Increased yield and nutrient content of *Tropaeolum majus* L. with use of chicken manure[1]

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ABSTRACT

Nasturtium (*Tropaeolum majus* L.) is an unconventional plant or vegetable grown for ornamental, food and medicinal purposes. However, information on cultivation of the species involving organic residue is incipient. Therefore, aimed to evaluate plant growth, flower yield, and nutrient contents of leaves and flowers of Nasturtium cultivated with addition of chicken manure. Five doses of chicken manure were studied, applied in the soil incorporated (I) (1, 6, 10, 14 and 19 t ha^{-1}) and cover (C) (1, 6, 10, 14 and 19 t ha^{-1}) forms, using the experimental array Plan Puebla III, leading to nine combinations of doses and forms of adding the chicken manure, in randomized blocks with four replicates. The greatest plant height (35.75 cm) was achieved at 168 days after transplanting (DAT) under 10 t ha^{-1} I and 10 t ha^{-1} C. The greatest yield terms of in number (15.4 million ha^{-1}) and fresh (10.45 t ha^{-1}) and dry weights (0.849 t ha^{-1}) of flowers were found by using doses close to 10 t ha^{-1} I and 10 t ha^{-1} C. To obtain the best development and yield of Nasturtium flowers, 10 t ha^{-1} I and 10 t ha^{-1} C of chicken manure should be used.

Keywords: nasturtium; vegetable production; organic residue; organic cultivation.

INTRODUCTION

Nasturtium (*Tropaeolum majus* L. Tropaeolaceae) is an unconventional food plant or vegetable, from mountainous regions of Mexico and Peru. In Brazil, it is cultivated in subtropical areas, especially in the South region and altitude areas of the Southeast, in addition to the Northeast and Midwest regions (Lorenzi & Matos, 2008). Leaves and flowers of Nasturtium are edible, used for preparation of salads, savory rolls and pâté, and the fruits, such as pickles and capers (Kinupp & Lorenzi, 2014). Flowers are found in a wide range of colors, and they are sources of fiber, protein, lipids and minerals such as calcium, copper, iron, potassium, magnesium, manganese, molybdenum, phosphorus, sodium, zinc and vitamin C, (Fernandes *et al*., 2016).

Nasturtium flowers have biological activities, associated with functional ones, in human food. Their composition includes anthocyanins, ascorbic acid, phenolic compounds (Garzón & Wrolstad, 2009), flavonoids, glucosinolates, fatty acids, among others (Brondani *et al*., 2016). They have diuretic (Gasparotto Junior *et al*., 2012) and antihypertensive (Gasparotto Junior *et al*., 2011) properties.

For the cultivation of vegetables, environmental factors, such as soil nutrient availability, have to be taken into account, as adequate nutrient levels are crucial for good development of species (Armond *et al*., 2016). Due to the fact that Brazilian soils have high aluminum content and low fertility, correction and fertilization techniques are employed to meet the nutritional needs of conventional vegetable cultivation (Aular & Natale, 2013).

However, excessive and irrational fertilization can damage the environment, in addition to generating unnecessary costs (Savci, 2012). Therefore, alternatives

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arise, e.g., chicken manure. It is a low-cost organic waste and, when added to the soil, it favors the maintenance of organic matter. As a result of its chemical composition, it meets the nutritional needs of plants (Zandonadi *et al.*, 2014). Such cultivation was successful in growing vegetables (Heid *et al.*, 2015) and medicinal plants associated with phosphate fertilizer (Vieira *et al.*, 2015), and also in the intercropping of Nasturtium with a native medicinal plant (Nascimento *et al.*, 2019).

Considering the importance of capuchin in food and biological potential, and excessive use of fertilizer, there are needs for cultivation using sustainable alternatives for nutritional supply. Based on the above-mentioned remarks, the hypothesis of the present study is that chicken manure can supply the nutritional needs in the development and productivity of Nasturtium. Therefore, the aim of this study was to assess plant growth, flower yield, and nutrient contents of leaves and flowers of Nasturtium (*Tropaeolum majus* L.) cultivated with addition of chicken manure to the soil.

MATERIAL AND METHODS

The experimental study was conducted between April and October 2016, at coordinates 22º11’43.7"S and 54º56’08.5"W, 452 m (Figure 1). The climate of the area is classified as Am (Tropical Monsoon Climate). Mean temperature, total rainfall and relative air humidity during the plant growth cycle were 19.9 °C, 496.4 mm and 68.23%, respectively.

The soil is classified as a dystroferric Red Latosol, originally under Cerrado vegetation, with clay texture (Santos *et al.*, 2013), and whose chemical attributes before cultivation (0-20 cm) are shown in Table 1. The analysis followed the methodology of Silva (2009).

The chicken manure in use was semi-decomposed from a broiler house, with the following chemical characteristics: pH in water = 8.40; N, P, K, Ca, Mg, S and C (g kg^{-1}) = 11.03; 6.17; 2.00; 14.85; 4.50; 8.23; 396.00, respectively; C/N ratio of 35.90; organic matter = 230.00 g kg^{-1}, Cu; Zn; Fe; Mn and B (mg kg^{-1}) = 90.00; 190.00; 6900.00; 650.00; 8.10, respectively.

Five doses of semi-decomposed chicken manure were incorporated to the soil (1, 6, 10, 14 and 19 t ha^{-1}) and used as cover (1, 6, 10, 14 and 19 t ha^{-1}). Treatments were defined using the experimental array Plan Puebla III (Turrent & Laird, 1975), leading to nine combinations of doses of chicken manure incorporated (I) and used as cover (C): 6 t ha^{-1} I + 6 t ha^{-1} C; 14 t ha^{-1} I + 6 t ha^{-1} C; 6 t ha^{-1} I + 14 t ha^{-1} C; 14 t ha^{-1} I + 14 t ha^{-1} C; 10 t ha^{-1} I + 10 t ha^{-1} C; 1 t ha^{-1} I + 6 t ha^{-1} C; 19 t ha^{-1} I + 14 t ha^{-1} C; 6 t ha^{-1} I + 1 t ha^{-1} C; 14 t ha^{-1} I + 19 t ha^{-1} C.

The experimental design consisted of randomized blocks, with nine treatments and four replicates. The plots had a total area of 3.0 m^2 (2.0 m long x 1.5 m wide) and useful area of 2.00 m^2 (2.00 m long x 1.00 m wide), with plants arranged in two rows, 0.50 m spacing between rows, with eight plants in each row, 0.25 m between plants, containing a total of 52800 plants ha^{-1}.

For plant propagation seeds of Nasturtium cv Dobrada sortida híbrida alta (Isla®) were used. An exsiccate with specimen of the study species is deposited at the Herbarium DDMS - Dourados – MS, under number 5474. Initial propagation was performed in 128-cell polystyrene trays, filled with Tropstrato® commercial substrate. When seedlings showed average height of 7.0 cm (30 days after sowing), they were transplanted into definitive beds.

The area was prepared using a plow and a leveling harrow, and then the beds were raised with a rotary tiller bed shaper. Before the second passage of the bed shaper, the distribution of chicken manure was performed for incorporation into the respective plots. After transplanting, chicken manure was added as cover, at corresponding doses and plots.

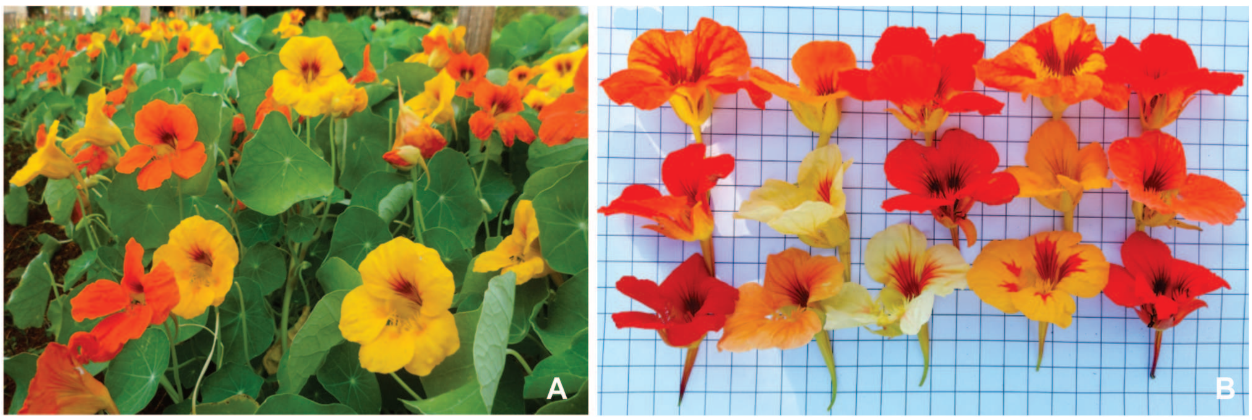

Figure 1: Flowers of Nasturtium (a, b), cultivated with use of chicken manure, at different doses, applied in the incorporated (I) and cover (C) forms.

Table 1: Chemical attributes of the soil before transplanting (initial) and after harvest of Nasturtium (maximum calculated amount), cultivated with use of chicken manure, at different doses, applied in the incorporated (I) and cover (C) forms

Chemical attributes	Initial	Equation	Maximum value	Doses of chicken manure ($t\ ha^{-1}$)	R^2
pH H_2O	5.42	$\hat{y} = 5.922+0.016^{**}I+0.048^{**}C-0.001^{**}I^2-0.002^{**}C^2+0.001^{**}IC$	6.45	19.00 I + 16.30 C	0.98
O. M. ($g\ dm^{-3}$)	19.30	$\hat{y} = 21.081+0.506^{**}I+0.600^{**}C-0.042^{**}I^2-0.047^{**}C^2+0.053^{**}IC$	29.25	15.04 I + 14.63 C	0.93
P ($mg\ dm^{-3}$)	23.62	$\hat{y} = 52.869+0.430^{*}I-0.951^{**}C-0.019^{*}I^2+0.143^{**}C^2$	88.81	10.91 I + 19.00 C	0.68
K ($cmol_c\ dm^{-3}$)	0.44	$\hat{y} = 3=0.78$	-	n/ad	
Ca ($cmol_c\ dm^{-3}$)	3.71	$\hat{y} = 4.493+0.139^{**}I+0.257^{**}C-0.004^{**}I^2-0.011^{**}C^2-0.001^{**}IC^2$	6.67	13.39 I + 10.00 C	0.98
Mg ($cmol_c\ dm^{-3}$)	1.91	$\hat{y} = 2.517-0.007^{**}I+0.111^{**}C+0.003^{**}I^2-0.003^{**}C^2-0.001^{**}IC$	3.99	19.00 I + 10.88 C	0.99
Cu ($mg\ dm^{-3}$)	13.97	$\hat{y} = 16.909+0.145^{**}I+0.228^{**}C-0.001^{**}I^2-0.011^{**}C^2-0.013^{**}IC$	18.96	19.00 I + 1.00 C	0.61
Mn ($mg\ dm^{-3}$)	62.70	$\hat{y} = 74.122+3.559^{**}I+5.042^{**}C-0.321^{**}I^2-0.405^{**}C^2+0.320^{**}IC$	119.44	10.74 I + 10.45 C	0.80
Fe ($mg\ dm^{-3}$)	104.49	$\hat{y} = 3=125.32$	-	n/ad	
Zn ($mg\ dm^{-3}$)	4.93	$\hat{y} = 8.385+0.157^{**}I-0.025^{**}C-0.004^{**}I^2+0.006^{**}C^2$	11.51	19.00 I + 19.00 C	0.94
H+Al ($cmol_c\ dm^{-3}$)	7.15	$\hat{y} = 5.235-0.039^{**}I-0.124^{**}C+0.004^{**}I^2+0.007^{**}C^2-0.008^{**}IC$	5.92	19.00 I + 19.00 C	0.99
SB ($cmol_c\ dm^{-3}$)	6.06	$\hat{y} = 8.140+0.126^{**}I+0.264^{**}C-0.002^{**}I^2-0.011^{**}C^2$	11.10	1.00 I + 19.00 C	0.98
CTC ($cmol_c\ dm^{-3}$)	13.22	$\hat{y} = 13.157+0.027^{**}I+0.241^{**}C+0.005^{**}I^2-0.008^{**}C^2-0.010^{**}IC$	15.67	19.00 I + 1.00 C	0.84
V (%)	45.00	$\hat{y} = 63.015+0.702^{**}I+0.859^{**}C-0.052^{**}I^2-0.061^{**}C^2-0.064^{**}IC$	66.22	3.59 I + 5.10 C	0.99

**Significant at 1% probability; *Significant at 5% probability; n/ad. – no regression adjustment; pH (H_2O) – hydrogen potential of soil in water; P – phosphorus extracted by Mehlich; K, Ca and Mg – exchangeable forms; O.M. – organic matter; H+Al – potential Acidity; SB- sum of bases; CEC – Cation exchange capacity; V (%) – base saturation index.

To determine the chemical attributes of the soil, samples were collected at 0-20 cm depth after application of chicken manure, before transplanting and at the end of the cultivation cycle (after harvest), in all plots of the nine study treatments and an analysis was performed according to the methodology of Silva (2009).

During the cultivation cycle, the following parameters were assessed: plant height, at 18 days and then every 18 days up to 180 days after transplanting-DAT and chlorophyll index using a portable chlorophyll meter CFL-1030 ClorofiLOG (Falker Automação Agrícola, Porto Alegre, RS, Brazil), until 126 DAT, before the beginning of plant senescence.

To assess flower yield, harvests were performed every three or four days and summed to obtain the weekly harvest rate, between 61 and 180 DAT. The first harvest occurred when there were flowers in 70% of the plants, and harvest time was signaled by open petals. Flower yield per plant(1) and flower yield per area (ha) were then calculated(2-3). Maximum production was achieved at 131 DAT, and final production, at 180 DAT, when the following parameters were determined: number of flowers, fresh weight, and dry weight; flower diameter and flower length(2-3). To determine dry weight, the material was packaged in paper bags, placed in a forced air circulation oven at a temperature of 60 ± 5° C, to constant dry weight.

$$(1)\ Number\ of\ flowers\ per\ plant = \frac{total\ flowers\ per\ harvest}{Number\ of\ plants}$$

$$(2)\ correction\ factor = \frac{\left(\frac{total\ hectare\ area}{total\ plot\ area}\right)}{kg\ in\ 1\ ton}$$

$$(3)\ Production\ per\ area\ (ha) = variables\ x\ correction\ factor$$

At 120 DAT, at the first signs of leaf senescence, two plants were collected from each plot by being cut close to the ground, for determination of leaf area (cm^2), using an area integrator (LI-COR, Model 3100 C; Nebraska-USA); leaf dry weight and calculated specific leaf weight (SLW): leaf dry weight/leaf area; specific leaf area (SLA): leaf area/ leaf dry weight.

Samples of dry weight from leaves harvested at 120 DAT and flowers harvested at the same week were ground in a Willey knife mill, homogenized and used to determine nutrient content (Malavolta, 2006).

Plant height, chlorophyll index and harvests during the cultivation cycle were assessed in plots subdivided in time, followed by analysis of variance and regression, on the basis of treatments and periods. The means of the data on leaf area, specific leaf weight, specific leaf area, leaf dry weight, flower yield (number of flowers, and fresh and dry weights), chemical attributes of the soil and nutrient content of leaves and flowers underwent analysis of variance and the F-test ($p < 0.05$) and sequential regression, testing the quadratic models and the square root base. The significant model by the t-test ($p < 0.05$) was presented in response surface plots. Statistical analyses were conducted in the SAEG software.

RESULTS

Effect of organic waste on soil chemical attributes

With an increased amount of chicken manure in the soil, there was an improvement of chemical attributes when compared with the analyses of the soil at the beginning of the experiment (Table 1). There was increase in pH (19%), and organic matter (51%). The contents of P, K, Ca, Mg, Cu, Mn, Fe, Zn, SB, CTC and base saturation index (V%) were increased by 275, 77, 79, 108, 35, 90, 19, 133, 83, 18 and 14%, respectively. There was a 17% reduction in potential acidity (H + Al).

The incorporation of 19 t ha^{-1} of chicken manure provided increases in some chemical attributes of soil, including pH and nutrients (Table 1). The other chemical attributes showed different results: the highest organic matter was found under 15.04 t ha^{-1} I and 14.63 t ha^{-1} C; Ca, under 13.39 t ha^{-1} I and 10 t ha^{-1} C; and P, under 10.91 t ha^{-1} I and 19 t ha^{-1} C.

Nutrient content of nasturtium

The highest contents of macro-nutrients Ca (17.88 g kg^{-1}) and Mg (3.56 g kg^{-1}) in leaves were found in the plants grown under doses close to 10 t ha^{-1} I and 10 t ha^{-1} C of chicken manure (Table 2); for P (6.50 g kg^{-1}), they were found under 19 t ha^{-1} I and 19 t ha^{-1} C. The highest contents of micro-nutrients Cu (13.97 mg kg^{-1}) and Fe (9394.64 mg kg^{-1}) were found under 1 t ha^{-1} I and 19 t ha^{-1} C and Zn (37.61 mg kg^{-1}), 1 t ha^{-1} I and 1 t ha^{-1} C. The contents of N (13.49 g kg^{-1}), K (24.63 g kg^{-1}) and Mn (74.89 mg kg^{-1}) showed no adjustment to the regression models in use. In flowers, the highest content of N (27.52 g kg^{-1}) occurred under 17.88 t ha^{-1} I and 1 t ha^{-1} C; Ca (4.97 g kg^{-1}), under 1 t ha^{-1} I and 1 t ha^{-1} C; Mn (26.45 mg kg^{-1}), under 8.56 t ha^{-1} I and 5.67 t ha^{-1} C; Fe (663.74 mg kg^{-1}), under 1 t ha^{-1} I and 19 t ha^{-1} C; and Zn (40.96 mg kg^{-1}), under 19 t ha^{-1} I and 1 t ha^{-1} C.

Growth indicators of nasturtium plants

The greatest maximum height of plants (35.75 cm) was achieved at 168 DAT, under 10 t ha^{-1} I and 10 t ha^{-1} C while the lowest maximum height (26.51 cm) was found at 135 DAT under 1 t ha^{-1} I and 6 t ha^{-1} C (Figures 2A and 2B).

The greatest leaf area (11457 cm^2 $plant^{-1}$) and leaf dry weight (84.32 g $plant^{-1}$) values were found under 1 t ha^{-1} I and 19 t ha^{-1} C. On the other hand, the smallest leaf area (cm^2 1545.51 $plant^{-1}$) and leaf dry weight (15.40 g $plant^{-1}$) values occurred under 19 t ha^{-1} I and 19 t ha^{-1} (C) and 19 t ha^{-1} I and 14 t ha^{-1} C, respectively (Figures 3A and 3B).

Specific leaf weight, specific leaf area and chlorophyll index were not influenced by combinations of forms of chicken manure addition, showing mean of 0.0184 g cm^{-2}, 118.36 cm^2 g^{-1} and 36.48, respectively.

Production indicators of nasturtium flowers

Flower yield per plant was influenced by the interaction between the study factors. The largest maximum number of flowers (44.43 $plant^{-1}$) occurred under 10 t ha^{-1} I and 10 t ha^{-1} C at 130 DAT, over 109.18% the lowest production value (21.24 $plant^{-1}$), achieved at 123 DAT under 19 t ha^{-1} I and 14 t ha^{-1} C (Figures 4A and 4B).

For flower fresh weight, the greatest maximum value was 31.91 g $plant^{-1}$, achieved at 127 DAT, under 10 t ha^{-1} I and 10 t ha^{-1} C, over 110.63% the lowest maximum yield (15.15 g $plant^{-1}$), which occurred at 121 DAT under 19 t ha^{-1} I and 14 t ha^{-1} C (Figures 4C and 4D).

Flower dry weight presented the same trend found for fresh weight, achieving the greatest maximum value (2.59 g $plant^{-1}$) at 127 DAT under 10 t ha^{-1} I and 10 t ha^{-1} C, over 119.49% the lowest maximum weight value (1.18 g $plant^{-1}$) at 124 DAT under 19 t ha^{-1} I and 14 t ha^{-1} C (Figures 4E and 4F).

The greatest flower production (15.4 million ha^{-1}); fresh mass (10.45 t ha^{-1}) and dry mass (0.849 t ha^{-1}) of Nasturtium flowers occurred under 9.80 t ha^{-1} I and 9.43 t ha^{-1} C (Figure 5A); 9.49 I t ha^{-1} and 9.51 t ha^{-1} C (Figure 5B) and 9.27 t ha^{-1} I and 9.57 t ha^{-1} C (Figure 5C), respectively, over 184.66% the lowest values found (5.41 million ha^{-1}), 148.22% (4.21 t ha^{-1}) and 143.27% (0.349 t ha^{-1}), using the highest doses of chicken manure (19 t ha^{-1} I and 19 t ha^{-1} C), respectively.

Flower yield, considered until the day of maximum yield, at 131 DAT, showed greater number of flowers (9.11 million ha^{-1}), fresh weight (7.00 t ha^{-1}) and dry weight (0.524 t ha^{-1}) under 8.48 t ha^{-1} I and 13.00 t ha^{-1} C (Figure 6A); 8.86 I t ha^{-1} and 11.26 t ha^{-1} C (Figure 6B) and 8.68 t ha^{-1} I and 11.09 t ha^{-1} C (Figure 6C) respectively, representing the following total yield percentages (Figures 5A, 5B and 5C) for number of flowers (59.16%), fresh weight (66.99%) and dry weight (61.72%) of flowers.

DISCUSSION

The improvements of soil chemical attributes, especially in terms of greater availability of P, Ca, Mg, Cu, Zn and Mn (Table 1), with doses above 10 t ha^{-1} of chicken manure incorporated in the soil, can be justified by the fact that they are a good source of nutrients, contributing to an increase in organic matter. The increase in soil pH, owing to the addition of the residue, reflected in the absence of Al (which is a toxic mineral for plants) (Miguel *et al*., 2010), thus improving soil fertility. However, after the mineralization of the chicken manure, the charges of the soil increased, which provided adsorption of H^+ ions present in mineral or organic particles, with variable charges available in the humic fraction of the waste (Lourenzi *et al*., 2016).

Furthermore, when adding the chicken manure, nutrients readily available in its composition were increased, providing adequate fertilization for the initial development of the plant. This fact indicates that the higher dose, the greater the addition of nutrients to the soil, which was proven in the final evaluation, because when adding higher doses, i.e., above 10 t ha^{-1}, there were more nutrients available.

The nutrient contents found in Nasturtium leaves and flowers were compared with the recommended range for optimal development of the main vegetables, according to Raij (2017), and described in Table 2. In Nasturtium leaves, the mean contents of N and K were below (Table 2). On the other hand, the contents of P, Ca, Mg, Cu, Mn and Zn were within the range and the content of Fe was above (Table 2). In flowers, the contents of N, K, Mg, Cu and Zn were within the recommended range while the contents of Ca and Mn were below it (Table 2). In comparison, P and Fe were above the range (Table 2). Therefore, chicken manure positively affected the N and Zn contents of the flowers. However, N content in the flowers (27.52 g kg^{-1}) was lower than the value found by Sangalli *et al.* (2004), who reported 35.6 g kg^{-1} in Nasturtium plants cultivated with 15 t ha^{-1} of semi-decomposed chicken manure applied to the soil; however, both values are within the recommended range (20-50 g kg^{-1}). On the

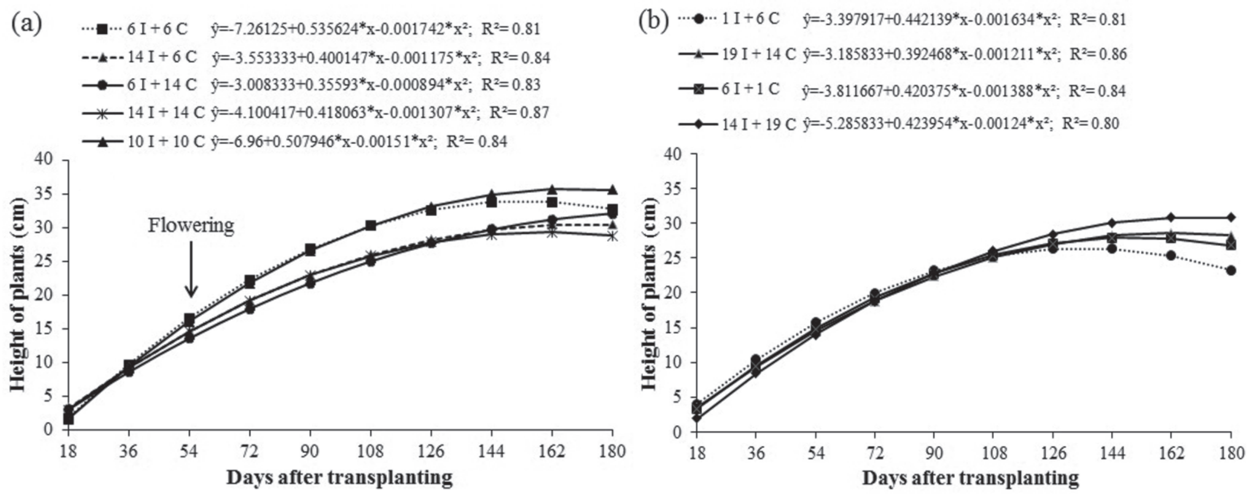

Figure 2: Height of plants (a, b) cultivated under addition of chicken manure to soil, at five doses, applied in the incorporated (I) and cover (C) forms.

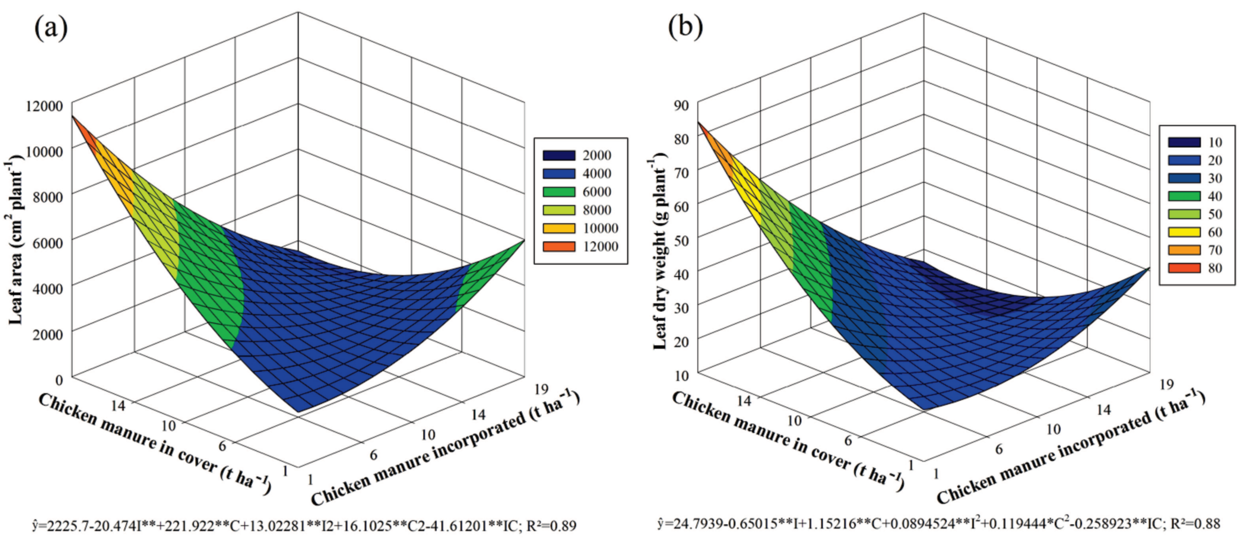

Figure 3: Leaf area (a) and leaf dry weight (b) of Nasturtium, cultivated under addition of chicken manure to soil, at five doses, applied in the incorporated (I) and cover (C) forms. * and ** Significant at 5% and 1% probability, respectively.

other hand, the content of P (6.50 g kg^{-1}) in flowers was above the one found by Sangalli *et al*. (2004), ranging between 3.0 g kg^{-1} under chicken manure associated with nitrogen and 3.9 g kg^{-1}, in comparison to those cultivated with nitrogen only.

The highest content of N in flowers in comparison to leaves of Nasturtium (Table 2) can be associated with mobilization of N, which was present in leaves, in which N was translocated for development in the reproductive phase (Taiz & Zeiger, 2013). However, Sangalli *et al*. (2004), testing organic waste and fertilization, found that the contents of N in leaves (30.2 to 35.6 g kg^{-1}) and flowers (31.4 to 35.6 g kg^{-1}) of Nasturtium were similar.

The large accumulation of P in flowers (Table 2) can be explained by the fact that this nutrient is preferentially allocated in reproductive organs (Araújo & Machado, 2006), while the high content of Fe in leaves and flowers of Nasturtium (Table 2) can be due to the high concen-

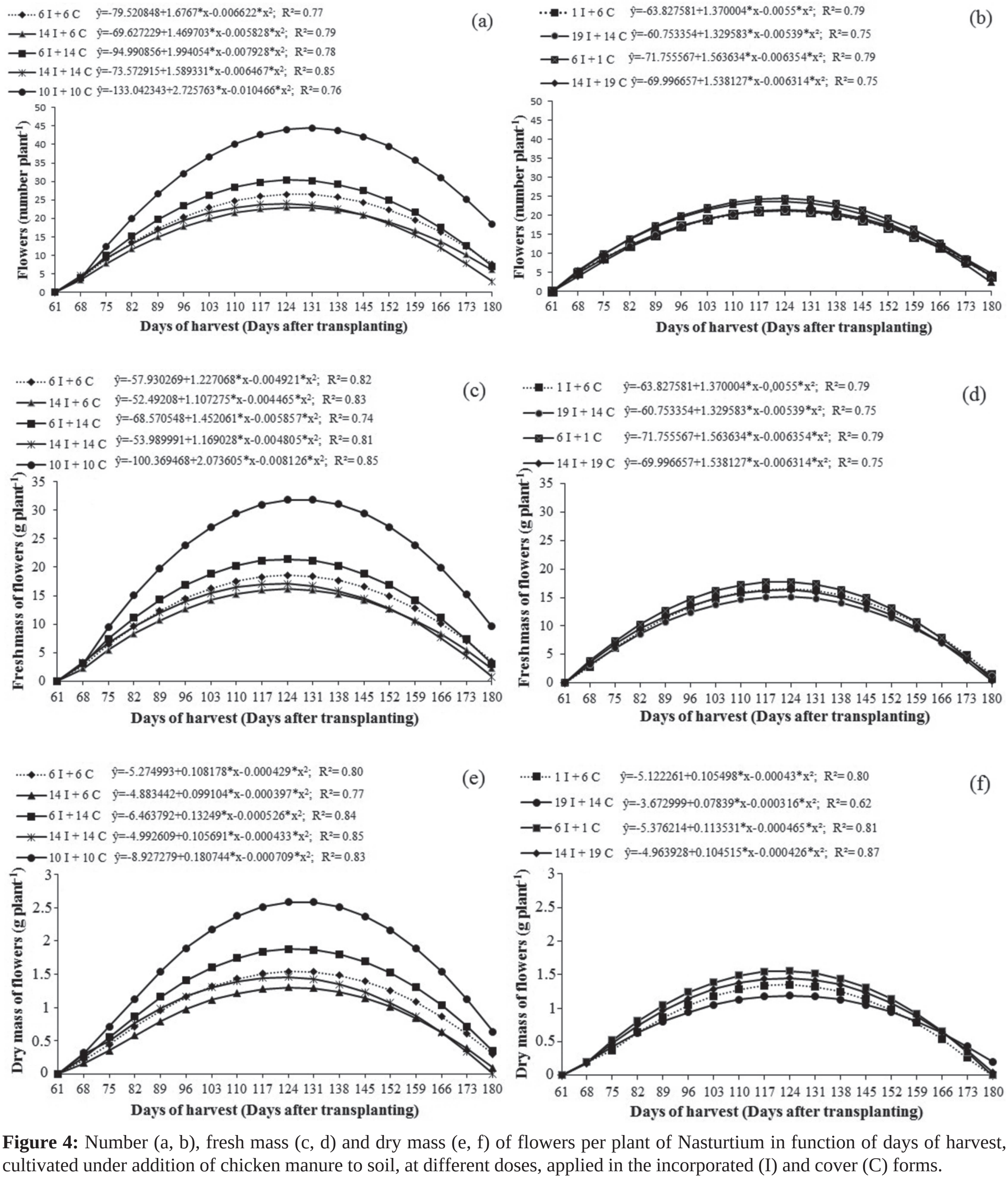

Figure 4: Number (a, b), fresh mass (c, d) and dry mass (e, f) of flowers per plant of Nasturtium in function of days of harvest, cultivated under addition of chicken manure to soil, at different doses, applied in the incorporated (I) and cover (C) forms.

tration of Fe in the soil (Table 1). This occurs because the soil of the region is rich in Fe oxide (Camargo *et al*., 2010), which is absorbed and accumulated in the leaves and flowers of Nasturtium.

The greater heights of Nasturtium plants demonstrate that balanced doses of 10 t ha^{-1} of chicken manure in incorporated and cover forms contribute to the growth of the species (Figures 2A and 2B), enabling greater yield in terms of number and weight of flowers (Figures 5 and Figure 6). This result may be due to the organic matter content, which led to the increase in pH and availability of soil nutrients, especially P (Table 1), provided with the addition of chicken manure in a balanced combination of incorporated and cover forms (Gasparim *et al*., 2005; Zandonadi *et al*., 2014). On the other hand, the smaller heights of plants under the lowest doses of chicken manure in the incorporated and cover forms can be due to the low supply of nutrients and organic matter from chicken manure available in the soil.

Nasturtium plants grew in height until 168 DAT. After this period, they showed the first signs of senescence, such as height reduction, yellowing and leaf drop, ending the cycle of development and production of flowers at 180 DAT. The senescence process, observed after 168 DAT, can be related to the synthesis of ethylene produced in plants, since this hormone regulates physiological responses during plant growth and development, provided by internal factors of the tissue itself and environmental factors or stress (Taiz & Zeiger, 2013).

Flower yield per plant of Nasturtium along the cultivation cycle showed the same trend found for plant height, with maximum production at 130 DAT, for number of flowers, and at 127 DAT for fresh and dry weight of

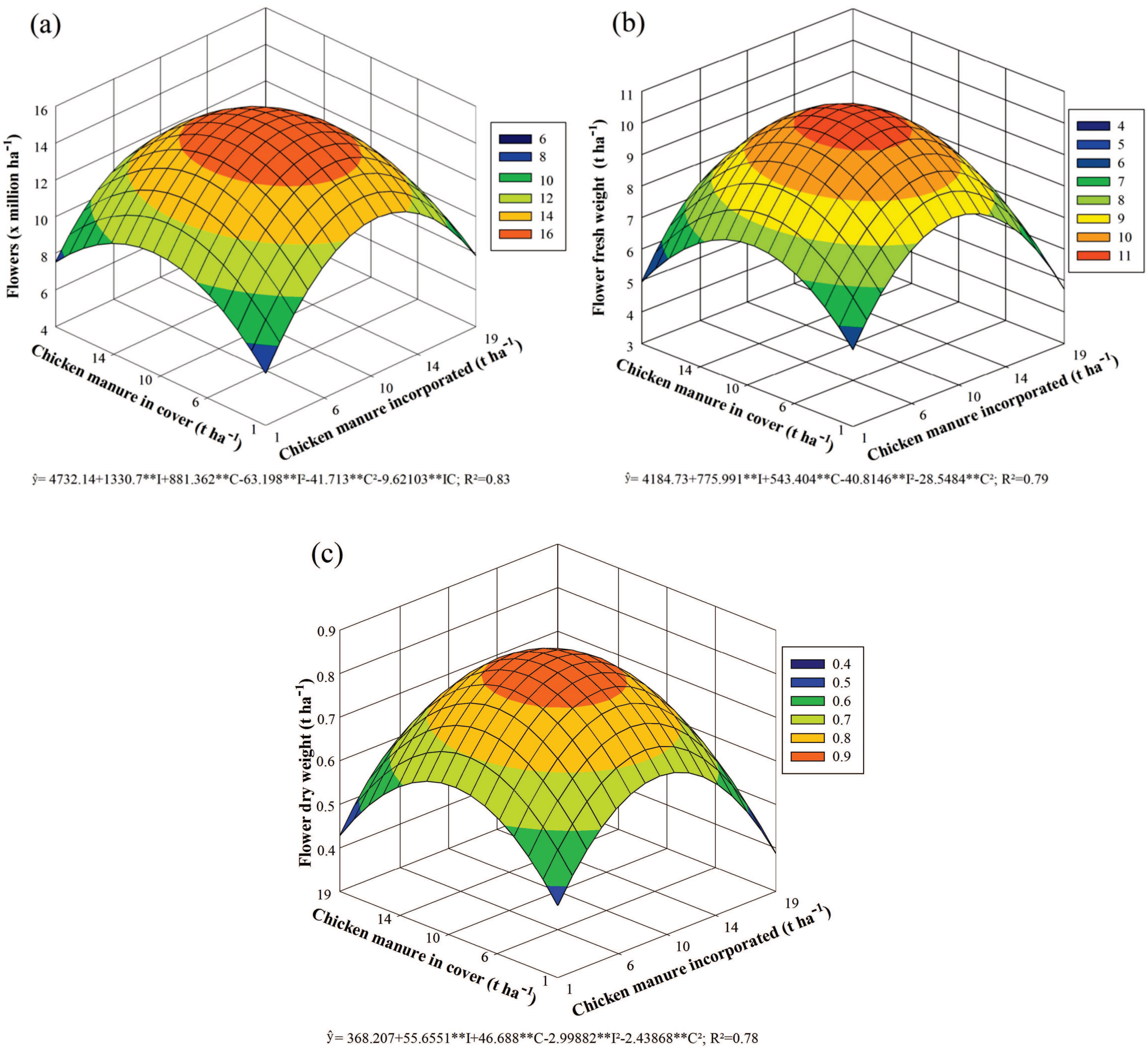

Figure 5: Number - NF (a), fresh weight - FW (b) and dry weight - DW (c) of Nasturtium flowers cultivated under addition of chicken manure to soil, at different doses, applied in the incorporated (I) and cover (C) forms. **Significant at 1% probability.

flowers, respectively, both under 10 t ha^{-1} I and 10 t ha^{-1} C. After this period, flower yield decreased (Figures 4A and 4B), which may be due to the process of plant senescence. This production corresponded in number of flowers (59.16%), fresh weight (66.99%) and dry weight (61.72%) of Nasturtium flowers (Figures 6A, 6B and 6C), when compared with total yield (Figures 5A, 5B and 5C). These results show that after reaching the maximum flower yield, harvest may still be possible by the end of the cultivation cycle.

The greatest total yield in terms of number of flowers, as well as fresh and dry weights of flowers (Figures 5A, 5B and 5C), under intermediate doses of chicken manure, may be associated with the appropriate characteristics promoted by the addition of chicken manure to the soil. One of them is moisture retention, which as a result of providing organic matter, improves soil microbiota and increases availability of essential nutrients for the plants (Table 2), such as P and N. This occurs because P participates in the formation of ATP and N is associated with elongation and vegetative growth, (Taiz & Zeiger, 2013), thus favoring the reproductive potential of plants. A similar result was found by Carbonari *et al*. (2006), who reported mean yield of 15.5 million flowers ha^{-1} using doses of P and chicken manure incorporated into the soil.

Adding chicken manure contributed to greater availability of nutrients and, subsequently, absorption by plants. Most of these nutrients in the leaves (Table 2) are within or above the range recommended for cultivation of vegetables (Table 2), showing that this source of organic waste is effective for cultivation of vegetables and medi-

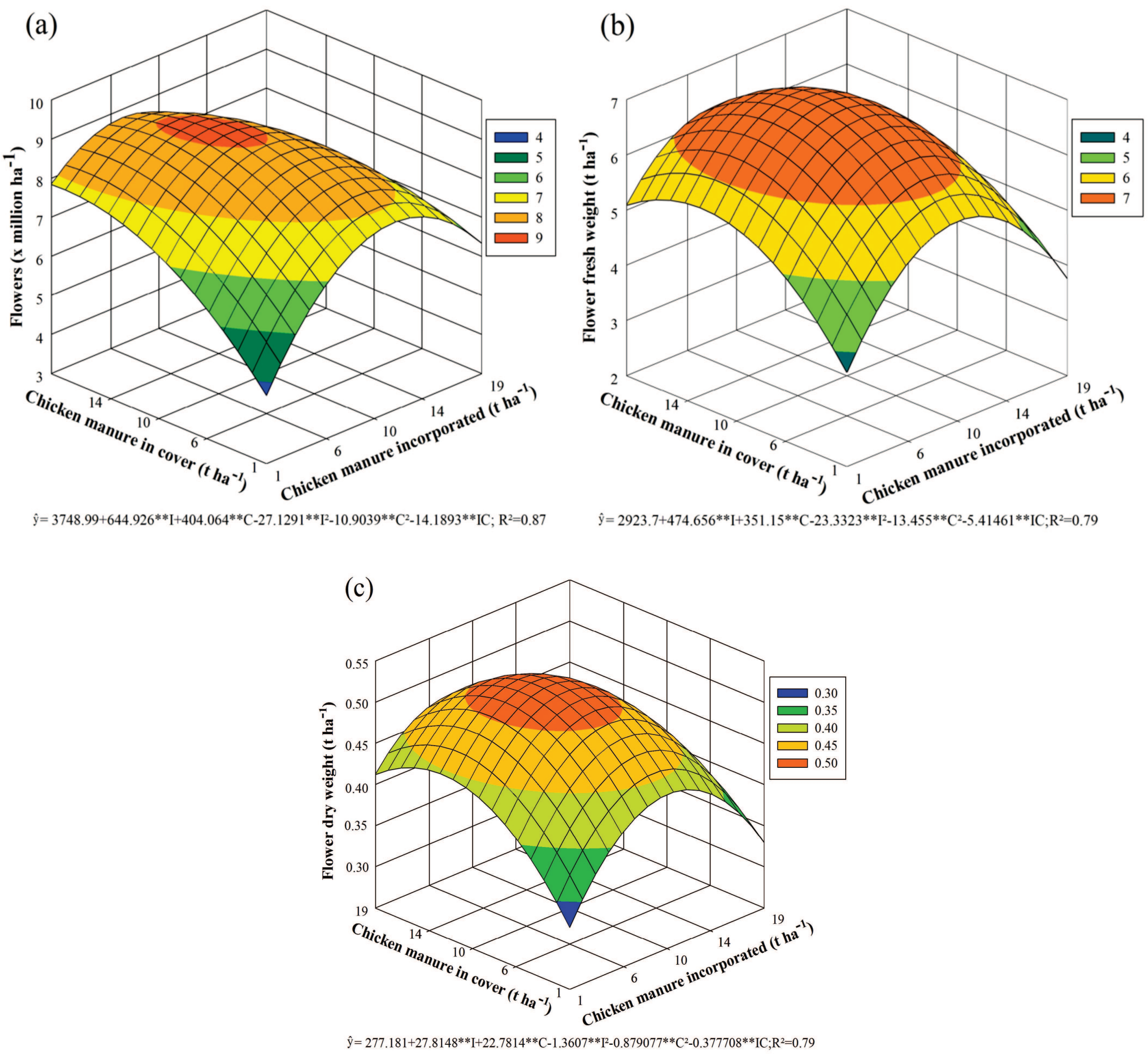

Figure 6: Number - NF (a), fresh weight - FM (b) and dry weight - DM (c) of flowers of Nasturtium obtained until 131 days after transplanting, cultivated under addition of chicken manure to soil, at different doses, applied in the incorporated (I) and cover (C) forms.

Table 2: Nutrient contents of leaves and flowers of Nasturtium, collected at 120 days after transplanting, grown under use of chicken manure, at different doses, applied in the incorporated (I) and cover (C) forms

Nutrient	Recommended range(Raij, 2017)	Equation	Maximum value	Doses of chicken manure ($t\ ha^{-1}$)	R^2
Nutrient contents of leaves					
N ($g\ kg^{-1}$)	20-50	$\hat{y} = 3 = 13.49$ -	-	-	n/ad
P ($g\ kg^{-1}$)	2-7	$\hat{y} = 4.752-0.054^{**}I+0.043^{*}C-0.005^{**}I^2-0.012^{*}C^2+0.023^{**}IC$	6.50	19.00 I + 19.00 C	0.98
K ($g\ kg^{-1}$)	30-80	$\hat{y} = 3 = 24.63$ -	-	-	n/ad
Ca ($g\ kg^{-1}$)	7-35	$\hat{y} = 10.134+0.816^{**}I+0.742^{**}C-0.053^{**}I^2-0.049^{**}C^2+0.025^{**}IC$	17.88	9.90 I + 9.98 C	0.95
Mg ($g\ kg^{-1}$)	3-12	$\hat{y} = 1.869+0.089^{**}I+0.255^{**}C-0.003^{**}I^2-0.010^{**}C^2-0.003^{**}IC$	3.56	6.25 I + 11.06 C	0.83
Cu ($mg\ kg^{-1}$)	5-20	$\hat{y} = 15.773-0.463^{**}I-1.418^{**}C+0.006^{**}I^2+0.042^{**}C^2+0.031^{**}IC$	13.97	1.00 I + 19.00 C	0.58
Mn ($mg\ kg^{-1}$)	30-250	$\hat{y} = 3 = 74.89$ -	-		n/ad
Fe ($mg\ kg^{-1}$)	40-300	$\hat{y} = 696.765+50.929^{**}I+377.20^{**}C+11.02^{**}I^2+6.33^{**}C^2-43.055^{**}IC$	9394.64	1.00 I + 19.00 C	0.85
Zn ($mg\ kg^{-1}$)	20-100	$\hat{y} = 39.899-1.121^{**}I-1.282^{**}C-0.135^{**}I^2-0.142^{**}C^2+0.397^{**}IC$	37.61	1.00 I + 1.00 C	0.75
Nutrient contents of flowers					
N ($g\ kg^{-1}$)	20-50	$\hat{y} = 18.190+1.092^{**}I+0.323^{**}C-0.030^{**}I^2+0.001^{**}C^2-0.038^{**}IC$	27.52	17.88 I + 1.00 C	0.79
P ($g\ kg^{-1}$)	2-7	$\hat{y} = 3 = 8.34$ -	-	-	ns
K ($g\ kg^{-1}$)	30-80	$\hat{y} = 3 =30.98$ -	-	-	ns
Ca ($g\ kg^{-1}$)	7-35	$\hat{y} = 5.152-0.176^{**}I-0.006^{**}C+0.003^{**}I^2-0.003^{**}C^2+0.007^{**}IC$	4.97	1.00 I + 1.00 C	0.53
Mg ($g\ kg^{-1}$)	3-12	$\hat{y} = 3 = 3.12$ -	-	-	ns
Cu ($mg\ kg^{-1}$)	5-20	$\hat{y} = 3 = 6.43$ -	-	-	ns
Mn ($mg\ kg^{-1}$)	30-250	$\hat{y} = 24.546 + 0.309^{**}I+0.206^{**}C-0.026^{**}I^2-0.038^{**}C^2+0.026^{**}IC$	26.40	8.56 I + 5.64 C	0.75
Fe ($mg\ kg^{-1}$)	40-300	$\hat{y} = 242.27 + 3.032^{**}I+19.260^{**}C+0.852^{**}I^2+0.256^{**}C^2-2.156^{**}IC$	663.74	1.00 I + 19.00 C	0.78
Zn ($mg\ kg^{-1}$)	20-100	$\hat{y} = 25.279 + 0.430^{**}I+1.058^{**}C+0.021^{**}I^2-0.028^{**}C^2-0.060^{**}IC$	40.96	19.00 I + 1.00 C	0.97

**Significant at 1% probability; ns= non-significant; n/ad. – no regression adjustment.

cinal plants. Heid *et al*. (2015) underscored that the combination of 19 t ha^{-1} of chicken manure as cover and 14 t ha^{-1} incorporated into the soil led to the increased yield of marketable roots of Peruvian carrot (*Arracacia xanthorrhiza* Bancr.).

Leaf area and leaf dry weight had similar responses after addition of chicken manure as cover to the soil (Figures 3A and B). This result could be due thickening to the content of P from chicken manure in soil and leaves of Nasturtium, promoting accumulation of photoassimilates, and consequently, expansion and of foliar limb and petiole elongation. A similar result for leaf area was found by Carbonari *et al*. (2006), who reported 11350.77 cm^2 $plant^{-1}$ with 4.3 kg ha^{-1} of P and 19 t kg ha^{-1} of semi-decomposed chicken manure incorporated into the soil. The greater leaf area favors solar radiation interception; simultaneously, there is increased production and distribution of photoassimilates, contributing to mass allocation (Figures 3A and 3B).

The diameter and length of Nasturtium flowers did not vary with use of chicken manure, probably because biometric characteristics of flowers were little influenced by the environment, showing mean values of 5.37 cm in diameter and 2.48 cm in length. However, flower diameter was close to the values found by Moraes *et al*. (2008) and Sangalli *et al*. (2004), i.e., 5.61 and 5.37 cm, respectively. The flower length values found in this study were similar to the ones found by Sangalli *et al*. (2004), who reported 2.55 cm, and lower than the value found by Moraes *et al*. (2008), of 6.38. Despite these results, the responses found in these evaluations have characteristics that are attractive to consumption, since the flowers have food properties and biological potential.

Thus, the addition of chicken manure into the soil promoted an increase in organic matter, contributing to the availability of nutrients to supply the nutritional need in the growth, development and productivity of Nasturtium plant flowers.

CONCLUSION

Adding chicken manure to the soil, incorporated and as cover, provided higher nutrient contents in the soil. Nasturtium plants that had greater height and yield in terms of number and weight of flowers were cultivated under 10 t ha^{-1} I (incorporated) and 10 t ha^{-1} C (cover) of chicken manure. Nutrient contents of P, Ca, Mg, Cu, Mn and Zn in leaves and flowers of Nasturtium were within the range recommended for good development of the main vegetable crops.

CONFLICT OF INTERESTS

The authors declared that there is no conflict of interests.

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