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Organic fertilization and forms of application in *Allium cepa* growth, yield and bulb quality[1]

Adubação orgânica e formas de aplicação no crescimento, rendimento e qualidade de bulbos de *Allium cepa*

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HIGHLIGHTS:

The organic fertilization, regardless of the form of application, is recommended in onion production.
Bovine manure application forms have different responses in the onion.
The growth, yield and quality characteristics of the onion are increased by incorporating bovine manure into the soil.

ABSTRACT: Onion is the third most cultivated vegetable in Brazil, and organic fertilization can increase its productivity. The objective of this study was to evaluate the effect of doses of cattle manure and forms of applications on the growth, yield and bulb quality of onion cv. IPA-11 Vale Ouro. The experimental design used was randomized blocks, with four replicates, in a 6 × 2 factorial scheme, corresponding to six doses of cattle manure (0; 10; 20; 30; 40 and 50 t ha^{-1}) and two forms of application (incorporated and topdressing). The onion growth increased with cattle manure doses. Using cattle manure fertilization is feasible for the production of onion, however high doses, regardless of the form of application are not recommended. Incorporated manure increases the leaf concentrations of primary macronutrients in onion and promotes 15 and 20% increment in total and marketable yield, respectively. The cattle manure incorporated into the soil increased the production of bulbs within the class of greater acceptance by consumers.

Key words: onion, cattle manure, IPA-11 Vale Ouro, organic fertilization

RESUMO: A cebola é a terceira hortaliça mais cultivada no Brasil e a adubação orgânica pode aumentar sua produtividade. Objetivou-se avaliar o efeito de doses de esterco de gado e formas de aplicações no crescimento, rendimento e qualidade de bulbos da cebola cv. Vale Ouro IPA-11. O delineamento experimental utilizado foi em blocos casualizados, com quatro repetições, em esquema fatorial 6 x 2, correspondente a seis doses de esterco de gado (0; 10; 20; 30; 40 e 50 t ha^{-1}) e duas formas de aplicação (incorporado e cobertura). O crescimento da cebola aumentou com as doses de esterco bovino. A adubação com esterco bovino é viável para a produção de cebola, porém doses elevadas, independente da forma de aplicação, não são recomendadas. O esterco incorporado aumenta as concentrações foliares dos macronutrientes primários na cebola e promove 15% e 20% de incremento na produção total e comercial, respectivamente. O esterco bovino incorporado ao solo aumentou a produção de bulbos dentro da classe de maior aceitação pelos consumidores.

Palavras-chave: cebola, esterco de gado, IPA-11 Vale Ouro, fertilização orgânica

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Introduction

Onion (*Allium cepa* L.) is the third most cultivated vegetable in Brazil, with a production of around 1.6 million tons in 2019, and the South and Northeast regions account for 50 and 22% of total production, respectively (IBGE, 2019). This crop is highly appreciated all over the world, and its main form of consumption is fresh, in the form of salads and as condiment and seasoning in the diet (Albuquerque et al., 2013).

In Brazil, this crop is mainly cultivated by small producers. So the demand for techniques suitable for family farming to increase the productivity of vegetables, such as onions, has become constant (Sediyama et al., 2014). According to EMBRAPA (2006), productivity in organic planting can surpass conventional planting about 38 t ha^{-1} of commercial onion bulbs, amount higher than the average recorded with traditional cultivation methods, being an attractive system to the producer.

As a measure to meet the nutritional needs of this crop, organic fertilization, through the addition of different sources of organic matter, has been shown to be very promising (Belem et al., 2020), and the demand for techniques suitable for family farming for onion production has become constant, especially aiming at agroecological methods (Santos et al., 2012).

Several processes are involved in the organic fertilization to improve soil properties in onion cultivation, such as the mineralization of the organic material by specific microorganisms required for nutrients release (Maluf et al., 2015). The forms application of manure (incorporated and topdressing) is extremely important for the maximum use of nitrogen, phosphorus and potassium, as well as, improvement in the physical, microbial properties of the soil and consequently crop yield (Duan et al., 2016), due to increased soil aeration, humidity and reduced N leaching, thus ensuring better development and assimilation of nutrients (Muhammad et al., 2018).

Thus, the objective of this study was to evaluate the effect of doses and forms of application of cattle manure on the growth, yield and bulb quality of onion cv. IPA-11 Vale Ouro.

Material and Methods

The experiment was conducted under field conditions in the experimental area of the Centro de Ciências Agrárias of the Universidade Federal da Paraíba from October 2017 to March 2018.

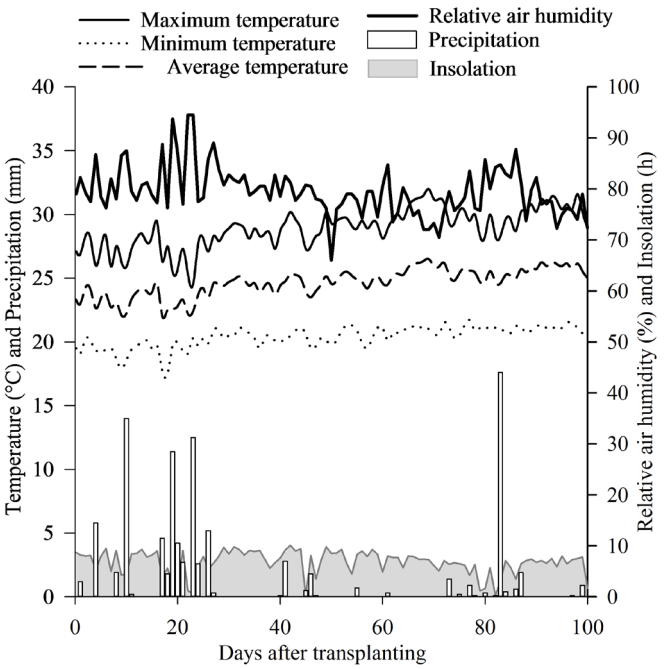
The experimental area is located in the municipality of Areia, Paraíba, Brazil, in the Brejo Paraibano Microregion, with altitude of 587 m, latitude 6° 57' 37" S and longitude 35° 45' 31" W and characterized by constant production of vegetables and application of fertilizer. The predominant climate in the area is As', according to Köppen's classification, which is characterized as hot and humid, with autumn-winter rains, where the average annual temperature fluctuates between 23 and 24 °C. The bioclimate is classified as sub-dry Northeastern 3dfh, with average annual rainfall around 1.200 mm, according to Gaussen's bioclimatic classification (Francisco et al., 2015).

The soil type of the experimental area is classified as Entisol with sandy loam texture. The meteorological data for the experimental period are shown in Figure 1.

The experimental design used was randomized blocks, with four replicates, in a 6 × 2 factorial scheme, corresponding to six doses of cattle manure (0; 10; 20; 30; 40 and 50 t ha^{-1}) in two forms of application (incorporated and topdressing). The experimental plot with an area of 1.0 m^2 and 30 cm height was composed of 100 plants arranged in 10 rows with spacing of 0.10 × 0.10 m, disregarding the border and considering 60 usable plants.

Soil samples were collected at 0-20 cm layer, prior to the installation of the experiment for chemical analysis (EMBRAPA, 2009), and the chemical attributes of the soil are described in Table 1.

Fertilization at planting was performed three days before transplanting the onion plants and consisted only of the manure doses as described in the experimental design, applied as topdressing and incorporated, turning the soil using a hoe. The manure used was obtained from cattle belonging to the Universidade Federal da Paraíba (UFPB), and the soil layer of the incorporated manure was 0-30 cm. The



Source: INMET Automatic Weather Station of Areia, PB, Brazil

Figure 1. Mean values of temperature, air relative air humidity, insolation and precipitation in the period of cultivation of onion cv. IPA Vale Ouro

Table 1. Chemical characteristics of the soil in the experimental area

pH	P	K^+	Na^+	$H^+ + Al^{3+}$	Al^{3+}	Ca^{2+}	Mg^{2+}	BS	CEC	OM
H_2O (1:2.5)	(mg dm^{-3})		($cmol_c$ dm^{-3})							(g kg^{-1})
5.8	90.45	56.18	0.06	2.84	0.00	2.44	1.15	3.79	6.63	17.43

OM - Organic matter (Walkley - Black); CEC - Cation exchange capacity; BS - Base saturation; P, K^+, Na^+ - Extractor Mehlich 1; $H^+ + Al^{3+}$ - Extractor calcium acetate 0.5M pH 7.0; Al^{3+}, Ca^{2+}, Mg^{2+} - Extractor KCl 1M

Table 2. Chemical characteristics of cattle manure

M (%)	N	P	K	Ca	Mg	OM
	(g kg^{-1})					
5.00	8.71	4.4	10.90	2.40	3.50	124.80

M - Moisture; OM - Organic matter (Walkley - Black)

chemical characteristics of the manure, analyzed according to EMBRAPA (2009), are described in Table 2.

For planting in the field, seedlings of the cultivar IPA-11 Vale Ouro were produced in conventional trays and transplanted at 40 days after sowing, when they were 15 to 20 cm tall.

Irrigation was applied using a drip system in the period of absence of precipitation, with 30 mm irrigation water depths, split into two to three days, with space between tapes and emitters according to the experimental spacing. Weed management was performed manually according to the technical recommendations and needs of the crop. Phytosanitary control was not performed, due to the absence of pests and diseases capable of causing economic damage.

At 60 days after transplantation (DAT), the height of five plants was measured from the soil to the tip of the leaf, with results expressed in cm (Belem et al., 2020). The leaves were detached and placed in paper bags to evaluate the fresh mass and dry mass of the shoots, with the fresh mass corresponding to the mass of the plants before drying and the dry mass obtained after drying in an oven with circulation at 65 °C for 96 hours. Subsequently, these materials were ground to determine the leaf concentrations of N, P and K according to the methodology of Tedesco (1995).

Harvest was carried out around 100 days after transplanting, when the plants had advanced signs of senescence, such as yellowing and drying of leaves in more than 70% of the mature plants. Subsequently, the bulbs were subjected to the pre-curing process (exposure of bulbs to the soil for four days) and transported to a shed to evaluate characteristics of production and bulb classification.

The total yield corresponded to the weight of all bulbs harvested and the marketable yield to the weight of bulbs with mass considered marketable, estimating the results in tons per hectare. Harvested bulbs were classified based on the largest cross-sectional diameter, with results expressed as a percentage, according to the classification of Hortibrasil (2009). This classification considers: Class 0 (noncommercial) bulbs, with a diameter of < 15 mm; Class 1 bulbs, with a diameter of 15-35 mm; Class 2 bulbs, with a diameter of 35-50 mm; Class 3 bulbs, with a diameter of 50-70 mm, Class 4 bulbs, with a diameter of 70-90 mm.

The statistical analysis was performed using the statistical program R (R Core Team, 2020) and the results were subjected to analysis of variance and polynomial regression. In the classification of bulbs, the means of each form of application were compared by F test and the doses of cattle manure were compared by Scott-Knott test.

Results and Dicussion

There was a significant interactive effect ($p \leq 0.05$) on the variables of growth, mass accumulation, leaf concentrations of primary macronutrients, production and quality of the onion cultivar IPA-11Vale Ouro (Table 3).

The height of onion plants (Figure 2) was higher with the use of incorporated cattle manure, and the dose of 23.1 t ha^{-1} was responsible for the maximum height of 50.2 cm; on the other hand, the use of manure applied as topdressing promoted higher height (45.9 cm) at the dose of 22.0 t ha^{-1}.

Possibly with manure application, ammonium was released and made available for plants (Malavolta, 2006). The increase in manure doses increased nitrogen in the soil promoting shoot growth (Taiz et al., 2017); however, excessive concentrations inhibit plant growth, possibly due to toxicity, deleterious effect or imbalance between nutrients in the soil, caused by excess manure. According to Araújo et al. (2016), large amounts of nitrogen promote increased flaccidity in chives leaves.

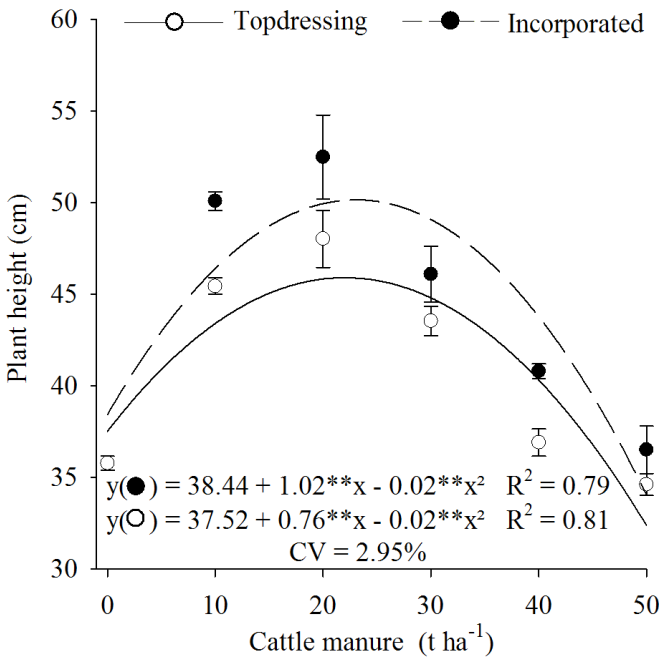
Biomass accumulation in the shoots of onion plants was also higher with the use of incorporated manure. The maximum shoot fresh mass was 77.1 g at the dose of 23.3 t ha^{-1} for the incorporated manure and 71.3 g at the dose of 23.1 t ha^{-1} for the topdressed manure (Figure 3A). Regarding dry mass (Figure 3B), the highest values were 8.9 g (incorporated manure) and 8.2 g (topdressed manure) at the respective doses of 24.9 and 25.0 t ha^{-1}.

This result occurs because the incorporation of the cattle manure, besides supplying nutrients, including nitrogen, phosphorus and potassium, improves physical characteristics, such moisture retention, and soil chemistry, among them

Table 3. Summary of the analysis of variance for plant height (PH), shoot fresh mass (SF), shoot dry mass (SD), total yield (TY), marketable yield (MY) and nitrogen (N), phosphorus (P) and potassium (K) concentrations of onion cv. IPA-11 Vale Ouro, fertilized with cattle manure in different forms of application

Source of variation	DF	Mean squares							
		PH	SF	SD	N	P	K	TY	MY
Forms of application (F)	1	76.27**	116.79**	1.46**	4.51*	3.50**	25.60*	174.68**	212.63**
Doses of cattle manure (D)	5	239.85**	2117.46**	19.50**	47.28**	22.57**	133.39**	526.64**	899.71**
Interaction (F x D)	5	4.82^{ns}	23.05**	0.13^{ns}	0.30^{ns}	0.41**	2.85^{ns}	15.82**	23.06**
Incorporated									
Linear regression	1	24.60**	182.84**	4.97 e^{-2} ^{ns}	3.25 e^{-1} ^{ns}	1.66e^{-6}**	15.32*	19.88*	72.80**
Quadratic regression	1	335.85**	3353.39**	4.47 e^{-1}**	111.13**	2.12e^{-17}**	316.78**	1243.66**	2165.96**
Topdressing									
Linear regression	1	33.92**	173.25**	1.01 e^{-2} ^{ns}	6.89 e^{-1} ^{ns}	1.53 e^{-5}**	8.11^{ns}	13.63*	35.58**
Quadratic regression	1	204.99**	2459.43**	3.41 e^{-1}**	79.39**	1.10 e^{-14}**	164.21**	554.12**	1127.64**
Blocks	3	1.505^{ns}	7.240^{ns}	0.024^{ns}	0.853^{ns}	0.086^{ns}	0.161^{ns}	0.580^{ns}	0.780^{ns}
Residue	33	2.358	3.550	0.081	0.985	0.087	4.247	3.230	3.180
CV (%)		2.95	2.49	3.29	4.25	5.68	7.26	3.01	3.97

ns, *, ** - Not significant, significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively



** - Significant at p ≤ 0.01 by F test

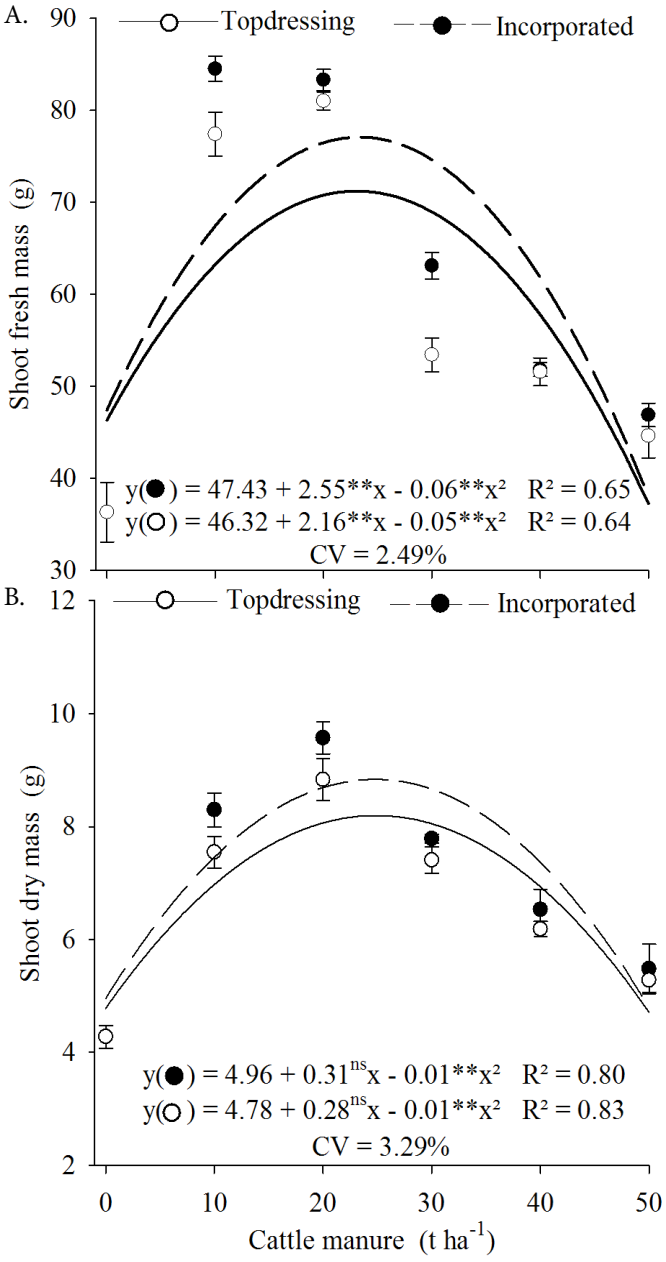
Figure 2. Height of onion plants cv. IPA-11 Vale Ouro in function of cattle manure doses in two forms of application

cation exchange capacity and organic matter content more markedly than just topdressing application of manure (Scheid et al., 2019; Ortiz et al., 2020).

The concentrations of primary macronutrients in the leaf tissue of the plants corroborated the growth variables, which also had higher values with manure incorporated into the soil. Nitrogen, phosphorus and potassium concentrations with maximum estimated points at doses of 24.5 and 24.4 t ha^{-1} for incorporated and topdressed manure, corresponding to 21.5 and 20.4 g kg^{-1} of nitrogen (Figure 4A), and at the doses of 23.0 t ha^{-1} of incorporated and topdressed manure, for the respective concentrations of 6.6 and 5.4 g kg^{-1} of phosphorus (Figure 4B) and at dose of 26.6 t ha^{-1} for 28.0 and 25.0 g kg^{-1} of potassium concentration (Figure 4C).

Therefore, it was noticed that the doses of cattle manure led to similar values in the two methods of application for each nutrient; however, the leaf concentrations were significantly higher at doses of 20 and 30 t ha^{-1} when manure was incorporated into the soil compared to its topdressing application, with the exception of nitrogen.

According to Backes et al. (2018), potassium is the element with the highest accumulation in onion crop, followed by nitrogen, as observed in the present study, which are highly required in the bulbification process (Kurtz et al., 2016). Araújo et al. (2016), when studying nutrient absorption in chives, found that nitrogen deficiency affects the absorption of other macronutrients, such as phosphorus, potassium, calcium and magnesium. Therefore, as cattle manure is rich in N, manure doses below 20 t ha^{-1} may not have supplied the ideal nitrogen absorption range and consequently affected the absorption of other macronutrients, and manure doses above 30 t ha^{-1} may have been excessive, which results in the reduction of growth and consequently yield of onion, reflecting the higher levels of nutritional accumulation in the range between 20 and 30 t ha^{-1}, which were also responsible also for the best yields of the crop.



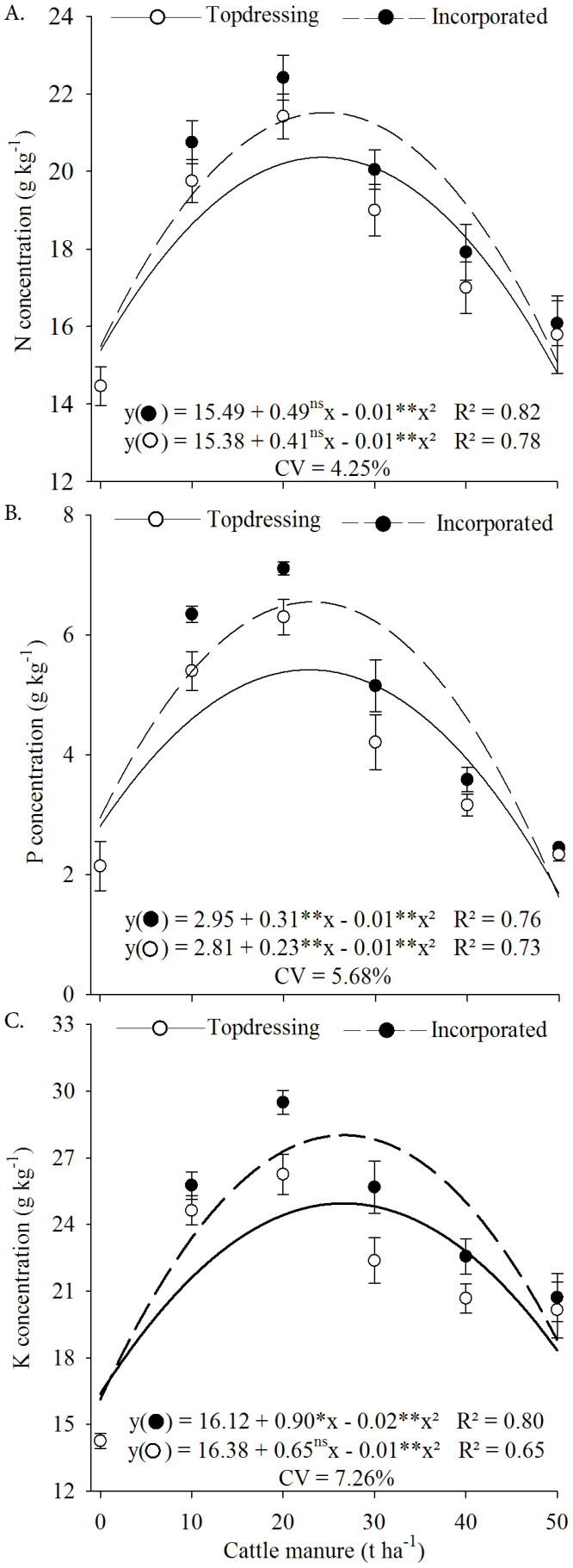
ns, ** - Not significant and significant at p ≤ 0.01 by F test, respectively

Figure 3. Fresh (A) and dry (B) mass of the shoots of onion cv. IPA-11 Vale Ouro in function of cattle manure doses in two forms of application

The total yield of bulbs (Figure 5A) reached a maximum of 58.6 t ha^{-1} at the dose of 24.1 t ha^{-1} of incorporated cattle manure, whereas in application of topdressing was obtained 51.0 t ha^{-1} in the dose of 23.9 t ha^{-1}.

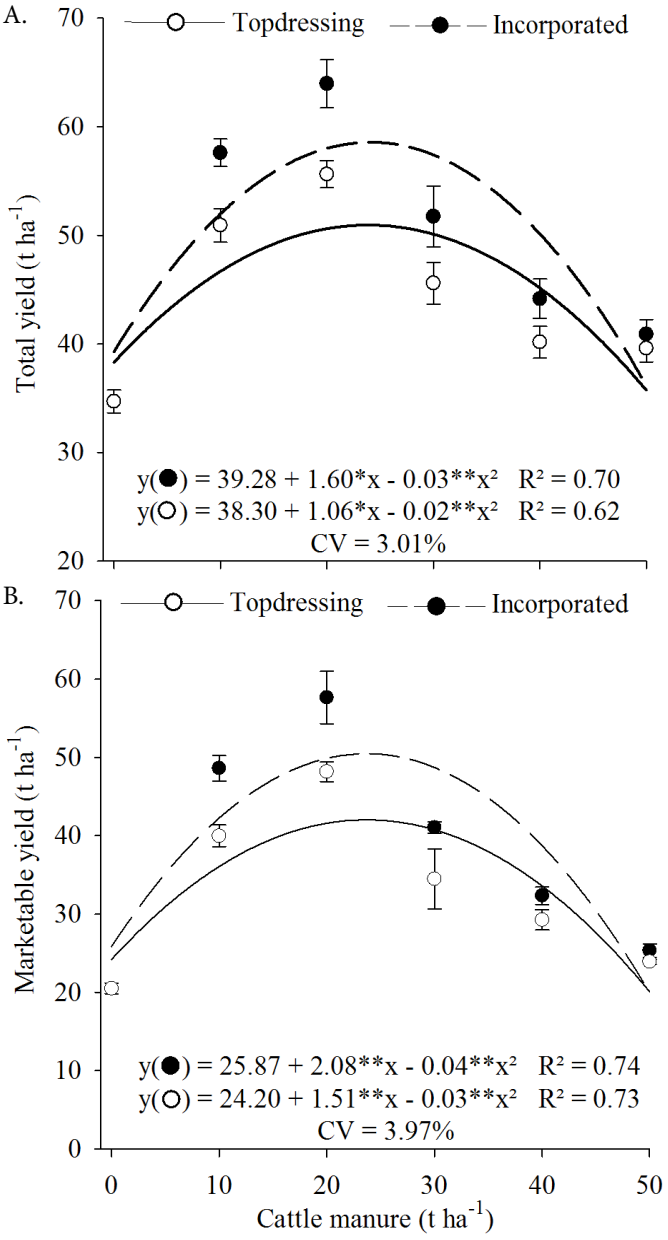
In relation to the marketable yield of the bulbs (Figure 5B), there was an increase up to 50.5 t ha^{-1} at the dose of 23.7 t ha^{-1} of incorporated manure, decreasing from these values, while the application of manure only as topdressing led to an increase in yield up to 42.1 t ha^{-1} at the dose of 23.7 t ha^{-1}. Thus, it can be noted that the use of manure incorporated into the soil was more efficient than the application of topdressing, as the same amount of input promotes an increase of 20% in marketable yield.

Mekonnen et al. (2017), when studying the yield of the onion cultivar Adama Red, found that the highest total yield of bulbs (58.74 t ha^{-1}) and yield of marketable bulbs (57.77 t ha^{-1})



ns, *, ** - Not significant, significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively

Figure 4. Nitrogen (A), phosphorus (B) and potassium (C) concentrations in the leaf of onion cv. IPA-11 Vale Ouro in function of cattle manure doses in two forms of application



*, ** - Significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively

Figure 5. Total (A) and marketable (B) yields of onion cv. IPA-11 Vale Ouro in function of cattle manure doses in two forms of application

were obtained in plants from the plots that received 30 t ha^{-1} of cattle manure and that excessive doses reduced these variables.

In the study with the use of cattle manure and nitrogen supplementation with onion cultivar IPA-11Vale Ouro Belem et al. (2020)observed that the cattle manure dose of 27 t ha^{-1} in the presence of N was responsible for the maximum marketable yield of bulbs of 50 t ha^{-1}, that is, these authors found marketable production values similar to those of the present study, which only performed incorporated fertilization with manure and also achieved higher profitability with a lower dose (23.66 t ha^{-1}). Thus, the use of fertilization with cattle manure incorporated into the soil in onion is feasible to achieve high marketable yield, possibly due to rapid decomposition and increased microbial activity and, consequently, greater release of nutrients such as nitrogen, phosphorus and potassium (Silva et al., 2014).

Table 4. Classification of bulbs of onion cv. IPA-11 Vale Ouro in function of cattle manure doses in two forms of application

Cattle manure	Class 0 (%)		Class 1 (%)		Class 2 (%)		Class 3 (%)		Class 4 (%)	
(t ha^{-1})	I	T	I	T	I	T	I	T	I	T
0	15.5 aA	15.5 aA	25.4 aA	25.4 aA	46.8 aA	46.8 aA	12.3 eA	12.3 fA	0 cA	0 cA
10	0 dA	0 dA	15.6 cB	21.5 bA	27.8 cA	23.8 dB	51.0 bA	49.3 bA	5.7 bA	5.5 bA
20	0 dA	0 dA	9.9 dA	13.4 cA	21.5 dA	21.6 dA	57.0 aA	54.5 aA	11.5 aA	10.5 aA
30	0 dA	0 dA	20.5 bA	24.3 bA	39.6 bA	38.3 cA	34.3 cA	31.6 cA	5.6 bA	5.8 bA
40	5.5 cA	2.2 cB	21.2 bA	24.9 bA	36.2 bB	43.1 bA	33.8 cA	26.1 dB	3.2 bA	3.6 bA
50	11.1 bA	7.7 bB	26.9 aA	26.9 aA	39.1 bA	38.4 cA	19.6 dA	20.6 eA	3.3 bA	1.3 cA
CV (%)	6.6		3.7		4.5		6.0		5.8	

Means followed by the same uppercase letter in the row in each class do not differ statistically by the F-test ($p \leq 0.05$) and means followed by the same lowercase letter in the column do not differ statistically by the Scott-Knott test ($p \leq 0.05$); I - Incorporated; T - Topdressed; CV - Coefficient of variation

In the classification of onion (Table 4), the bulbs considered class 0 (narrowly curled-up, rotten, or with mechanical damage), which are not commercially interesting, were observed more frequently in the absence of manure application, followed by higher doses of manure (50 and 40 t ha^{-1}). Thus, it demonstrates that the application of organic inputs promotes beneficial effects on the quality of onion bulbs, but excessive doses are harmful.

According to Resende et al. (2016), the increase in N doses, in the case of manure supplementation, caused a gradual reduction in scrap production and increased marketable bulbs. It was also found that, at doses of 40 and 50 t ha^{-1} the incorporated manure was statistically superior to the topdressed manure, possibly due to cattle manure effects on structural stability and water retention capacity (Nyamangara et al., 2001)

In class 1, in relation to manure doses, there were higher percentages of bulbs cultivated with absence of manure and at the dose of 50 t ha^{-1} of manure. In addition, it was noticeable that the use of manure applied as topdressing led to higher values. Similarly, bulbs belonging to class 2 showed higher percentages (46.8%) in the treatment without manure. Similar results were found by Vidigal et al. (2010) with onion cv. CNPH 6400, as higher concentration of bulbs in classes 1 and 2 was obtained in the treatment without application of organic compost.

Regarding class 3, which has the highest commercial value, due to consumer acceptance, the highest percentage was found with application of 20 t ha^{-1} of manure in both application methods. Gonçalves et al. (2019) observed an increase in marketable bulbs with increased nitrogen fertilization, being reduced with excessive concentrations of N, which can be explained by the fact that nitrogen is intrinsically related to the increase in bulb diameter. At the dose of 40 t ha^{-1}, the use of manure incorporated into the soil was statistically superior to that applied only as topdressing. Probably, the incorporation of manure better distributed the nutrients contained in the organic inputs and improved the physical characteristics of the soil (Duan et al., 2016; Muhammad et al., 2018).

Regarding the bulbs in class 4, higher percentages were observed at the manure dose of 20 t ha^{-1}, with 11.5% for incorporated manure and 10.5% for topdressed manure, and it was also found that there were no significant differences in this class as a function of the methods of application of the input.

Conclusions

1. Use of cattle manure fertilization is feasible for the production of onion cv. IPA-11 Vale Ouro, however, high doses, regardless of the form of application are not recommended.

2. The onion growth increased with cattle manure doses.

3. Incorporated manure increases the leaf concentrations of primary macronutrients in onion and promotes 15% and 20% increment in total and marketable yield, respectively.

4. The cattle manure incorporated into the soil increased the production of bulbs within the class of greater acceptance by consumers.

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