SCAP
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Onion yield as a function of nitrogen dose

Produtividade de cebola em função de doses de nitrogênio

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A B S T R A C T

Nitrogen (N) is the second most required nutrient by onion (*Allium cepa* L.); however, crop response to N fertilization depends on the applied dose. This study aimed to evaluate the effects of different N doses on onion bulb yield. The experiments were conducted during the period December 2011 to April 2012, with a second from August to December 2012, in a randomized block design with four replications. The treatments were six N doses: 0, 34, 67, 101, 134 and 168 kg ha^{-1}. It may be concluded that the productive components of the onion were affected by N fertilization. The application of 67 kg ha^{-1} N, regardless of planting time, provided the maximum economic return for the onion crop.

Keywords: *Allium cepa*, plant nutrition, nitrogen, production cost.

R E S U M O

O nitrogênio é o segundo nutriente mais requerido pela cebola (*Allium cepa* L.). Todavia, a resposta da cultura a adubação nitrogenada depende da dose aplicada. Este trabalho teve como objetivo avaliar os efeitos de diferentes doses de nitrogênio na produtividade de bulbos de cebola. Os experimentos foram realizados durante o período de dezembro de 2011 a abril de 2012 e o segundo de agosto a dezembro de 2012, no delineamento de blocos casualizados, com quatro repetições. Os tratamentos foram constituídos de seis doses de nitrogênio: 0, 34, 67, 101, 134 e 168 kg ha^{-1}. Pode-se concluir que as produtividades de cebola foram afetadas pela adubação nitrogenada. A dose de 67 kg ha^{-1} de N, independentemente da época de plantio proporcionou o retorno econômico máximo para a cultura de cebola.

Palavras-chave: *Allium cepa,* nutrição de planta, custo de produção

INTRODUCTION

Onion is one of the most cultivated vegetables in the world, being consumed fresh, as a condiment, or in the processed form. Brazil is the eighth largest world producer, with a planted area in 2014 of 59,200 ha, production of 1.65 million t and productivity of 27.8 t ha^{-1} (IBGE, 2015). The southern region accounted for 59.1% of the area, followed by the northeast (21.0%), southeast (15.6%) and midwest (4.3%).

Nitrogen (N) is the second most important nutrient for onions after potassium (Pôrto *et al*., 2007). N excess induces exuberant vegetative growth by increased protein synthesis and plant water content, and decreases plant resistance to diseases and bulb quality (Robles and Garcia, 2013).

N fertilization significantly increases bulb yield, as reported by Cecílio Filho *et al*. (2010), who showed that the application of 150 kg ha^{-1} N plus 150 kg ha^{-1} K_2O favored the maximum productivity of bulbs (89.5 t ha^{-1}). Kurtz *et al*. (2012) found that the maximum economic returns in two cycles were obtained with doses of 131 and 102 kg ha^{-1} N. Resende and Costa (2014) obtained the highest commercial yields with doses of 161.4 kg ha^{-1}

N (cultivar Alpha Tropical) and 215.9 kg ha^{-1} N (cultivar Alfa San Francisco), associated with the most economical doses of 159.6 and 213.8 kg ha^{-1} N, respectively. Batal *et al*. (1994), however, found no positive response when the N dose ranged from 84 to 224 kg ha^{-1}.

Considering the differential response of onion cultivation as a function of the quantity of N fertilization, it is necessary to carry out research on plantings in different geographical regions, in order to improve fertilization efficiency, and to avoid excesses that cause damage to the environment. In this context, the aim of this study was to evaluate the effects of the N dose, applied by fertirrigation, on the yield of onion bulbs.

MATERIAL AND METHODS

Site location and characterization

The experiments were conducted in the experimental area of the Department of Plant Sciences at the Federal Rural University of Semi-Arid, Mossoro-RN, Brazil (5°12′26′′S, 37°19′04′′W, average altitude 18 m) during the period of December 2011 to April 2012 (first experiment) and August to December 2012 (second experiment). The soil of the area was classified as a Eutrophic Red-Yellow Ultisol, hyperxerophilic caatinga phase with plan relief (EMBRAPA, 2006).

The soil chemical attributes in the 0-20 cm layer for the experiments conducted from December 2011 to April 2012 and August to December 2012 are, respectively: 7.4 and 7.6 pH(H_2O); 5.7 and 5.7 g dm^{-3} organic matter; 24.5 and 38.4 mg dm^{-3} $P_{(Mehlich)}$; 0.2 and 0.3 $cmol_c$ dm^{-3} K; 2.4 and 2.6 $cmol_c$ dm^{-3} Ca; 0.4 and 0.3 $cmol_c$ dm^{-3} Mg; and 0.02 and 0.03 $cmol_c$ dm^{-3} Na.

Treatments and experiment design

The experiments were designed as complete randomized blocks, with six treatments and four replications. The treatments consisted of N doses of 0, 34, 67, 101, 134 and 168 kg N ha^{-1}, provided through irrigation water. Each experimental unit consisted of a 3 x 0.8 m bed, containing eight rows of plants, spaced 0.10 x 0.10 m apart. Only the six central rows of plants in this bed were harvested, with the plants outside of this being discarded.

Field establishment

Soil preparation consisted of plowing and harrowing, followed by lifting of the beds and adding fertilizer, based on soil analysis and the recommendation of Cavalcanti (2008), comprising phosphorus at a dose 90 kg P_2O_5 ha^{-1} in the form of triple superphosphate. N (in the respective treatment doses) and potassium (K) (135 kg K_2O ha^{-1}) were applied through fertirrigation.

Fertirrigation was initiated at 10 days after transplanting (DAT), extending up to 70 DAT, being its distribution throughout the cycle, established from the march of nutrient uptake by the onion crop according to Marrocos *et al*. (2009). The sources of N and K used were ammonium sulfate, urea, calcium nitrate and potassium chloride. As a source of micronutrients, 1 kg ha^{-1} of the commercial product Rexolin® was applied (11.6% K_2O, 1.28% S, 0.86% Mg, 2.1% of B, 0.36% Cu, 2.66% Fe, 2.48% Mn, 0.036% Mo and 3.38% Zn), divided into four biweekly applications via fertirrigation, from 30 DAT.

A drip irrigation system was used, with two hoses per bed spaced at 0.4 m apart, the drippers being the self-compensating type, with an average flow rate of 1.4 L h^{-1}, spaced 0.2 m apart. Irrigation was performed daily, based on the crop evapotranspiration (CE_c), estimated by multiplying the reference evapotranspiration (RE_o) by the crop coefficient (K_c) at various stages of development of the culture.

Onion seedlings of cultivar IPA 11 were produced in a seedbed with dimensions of 0.8 m long by 0.2 m wide, with 10 g m^{-1} of seeds per seedbed, planted in furrows parallel to the length of the bed, at a depth of 1 cm, and with a distance between the furrows of 0.1 m. NPK formulation 6-24-12 was applied as a fertilizer to the seedbed, with 50 g m^{-1} incorporated into the soil before sowing, in order to avoid contact with the seeds. A complementary application of 10 gm^{-1} ammonium sulfate was performed at 20 days after sowing (DAS) (Costa *et al*., 2007). Transplanting was done 40 DAS, when the seedlings had reached 15 to 20 cm in height.

Aiming at the prevention and control of diseases, such as purple stain, spraying was performed with products based on Mancozeb (2.5 g L^{-1}) at intervals of seven days. The control of pests, such as thrips and/or mites, was effected through alternating spraying, at fortnightly intervals, with products based on Clorfernapir (0.5 mL L^{-1}) or deltamethrin (0.3 mL L^{-1}). Weed control was achieved through hand hoeing whenever necessary.

Harvesting and evaluated parameters

Harvesting was performed when 70% of the onion plants had toppled over, at 90 and 95 DAT, respectively (first and second experiments). After harvesting, the bulbs remained in the field for five days to cure in the sun. After that, they were taken to the laboratory at the Department of Plant Sciences of UFERSA, where they remained for five days to complete the process of curing in the shade. After the cure period, it was made the separation of onion shoots of the roots.

The total productivity (TP) of bulbs (t ha^{-1}) is the total mass of harvested bulbs in the harvest area of the plot. The productivity of commercial bulbs (CP) (t ha^{-1}) is the total weight of bulbs with a diameter of >35 mm (considered as commercial grade). The productivity of non-commercial bulbs (NCP) (t ha^{-1}) is the total weight of bulbs with a diameter of <35 mm (considered as non-commercial grade). Leaf N content (g kg^{-1}) was determined by taking the tallest leaf of 15 plants from the harvest area of the plot at 45 DAT. These samples were washed in distilled water and dried in an oven with forced ventilation at 65°C until constant mass was reached.

An economic analysis of the data from the experiments was conducted, based on an equation adjusted for CP. We calculated spending on fertilizer, increased productivity, the cost/benefit ratio and economic return. Increased productivity was determined by calculating the difference between the yield obtained by the dose used, and productivity without N. The cost/benefit ratio resulted from the division of the increase in production by the cost of N fertilizer. The economic return was obtained by multiplying the value of the cost/benefit ratio by the price of 1 t of commercial onion at harvest (US $721.0 and US $448.0, respectively, for the first and second experiments).

We used the cost of a unit of N (US $ kg^{-1}) to calculate the cost of the fertilizer, with a bag of 50 kg of urea (45% N) being purchased at a cost of US $65.4 to US $83.1, respectively (first and second experiments). The fixed cost, which corresponds to the summation of production and management costs, was not considered, as it is the same for all treatments.

Statistical analysis

Analysis of the variance of the evaluated characteristics was performed separately for each experiment. Following this, a joint analysis of the data from both experiments was performed with the help of SAS software. Fitting of a response curve to each characteristic was carried out as a function of the N dose, using the software Table Curve Package (Jandel Scientific, 1991).

RESULTS AND DISCUSSION

There was a significant effect ($P < 0.05$) of the interaction of N dose and planting time for leaf N content. The means of the leaf content were adjusted to a quadratic regression model, for two cropping seasons. The estimated maximum values are 32.7 g kg^{-1} obtained from a dose of 168 kg N ha^{-1} in the first experiment, and 41.2 g kg^{-1} from a dose of 67 kg N ha^{-1} in the second experiment (Figure 1).

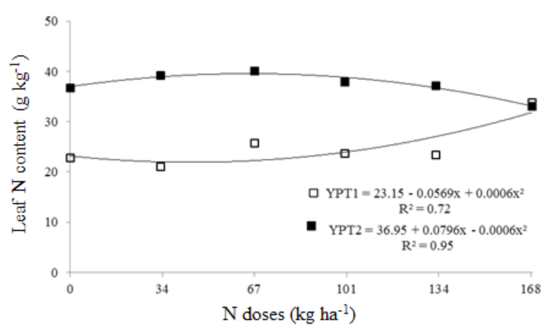

Figure 1 - Nitrogen content in onion leaf in function of nitrogen (N) doses in the first (PT1) and second experiment (PT2).

N application also increased leaf N content of onion in studies performed by Kurtz *et al*. (2012), wherein they found maximum levels of 40, 35 and 32 g kg^{-1} with the addition of 237, 136 and 150 kg N ha^{-1}, respectively, in three consecutive croppings of onion.

In both experiments, the leaf N levels were in the usual range for onion, at around 40 g kg^{-1}, according to Caldwell *et al*. (1994), even in the treatment without N; however, in the first planting, without the application of N, the plants showed lower growth and characteristic symptoms of N deficiency (older leaves yellowed). There was also an unevenness of damping-off, where some plants remained green and upright until harvest.

There was a significant interaction between N dose and planting time for CP and TP, whereas for NCP, only N dose was significant.

A plateau linear regression model was adjusted for TP and CP (Figures 2A, B). This type of model provides a simplified interpretation of the response curve, assuming that the use of a limiting nutrient is constant until its requirement is supplied, and that no further response and/or significance in performance occurs above this point.

In the first experiment, the maximum values of TP (28.93 t ha^{-1}) and CP (28.90 t ha^{-1}) were obtained with 67.5 and 77.7 kg N ha^{-1}, respectively. These doses provided increases of 207.4 and 606.6%, respectively, in the TP and CP of the culture that did not receive N fertilizer. In the second experiment, the estimated doses that provided the largest TP and CP were 113.66 (51.8 t ha^{-1}) and 116.2 kg N ha^{-1} (51.97 t ha^{-1}), respectively, with increments of 266 and 207.4% in the TP and CP, respectively, in the absence of N application. These productivities are higher than the national average productivity (27.8 t ha^{-1}), according to the Brazilian Institute of Geography and Statistics (IBGE, 2015).

These significant increases show the responsiveness of onion to N application, and confirm the conclusions of various authors who have reported that N contributed markedly to increase the plant metabolic rate, wherein more carbohydrate is synthesized, increasing the mass of the bulbs, and consequently the productivity (Cecílio Filho *et al*., 2010; Kurtz *et al*., 2012; Resende and Costa, 2014).

Vilas Boas *et al*. (2014) found that the addition of a unit (kg ha^{-1}) of N dose increased the TP and CP of bulbs, producing 182.67 and 187.71 kg ha^{-1}, respectively. The maximum estimated values for TP, and CP, occurred with a dose of 180 kg N ha^{-1}, resulting in 80.6 and 80 t ha^{-1}, respectively.

The highest productivities obtained in the second experiment (August to December 2012) are probably due to the more favorable climatic factors, mainly the lack of rain. In the first experiment (December 2011 to April 2012), the amount of rainfall (178.7 mm), together with high temperatures, favored the appearance of purple blotch disease, or burning of the tips (*Alternaria porri*), and also higher nitrate leaching, thus decreasing the efficiency of N fertilization.

The doses resulting in higher productivities, considering the adjustments obtained in Figure 3, were below the reference value used in this work (135 kg N ha^{-1}), which is the official recommendation of nitrogen for the State of Pernambuco,

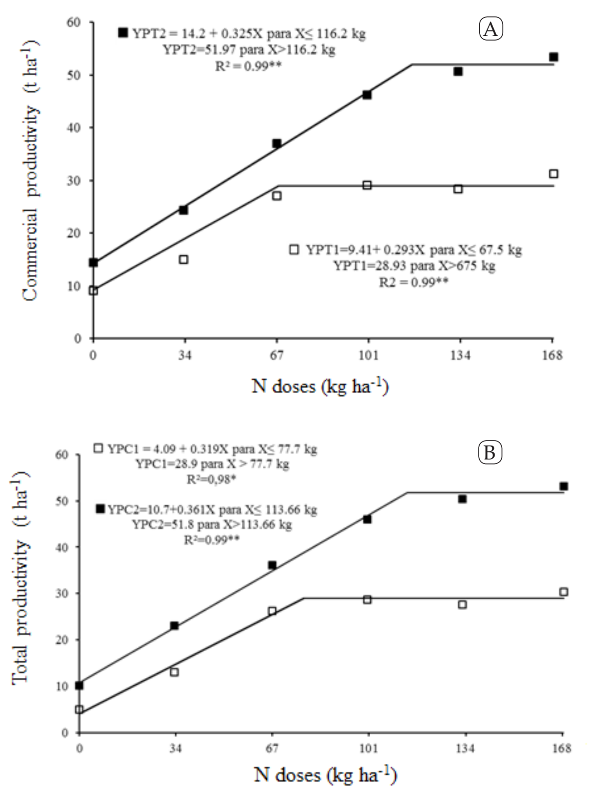

Figure 2 - Commercial productivity (a) and total productivity (b) of onion bulbs in function of nitrogen (N) doses in the first (PT1) and second experiment (PT2).

on irrigated onion (cultivar IPA 11) cultivation, according to Cavalcanti *et al*. (2008).

The NCP (scrap) decreased quadratically with doses of N. Regarding treatment without N, the reduction was approximately 90.3% at a dose of 168.0 kg N ha^{-1} (Figure 3). According Gessesew *et al*. (2015), the reduction in production of non-commercial bulbs with a higher N dose can be attributed to reduced competition for nutrients, which results in larger bulbs that can be marketed. These results agree with those obtained by May *et al*. (2007) and Resende and Costa (2008), who also reported reductions in the quantity of scrap bulbs with the application of N.

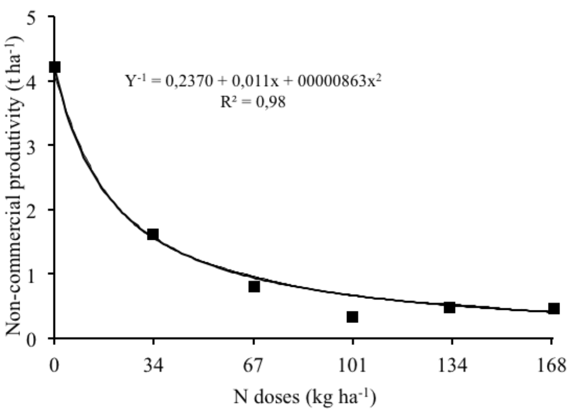

Figure 3 - Non-commercial productivity of onion bulbs in function of nitrogen (N) doses.

The CP as a function of N doses was adjusted to a linear plateau regression model (Figure 2), and the calculation of the economic return showed that maximum economic efficiency was achieved with an application of 67 kg N ha^{-1}, for the two cultivations. For every dollar invested in a N unit, the return would be US $158.24 and US $94, respectively (first and second experiments: Table 1); however, above this dose, there was a significant decrease, reaching 55 and 36%, respectively, (first and second experiments) of the maximum return at the highest dose of N applied (168 kg N ha^{-1}).

Although the CP from the first experiment (26.28 t ha^{-1}) was 27% lower, compared to that from the second experiment (36.15 t ha^{-1}), the more favorable price for this (US $721 per t) provided a profitability of 67% higher, using the same dose of N (67 kg N ha^{-1}).

Table 1 - Commercial productivity (CP), cost with nitrogen fertilizer (CNF), increased productivity (IP), cost/benefit ratio (C/B) and economic return (ER) in function of doses of nitrogen in the onion crop in the planting of December/2011 (PT1) and August/2012 (PT2)

PT 1					
Doses of N (kg ha^{-1})	CP (t)	CFN (US$)	IP (t)	C/B (t/US$)	ER
0.0	4.92	0.00	-	-	-
34.0	12.98	49.39	7.97	0.16	116.35
67.0	26.28	97.33	21.36	0.22	158.24
101.0	28.90	146.72	23.98	0.16	117.84
134.0	28.90	194.65	23.98	0.12	88.82
168.0	28.90	244.04	23.98	0.10	70.85
PT 2					
Doses of N (kg ha^{-1})	CP (t)	CFN (US$)	IP (t)	C/B (t/US$)	ER
0.0	10.11	0.00	-	-	-
34.0	23.00	62.81	12.89	0.20	91.94
67.0	36.15	123.77	26.04	0.21	94.25
101.0	45.94	186.58	35.83	0.19	86.03
134.0	51.80	247.55	41.69	0.17	75.44
168.0	51.80	310.36	41.69	0.13	60.18

CONCLUSIONS

The production components of the onion were affected by N fertilization. The application of 67 kg ha^{-1} N, regardless of planting time, provided the maximum economic return for the onion crop.

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