth and yield of leafy vegetables;

Cattle manuring increases the yield of lettuce, as well as of arugula and common chicory grown afterwards.

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