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RESEARCH PAPER

Cattle manure and N-urea in radish crop (*Raphanus sativus*)

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Abstract

J.W. Mendoza Cortez, A.B. Cecílio Filho, E.L. Coutinho, and A. Alves. 2010. Cattle manure and N-urea in radish crop *(Raphanus sativus)*. Cien. Inv. Agr. 37(1): 45 – 53. This work was carried out in Jaboticabal (575 m altitude, 21°15´ 22˝ S and 48° 15´ 58˝ W), São Paulo, Brazil, aiming to investigate the effects of cattle manure and nitrogen (urea) doses on radish height and yield. Randomized blocks were used with a 2x4x4 factorial scheme and 3 replications. The treatments were combinations of cultivars (25 and 19), cattle manure doses (0, 25, 50, and 75 t ha^{-1} dry basis) and N doses (0, 60, 120 and 180 kg ha^{-1}). Increased cattle manure and urea doses provided higher plant height and commercial yield in both cultivars, but the N produced more significant effects than the cattle manure. The maximum commercial yield of cultivar (cv) 19 (20.34 t ha^{-1}) was obtained using 75 t ha^{-1} of cattle manure and 139 kg ha^{-1} of N, whereas that of cv 25 (11.90 t ha^{-1}) occurred with 75 t ha^{-1} of cattle manure and 180 kg ha^{-1} of N. The maximum economic efficiency doses for cv. 25 were 65.1 t ha^{-1} and 180 kg ha^{-1} of cattle manure and N, respectively, whereas those for cv 19 were 63.6 t ha^{-1} and 144.7 kg ha^{-1} of cattle manure and N, respectively.

Key words: *Raphanus sativus*, fertilization, yield.

Introduction

The annual Brazilian production of radish (*Raphanus sativus*) is around 9,000 t. Between 1997 and 2003, the state of São Paulo produced 2,732 t of radish per year, with most of the planted area being between approximately 2 and 5 ha (Ferreira and Zambon, 2004). However, despite its high profitability, radishes are considered to be an economically minor crop (Cecílio Filho and May, 2002). Radishes have a very short vegetative cycle, which provides for a rapid return of capital. Therefore, radish is often included within rotation programs. Radish crops lack technical information, especially on topics related to growth development and yields that depend on fertilization.

In production systems, nitrogen (N) availability is almost always a restricting factor. Nitrogen affects plant growth more than any other nutrient because it is related to the most important biochemical and physiological processes of the plant (Carmello, 1999). Marcolini *et al.* (2006) reported that N is the most accrued nutrient in radishes (with 63 kg ha^{-1}). When N is deficient, the plants become chlorotic, beginning in the oldest leaves and eventually reaching the whole plant at harvest, causing 28 and 23% reductions of the dry mass of the aerial part and a thickened hypocotyl, respectively (Cecílio Filho *et al.*,

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1998). In contrast, excessive N may also cause severe losses, because the plant height increases considerably, leading to intraspecific competency, mainly by light and diminished yields.

Both organic and inorganic fertilization have been recommended for radish crops (Trani *et al.,* 1997). Although the advantages of organic fertilizers on vegetables are known, their costs restrict their use. There is limited information on the release rate of mineral N from organic fertilizers in Brazilians soils (Tedesco *et al.*, 1999), and it is difficult to synchronize periods of the highest N release with periods of high N demands by plants (Lisboa, 2004). Few reports have evaluated the use of manure on short-cycle crops. Because the use of organic fertilizers in crop management is not fully understood, it is necessary to study their technical and economic impacts before expanding their application. Therefore, the objective of this study was to evaluate the effects of cattle manure and N-urea on radish yields and plant height at harvest.

Materials and methods

Location and soil characterization

The experiment was conducted in Jaboticabal (575-m high, 21°15′ 22″ S and 48° 15′ 58″ W), São Paulo, Brazil, in Eutrustox soil (USDA, 1975), which was 0 to 20-cm deep; pH ($CaCl_2$) = 5.3; organic matter = 22 g dm^{-3}; $P_{(resin)}$ = 33 mg dm^{-3}; K, Ca, Mg, H+Al and CIC = 2.7; 20; 8; 22 and 52.7 $mmol_c$ dm^{-3}, respectively; V = 58%, B, Cu, Fe, Mn, Zn and S-SO_4^{2-} = 0.22; 3.9; 9.0; 16.1; 0.7 and 46 mg dm^{-3}, respectively.

The total annual precipitation, means of relative humidity and temperature were 156.9 mm, 77.1% and 21.3°C, respectively, during the experimental period (Volpe *et al.*, 2008).

Nitrogen treatments

The cattle manure used in this study was analyzed chemically (Tedesco *et al.,* 1995). On a dry basis, the manure had a pH = 6.6; humidity = 409 g kg^{-1}; C/N=10; N, P, K, Ca, Mg and S=23, 5.6, 8.9, 11.4, 5.0, and 4.4 g kg^{-1}, respectively; B, Cu, Fe, Mn and Zn = 8, 110, 3875, 675, and 203 mg kg^{-1}, respectively. The whitewash was made to increase the saturation of the soil bases to 80% (Trani *et al.*, 1997), using lime with 122% of the total neutralizing power 30 days before sowing.

On the sowing day (April 3, 2008), the manure doses were distributed and incorporated into the experimental plots, according to the various treatments. Then, 1 kg ha^{-1} B (boric acid), 240 kg ha^{-1} P_2O_5 (simple superphosphate) and 120 kg ha^{-1} K_2O (potassium chloride) were applied (Trani *et al.*, 1997). A total dose of N (urea) was applied at sowing (distributed in the total area of the plot) (40%), ten days after the emergence (DAE) (30%) and twenty DAE (30%). The urea was applied from 10 to 20 DAE, and it was distributed along the plant lines. Potassium chloride (60 kg ha^{-1} K_2O) was also applied fractionally at 10 DAE (50%) and 20 DAE (50%).

Crop management

Thinning was performed at 7 days, adapting the distance among the plants to 0.05 m. Weed control was performed manually. Radish plants were irrigated daily by aspersion to provide a 3-mm water surface at the initial crop phase (first 15 days). The water surface was increased to 6 mm to promote good crop development. The plants were harvested on May 6, 2008, after a total of 34 days, when the thickened hypocotyls exhibited commercial characteristics.

Evaluation

The evaluation included the following. a. Total N content of the leaves: the leaves were washed in deionized water and then dried in a forced air circulation oven for 96 h at 65±1°C until they reached a constant weight. They were further ground in a Willey type mill with a 20-sieve mesh. A sample was used to determine the total N content (Bataglia *et al.*, 1983). b. Plant height: measured from the soil surface to the highest part of the plant. c. Commercial yield: this corresponded to the total fresh mass of thickened hypocotyls of commercial quality, except for the thickened hypocotyls with splits. d. Non-commercial yield: this corresponded to the thickened hypocotyls with splits. e) doses of maximum economical efficiency: determined by the derivative of the liquid income [IL = P_P x C_P - (E x P_E + N x P_N), where P_P = product price (t^{-1}); C_P = amount produced (t ha^{-1}); E = manure (t ha^{-1}); P_E = manure price (t^{-1}); N = nitrogen (kg ha^{-1}); and P_N = N price (kg^{-1})]. The C_P term estimating the IL was substituted by the function (Z) of the commercial yield obtained in the study of the response surface [Z= b_0 + b_1 x (manure) + b_2 x (N) + b_3 x $(manure)^2$ + b_4 x (N) x (manure) + b_5 x $(N)^2$, where b_0=intercept; b_1= linear coefficient for manure; b_2= linear coefficient for N; b_3= quadratic coefficient for manure; b_4=coefficient of N and manure interaction; and b_5= quadratic coefficient for N]. Then, the partial derivatives for each factor (manure and N) were found in each cultivar according to the following equation: $\partial IL / \partial E = (P_P \times b_1 - P_E) + 2P_P \times b_3 \times E + P_P \times b_4 \times N = 0$ and $\partial IL / \partial N = (P_P \times b_2 - P_N) + 2P_P \times b_5 \times N + P_P \times b_4 \times E = 0$. According to AGRIANUAL (2009) and CEAGESP (2009), the actual prices of the product (radish), manure and N for estimating the economical costs were R$ 2500.00 per t; R$ 150.00 per t and R$ 1.80 per kg, respectively.

Design and statistical analysis

Treatments were distributed as completely randomized blocks in a 2x4x4 factorial design with three replicates. The variable factors were cultivars (25 cultivars and 19 hybrids 19) with thickened red and rounded hypocotyls, cattle manure doses (0, 25, 50 and 75 t ha^{-1} in dry base) with 18% humidity, and N doses (0, 60, 120 and 180 kg ha^{-1}) as urea. The experimental plots were 1.1x2.0 m, with four rows of radishes planted at 0.25 m within each row. The middle rows (1x1 m) were used for evaluation.

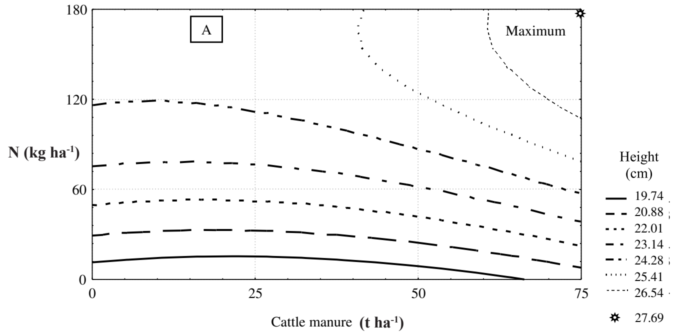
The results were subjected to analyses of variance (F test). The surface of the quadratic polynomial response was studied for each cultivar [Z= b_0 + b_1 x (manure) + b_2 x (N) + b_3 x $(manure)^2$ + b_4 x (N) x (manure) + b_5 x $(N)^2$, where b_0=intercept; b_1= linear coefficient for manure; b_2= linear coefficient for N; b_3= quadratic coefficient for manure; b_4=coefficient of N and manure interaction; and b_5= quadratic coefficient for N]. When significant ($p \leq 0.05$), the equation was used to study the interaction of the manure and N.

Results and discussion

The plant height was significantly affected by the cultivar, manure and N treatments. Hybrid 19 exhibited an average height of 22 cm, which was shorter than the average height of radish 25 (23.3 cm). Similar results have been reported previously (Reis *et al.*, 2004), where radish hybrid 19 was smaller than radishes 'Crimson Gigante' and 'Vermelho Comprido', both of which have thickened, red and globose hypocotyls.

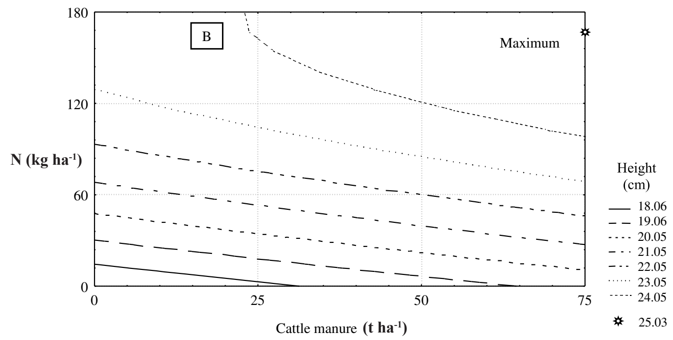
For each cultivar, a significant fit of the response surface was found for the combined effects of manure and N. The highest height of the radish plants was achieved by increasing the manure and/or N doses (Figure 1), in accordance with the results obtained by El-Desuki *et al.* (2005). The maximum plant heights of cultivars 19 (25.0 cm) and 25 (27.7 cm) were obtained with 168 and 176 kg ha^{-1} of N, respectively, and 75 t ha^{-1} of manure (Figure 1).

With the optimal dose of N for each cultivar (168 and 176 kg ha^{-1} of N), but without the addition of manure, the plant heights of radishes 19 and 25 were 23.5 and 24.5 cm, respectively. These results reveal the small contribution from manure. As expected, urea is a fertilizer that increases the N availability for plants. In Brazilian soils, rapid urea hydrolysis can occur, depending on the temperature, humidity, pH, concentration of the substrate and soil type (Longo and Melo, 2005), whereas manure does not undergo this same reaction. Considering that radish is a short-cycle crop, with harvest occurring 25 to 35 days after sowing, rapid N release is crucial for the plant. Radishes may absorb N prematurely and possibly in higher amounts by raising the content of nitrogenated compounds that contribute to its structural functions. Nevertheless, increased radish height is not a desired feature for obtaining a higher yield. In contrast, a balanced fertilization is ideal to hinder exag-



$$Z = 18.931 - 0.027931\,x + 0.074113\,y + 0.000604\,x^2 + 0.000142\,xy - 0.000241\,y^2$$

F Test: 19.75**; R^2: 0.70; Coefficient of variability (CV): 8.2%



$$Z = 17.06 + 0.032818\,x + 0.072298\,y - 0.00002833\,x^2 - 0.00006382\,xy - 0.000201\,y^2$$

F Test: 20.61**; R^2: 0.71; Coefficient of variability (CV): 7.7%

Figure 1. Plant height (cm) of radish cultivars 25 (A) and 19 (B) as a function of cattle manure and N-urea doses.

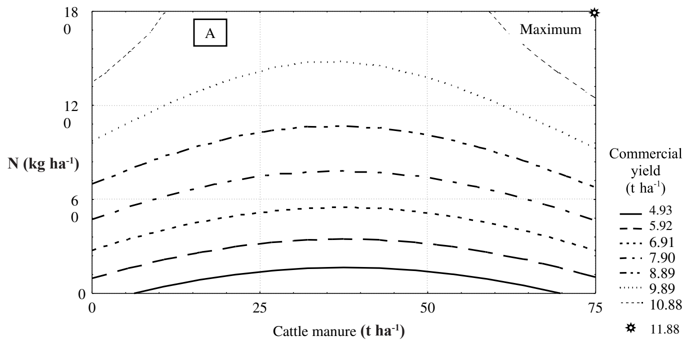
gerated leaf growth, thereby competing with the growth of thickened hypocotyls, which is a relevant feature for a commercial product.

The foliar N content was significantly influenced by the manure doses. A significant fit of the response surface was not observed. The N content in the leaf ($Y = 22.53 - 0.0251X$; $R^2 = 0.82$) decreased with increased manure dose. The N immobilization, which is caused by the soil microorganisms, likely occurred at a higher intensity than the liquid mineralization.

In this experiment, the amounts of N present on a dry basis in 25, 50 and 75 t ha^{-1} of cattle manure were approximately 690, 1380, and 2070 kg ha^{-1} of N, respectively. Therefore, 0.46, 0.91, and 1.37 kg ha^{-1} day^{-1} of mineralized N would be obtained for 25, 50 and 75 t ha^{-1} of manure, assuming a mean daily rate of N mineralization equal to 0.066%, which was estimated from the average rates of mineralization cited by Menezes and Salcedo (2007) of 6.3% for 120 days of incubation and by Abassi *et al.* (2007) of 9 to 10% for 120 days.

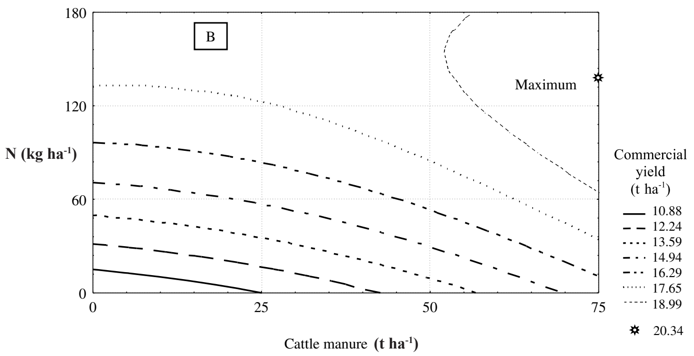
According to the chemical analysis, the manure used in these experiments had a C/N ratio equal to 10 and a high N content (2.3%). These features should have promoted their mineralization and consequently provide a high N availability for the radish plants. Probert *et al.* (2005) reported that mineralization occurred if the C/N ratio was lower than 20, whereas Chadwick *et al.* (2000) indicated that this ratio must be lower than 15. By contrast, Kiehl (1985) reported that organic materials with a C/N ratio between 18 and 10 were classified as semicurate and curate and are characterized by a slow decomposition. However, when the plants were transferred to soil, they exhibited a lower N availability in a shorter time period. Therefore, the low C/N ratio may explain the small contribution of manure to the radish plant height.

According to the analysis of variance, the commercial yield, which corresponds to the thickened hypocotyls of commercial quality, was not influenced by the interaction of the tested factors, but it was influenced by them individually. A significant fit of the response surface for each cultivar was observed. A higher yield of cv. 25 (11.9 t ha^{-1}) was obtained with 75 t ha^{-1} of manure and 180 kg ha^{-1} of N (Figure 2), but when only 180 kg ha^{-1} of N was applied, the yield was 11.5 t ha^{-1}, which is close to 97% of the maximum obtained. In contrast, increases in the manure doses, without N application, did not promote an increased commercial yield, as 5.36, 4.11, 4.08 and 5.28 t ha^{-1} of thickened hypocotyls were obtained with manure doses of 0, 25, 50 and 75 t ha^{-1}, respectively (Figure 2). A lower commercial yield of cv. 25 (3.94 t ha^{-1}) was obtained with a 38 t ha^{-1} dose of manure and without N application, corresponding to 33.2% of the maximum produced. For hybrid 19, the highest yield (20.34 t ha^{-1}) was obtained with the highest manure doses and 139 kg ha^{-1} of N (Figure 2). Therefore, hybrid 19 was 41.6% more productive than cv. 25 with a lower N dose. Similar to cv. 25, hybrid 19 responded positively when the N doses were increased and when manure was not applied. As the same N doses without manure application maximized the commercial yield of hybrid 19, a commercial yield of 17.82 t ha^{-1} was obtained, which is barely 12.4% lower than the maximum commercial yield. Unlike cv. 25, hybrid 19 responded to the application of manure when N was not applied. The lowest commercial yield of hybrid 19 (9.5 t ha^{-1}) was obtained without the application of manure and N, corresponding to 46.8% of the maximum achieved.



$$Z = 5.355 - 0.074416\,x + 0.061196\,y + 0.000979\,x^2 + 0.000033\,xy - 0.000150\,y^2$$

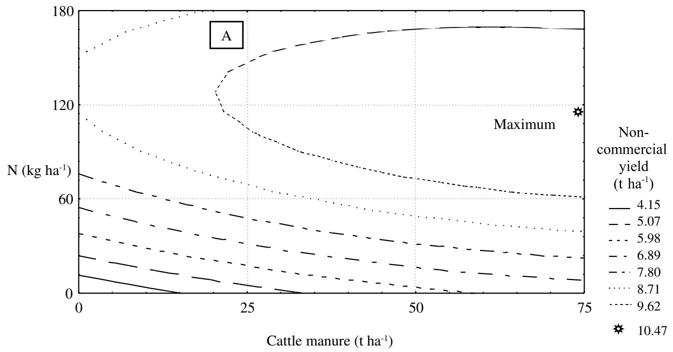
F Test: 6.65**; R^2: 0.44; Coefficient of variability (CV): 35.8%



$$Z = 9.530 + 0.040143\,x + 0.094108\,y + 0.000543\,x^2 - 0.000340\,xy - 0.000248\,y^2$$

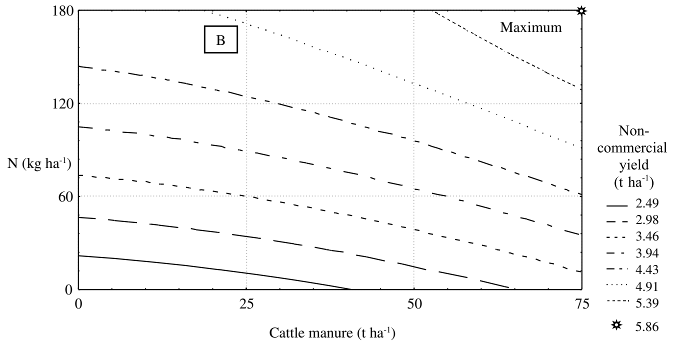
F Test: 10.76**; R^2: 0.56; Coefficient of variability (CV): 17.6%

Figure 2. Commercial yield (t ha^{-1}) of radish cultivars 25 (A) and 19 (B) as a function of cattle manure and N-urea doses.



$$Z = 3.242 + 0.065712\,x + 0.084241\,y - 0.000328\,x^2 - 0.000146\,xy - 0.000319\,y^2$$

F Test: 8.69**; R^2: 0.51; Coefficient of variability (CV): 26.4%



$$Z = 2.017 + 0.006473\,x + 0.022711\,y + 0.000127\,x^2 - 0.000006\,xy - 0.000042\,y^2$$

F Test: 6.99**; R^2: 0.45; Coefficient of variability (CV): 32.2%

Figure 3. Non-commercial yield (t ha^{-1}) of radish cultivars 25 (A) and 19 (B) as a function of cattle manure and N-urea doses.

The presence of split-thickened hypocotyls, which corresponded to the non-commercial yield, was influenced by the individual factors tested in this study and also by the cultivar x N interaction. A significant fit of the response surface for each cultivar was observed. The lowest amounts of split-thickened hypocotyls from hybrid 19 (2.02 t ha^{-1}) and cv. 25 (3.24 t ha^{-1}) were obtained without application of manure and N (Figure 3). Under this condition, very low commercial yields were obtained (46.8 and 45.1% of the maximum yields obtained for cultivars 19 and 25, respectively). Increased N and manure doses resulted in different responses from the cultivars. While cv. 25 (10.47 t ha^{-1}) reached the maximum amount of split-thickened hypocotyls with 74 t ha^{-1} of manure and 115 kg ha^{-1} of N, the amount of split-thickened hypocotyls increased for hybrid 19 (5.86 t ha^{-1}) with maximum manure and N doses (Figure 3). In the combinations in which the maximum commercial yields from cultivars 19 and 25 were obtained, 5.5 and 9.2 t ha^{-1} of split-thickened hypocotyls were recorded, respectively, corresponding to 27 and 77.3% losses in commercial yield. Therefore, hybrid 19 exhibited a higher resistance to the disturbance from split-thickened hypocotyls. According to SAKATA Company (2008), the owner of hybrid 19, one of the main features of this hybrid is its high resistance to split-thickened hypocotyls.

Several factors may have caused the occurrence of split-thickened hypocotyls. In addition to genetic factors, splitting may be caused by variations in the water and thermal properties of the soil. High temperatures lead to a lack of crops remaining in the soil, which favors rapid drying and hydration of the soil surface, ultimately affecting the growth of thickened hypocotyls. According to Filgueira (2003), water oscillations may cause splits in thickened radish hypocotyls. Nitrogen fertilization also promotes splits. Cardoso and Hiraki (2001) reported that nitrogen fertilization increases production but also leads to higher numbers of split-thickened radish hypocotyls, probably due to their larger size.

According to Filgueira (2003), splits in carrot roots and thickened beet hypocotyls are related to boron deficiency. In our experiment, we did not assume the lack of this nutrient, as it was applied according to Trani *et al.* (1997). There were also no differences regarding this nutrient in the thickened radish hypocotyls.

The application of organic fertilizers may have affected the occurrence of splits in thickened radish hypocotyls. Costa *et al.* (2006) reported a high incidence of this disturbance when using worm humus and cattle manure.

The optimal economical yield for cv. 25 was 11.3 t ha^{-1}, which was obtained with 64.2 t ha^{-1} of manure and 207.6 kg ha^{-1} of N. Nevertheless, the N dose was higher than the highest doses used in the experiment, 180 kg ha^{-1} is considered as the economical N dose. This dose, which is associated with the 64.2 t ha^{-1} of manure, provides an optimal economical yield of 11.2 t ha^{-1}. In comparison, the optimal yield of hybrid 19 was 19.5 t ha^{-1}, which was obtained with 62 t ha^{-1} and 145 kg ha^{-1} of N.

According to our results, we concluded that the cultivars differ in regards to most of the features evaluated, except by the total N content in the leaves. Hybrid 19 is shorter and more productive than cv. 25 and has a lower yield percentage of the split-thickened hypocotyls. Increased manure and N doses led to higher plant heights and commercial yield in both cultivars, but N had a higher contribution than that of manure. These differences may be explained by the small rate of liquid manure mineralization in the short cycle of radishes.

Acknowledgments

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Resumen

J.W. Mendoza Cortez, A.B. Cecílio Filho, E.L. Coutinho y A. Alves. 2010. Estiércol de ganado y N-urea en el cultivo de rabanito (*Raphanus sativus*). Cien. Inv. Agr. 37(1):45- 53. El trabajo fue realizado en la ciudad de Jaboticabal (575 m de altitud, 21°15´ 22˝ S y 48° 15´ 58˝ W), São Paulo, Brazil, con el objetivo de determinar el efecto de las dosis de estiércol de ganado y de nitrógeno (urea) en la altura y en el rendimiento de rabanito. El diseño experimental utilizado fue de bloques al azar, en esquema factorial 2x4x4 con tres repeticiones. Los tratamientos resultaron de la combinación de los factores cultivares (cv. 25 e híbrido 19), dosis de estiércol (0, 25, 50 y 75 t ha^{-1} en base seca) y dosis de N (0, 60, 120 y 180 kg ha^{-1}). El aumento en la dosis de estiércol y N promovieron mayor altura de plantas y rendimiento comercial de ambos cultivares, pero con una mayor contribución de N en comparación con el estiércol. La máxima productividad del híbrido 19 (20.34 t ha^{-1}) se obtuvo con 75 t ha^{-1} de estiércol y 139 kg ha^{-1} de N, mientras que para el cv. 25 (11.9 t ha^{-1}) con 75 t ha^{-1} de estiércol y 180 kg ha^{-1} de N. Las dosis de máxima eficiencia económica observadas en el cv. 25 fueron 65.1 t ha^{-1} y 180 kg ha^{-1} de estiércol y N, respectivamente, mientras que para el híbrido 19 fueron de 63.6 t ha^{-1} y 144.7 kg ha^{-1} de estiércol y N, respectivamente.

Palabras clave: *Raphanus sativus*, fertilización, rendimiento.

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