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Effect of phosphorus fertilization on yield and quality of onion bulbs

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Obtaining information about the onion responses to different doses of phosphorus can contribute to optimizing the use of fertilizers and consequently make the activity more profitable with less impact on the environment. Therefore, this study aimed to evaluate the effects of different phosphorus doses on yield and quality of onion bulbs. The design of the experiment was in a randomized block design with four replications. The treatments were seven phosphorus doses 0.00; 33.75; 67.50; 101.25; 135.00 and 168.75 kg ha^{-1} P_2O_5. The application of 168.75 kg ha^{-1} of P_2O_5 provided the maximum yield commercial of bulbs, gross income, net income, rate of return and profitability rate in onion crops. However, there was no effect on the quality of the bulbs.

Key words: *Allium cepa* L., plant nutrition, fertigation, phosphate fertilizer, pungency.

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important vegetable crops grown in Brazil, particularly in the south and northeast regions because of its socioeconomic importance, (Trani et al., 2014). In 2015, approximately 56,200 hectares of land were cultivated with onion in Brazil, with an output of more than 1.5 million tons and average yield of 26.9 t ha^{-1} (IBGE, 2015). Fertilizer application is one of the most important factors in onion

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Table 1. Chemical characteristics of the soil to a depth 0-20 cm, sampled prior to the experiment.

Parameter	Values
pH (water)	7.8
$P_{(mehlich)}$ (mg dm^{-3})	10.60
K ($Cmol_c$ dm^{-3})	0.28
Ca ($Cmol_c$ dm^{-3})	1.50
Mg ($Cmol_c$ dm^{-3})	0.12
Al ($Cmol_c$ dm^{-3})	0.00
M.O. (g kg^{-1})	3.80

M.O. = organic matter.

production because it directly affects growth, development and yields (Kurtz et al., 2013). Phosphorus (P) deficiency is one of the biggest constraints to crop production in many tropical soils, due to low native content and high P immobilization within the soil (Fairhust et al., 1999). A characteristic of the onion plant with regard to P is its inefficient extraction of this nutrient from the soil because the root hairs are mostly shorter than the length of phosphate diffusion. This requires a special care from growers with respect to the levels of this nutrient in the soil as well as the sources and forms of application of phosphate-based fertilizers (Brewester, 1994). The response of onion to phosphorus fertilization depends on the genotype used, P level in the soil, P source, soil and weather conditions (Grant et al., 2005).

Onion response to the application of up to 90 kg ha^{-1} P_2O_5 was reported by Costa et al., (2009), achieving a yield of 33.4 t ha^{-1}. Fonseca et al., (2011) obtained higher yields with an application of 120 kg ha^{-1} P_2O_5. Resende et al., (2016) observed better yields for onion cultivars: Franciscana IPA-10 and Vale Ouro IPA-11 with a dose of 132 kg ha^{-1} P_2O_5, comparable to economic dose of 130 kg ha^{-1} P_2O_5. Fertigation enables the application of soluble fertilizers and other chemicals along with irrigation water, uniformly and more efficiently. Work done with vegetables show that they respond very well to fertigation. As in potato (Badr et al., 2011), capsicum (Brahma et al., 2010) cucumber (Moujabber et al., 2002) tomato (Shedeed et al., 2009) and some leafy vegetables (Ueta et al., 2009). In onion, Rumpel et al. (2004) obtained higher marketable onion yields when the 50 kg ha^{-1} N rate was applied through drip fertigation (41% increase) and highest after applying 150 kg ha^{-1} N through fertigation (79% increase) as compared to the control (without fertigation and irrigation). Dingre et al. (2012) showed that drip fertigation resulted into 12 to 74% increase in the productivity of onion seed as compared to conventional method. Rajput and Patel (2006) recorded the highest onion yield in daily fertigation followed by alternate day fertigation. Lowest yield was recorded in monthly fertigation frequency. The study therefore sought to assess the effect of phosphate fertilization through fertigation on bulb yield and quality of onion under semiarid conditions.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted from April to September 2013 at the experimental field of the Department of Plant Sciences, Federal Rural University of Semi-Arid, Mossoro-RN, Brazil (Latitude 5°12' 26" south, and longitude 37°19’ 04" west and altitude of 18 m). The soil at the experimental site was classified as Red Yellow Argisol. The chemical characteristics of the soil are found in Table 1. The total rainfall was 610.01 mm and average temperature was 25.4°C during the period of the experiment.

Treatments and experimental design

Six treatments doses of phosphorus (0.00; 33.75; 67.50; 101.25; 135.00 and 168.75 kg ha^{-1} P_2O_5) were evaluated in a randomized complete block design with four replications. Each experimental unit consisted of a bed of 3.0 × 0.8 m, containing eight rows of plants spaced 0.10 × 0.10 m. The six central rows were harvested as useful plants without the border plants.

Planting and agronomic practices

The soil was prepared by one round of ploughing and harrowing. This was followed by construction of the beds and phosphorus fertilizer application in the form of triple superphosphate (41% P_2O_5) at half the dosage recommended for each treatment. The onion cultivar, Vale Ouro IPA-11, was used for the experiment. The seeds of the onion cultivar were nursed on seed beds measuring 1.0m wide and 0.2m high at the rate of 10 g m^{-2} in grooves of 0.01 m deep and 0.1m spacing between grooves dug across the bed length. Transplanting was done 53 days after sowing, when the seedlings were 15 to 20 cm high. Drip irrigation was used for watering the beds. Each bed was supplied with two hoses spaced at 0.4 m with self-compensating drippers of average flow rate of 1.40 l h^{-1} spaced at 0.2m apart. The onion was irrigated daily, based on crop evapotranspiration estimated by multiplying the reference evapotranspiration by the crop coefficient, at various stages of growth and development. Fertigation began 10 days after transplanting (DAT) and continued up to 70 DAT during which nitrogen was applied as urea and ammonium sulfate at the rate of 135.0 kg ha^{-1} N and potassium was applied as potassium chloride at the rate of 135 kg ha^{-1} K_2O. The other half of phosphorus treatment dosage was also applied through fertigation as phosphoric acid. The distribution of fertilizers was performed according to Table 2.

Mancozeb was sprayed at 7 days interval at the rate of 2.5 g l^{-1} to control disease such as stain purple. Clorfernapir and deltamethrin were applied alternately at 14 days interval at the rate of 0.5 ml l^{-1} and 0.3 ml l^{-1} respectively to control thrips and mites. Weed was controlled as and when necessary by hoeing. More than 70% of the onion was harvested at 153 DAP. The remaining (less than 30%) was harvested 7 days later. The delay was to enable supplementary healing process.

Data collection

Data were collected on yield of commercial bulbs (total weight of bulbs with diameter> 35 mm); yield of non-commercial bulbs (total

Table 2. Percentage distribution of nitrogen, phosphorus and potassium throughout the cycle Onion.

DAT*	N (%)	P (%)	K (%)
10 - 20	9.0	0.0	9.0
21 - 30	15.0	0.0	15.0
31 – 40	25.0	30.0	20.0
41 – 50	35.0	45.0	30.0
51 – 60	10.0	20.0	20.0
61 - 70	6.0	5.0	6.0

*DAT: Days after transplanting.

weight of bulbs with diameter < 35 mm); total yield of bulbs (sum of commercial and non-commercial yield of bulbs); bulb shape ratio (longitudinal diameter of bulb divided by transverse diameter); Phosphorus content in leaf (g kg^{-1}) was collected the highest sheet of 15 plants of the harvest area of the plot at 45 days after transplanting. Ten onion bulbs from each plot were analyzed for quality characteristics. The bulbs were ground in a food processor and then filtered in a funnel with filter paper to extract the juice. Soluble solids were determined by direct reading in digital refractometer; Titratable acidity (percent of pyruvic acid) was determined in a sample of 20 ml of the bulb juice to which three droplets of 1% phenolphthalein were added. Subsequently, titration was performed to the endpoint with a NaOH (0.1N) solution, which was previously standardized.

Then, the ratio of soluble solids to titratable acidity (SS/TA) was determined. The onion pungency (μmol of pyruvic acid g^{-1}) was determined by quantifying the pyruvic acid concentration, which was estimated by using the 2.4-dinitrophenylhydrazine (DNPH) reagent, according to the method described by Schwimmer and Weston (1961). The pH value was determined by using a digital pH meter, according to the method recommended by IAL (2008). Gross income was calculated considering the estimated commercial yield of onion and the price per kilo paid to producer at the time of harvest (US$ 0.45 per kilo). Net income was determined by the difference between the gross income and production costs. The rate of return was determined by the ratio of gross income to the production costs in each treatment, corresponding to the value obtained for each dollar spent in production costs. Profitability was the result from the ratio of net income to gross income expressed in percentage.

Statistical analysis

Data were subjected to analysis of variance using the Sisvar software (Ferreira, 2011). Whenever the means were significant, regression analysis was carried out and the models were chosen based on the significance level, by adopting 1% probability, and on the coefficients of determination (R^2).

RESULTS AND DISCUSSION

Plant dry mass and leaf phosphorus content

Plant dry mass and leaf phosphorus content were significantly influenced ($p< 0.05$) by phosphorus doses. The means of plant dry mass (PDM), in reason of the different phosphorus doses were adjusted to the quadratic regression model, with a maximum estimate of 12.26 g $plant^{-1}$ with the dose of 139.5 kg ha^{-1} P_2O_5. Regarding the treatment without P application (9.07 g $plant^{-1}$) there was an increase of 26.02% in the PDM. However, at the dose of 168.75 kg ha^{-1} P_2O_5, reduction of PDM was of 1.06%, compared to the maximum dose (Figure 1A). The PDM increase is due to the P participation in the plant processes such as photosynthesis, cellular division, absorption and transportation of ions. It also acts on the roots growth, especially on secondary roots, which are more efficient in absorbing water and nutrients (Fageria, 2009; Hawkesford et al., 2012).

The phosphorus content in leaf in regard to the P doses was adjusted to the quadratic regression model. In the treatment without P application, the P content was 5.36 g kg^{-1}; however, with P supply, leaf content increased up to the dose of 70.88 kg ha^{-1} P_2O_5 (6.34 g kg^{-1}). From this point there were reductions in the leaf P contents, and the minimum estimated content was 4.97 g kg^{-1} for the dose of 168.75 kg ha^{-1} P_2O_5, which was below that obtained in the control treatment, i.e., without P application (Figure 1B). All P levels found, irrespective of the applied dosage, fell into the range considered appropriate for onion crop, according to Trani et al. (2014), which is 2 to 5 g kg^{-1}.

Yield and quality of bulbs

The commercial yield (CY) and total yield (TY) increased linearly with the addition of phosphate fertilization. The maximum estimates for CY (48.87 t ha^{-1}) and TY (49.03 t ha^{-1}) were obtained with the application of 168.75 kg ha^{-1} P_2O_5 (Figure 1C and D). This dose was 25% higher than that recommended by Cavalcanti, (2008) for soils with P contents ranging from 6 to 12 mg dm^{-3}. It was also higher than the values found in other experiments with onion plants in Brazil, that is, 71 kg ha^{-1} P_2O_5 found by Costa et al. (2009), 60 kg ha^{-1} P_2O_5 by Wamser et al. (2011) and 130 kg ha^{-1} P_2O_5 by Resende et al. (2016). These results show the ability of Onion to respond to phosphorus application and undergird reports by different authors that the element contributes markedly to better productivity on the culture, especially in the production of bulbs size.

In some studies, onion bulbs responded significantly to phosphorus application at doses of 50 kg ha^{-1} P_2O_5 (Dudhat et al., 2010), 42 kg ha^{-1} P_2O_5 (Simon et al., 2014), 20 and 60 kg ha^{-1} P_2O_5 (Agumas et al., 2014). The onion yield of 49.0 t ha^{-1} produced by the cultivar Vale Ouro IPA-11 in this study was higher than the average national yield of 26.9 t ha^{-1} in Brazil (IBGE, 2015). The climate and phytosanitary conditions during the growing period favored the good crop performance. Onion bulb quality characteristics (bulb shape ratio, soluble solids, titratable acidity, soluble solids to titratable acidity ratio, pungency and hydrogen potential) were not significantly ($P>0.05$) affected by P fertilization (Table 3).

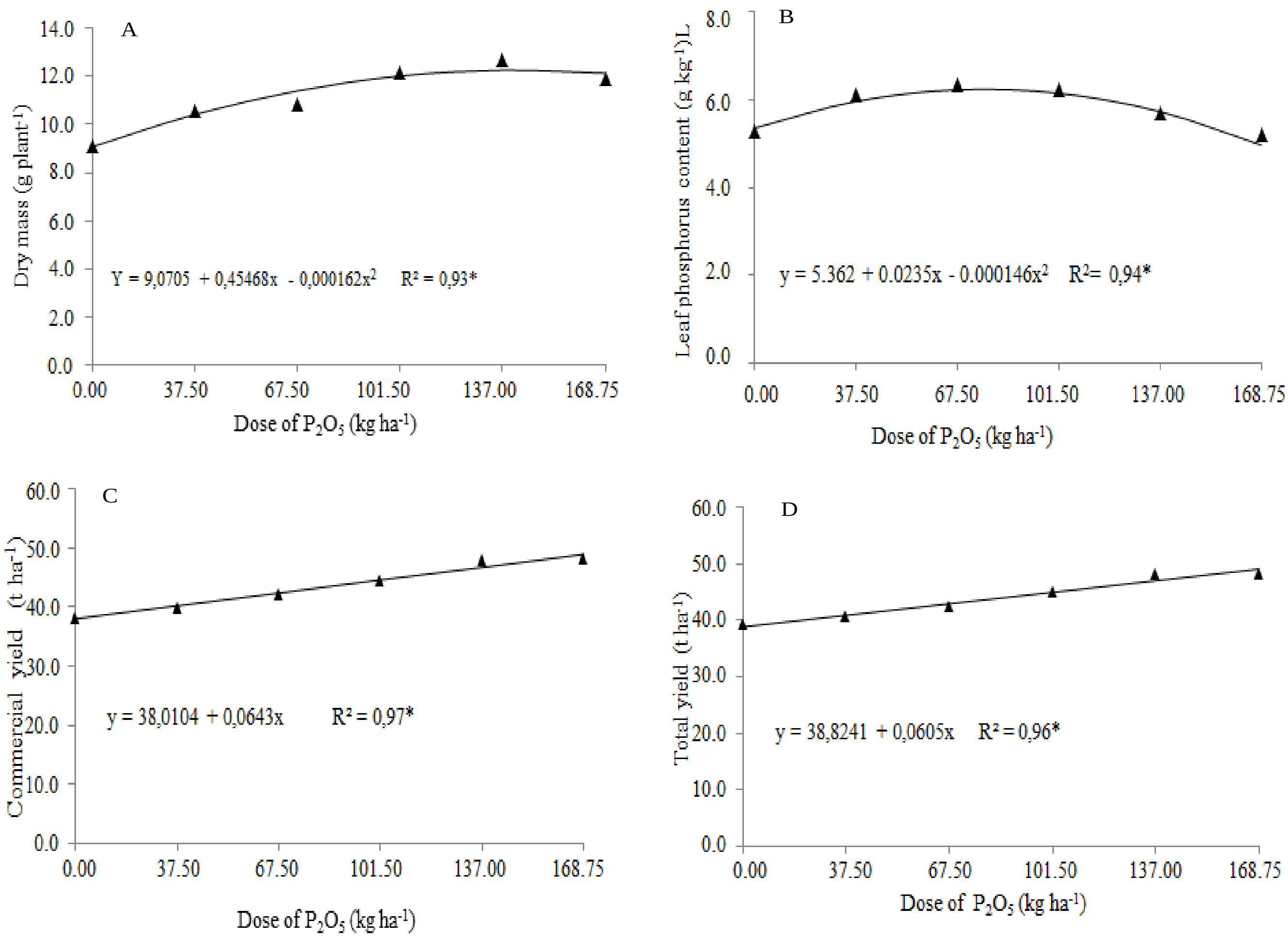

Figure 1. Plant dry mass (A), leaf phosphorus content (B), commercial yield (C) and total yield (D) in reason of phosphorus doses applied to onion cv. IPA-11.

Table 3. Quality characteristics of onion cultivar IPA-11 as influenced by phosphorus.

Doses (kg ha^{-1} of P_2O_5)	BSR	SS (%)	TA (% pyruvic acid)	SS/TA	PG (µmol of pyruvic acid g^{-1})	pH
0.00	0.83	10.35	3.93	2.65	6.72	5.46
33.75	0.83	10.43	4.29	2.43	7.55	5.51
67.50	0.84	10.55	3.93	2.74	7.60	5.47
101.25	0.85	10.60	4.42	2.41	7.02	5.48
135.00	0.82	10.05	4.29	2.35	6.48	5.49
168.75	0.87	10.28	4.29	2.40	7.53	5.48
Means	0.84	10.37	4.19	2.38	7.15	5.48
CV (%)	4.91	10.00	7.05	26.06	16.63	1.00

The results corroborate those found by Álvarez-Hernández et al. (2011), Tekalign et al. (2012) and Agumas et al. (2014). The onion cultivar Vale Ouro IPA-11 produced bulbs with quality characteristics that met the requirement s of the Brazilian consumer.

Economic analysis

The net income was positive for all treatments, and the dosage of phosphorus that provided the maximum commercial yield was also responsible for the highest

Table 4. Commercial yield (CY), production costs (PC), gross income (GI), net income (NI), rate of return (RR) and profit ratio (PR) as a function of phosphorus dosages applied to onion cv. IPA-11.

Doses of P_2O_5	CY	PC	GI	NI	RR	PR
(kg ha^{-1})	(t ha^{-1})		(US\$ ha^{-1})			(%)
0	38.01	4,680.90	17,104.68	12,423.78	3.65	72.63
33.75	40.19	4,738.31	18,085.50	13,347.19	3.82	73.80
67.50	42.35	4,795.71	19,058.94	14,263.23	3.97	74.84
101.25	44.56	4,853.12	20,051.96	15,198.84	4.13	75.80
135.00	46.70	4,910.53	21,013.16	16,102.63	4.28	76.63
168.75	48.87	4,967.93	21,991.73	17,023.80	4.43	77.41

gross income, net income, rate of return, and profit ratio, that is, of US\$ 21,991.73; US\$ 17,023.80; US\$ 4.43 and 77.41, respectively (Table 4). Without the application of phosphorus resulted in less GI, NL, RR and PR, with values of US\$ 17,104.68; US\$ 12,423.78; US\$ 3.65 and 72.63%, respectively, and commercial yield of 38.01 t ha^{-1}. As can be seen, even without phosphorus addition, net income was high, a reflection of the high commercial yield achieved and the price paid for onion during harvest. This result corroborates the results by Resende et al. (2016), who found yield of 69.1 t ha^{-1} of onion bulbs without phosphate fertilization.

Conclusion

The application of 168.75 kg ha^{-1} of P_2O_5 provided the maximum yield commercial of bulbs, gross income, net income, rate of return and profitability rate in onion crops. However, there was no effect on the quality of the bulbs.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Agumas B, Abewa A, Abebe D (2014). Response of irrigated onion (*Allium cepa* L.) to nitrogen and phosphorus fertilizers at Ribb and Koga irrigation schemes in Amhara Region, North Western Ethiopia. Int. Res. J. Agric. Sci. Soil Sci. 4:95-100.

Álvarez-Hernández JC, Flores SV, Ayala CS, Vargas AC, Sánchez LZ (2011). Uso de fertilizantes químicos y orgánicos en cebolla (*Allium cepa* L.) em Apatzingán, Michoacán, México. Revista de investigación y difusión científica agropecuária 15:29-43.

Badr MA, Taalab AS, Tohamy El WA (201). Nitrogen application rate and fertigation frequency for drip irrigated potato. Aust. J Basic Appl. Sci. 5:817-825.

Brahma S, Saikia L, Barua P, Hazarika T,Sharma B (2010). Studies on effect of fertigation with different levels of N and K fertilizers on growth, yield, quality and economics of early season capsicum (Capsicum annum L. var. grossum) under cover. Veg. Sci. 37:160-163.

Brewester JL (1994). Onions and other vegetable Alliums. CAB International, Wallingford, UK P 236.

Cavalcanti FJA (2008). Recomendações de adubação para o Estado de Pernambuco: 2ª aproximação. 3ª ed. Recife, IPA 212p.

Costa ND, Resende GM, Araújo JF, Santos CAF, Lima MAC, Candeia JC, Bandeira GRL (2009). Resposta de cultivares de cebola (*Allium cepa* L.) a doses de fósforo em cultivo orgânico no Vale do São Francisco. Hortic. Bras. 27:S3428-S3432.

Dingre SK, Pawar DD, Kadam KG (2012). Productivity, water use and quality of onion (Allium cepa) seed production under different irrigation scheduling through drip. Indian J. Agron. 57:186-190.

Dudhat MS, Chovatia PK, Sheta BT, Rank HD, Parmar HV (2010). Effect of nitrogen, phosphorous and potash on growth and bulb yield of onion (Allium cepa L.). Asian J. Soil Sci. 5:189-191.

Fageria NK (2009). The use of nutrients in crop plants. Taylor & Francis Group, Boca Raton: Florida, USA. 430p.

Fairhust T, Lefroy R, Mutert E, Batijes N (1999). The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. Agrofor. Forum 9:2-8.

Ferreira DF (2011). Sisvar: Um sistema computacional de análise estatística. Ciência e Agrotecnologia 35:1039-1042.

Grant C, Bittman S, Montreal M, Plenchette C, Morel C (2005). Soil and fertilizer phosphorus: Effects on plant P supply and mycorrhizal development. Canadian J. Plant Sci. 85:3-14.

Hawkesford M, Horst W, Kichey T, Lambers H, Schjoerring J, Moller SI, White P (2012). Functions of macronutrients. In: Marschner, P. (ed.). Marschner's mineral nutrition of higher plants. NewYork: Elsevier pp. 135-189.

IAL - Instituto Adolfo Lutz. (2008). Métodos físico-químicos para análise de alimentos. São Paulo: Instituto Adolfo Lutz 1020 p.

IBGE - Instituto Brasileiro de Geografia e Estatística (2015). Levantamento Sistemático da Produção Agrícola. Brasília, IBGE P.1-68.

Kurtz C, Ernani PR, Pauletti V, Menezes Junior FOG, Vieira Neto J (2013). Produtividade e conservação de cebola afetada pela adubação nitrogenada no sistema de plantio direto. Hortic. Bras. 31:559-567.

Moujabber EI, Atallah M, Darwish T (2002). Crop modeling and water use efficiency of protected cucumber. Int. Atomic Energy Agency Tech Documents 1266:61-67.

Rajput TBS, Patel N (2006). Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments. Agric. Water Manage. 79:293-311.

Resende GM, Costa ND, Yuri JE (2016). Efeito de doses de fósforo na produtividade e armazenamento pós-colheita de dois cultivares de cebola. Rev. Ceres 63:249-255.

Rumpel J, Kaniszewski S, Dysko J (2004). Effect of drip irrigation and fertilization timing and rate on yield of onion. J. Veg. Crop Prod. 9:65-73.

Schwimmer S, Weston WJ (1961). Enzymatic development of pyruvic acid in onion as a measure of pungency. J. Agric. Food Chem. 9:301-304.

Shedeed SI, Zaghloul SM, Yassen AA (2009). Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. Ozean J. Appl. Sci. 2:139-147.

Simon T, Tora M, Shumbulo A, Urkato S (2014). The Effect of Variety, Nitrogen and Phousphorous Fertilization on Growth and Bulb Yield of

Onion (*Allium Cepa* L.) at Wolaita, Southern Ethiopia. J. Biol. Agric. Healthcare 4:89-97.

Tekalign T, Abdissa Y, Pant LM (2012). Growth, bulb yield and quality of onion (A*llium cepa L*.) as influenced by nitrogen and phosphorus fertilization on vertisol. II: Bulb quality and storability. Afr. J. Agric. Res. 7:5980-5985.

Trani PE, Breda Júnior M, Factor TL (2014). Calagem e adubação da cebola (*Allium cepa* L.). Campinas: Instituto Agronômico 35 p.

Ueta T, Ikeba T, Ahn-DongHyuk, Kato K, Kawano T, Matsumoto E (2009). Effects of drip fertigation on yield and quality of leaf vegetables and on efficiency of nitrogen fertilization in outdoor plant. Japanese J. Soil Sci. Plant Nutr. Cult. 80:477-486.

Wamser AF, Suzuki A, Mueller S, Gonçalves MM, Valmorbida J, Becker WF (2011). Adubação fosfatada e potássica da cebola em área com resíduos de adubação do tomateiro. Agropecuária Catarinense 24:86-88.