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Bulb yield and economic viability of onion in response to sulfur fertilization¹

Rendimento e viabilidade econômica da cebola em resposta à adubação com enxofre

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HIGHLIGHTS:

To achieve greater yield with a particular onion cultivar, sulfur fertilization should be considered.

The inputs were the items that contributed the most towards the increase in the total operating cost for both cultivars.

The application of sulfur at dose of 34 kg ha⁻¹ favored the increase of commercial bulbs in the cultivar Rio das Antas.

ABSTRACT: The cultivation of onion in the Brazilian Northeast region has been gaining prominence due to the favorable edaphoclimatic conditions and the use of technology. However, the increase in production costs, price fluctuations and the suppression of sulfur in fertilizer formulations constitute a risk for the farmers. Thus, the aim of this study was to evaluate the productive and economic aspects of onion production as a response to sulfur fertilization. Two experiments were carried out from June to November 2018 and 2019, at the Rafael Fernandes Experimental Farm, belonging to the Universidade Federal Rural do Semi-árido, in the municipality of Mossoró, Rio Grande do Norte, Brazil, in an Ultisol. The experimental design was randomized complete blocks with 14 treatments and four replicates, corresponding to the combination of two onion cultivars and seven doses of sulfur. The following characteristics were evaluated: sulfur content in the diagnostic leaf, bulb yield, total operating costs, gross revenue, net revenue, rate of return and yield index. Regardless of the cultivar, input costs add up to higher expenses, reaching approximate values of 60.6 and 48.4% of the total operating cost for the Rio das Antas and IPA 11 cultivars, respectively. Rio das Antas was more sulfur efficient, achieving greater bulb yield and net revenue. The 34 kg ha⁻¹ sulfur dose promoted maximum yield and net revenue for Rio das Antas. The application of sulfur did not influence the yield of the IPA 11 cultivar.

Key words: *Allium cepa* L., plant nutrition, bulb yield, total operating cost

RESUMO: O cultivo da cebola na região Nordeste vem ganhando destaque devido às condições edafoclimáticas favoráveis e ao uso de tecnologia. No entanto, o aumento dos custos de produção, as oscilações de preços e a supressão do enxofre nas formulações dos fertilizantes constituem um risco para o produtor. Nesse sentido, objetivou-se avaliar os aspectos produtivos e econômicos da cebola em resposta a adubação com enxofre. Dois experimentos foram realizados de junho a novembro de 2018 e 2019, ambos na Fazenda Experimental Rafael Fernandes, pertencente à Universidade Federal Rural do Semiárido, município de Mossoró, Rio Grande do Norte, Brasil, em Argissolo. O delineamento experimental foi em blocos casualizados com 14 tratamentos e quatro repetições, correspondendo à combinação de duas cultivares de cebola e sete doses de enxofre. Foram avaliados: teor de enxofre na folha diagnóstica, rendimento de bulbos, custos operacionais totais, receita bruta, receita líquida, taxa de retorno e índice de lucratividade. Independente da cultivar utilizada, os custos dos insumos somam as maiores despesas, atingindo valores aproximados de 60,6 e 48,4% do custo operacional total para as cultivares Rio das Antas e IPA 11, respectivamente. A Rio das Antas foi mais eficiente no uso do enxofre, obtendo maior rendimento e receita líquida. O fornecimento de 34 kg ha⁻¹ de enxofre proporcionou rendimento e receita líquida máxima para a Rio das Antas. A aplicação de enxofre não influenciou o rendimento da cultivar IPA 11.

Palavras-chave: *Allium cepa* L., nutrição de plantas, rendimento do bulbo, custo operacional total

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INTRODUCTION

Onion (*Allium cepa* L.) is ranked in the third position in terms of economic importance in Brazil with total production of 1,495,618 tons and 47,487 ha of planted area in 2020 (FAOSTAT, 2022).

The role of sulfur (S) in onions consists in regulating, assimilating, and synthesizing amino acids necessary for protein production (Prasad & Shivay, 2018). It also acts in the photosynthetic and respiratory electron pathway by agglomerating iron-sulfur clusters, which makes S essential for the growth and yield of onions (Aghajanzadeh et al., 2016).

The nutritional status of onions affects yield and bulb size (Kurtz et al., 2013; Trani et al., 2014; Backes et al., 2018). To minimize the damage to the growth and development of this crop, applying 30 to 60 kg ha⁻¹ of S has guaranteed the desirable yield (Trani et al., 2014).

The use of S in onion has been discussed mainly due to its suppression in mineral formulations. In Brazil, the most widely used sources of S are Single Superphosphate (10% S) and ammonium sulfate (22% S), which, in turn, are associated with high NPK concentration. Thus, the demand for S in onions is not met (Broch et al., 2011). The acquisition of S in Rio Grande do Norte State, Brazil, is still debatable, either due to the scarcity of information or high cost of inputs, a fact that leads to the use of ready NPK formulations. The high cost of inputs and fluctuations in prices paid to the farmer represent the causes for failure in this business (Chattoo et al., 2019; Przygocka-cyna et al., 2020; Nivetha et al., 2020).

Therefore, the demand of onions for S and the suppression of this nutrient in mineral formulations justify this research. The aim of this study was to evaluate the productive and economic aspects of onion production as a response to sulfur fertilization.

MATERIAL AND METHODS

The experiments were conducted at the Rafael Fernandes Experimental Farm belonging to the Universidade Federal Rural do Semi-árido (UFERSA), located in the district of Alagoinha, rural area of the municipality of Mossoró, Rio Grande do Norte, Brazil, at coordinates of 5° 3' 33" S and 37° 23' 50" W and an altitude of 72 m, from June through November 2018 (Experiment 1 - E1) and 2019 (Experiment 2 -E2).

The climate in the study area, according to Köppen's Classification, is BSh (Alvares et al., 2013), characterized as dry and very hot. Annual rainfall is around 674 mm. The average temperatures and relative humidity of air during the experimental period are presented in Figures 1A and 1B. During the conduction of the experiments, rainfall levels of 34.4 and 31.4 mm were recorded for E1 and E2. The water volume supplied via irrigation for E1 was 97.63, 138.01, 426.79, and 260.02 mm, for the initial, vegetative, bulbing and maturation phases, respectively. For E2 the values were 97.42, 163.53, 348.23, and 337.72 mm, respectively.

The experimental design used was randomized complete blocks, in a 2 × 7 factorial scheme, with four replications. The treatments consisted of a combination of two onion cultivars

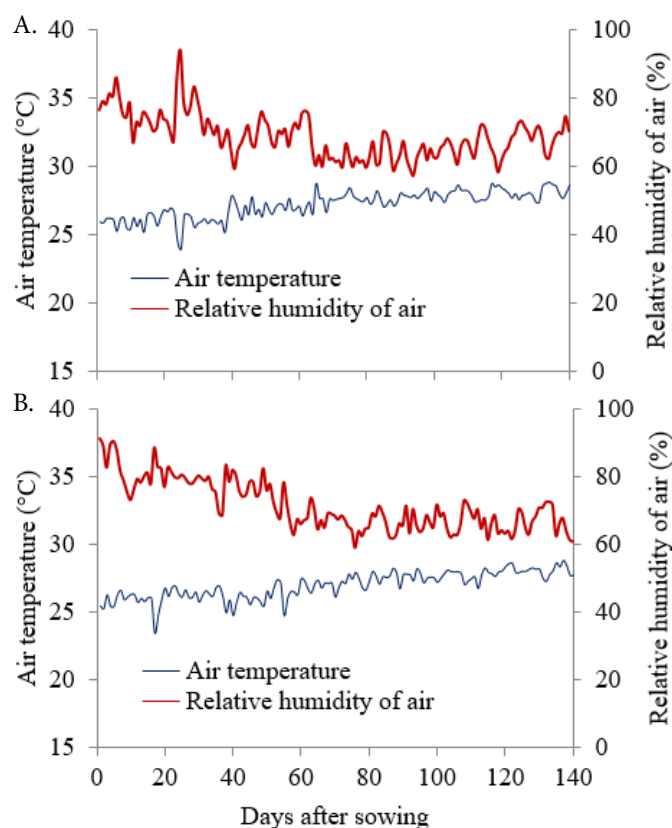


Figure 1. Air temperature and relative humidity of air in Experiment 1(A) and Experiment 2 (B), from June to November 2018 and 2019

(Rio das Antas and IPA 11) and seven doses of S (0, 10, 20, 30, 40, 50, and 60 kg ha⁻¹). For the definition of S doses, the fertilization and liming manual (Trani, et al., 2014) was taken as a basis, with regard to the need for sulfur in the diagnostic leaf, as well as the recommendations used in the onion production centers in the municipalities of Baraúnas and Mossoró/RN.

Each experimental plot consisted of a 3.0 m long, 1.0 m wide and 0.20 m high bed, with eight plant rows, spaced 0.10 × 0.06 m. The six central rows were considered as the usable area, disregarding two plants at the end of each row. Sowing was carried out manually, placing two to three seeds per hole at 2 cm depth. Thinning was carried out at 20 days after sowing (DAS), leaving one plant per hole.

The soil was classified as Ultisol. Soil sampling for physical and chemical analyses was carried out at a depth of 0-20 cm, and for Experiment 1 the results were: pH in H₂O of 4.8; EC_{se} of 0.17 dS m⁻¹; 5.0 mg dm⁻³ of P (Mehlich); 76.0 mg dm⁻³ of K; 4.0 mg dm⁻³ S-SO₄²⁻; concentrations of Ca, Mg, H + Al and effective CEC were 0.41, 0.13, 1.57, and 2.20 cmol_c dm⁻³, respectively. The contents of sand, silt and clay were 906, 24, and 70 g kg⁻¹, respectively. For Experiment 2 the results were: pH in H₂O of 4.9; EC_w of 0.12 dS m⁻¹; 1.3 mg dm⁻³ of P (Melich); 42.3 mg dm⁻³ of K; 6.0 mg dm⁻³ S-SO₄²⁻; concentrations of Ca, Mg, H + Al and effective CEC were 0.40, 0.60, 0.99 and 2.17 cmol_c dm⁻³, respectively. The contents of sand, silt and clay were 900, 30 and 70 g kg⁻¹, respectively.

Basal dressing was carried out with 210 kg ha⁻¹ of P₂O₅ in the form of triple superphosphate, applied to the experimental plots and incorporated at a depth of 5.0 cm. Top-dressing was carried out via fertigation, weekly, starting at 21 DAS, using

a total of 90 kg ha⁻¹ of N, 200 kg ha⁻¹ of K₂O, 50 kg ha⁻¹ of Ca, and 14 kg ha⁻¹ of Mg. The sources used were: urea (N), calcium nitrate (Ca(NO₃)₂), potassium nitrate (KNO₃), magnesium nitrate (Mg(NO₃)₂), ammonium sulfate ((NH₄)₂SO₄), potassium sulfate (K₂SO₄), and potassium chloride (KCl). The triple superphosphate used in the basal fertilization did not contain sulfur in its composition, thus avoiding interference in the treatments.

The doses of N and K were established according to the recommendation for the crop by Gonçalves et al. (2019a, 2019b). S was applied according to the treatments, using ammonium sulfate and potassium sulfate as sources, balanced with nitrogen and potassium in the form of urea (N) and potassium chloride (KCl), respectively, via fertigation.

For the purpose of experimentation and to guarantee the initial stand of the crop, the irrigation system used up to 22 DAS was micro-sprinkling, with the objective of guaranteeing the initial stand of the crop under the effect of experimentation and for the remainder period of the crop cycle, drip irrigation was used, with four tubes per bed, spaced at 0.20 m, with pressure-compensating drippers every 0.30 m and average flow rate of 1.5 L h⁻¹. The irrigations were performed daily, and the irrigation depth was determined based on the evapotranspiration of the crop (Allen et al., 2006), applying a total irrigation depth of 922.44 and 946.90 mm ha⁻¹ for E1 and E2, respectively.

The water used for irrigation came from a deep tubular well of the Arenito Açu aquifer, with the following characteristics: pH 7.1, EC = 0.61 dS m⁻¹, 0.65, 1.73, 2.50, 1.90, 1.60, 0, and 4.00 mmol_c L⁻¹ of K⁺, Na⁺, Ca²⁺, Mg²⁺, Cl⁻, CO₃²⁻ and HCO₃⁻ and SAR of 1.2 (mmol L⁻¹)^{0.5}, respectively.

Irrigation was suspended at 123 (E1) and 122 DAS (E2), when 70% of the plants were lodged, initiating the curing process. After 22 (E1) and 14 (E2) days of irrigation suspension, the bulbs were harvested, eliminating the leaves and roots. During the experimental period, manual weed control was carried out whenever necessary. Pest control was carried out with the application of an insecticide from the Chlorfenapyr group, for the control of thrips and mites.

The analyzed variables were the S content in the diagnostic leaf (SCDL, g kg⁻¹), the longest leaves of 20 plants from the usable area of the plot were collected at 60 DAS, which is approximately halfway through the crop cycle, for both E1 and E2 (Malavolta et al., 1997). S extraction was carried out by means of nitric digestion in a microwave oven (Embrapa, 2009), and the S content was determined according to Malavolta et al. (1997).

Bulb classification was carried out on the basis of transverse diameter, according to the standards of the Ministry of Agriculture, Livestock and Supply in: class 1 (bulbs with diameter < 35 mm and double bulbs); class 2 (C2Y - bulbs with diameter between 35 and 50 mm); class 3 (C3Y - bulbs with diameter between 50 and 75 mm); class 4 (C4Y - bulbs with diameter between 75 and 90 mm) (Brasil, 1995). The commercial bulb yield (CBY, t ha⁻¹) was obtained from the total weight of bulbs with diameter > 35 mm. The non-commercial bulb yield (NCY, t ha⁻¹) was obtained from the total weight of bulbs with diameter < 35 mm. The total bulb yield (TBY,

t ha⁻¹) was obtained from the total weight of commercial and non-commercial bulbs.

To determine the Total Operating Cost (TOC) for the cultivation of 1 ha of onions, we used the methodology proposed by National Supply Company (Conab, 2010) with adaptations, considering disbursements made by the farmer during the crop's production cycle, including expenses with labor, inputs, in addition to administrative expenses, technical assistance, rural land tax (ITR), financing interest rates, fixed costs (depreciation and maintenance of machinery and improvements) and remuneration on fixed capital and leasing. The unit values of each item refers to the month of June of each year. The cost of labor was calculated based on the daily rate paid to rural workers in Mossoró-RN.

In relation to the financing interest rate, values used in the Family Agriculture Crop Plans were used, corresponding to 2.5 and 3.0% per year for Experiments 1 and 2, respectively. Administrative expenses represent 3% of the cost of a crop, and technical assistance represents 2%, and these values were estimated during the conduction of the experiments.

Gross revenue (GR, R\$ ha⁻¹) was obtained by the product of the yield and the price paid for one kg of commercial quality onions: R\$ 1.00 kg⁻¹ (E1) and R\$ 0.90 kg⁻¹ (E2). Net revenue (NR, R\$ ha⁻¹) was calculated by the difference between GR and TOC, both estimated for 1 ha of effective built area, equivalent to 6,000.00 m². The calculation of the rate of return (RR) was obtained by the ratio between GR and TOC, expressing the capital obtained for each BRL (R\$) invested. For the evaluation of the profitability index (PI), the ratio between NR and GR was used.

The data were subjected to analysis of variance by the F test, at 0.05 probability. To compare the two experiments, a joint analysis was applied based on the evaluation of the homogeneity of variance between the data. When a significant effect was observed, the averages were compared using Tukey test at 0.05 probability. The regression analysis was performed for the quantitative factor, using SISVAR statistical software v. 5.3 (Ferreira, 2019).

RESULTS AND DISCUSSION

Sulfur content in the diagnostic leaf (SCDL) increased with S doses, reaching up to 2.8 g kg⁻¹, at 60 kg ha⁻¹ (Figure 2). These values are below the appropriate range, which according to Trani et al. (2014) is from 5.0 to 8.0 g kg⁻¹. Even so, deficiency symptoms were not verified in any of the treatments. According to Barker & Pilbeam (2015), the low S content may be related to the rate of absorption of the nutrient by the plants, or the availability of the nutrient in the soil, as well as the genotype's ability to redistribute the soluble and insoluble fractions throughout the plant. These factors are linked to the nutritional status of the plant. The highest SCDL was observed in E2. The higher S content (6.0 mg dm⁻³) found in the soil in E2 may have contributed to this result.

The total bulb yield (TBY), commercial bulb yield (CBY), class 3 bulb yield (C3Y) and class 4 bulb yield (C4Y) as a function of the S doses, for the Rio das Antas and IPA 11 cultivars, are shown in Figure 3.

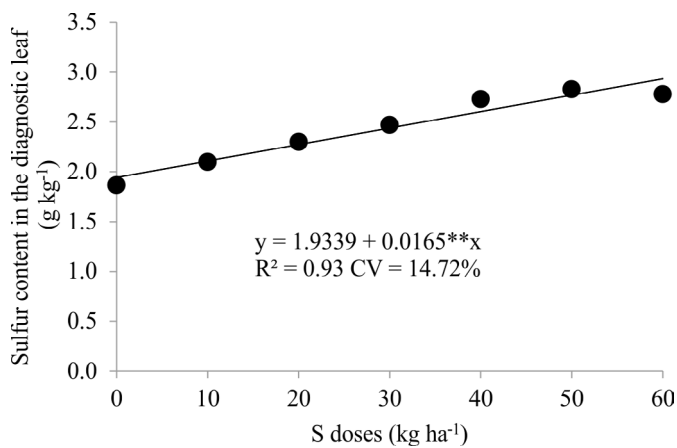
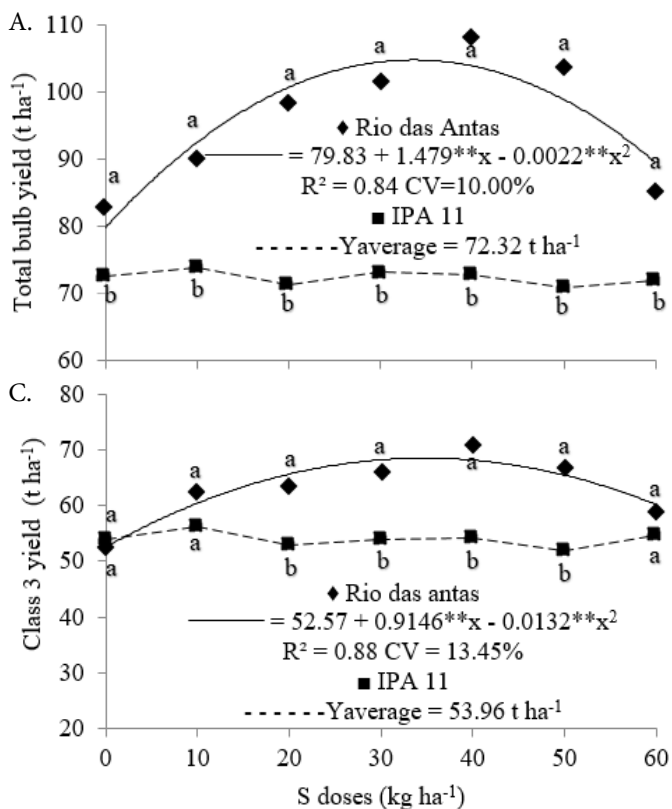


Figure 2. S content in the diagnostic leaf as a function of the S doses, for Rio das Antas and IPA 11 onions

The TBY as a function of S doses for the Rio das Antas cultivar was described by the quadratic regression model, with an increase up to the estimated dose of 33.62 kg of S ha⁻¹, with 104.69 t ha⁻¹ bulb yield (Figure 3A).

The TBY increase observed for Rio das Antas was 30.86%, in comparison to the treatment with absence of S fertilization. Higher doses caused a decrease in Rio das Antas onion yield of 22.80%. For the IPA 11 cultivar, there was no fit of the regression model, with an average value of 72.32 t ha⁻¹ (Figure 3A).

The increase in onion yields with the application of S corroborates the results obtained by Souza et al. (2015), who observed a yield increase up to the dose of 45 kg ha⁻¹, obtaining 79 t ha⁻¹, in clay soil with low S content.

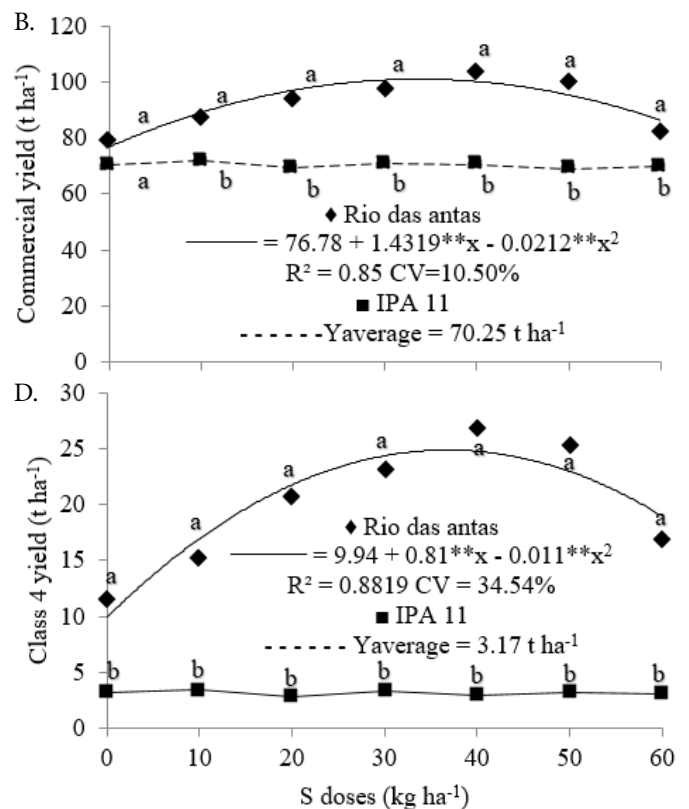


The Rio das Antas hybrid was superior to the IPA 11 cultivar, not only in terms of TBY (Figure 3A), but also in terms of commercial bulb yield (Figure 3B), class 3 bulb yield (Figure 3C) and class 4 bulb yield (Figure 3D) for all S doses, except for the 0 kg S ha⁻¹ dose for commercial bulb yield and 0, 10, and 60 kg S ha⁻¹ for class 3 bulb yield (Figures 3B and C). The hybrid vigor, high genetic standard, which involves molecular mechanisms of nutrient absorption and utilization, different nutritional requirements, good ability to redistribute the nutrient in the plant, high planting density tolerance, allied with adequate climatic and management conditions, probably contributed to these results, promoting high yields. The non-significant effect of S observed for the IPA 11 cultivar may be related to a greater requirement for the nutrient in its metabolism, or with the reduction in the redistribution of the nutrient to the points of development of the plant.

The maximum commercial bulb yield (CBY) for the Rio das Antas cultivar was 101.0 t ha⁻¹, obtained with the 33.7 kg S ha⁻¹ dose (Figure 3B). Higher than estimated doses caused a decrease of 21.40% in onion yield. For the IPA 11 cultivar, no regression model was fitted satisfactorily, and the CBY was 70.26 t ha⁻¹ on average.

The influence of S on onion yield may be related to the role of the nutrient in the formation of plant proteins and some hormones, in addition to S being necessary for the enzymatic action, formation of chlorophyll, synthesis of certain amino acids (cysteine and methionine) and vitamins, therefore ensuring a good vegetative growth, leading to high yields (Barker & Pilbeam, 2015).

The yield of class 3 bulbs (C3Y) increased with the S doses, with an estimated maximum of 68.4 t ha⁻¹, obtained



For each evaluated characteristic, means followed by the same lowercase letter do not differ significantly by Tukey's test ($p \leq 0.05$)

Figure 3. Total bulb yield (A), commercial bulb yield (B), class 3 bulb yield (C) and class 4 bulb yield (D) as a function of S doses in Rio das Antas (♦) and IPA11 (■) onion cultivars

with the application of 34.6 kg S ha⁻¹ (Figure 3C). This value corresponds to 65.33% of the total yield. The increase in the S dose in relation to the treatment without S fertilization was of 23.30%. A higher than estimated dose caused a 14.1% decrease in Rio das Antas onion yield.

The increase in onion yield due to the application of S in the larger bulb classes (C3Y and C4Y) can be attributed to its supply in the synthesis of coenzyme A and amino acid for the production of proteins and the formation of certain disulfide bonds, which have been associated with structural characteristics of plant protoplasm, thus promoting an increase in the diameter and in the weight of the bulbs (Gondane et al., 2018).

The importance of S in increasing the size of the bulb was also observed by Mondal et al. (2020), in an acidic soil with low nutrient content, with a 26% increase in bulb weight, with application of S in the range of 30 to 50 kg ha⁻¹ and a 9.8% increase in bulb diameter when fertilized with 40 kg ha⁻¹ compared to the control treatment (0 kg ha⁻¹).

These results demonstrate the ability of the Rio das Antas hybrid to produce larger bulbs. Hybrid cultivars have aroused the interest of producers in the Brazilian Northeast region, mainly because they are pest and disease resistant and hold a high yield potential.

The increase in S doses promoted an increase in the yield of class 4 bulbs (C4Y) up to the estimated dose of 36.82 kg S ha⁻¹, with a yield of 24.80 t ha⁻¹ (Figure 3D). This corresponded to 23.60% of the total bulb yield. In relation to the treatment without the application of S the increase was 113.00%.

The yield of class 2 bulbs (C2Y) was 11.08 and 15.20 t ha⁻¹, respectively for Rio das Antas and IPA 11. The yield of non-commercial bulbs (NCY) as a function of S doses was 2.8 t ha⁻¹, obtained with the dose of 27 kg S ha⁻¹. The decrease in the yields of smaller bulbs and the increase in C3Y and C4Y bulb yields with the application of S reflects a favorable trend to onions, given that larger bulbs reach better market prices. Santos et al. (2018) observed the superiority of the Rio das Antas hybrid compared to the open pollination cultivar IPA 11, corroborating the results found in the present study.

The total operating cost (TOC) for planting 1 ha of Rio das Antas and IPA 11 onion in the E1 and E2 are shown in Table 1.

The variations between the TOC of E1 and E2 for maximum and minimum doses of S in Rio das Antas and IPA 11 cultivars were approximately R\$ 1,840.00 and 1,580.00 ha⁻¹, respectively. E2 had the highest TOC values, from readjustments in labor (+ 25%), inputs and materials (+ 4.6%), administrative costs (+ 5.0%), except depreciation (-1.9%), since the E1 cycle was longer for both cultivars (Table 1).

For the Rio das Antas cultivar, the costs with seeds, labor, and fertilizers contributed with 36.0, 20.0, and 18.0%, respectively in E1, and 35.0, 21.0, and 20.0% in E2, in relation to variable costs (Table 1). For the IPA 11 cultivar, fertilizers, labor and seeds contributed with 30.2, 26.2, and 14.5% for E1, respectively. For E2, the values were 30.1% (fertilizer), 30.0% (labor) and 14.2% (seeds).

The participation of fertilization in the TOC for Rio das Antas was 18.1 and 18.7% in E1 and E2, respectively. For IPA

Table 1. Total operating cost (TOC) for 1 ha of onion crop for the cultivars Rio das Antas and IPA 11 in two experiments as a function of S doses

Doses of S (kg ha ⁻¹)	Experiments	OCP ¹	IMC ²	Depreciation	COE ³	TOC ⁴
		Cost of Rio das Antas (R\$ ha ⁻¹)				
0	1	4,693.00	12,187.29	1,358.58	1,849.51	20,088.38
	2	5,645.00	13,031.21	1,332.87	1,938.69	21,947.77
10	1	4,693.00	12,462.30	1,358.58	1,865.99	20,379.87
	2	5,645.00	13,175.49	1,332.87	1,947.51	22,100.88
20	1	4,693.00	12,574.33	1,358.58	1,872.70	20,498.61
	2	5,645.00	13,429.90	1,332.87	1,963.08	22,370.85
30	1	4,693.00	12,665.14	1,358.58	1,878.14	20,594.86
	2	5,645.00	13,597.39	1,332.87	1,973.32	22,548.59
40	1	4,693.00	12,828.40	1,358.58	1,887.93	20,767.91
	2	5,645.00	13,763.77	1,332.87	1,983.50	22,725.15
50	1	4,693.00	12,831.44	1,358.58	1,888.11	20,771.13
	2	5,645.00	13,696.38	1,332.87	1,979.38	22,653.64
60	1	4,693.00	12,627.70	1,358.58	1,875.90	20,555.18
	2	5,645.00	13,282.11	1,332.87	1,954.04	22,214.02
Cost of IPA 11 (R\$ ha ⁻¹)						
0	1	4,693.60	7,184.24	1,358.58	1,549.67	14,785.49
	2	5,645.00	7,738.57	1,332.87	1,614.89	16,331.33
10	1	4,693.60	7,243.32	1,358.58	1,553.21	14,848.10
	2	5,645.00	7,839.88	1,332.87	1,621.09	16,438.85
20	1	4,693.60	7,282.53	1,358.58	1,555.21	14,889.67
	2	5,645.00	7,785.40	1,332.87	1,617.76	16,381.03
30	1	4,693.60	7,330.02	1,358.58	1,558.40	14,940.00
	2	5,645.00	7,914.87	1,332.87	1,625.68	16,518.42
40	1	4,693.60	7,362.80	1,358.58	1,560.37	14,974.75
	2	5,645.00	7,959.61	1,332.87	1,628.42	16,565.90
50	1	4,693.60	7,415.54	1,358.58	1,563.53	15,030.65
	2	5,645.00	7,931.38	1,332.87	1,626.69	16,535.94
60	1	4,693.60	7,471.24	1,358.58	1,566.87	15,089.68
	2	5,645.00	7,992.03	1,332.87	1,630.40	16,600.30

¹Operating cost: machine rental + labor; ²Input and material costs: fertilizers + pesticides + seeds + sacks + equipment + soil analysis + electricity; ³Cost of other expenses: administrative expenses + technical assistance + Territorial tax + interest on financing + Periodic maintenance of facilities + Expected remuneration on fixed capital + leasing; ⁴Total operating cost

11, it was 25.0 and 25.9%. The participation of S fertilization in the costs varied with the doses. In E1, it was: 0.0, 3.29, 6.46, 9.60, 12.3, 14.66 and 15.4%. In E2, the trend was similar: 0.0, 3.12, 6.12, 9.14, 11.69, 13.94, 16.5% for doses of 0, 10, 20, 30, 40, 50 and 60 kg ha⁻¹ S, for both cultivars.

Expenditures on mechanization, which included renting machines for tillage and for raising the seedbeds, contributed with 6.4 and 5.8% of the TOC for the cultivar Rio das Antas in E1 and E2, respectively. For the IPA11 cultivar, mechanization costs were 8.86 and 8.02%.

On the other hand, labor costs were quite significant, 16.4% (E1) and 19.2% (E2) of the TOC for Rio das Antas and 22.5% (E1) and 26.2% (E2) for IPA 11. These amounts correspond to 71.8 and 76.6% of the total operating costs for E1 and E2, respectively. In commercial crops, depending on the production system, the contribution of labor varies between 7.1 and 17.7% (CONAB, 2010). Onion cultivation requires a large amount of labor, for example in the harvest and post-harvest stages, which accounted for 58.89 and 45.00% of labor costs for E1 and E2, respectively.

The costs of inputs and materials corresponded to 61.5 and 60.3% of the TOC for Rio das Antas in E1 and E2, respectively. For the IPA11 cultivar, the percentages were 49.1 and 47.9% for E1 and E2, respectively. The highlights for the Rio das Antas cultivar were seeds (52.5 and 52.8%), fertilizers (29.6 and 31.15%) and sacks (15.9 and 13.9%) of the costs with inputs and materials for E1 and E2, respectively. For IPA 11, the order of contribution in relation to inputs and materials was fertilizers

(52.0 and 54.0%), seeds (25.1 and 25.9%) and sacks (20.4 and 16.9%) for E1 and E2, respectively.

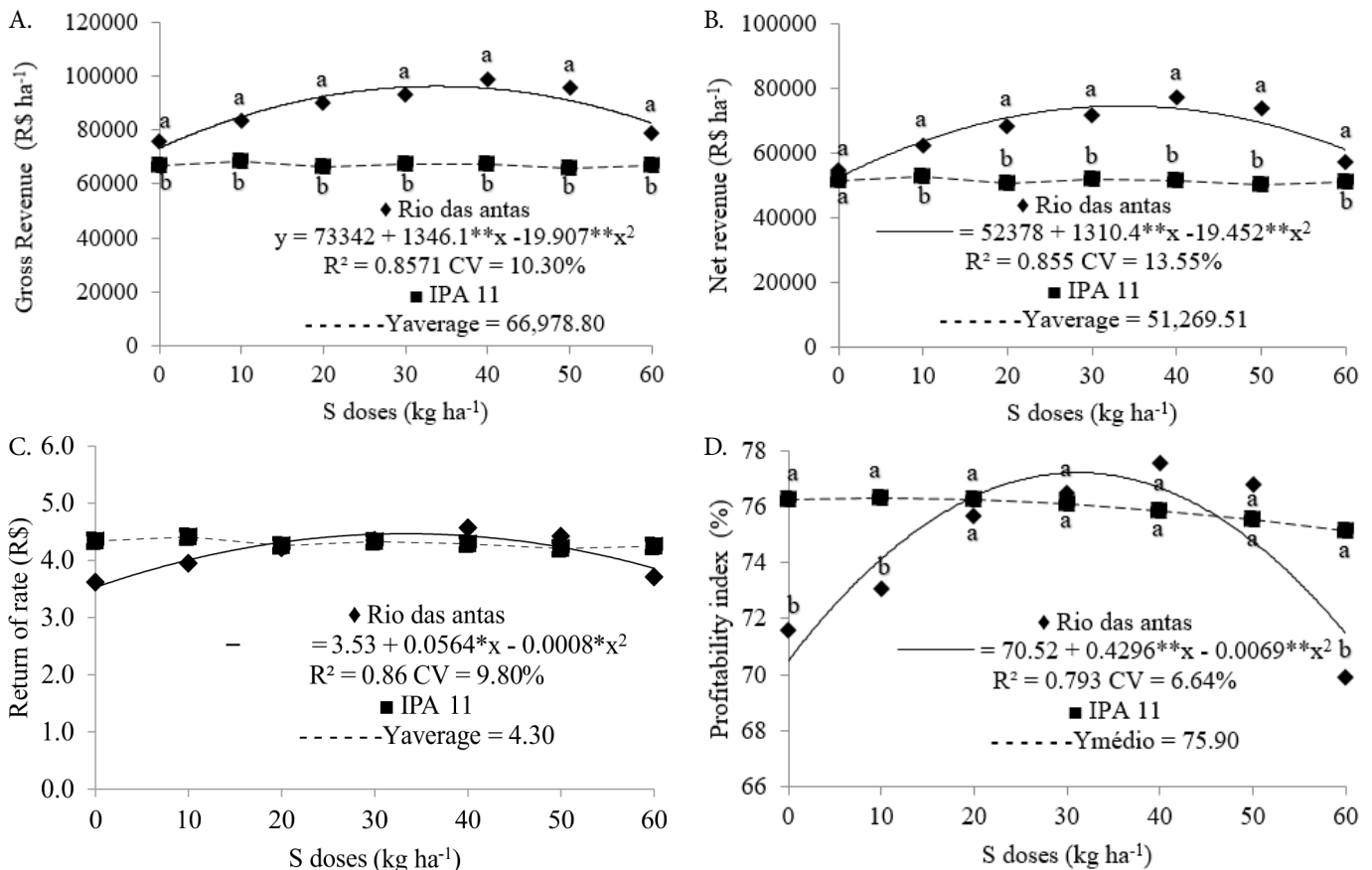
The depreciation values of the irrigation system for both cultivars were R\$ 1,358.58 and R\$ 1,332.87 ha⁻¹ for E1 and E2, respectively. These values corresponded to 6.0 and 5.9% in relation to the TOC for Rio das Antas. For IPA11, it was 9.0 and 8.1%, for E1 and E2.

Among the costs that did not vary with the treatments is the land lease, which varied according to the crop cycle, being R\$ 595.85 and R\$ 558.90 ha⁻¹ in the 145- and 136-day cycles for E1 and E2, respectively. The maintenance of farming facilities varied according to the experiments (E1 and E2), as they were calculated according to the days of cultivation in each experiment (R\$ 34.00 and 33.35 ha⁻¹, for E1 and E2, respectively).

The cost with the other expenses encompassed administrative expenses that totaled R\$ 520.74 and 577.27 ha⁻¹ for E1 and E2, respectively; technical assistance (R\$ 347.16 and 384.85 ha⁻¹); expected remuneration over fixed capital, which corresponds to 3% per year (R\$ 203.99 and 200.13 ha⁻¹); rural land tax (R\$ 3.97 and 3.73 ha⁻¹) and financing costs (R\$ 172.39 and 215.09 ha⁻¹) for E1 and E2, respectively.

The Gross revenue (GR), net revenue (NR), rate of return (RR) and profitability index (PI) as a function of onion cultivars and S doses are shown in Figure 4.

The gross revenue (GR) as a function of S doses was described by the quadratic regression model for the Rio das Antas cultivar, with the highest GR estimated at R\$ 96,100.00 ha⁻¹ at the 33.8 kg S ha⁻¹ dose (Figure 4A).



For each evaluated characteristic, means followed by the same lowercase letter do not differ significantly by Tukey's test ($p \leq 0.05$)

Figure 4. Gross revenue (GR), net revenue (NR), rate of return (RR) and profitability index (PI) as a function of S doses and the onion cultivars Rio das Antas (♦) and IPA 11 (■)

Compared to the treatment without S the increase was of 27.10%. For the IPA 11 cultivar, no satisfactory fit was observed, with an average of R\$ 6,6978.80 ha⁻¹.

GR is a parameter conditioned on two specific factors: the yield of the crop and the amount paid to the farmer. In the present work, the increase in S doses promoted an increase in the yield of Rio das Antas and, consequently, in GR.

According to Figure 4A, there is a statistical difference for the Rio das Antas cultivar compared to IPA 11 at all doses. The greatest GR average was obtained at 40 kg S ha⁻¹ (R\$ 98,851.63 ha⁻¹). The greater yield observed for the Rio das Antas cultivar led to greater GR averages, as previously discussed.

For the IPA 11, the fact that the S doses did not influence the CBY (Figure 3B) caused the GR and NR values to be lower than those recorded for Rio das Antas.

The net revenue (NR) (Figure 4B) had a maximum estimated value of R\$ 74.447 ha⁻¹ at 33.7 kg S ha⁻¹. In this case, the values were satisfactory for Rio das Antas, except in the absence of S fertilization (0 kg S ha⁻¹) and at the extreme dose (60 kg S ha⁻¹), when they did not differ statistically from those of the IPA11 cultivar, which, in turn, obtained the lowest NR averages (Figure 4B).

The greater profit obtained by Rio das Antas at 40 kg S ha⁻¹ dose is related to the yield increase achieved with the increase in S doses. On the other hand, the low NR observed at the extreme doses (0 and 60 kg S ha⁻¹) is related to the low yield that these treatments obtained.

The rate of return is a parameter conditioned on the yield, the amount paid for the product and the production costs. For the Rio das Antas cultivar, the maximum estimated RR (R\$ 4.50 ha⁻¹) was obtained at 33.6 kg S ha⁻¹ dose (Figure 4C). On the other hand, the IPA 11 cultivar did not obtain satisfactory fit for any regression model, with average of R\$ 4.30 ha⁻¹.

The highest average was recorded for Rio das Antas with a value of up to R\$ 4.57 for each R\$ 1.00 invested at 40 kg S ha⁻¹ (Figure 4C). However, no significant difference was observed for IPA 11, which, in turn, had a higher average: R\$ 4.40 at 20 kg S ha⁻¹, differing significantly from the Rio das Antas cultivar.

The estimated profitability index (PI) for the Rio das Antas cultivar was 77.2% at the 31.1 kg S ha⁻¹ dose (Figure 4D). On the other hand, for the IPA 11 cultivar no regression model fitted satisfactorily, with an average of 75.90% ha⁻¹.

In Figure 4D, it is observed that the values were favorable for both cultivars, at 76% level. The IPA 11 cultivar was superior at most doses, except at doses of 30, 40, and 50 kg S ha⁻¹, in which the Rio das Antas cultivar was superior, without, however, showing a significant difference in comparison to IPA 11. In general, the cultivation of onions in the study area showed satisfactory economic results. The variations between the indexes were favorable for both cultivars, with emphasis on Rio das Antas at doses of 30, 40 and 50 kg S ha⁻¹, with a return around 77%, and the benefit-cost ratio with a return of R\$ 4.50 per each BRL (R\$) used in the TOC of 1 ha of onion.

CONCLUSIONS

1. The Rio das Antas cultivar had high yield and satisfactory economic indexes with the application of S.

2. S doses between 30 and 40 kg ha⁻¹ favor greater yield for the Rio das Antas cultivar.

3. S Fertilization increased the percentage of larger bulbs (> 50 mm) and reduced the percentage of smaller bulbs (< 35 mm).

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