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Doses of organic compost on yield and accumulation of macronutrients on endive

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ABSTRACT

The authors evaluated the effects of doses of organic compost on the production and accumulation of macronutrients in endive plants in two areas with different fertility levels. The experiments were carried out at Fazenda Experimental São Manuel, located in the municipality of São Manuel, São Paulo State, Brazil. The study was carried out in a completely randomized design with seven treatments, six doses of organic compost (0, 35, 70, 105, 140 and 175 t/ha) and one additional treatment with inorganic fertilizer (N-P-K 4-14-8) and four replicates. In both areas, when the dose of organic compost was increased, the authors noticed a linear increase in fresh matter weight, number of leaves and plant height. In high-fertility area, compared to control (dose 0), using the highest dose (175 t/ha), the authors observed an increase of 280, 58 and 101% in fresh matter weight, number of leaves and plant height, respectively. For dry weight, we observed a linear increase in low fertility area and quadratic effect in high fertility area, with maximum estimated dry matter of 22.26 g applying 144 t/ha of organic compost. The nutrient accumulation was proportional to dry matter, with a linear increase in low fertility area and quadratic effect in high fertility area. The decreasing order of accumulated nutrients was K>N>Ca>P>S>Mg, with the highest values, in high fertility area, of 1,269, 471, 185, 91, 53 and 35 mg/plant, respectively, for doses varying from 121 to 158 t/ha.

Keywords: *Cichorium endivia*, soil fertility, plant nutrition.

RESUMO

Doses de composto orgânico na produtividade e acúmulo de macronutrientes em chicória

Objetivou-se com este trabalho, avaliar o efeito de doses de composto orgânico na produção e no acúmulo de macronutrientes em chicória em duas áreas com diferentes níveis de fertilidade. Os experimentos foram conduzidos na Fazenda Experimental São Manuel, localizada no município de São Manuel-SP. O delineamento experimental utilizado foi de blocos ao acaso, com sete tratamentos, sendo seis doses de composto orgânico (0, 35, 70, 105, 140 e 175 t/ha) e um tratamento adicional com adubação inorgânica à base do formulado 4-14-8, e quatro repetições. Em ambas as áreas, quando aumentou-se a dose de composto orgânico, houve também um aumento linear no peso da matéria fresca, número de folhas e altura da planta. Na área de alta fertilidade, em relação ao controle (dose 0), na dose máxima (175 t/ha) observou-se aumento de 280, 58 e 101% do peso fresco, número de folhas e altura da planta, respectivamente. Para o peso seco, observou-se aumento linear na área de baixa fertilidade e efeito quadrático na área de alta fertilidade, com estimativa máxima de matéria seca em 22,26 g quando aplicados 144 t/ha de composto orgânico. O acúmulo de nutrientes foi proporcional à matéria seca, com aumento linear na área de baixa fertilidade e efeito quadrático na alta fertilidade. Além disso, a ordem decrescente dos acúmulos pela parte aérea da planta de chicória foi: K>N>Ca>P>S>Mg, com valores máximos de 1.269, 471, 185, 91, 53 e 35 mg/planta, respectivamente.

Palavras-chave: *Cichorium endivia*, adubação orgânica, nutrição de plantas.

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Endive (*Cichorium endivia*) is an herbaceous vegetable and belongs to the Asteraceae family. It is similar to lettuce, but more fibrous. This herbaceous plant grows best at temperatures ranging from 20 to 26ºC. Sowing is done generally in autumn and winter. Even though, it can be planted all year long in high elevation area (Ryder, 1998; Filgueira, 2008).

In Brazil, little information is available on endive nutritional requirements (Furlani & Purquerio, 2010). Therefore, lettuce and other leafy green vegetables are used as reference for endive fertilizer recommendations. However, they are not the same species, and the recommendations could be different. According to Feltrin *et al*. (2008), nitrogen (N) and potassium (K) are the most extracted nutrients by endive.

Organic and inorganic fertilizers provide necessary nutrients for plants, so it is extremely important to apply fertilizers when cultivating vegetables. In organic systems, producers have been using manure, compost or worm humus (Souza & Resende, 2014). Organic fertilization increases cation exchange capacity (CEC), nutrient content and soil base saturation (Damatto Junior *et al*., 2006; Cardoso *et al*., 2011), and it also optimizes plant nutrients and productivity in several crops. Organic compost shows to be a promising

alternative which is capable of reducing the application of inorganic fertilizers. Moreover, the importance of studying different doses of organic fertilizer for vegetables in organic systems is indisputable.

Despite the importance of organic fertilizer and its benefits to soil and crop productivity, no studies on endive were found. In lettuce, which belongs to the same family, many researches related that the use of organic matter has increased production and nutrient content (Villas Boas *et al*., 2004; Yuri *et al*., 2004; Lopes *et al*., 2005; Oliveira *et al*., 2006; Quadros *et al*., 2012).

Therefore, the present study was carried out to evaluate the effect of different doses of organic compost in the production and macronutrients accumulation of endive in soils with different initial fertility levels.

MATERIAL AND METHODS

The experiments were carried out at Fazenda Experimental São Manuel, belonging to Faculdade de Ciências Agronômicas of Universidade Estadual Paulista, Botucatu, São Paulo State, Brazil. The local climate, according to Köppen classification, is Cfa type, warm temperate (mesothermal) humid with average annual rainfall of 1,377 mm (Cunha & Martins, 2009). The average temperature in the hottest month is 22.0°C and in the coldest month is 17.5°C, with average annual temperature of 21°C and average annual rainfall of 1,445 mm (Cunha & Martins, 2009).

Two experiments were carried out in two areas denominated "high" and "low" fertility areas. The soil of both areas is classified as typical dystrophic Red Latosol (Oxisoil) (Embrapa, 2013).

According to soil analysis, "low" fertility area presented: $pH_{(CaCl2)}$= 5.2; organic matter (OM)= 9 g/dm^3; P_{resin}= 0 mg/dm^3; H+Al= 17 mmol$_c$/dm^3; K= 1.4 mmol$_c$/dm^3; Ca= 16 mmol$_c$/dm^3; Mg= 4 mmol$_c$/dm^3; SB= 22 mmol$_c$/dm^3; CEC= 39 mmol$_c$/dm^3 and V= 56%. These values show zero phosphorus content, low potassium, high calcium and low magnesium, according to Raij *et al*. (1997). The "high" fertility area presented: $pH_{(CaCl2)}$= 5.8; OM= 12 g/dm^3; P_{resin}= 99 mg/dm^3; H+Al= 13 mmol$_c$/dm^3; K= 2 mmol$_c$/dm^3; Ca= 28 mmol$_c$/dm^3; Mg= 6 mmol$_c$/dm^3; SB= 36 mmol$_c$/dm^3; CTC= 49 mmol$_c$/dm^3 and V= 74%. According to Raij *et al*. (1997), phosphorus and calcium content can be considered high and potassium and magnesium content are medium in this area. Liming was carried out two months before planting to increase the base saturation to 70%, in the "low" fertility area, as recommended by Trani *et al*. (1997).

The study was carried out in a completely randomized design, with seven treatments, six doses of organic compost (0, 35, 70, 105, 140 and 175 t/ha on wet basis, with 31% humidity) and one additional treatment with inorganic fertilizer and four replicates.

The inorganic fertilization consisted of formulated 4-14-8 (N-P_2O_5-K_2O) at doses of 2.85 and 1.45 t/ha [recommended by Trani *et al*. (1997) for endive] in "low" and "high" fertility areas, respectively.

We used the organic compost Provaso. Its chemical analysis presented the following characteristics, according to the methodology described by MAPA (2007), given as a percentage of dry matter: N= 0.5; P_2O_5= 0.6; K_2O= 0.4; Ca= 1.4; Mg= 0.2; S= 0.2; U-65°C= 31.0; total OM= 15.0; total C=8.0. For every 100 t/ha of the compost, the authors applied 345, 414 and 276 kg/ha of N, P_2O_5 and K_2O, respectively.

Organic compost and formulated fertilizer (4-14-8) were evenly distributed over the seedbeds surface and incorporated with hoes to a depth of 20 cm. This incorporation was carried out five days before seedling transplanting.

The authors used Malan cultivar, sown on May 17, 2013, in polypropylene trays with 200 cells, containing commercial substrate for vegetable seedling production. On June 20, 2013 (i.e. 33 days after sowing). Seedlings were transplanted into 1.2-meter- length seedbeds, in four longitudinal lines and eight plants per line in each plot, spaced 30 cm between rows and 25 cm between plants, totalling 32 plants per plot. Only the four plants transplanted into the middle of each plot were evaluated.

Top dressing fertilization was carried out 20 days after the seedling transplanting with 360 kg/ha of ammonium sulphate in inorganic fertilizer treatment (Trani *et al*., 1997) and 750 kg/ha of castor bean cake in the other six treatments, including control (zero dose of compost), (Silva *et al*., 2016). The castor bean showed 9% moisture and 4.79% of N in dry matter, which resulted in an application of 36 kg/ha of N.

Weed control was carried out using hoes when necessary. In the lack of rainfall, irrigation was daily, about 3 mm, using sprinkler system. The authors did not notice any need for controlling pests and diseases.

Harvest was carried out on August 6, 2013, when the most developed plants occupied completely the area. The evaluated traits were shoot fresh weight and shoot dry matter weight; plant height; number of leaves per plant and accumulation of nutrients in shoots. To obtain dry matter, plants were put in drying chamber with forced-air ventilation at 65ºC until constant weight.

To determine the amount of accumulated nutrients, the authors used one plant per plot, which was washed before drying. After removing the excess of water, the samples were placed in paper bags, identified and taken into the drying oven with forced-air circulation at 65ºC until constant weight. After drying, the samples were weighed. Then, each sample was ground in a Wiley mill. After grinding, all samples were taken to Plant Analysis Laboratory, Department of Soil and Environmental Resources, to obtain the contents (g/kg) of nutrients: nitrogen, phosphorus, potassium, calcium, magnesium and sulphur, according to the methodology described by Malavolta *et al*. (1997). The amount of extracted nutrients was obtained by multiplying the content of each nutrient by dry matter weight of the sample.

Data were subjected to analysis of variance and regression, to verify the effect of compost doses in the evaluated traits. Joint analysis was also used to compare the two areas, according to

Banzatto & Kronka (2006), using F test. To compare organic with inorganic fertilizers treatments, the authors used Dunnett's test (5% probability). Analysis was carried out using Sisvar 5.0 program (Ferreira, 2010), except Dunnett's test, which the authors analyzed using Assistat 7.7 beta program (Silva, 2008).

RESULTS AND DISCUSSION

Doses of organic compost

In both areas, when the organic compost dose was increased, the authors noticed a linear increase in fresh matter weight, number of leaves and plant height (Figure 1).

In the "high" fertility area, for each 10 t/ha of organic compost, fresh weight (16.11 g), number of leaves (1.06) and plant height (0.60 cm) increased (Figure 1). Compared to control (dose 0), in the highest dose (175 t/ha) the authors observed an increase of 280, 58 and 101% in fresh weight, number of leaves and plant height, respectively. On the other hand, in the "low" fertility area, for each 10 t/ha of organic compost, fresh matter (12.75 g), number of leaves (1.55) and plant height (0.38 cm) increased. Compared to control (dose 0), in the highest dose (175 t/ha) the authors verified an increase of 725, 125 and 94% in fresh weight, number of leaves and plant height, respectively. These high increases, in both soils, demonstrate the importance of application of organic compost for endive production. During the experiment, the average temperature was 18°C, which is below the ideal temperature for the proper development of endive (i.e. 20 to 26°C), according to Ryder (1998). Even at this temperature, endive has developed in a satisfactory manner, but slower than expected, with a total cycle time of 80 days.

For dry matter production, the authors observed a linear increase in low fertility area, with an increase of 0.70 g/plant for each 10 t/ha of organic compost (Figure 1). For the high fertility area, quadratic effect was observed, with the maximum dry matter mass of 22.26 g, for the dose of 144 t/ha of organic compost. This was due to the fact that the high fertility area presented higher initial amounts of nutrients when compared to the low fertility area. Thus, with lower doses of the compost, the necessity of the plants could have been supplied in the high fertility area and, when using too high doses, the dry matter mass decreased.

Yuri *et al*. (2004) studied doses of organic compost (0-80 t/ha) on lettuce, which showed significant outcomes for all evaluated traits (fresh matter weight, head circumference and stem diameter) with a quadratic effect for all. They obtained maximum yield by applying 56.0 t/ha before planting, i.e., much lower dose than the ones used in the present research with endive. However, the compost used in the present study had low values of N and K (0.5% N and 0.4% K_2O, both as % of dry matter), while Yuri *et al*. (2004) had 1.0% N and 0.7% K_2O. Also Oliveira *et al*. (2006) had a significant effect of lettuce cultivar Vera in response to top-dressing with poultry litter, reaching maximum production of fresh matter with 23.4 t/ha. However, poultry litter is richer in nitrogen (3.5% N) and potassium (3.0% K).

Unlike inorganic fertilizers, the mentioned doses of organic fertilizers may not be good enough for a recommendation. It is essentially

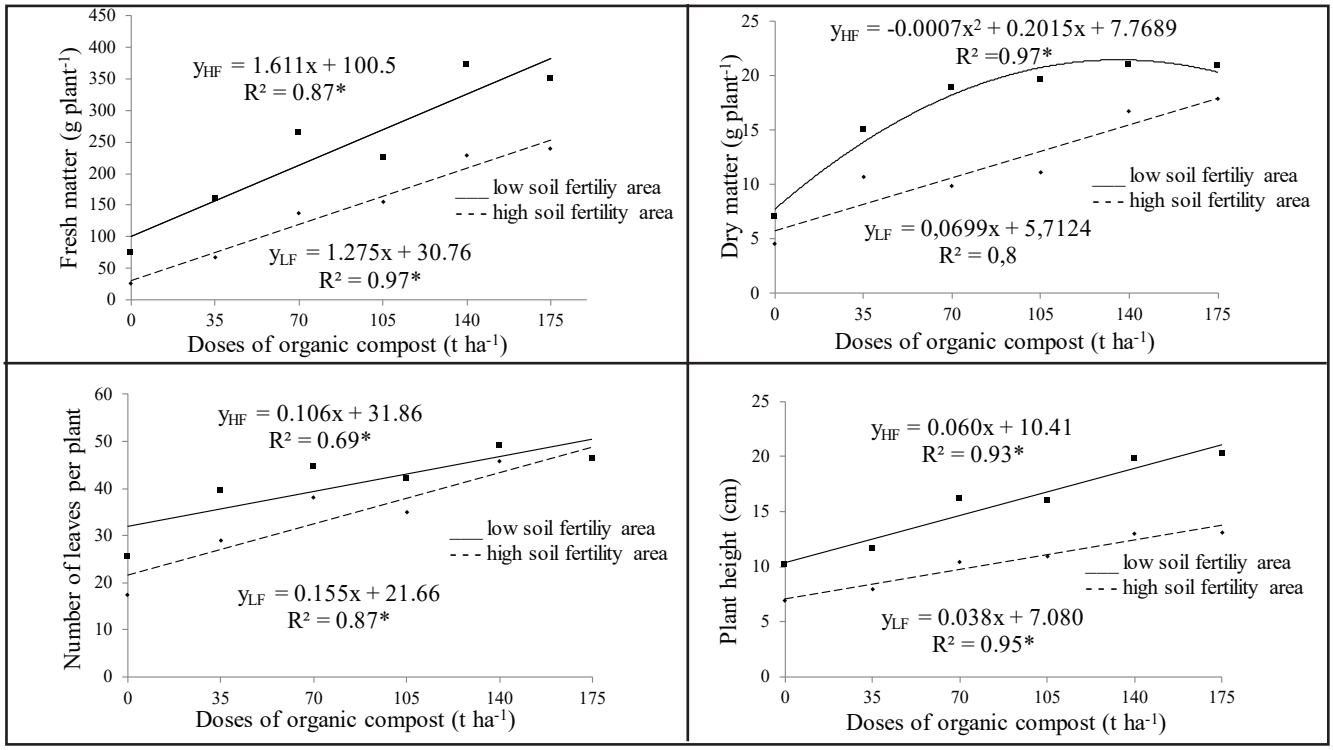

Figure 1. Fresh and dry matter weight, number of leaves, plant height according to different doses of organic compost in the "high" (y_{HF}) and "low" (y_{LF}) soil fertility area. São Manuel, UNESP, 2013.

important to know the fertilizer chemical composition to be able to estimate the amount of each nutrient that is being applied. In the present study, the doses which demonstrated better results for dry matter production were much higher than the highest dose (80 t/ha) recommended by Trani *et al*. (1997) for endive. In addition, for different amounts of nutrients in organic fertilizer, an official recommendation, described by some cited authors, also include inorganic fertilizer. However, a producer, who only works with organic system, has only organic fertilizers as an option. Whilst, organic fertilizers release nutrients over a fairly long period, being not that immediate as inorganic, which also explains the need for higher doses.

In both areas, some influences of organic compost on the nutrient accumulation of endive could be noticed. In the "low" fertility area, a linear effect for all macronutrients was observed. However, in the "high" fertility area, analysis showed quadratic effect for all macronutrients (Figure 2), which was expected, because accumulation is generally proportional to the dry matter weight, as seen in Figure 1. The increase in accumulation is due to the release of nutrients by organic compost. The soils had low organic matter and in tropical conditions, the decomposition is very fast (Souza & Resende, 2014), and it is necessary to add organic fertilization in high quantities.

The decreasing order of macronutrients accumulation on endive was K>N>Ca>P>S>Mg. However, Feltrim *et al*. (2008) obtained a different order: N>K>Ca>Mg>S>P. In the "high" fertility area, the highest accumulation rates were 1,269, 471, 185, 91, 53, and 35 mg/plant of K, N, Ca, P, S and Mg, respectively, with doses of organic compost ranging from 121 to 158 t/ha. Feltrim *et al*. (2008) had already

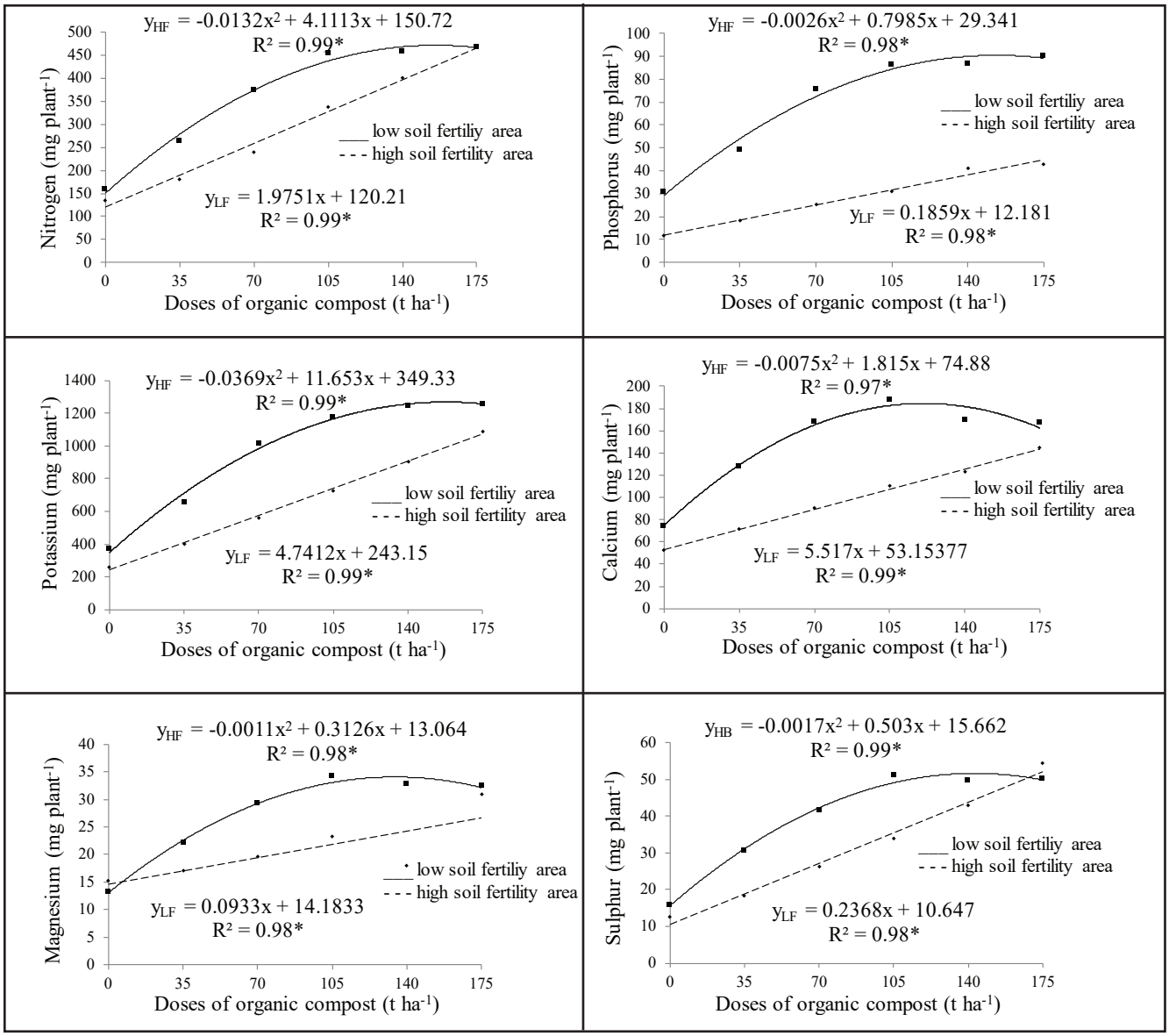

Figure 2. Nitrogen, phosphorus, potassium, calcium, magnesium and sulphur accumulation in endive, according to different doses of organic compost in the "high" (y_{HF}) and "low" (y_{LF}) soil fertility area. São Manuel, UNESP, 2013.

Table 1. Comparison of organic compost doses with inorganic fertilizer averages for fresh and dry matter weight, height and number of leaves per plant of endive in the "low" and "high" soil fertility areas. São Manuel, UNESP, 2013.

Doses of organic compost (t/ha)	Fresh matter (g/plant)	Dry matter (g/plant)	Plant height (cm)	Number of leaves per plant
	"Low" fertility area			
0	27.02*	4.61*	6.97*	17.50*
35	86.54*	10.75	7.97	29.00*
70	136.45*	9.88	10.43	38.25*
105	156.10*	11.12	10.90	35.00*
140	228.26	16.74	13.00	45.75
175	239.07	17.90	13.18	46.25
Inorganic fertilizer	221.04	13.66	10.94	46.25
CV (%)	16.82	19.74	15.22	10.40
	"High" fertility area			
0	75.19*	7.01*	10.28*	25.50*
35	161.05	15.04	11.68*	39.50
70	264.13	18.89	16.25	44.50
105	225.70	19.64	16.00	42.25
140	372.03**	21.07	19.84	49.25
175	351.01	20.87	20.34	46.25
Inorganic fertilizer	256.33	20.25	16.84	43.25
CV (%)	23.52	23.52	11.28	17.75

*Statistically lower average than the inorganic fertilizer by Dunnett test at 5% probability. **Statistically superior average than the inorganic fertilizer by Dunnett test at 5% probability.

reported total accumulation of 862, 67, 519, 224, 146 and 90 mg/plant of N, P, K, Ca, Mg and S, respectively. In the present study, we obtained higher accumulation of P and K compared to that obtained by Feltrim *et al*. (2008), with emphasis on K values, 247% higher in the present study. This result is even more significant when comparing to dry matter. In this study, the weight of the maximum dry matter was 21 g/plant, whilst Feltrim *et al*. (2008) obtained values above 30 g/plant. A luxury absorption of K in higher doses of organic compost may have occurred, as it is the fastest nutrient released during mineralization of organic matter (Magro *et al*., 2010; Cardoso *et al*., 2011; Quadros *et al*., 2011). In addition, the lower accumulation of N in relation to the data reported by Feltrim *et al*. (2008) should be related to low N content (0.5%) in the compost used in this experiment.

Comparison of doses of organic compost with inorganic fertilizer

The authors could observe that in "low" fertility area, the treatment with inorganic fertilizer did not differ from higher doses of organic compost (140 and 175 t/ha) for the fresh matter weight and number of leaves per plant (Table 1). However, for plant height and dry matter weight, only the treatment without fertilization (0 t/ha) showed lower values than the treatment with inorganic fertilizer. In "high" fertility area (Table 1), the authors observed that the absence of fertilization (0 t/ha) resulted in plants with lower fresh and dry matter weight, plant height and number of leaves per plant when compared to the treatment with inorganic fertilizer. On the other hand, for the highest dose (175 t/ha) of organic compost, plants showed greater fresh matter than the ones with inorganic fertilizer, showing that it is possible to obtain good yields using only organic fertilizer. This result also shows that only inorganic fertilizer at the recommended dose is not enough to obtain the highest weight per plant. So, based in this comparisons, the highest dose can be recommended (175 t/ha) of organic compost to obtain higher fresh weight in endive in both areas, when only organic compost is used.

The values obtained in the best "high" fertility area treatments (Table 1) were similar to those reported by other authors, who also studied endive. Cardoso & Ustulim Filho (2013), using the same cultivar, obtained an average height of 18.4 cm and the highest fresh matter of 389 g. For fresh matter, Reghin *et al*. (2007) obtained 332-407 g, very similar results obtained in this study (372 g of fresh matter in the best treatments). The values are also similar to those obtained by Feltrim *et al*. (2006) and Sá & Reghin (2008).

In the "high" fertility area, only in the treatments with two lower doses (0 and 35 t/ha), the authors obtained smaller accumulation of N, P, Ca, Mg and S in relation to the inorganic fertilizer (Table 2). For K, except for the

Table 2. Comparison of organic compost doses with inorganic fertilizer averages for the accumulation rates of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur in endive in the "low" and "high" fertility areas of the soil. São Manuel, UNESP, 2013.

Doses of organic compost (t/ha)	N	P	K	Ca	Mg	S
	(mg/plant)					
	"Low"fertility area					
0	134.09*	11.89*	261.94*	52.39*	15.27*	12.44*
35	181.07*	18.51*	402.08*	71.81*	17.13*	18.43*
70	238.96*	25.44*	561.53*	90.18	19.63	26.21*
105	337.11	30.85	728.74	110.03	23.18	34.02*
140	399.82	41.26	905.97	122.83	27.90	42.86*
175	467.10**	42.70	1087.77**	144.50**	30.96	54.25
Inorganic fertilizer	382.76	36.21	789.23	109.74	26.49	50.69
CV(%)	10.66	15.82	12.36	15.67	17.93	9.74
	"High" fertility area					
0	158.41*	30.88*	370.43*	74.39*	13.21*	15.93*
35	262.65*	49.62*	661.12	127.46*	22.16*	30.59*
70	373.67	75.62	1011.96	168.35	29.20	41.66
105	455.58	86.29	1176.05	188.39	34.25	51.22
140	456.13	86.94	1250.62	170.15	32.74	49.75
175	467.82	90.18	1255.70	167.46	32.57	50.30
Inorganic fertilizer	498.20	85.79	1067.13	200.14	32.85	53.73
CV(%)	28.56	18.33	21.89	21.72	17.63	20.94

*Statistically lower average than the inorganic fertilizer by Dunnett test at 5% probability. **Statistically superior average than the inorganic fertilizer by Dunnett test at 5% probability.

Table 3. Average of fresh (FM) and dry matter (DM), plant height (HP), number of leaves per plant (NL) and accumulation of phosphorus (P), potassium (K), calcium (Ca) magnesium (Mg) and sulphur (S) in endive plants in the "high" and "low" soil fertility areas. São Manuel, UNESP, 2013.

Initial fertility of the soil	FM (g/plant)	DM (g/plant)	HP (cm)	NL	P	K	Ca	Mg	S
					(mg/plant)				
"Low"	142.3 b	12.09 b	10.4 b	35.2 b	29.55 b	676.7 b	100.2 b	22.94 b	34.13 b
"High"	241.5 a	20.02 a	15.7 a	41.2 a	72.19 a	970.4 a	156.6 a	28.14 a	41.88 a
CV (%)	20.41	30.48	13.87	12.27	21.77	20.89	20.16	17.61	19.13

Averages followed by different letters in the columns differ by F test, 5%.

treatment without fertilization (0 t/ha), no difference between doses of organic compost and inorganic fertilizer was noticed. Possibly, it occurred because the organic compost had really been a good source of K for plants, as described by many authors (Damatto Júnior *et al*., 2006; Magro *et al*., 2010; Cardoso *et al*., 2011; Souza & Resende, 2014).

Despite that lower doses resulted in lower nutrients accumulation in relation to the inorganic fertilizer in the "low" fertility area (Table 2), the highest dose of organic compost (175 t/ha) showed greater accumulation of N, K and Ca. This soil presented "low fertility" at the beginning, showing that only inorganic fertilizer was probably not enough to meet the needs of endive.

Comparative analysis of "high" and "low" fertility areas

For all the traits (fresh and dry matter weight, plant height and number of leaves), regardless of dose, the averages in the "high" fertility area were higher than those in the "low" fertility area (Table 3), which confirms the importance of the initial fertility of the soil on endive production.

Villas Boas *et al*. (2004) studied the influence of different doses of organic compost, in two type of soils [Oxisol (Dark Red Latosoil) (LE), sandy phase, and an Inceptisol (AQ)], on lettuce production. They also presented higher values for fresh and dry matter and number of leaves in the soil (LE) with higher initial fertility levels. According

to these authors, the recommended dose can vary widely, depending on the species, quality and origin of the organic materials used, soil characteristics, management and climatic conditions. Therefore, as the authors recommend the inorganic fertilization, they also recommended that the amounts of organic fertilizer should be adjusted according to soil fertility. However, Villas Boas *et al*. (2004) was the only research paper which was found that compares different doses of organic fertilizer in different soils. This study is essential in order to make an accurate recommendation for organic fertilizer.

The authors did not use a joint analysis of nitrogen accumulation, because, according to Banzatto & Kronka (2006), this is not recommended when the ratio between the mean squares of errors is greater than 7, as occurred with this nutrient. The average for N accumulation was 293 and 362 mg/plant in the "low" and "high" fertility areas, respectively. For all other macro nutrients (P, K, Ca, S, and Mg) the highest accumulation was obtained in the "high" fertility area, regardless of the treatment in relation to "low" fertility area (Table 3). These results were expected because dry matter in "high" fertility area was greater than in "low" fertility area.

We observed that the higher the dose of organic compost (in the studied range), the higher the endive production (fresh matter) in either "high" or "low" fertility of the soil. In endive, the decreasing order of macronutrients accumulation was: K>N>Ca>P>S>Mg.

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