Effects of levels of potassium and nitrogen on yields and post-harvest conservation of onions in winter

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ABSTRACT

Potassium and nitrogen are the elements present in the highest percentage in the onion dry matter. The objective of this experiment was to evaluate yield and post-harvest conservation of Vale Ouro IPA-11 onion cultivar regarding to nitrogen and potassium levels. The experiment was carried out in Petrolina-PE, Brazil, from June to September 2009. The experimental design was a completely randomized block in a 4 x 3 factorial design, composed of four nitrogen levels (0, 60, 120 and 180 kg ha^{-1}) and three potassium levels (0, 90 and 180 kg ha^{-1}) with three replications. The highest yield of commercial bulbs was achieved at an estimated N level of 172.6 kg ha^{-1}. The lowest yield of noncommercial bulbs was estimated at N level of 147.0 kg ha^{-1}. Lower percentage of smaller bulbs (class 2) were obtained by increasing levels of N x K, with a quadratic effect at the dose of 90 kg ha^{-1} K_2O and minimum production point with 127.6 kg N ha^{-1} (20.3%). Regarding larger caliber bulbs (class 4), linear effects were found both in the absence and for the level of 90 kg ha^{-1} of K_2O as levels of N were increased. When the highest level of 180 kg ha^{-1} K_2O was applied, the level of 92.8 kg ha^{-1} of N was estimated as the one that would promote the highest bulb yield of this class (35.4%), and 5.3% was found in the lack of potassium fertilization.

Key words: *Allium cepa*, yield, nutrition, storage.

RESUMO

Efeitos de doses de nitrogênio e potássio na produtividade e conservação pós-colheita da cebola no inverno

Os elementos presentes, em maior percentagem, na matéria seca da cebola são potássio e nitrogênio. Com o objetivo de avaliar a produtividade e conservação pós-colheita do cultivar de cebola Vale Ouro IPA-11, em função de doses de nitrogênio e potássio, foi conduzido experimento, de junho a dezembro de 2009, em Petrolina-PE. O delineamento experimental foi o de blocos ao acaso, no esquema fatorial 4x3, compreendendo quatro doses de nitrogênio (0; 60; 120 e 180 kg ha^{-1}) e três doses de potássio (0; 90 e 180 kg ha^{-1}), com três repetições. A maior produtividade comercial de bulbos foi estimada com a dose de 172,6 kg ha^{-1} de N. A menor produção de refugos foi obtida com a dose de 147,0 kg ha^{-1} de N**.** Menor percentual de bulbos menores (classe 2) foram obtidos com o aumento das doses de N e K, ocorrendo, para a dose de 90 kg ha^{-1} de K_2O, efeito quadrático, com ponto de mínima produção com 127,6 kg ha^{-1} de N (20,3%). Com relação a bulbos de maior calibre (classe 4), foram obtidos efeitos lineares, tanto na ausência quanto com a dose de 90 kg ha^{-1} de K_2O, com o incremento das doses de N. Quando se aplicou a dose maior, de 180 kg ha^{-1} de K_2O, estimou-se a dose de 92,8 kg ha^{-1} de N como a que promoveria a maior produção de bulbos dessa classe (35,4%), verificando-se 5,3%, com a ausência da adubação potássica.

Palavras-chave: *Allium cepa*, rendimento, nutrição, armazenamento.

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INTRODUCTION

Among vegetables, onion (*Allium cepa*) ranks third place in economic importance in Brazil. In 2011, the Brazilian average yield was 22.6 t ha^{-1}, whereas, in the states of Pernambuco and Bahia, the largest producers in the Northeast, the average yield of 20.2 and 21.4 t ha^{-1}, were achieved, respectively (IBGE, 2012).

Nitrogen (N) contributes markedly to improving the production of onion, being absorbed in large amounts, exceeded only by potassium (K) (Porto *et al*., 2007, May *et al*., 2008). Besides photosynthesis, N takes place in other physiological processes vital to the life cycle of plants, such as ion absorption, respiration, cell multiplication and differentiation and inheritance (Epstein & Bloom, 2006). The beneficial effect of potassium can be found in different traits of agricultural products, such as color, acidity, resistance to shipping, handling and storage, nutritional value and industrial qualities (Malavolta, 2006). Although onions extract large amounts of potassium, in general, responses by the crop to this nutrient have not been found (Filgueira, 2008) and there are few results that confirm a significant effect of K fertilizer on the yield.

With respect to K fertilization, Kumar *et al*. (2001), working with the cultivar Pusa Madhavi, reported an increase in onion yield by applying 40 kg ha^{1} of K_2O and lack of response to levels of 80 and 160 kg ha^{1}, as well as an increase in diameter and fresh matter of the bulb, with the application of 60 kg ha^{1} of K_2O, for Nasik Red cultivar (Mohanty & Das, 2001). Akhtar *et al*. (2002), when studying five cultivars (Phulkara, Burgundy, White Creole, Swat and Texas Early Grano), found that the application of 200 kg ha^{-1} K_2O increased yield of onion bulbs, and lowest yields were shown by all cultivars in the lack of K fertilization.

As for the response of this crop to levels of N, different authors found that the nutrient contributes markedly to increase yield. Kumar *et al*. (2001) found that the yield of onion bulbs responded significantly to N application up to 120 kg ha^{1}. Larger diameter, weight and yield of bulbs were achieved by Mohanty & Das (2001), also with 120 kg ha^{-1} of N, not differing from the results achieved with levels of 90 kg h $^{-1}$ N. However, Yadav *et al*. (2003) found that for the cultivar Agrifound Dark Red, the application of 100 kgha^{-1} N produced significantly higher yields than the dose of 50 kg N ha $^{-1}$ and the application of 150 kg ha^{-1} N did not increase the yield of bulbs, in relation to 100 kg ha^{-1} N. When evaluating cultivar Vision, Shock *et al*. (2004) did not found a positive effect on the total and commercial yield for the level equal to or higher than 145 kg ha^{-1} of N.

The objective of this study was to evaluate the effects of nitrogen and potassium on yield and post-harvest quality of onion, grown in the winter, in São Francisco Valley.

MATERIAL AND METHODS

The experiment was set and carried out from June to September 2009 at the Experimental Field of Bebedouro, Petrolina (9º9' S, 40º29'' W, 365.5 above sea level). According to the Köppen climate classification, the climate of the region is BSWh', semiarid. The values of annual averages of climatological variables are as follow: air temperature = 26.5°C; rainfall = 541.1 mm, air relative humidity = 65.9%, class A evaporation pan= 2500 mm and speed wind = 2.3 m s^{-1}. Rainfall is unevenly distributed in space and time, with higher averages in the months from December to April; the annual insolation is higher than 3,000 h (Azevedo *et al*., 2006). The soil was classified as Oxysol (Santos *et al*., 2006.), pH (H_2O) = 6.6; Ca = 1.8 cmol$_c$ dm^{-3}; Mg = 0.6 cmol$_c$ dm^{-3}; Na = 0.01 cmol$_c$ dm^{-3}; K = 0.48 cmol$_c$ dm^{-3}; Al = 0.00 cmol$_c$ dm^{-3}, P(Mehlich) = 25.0 mg dm^{-3} and O.M. = 3.6 g kg $^{-1}$. Cultivar Golden Valley IPA-11 was used in the experiment.

The experimental plot consisted of eight 3.0-m long rows, spaced by 0.15 m, with 0.10 m between plants, with a total area of 3.6 m^2 (3.0 x 1.2 m) area. The six central rows were used as the useful area, subtracting 0.50 m at each edge (1.80 m^2). Fertilization consisted of the application of 135.0 kg P_2O_5 ha^{-1} as superphosphate at planting. Nitrogen and potassium fertilization were split into three times. The first fertilization was carried out on planting (1/3) and the rest (2/3) as two side dressing fertilizations on days 25 and 50 after transplanting. Urea and potassium chloride were used as sources of nitrogen and potassium, respectively.

Soil preparation consisted of plowing, harrowing and beds raised at beds 0.20 m. Seedlings transplanting occurred on day 30 after sowing (May). The irrigations were applied by sprayer, with two-day shift and 9 mm of water depth, calculated as a function of the class A evaporation pan. The phytosanitary treatments were common to the onion crop.

Onions were harvested in August, when the plants showed signs of advanced senescence, as yellowing and dry leaves, and when more than 70% of the plants were found dead. Curing was carried out in the field for three days, followed by 12 days in a shaded ventilated barn. The cured bulbs were stored for a period of 60 days.

It was evaluated the yields of commercial (perfect bulbs with cross diameter above 35 mm) and noncommercial (waste, less than 35 mm diameter) bulbs, expressed in t ha^{-1}, 15 days after curing. The average fresh mass of bulb (g. bulb^{-1}) was determined by dividing the total mass of commercial bulbs, after curing, by the number of bulbs. The classification of commercial bulbs, in percentages, according to the cross-sectional diameter (mm) was made in Class 2: greater than 35 to 50 mm in diameter; Class 3: greater than 50 to 70 mm; Class 4: greater than 70 to 90 mm and Class 5: greater than 90 mm (Resende *et al*., 2009). Percentage data were transformed into $\sqrt{P/100}$ arcsine, for effects of statistical analysis.

The experimental design was a randomized block in 4x3 factorial arrangement, comprising four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) and three doses of potassium (0, 90 and 180 kg ha^{-1}), with three replications. The data collected were submitted to analysis of variance and regression, based on the polynomial model, using the F test for comparison at 5% of probability. The levels nitrogen and potassium were adjusted to polynomial regression equations, adopting the significant effect by F test at 5% probability as a criterion for choosing the model and the magnitude of the coefficients of determination, using the SISVAR 5.0 program (Ferreira, 2010).

RESULTS AND DISCUSSION

The results evidenced significant effects for the levels of nitrogen and potassium, as well as for N x K interaction, varying according to the characteristics evaluated.

For commercial yield, a significant effect was found only for the levels of N. The highest commercial yield (65.7 t ha^{-1}) was estimated from the dose of 172.6 kg N ha^{-1} (Figure 1). These results are consistent with those found by different authors, who obtained positive responses of N application on onion crops, up to doses of 150 kg ha^{-1} (Diaz-Perez *et al.*, 2003; Singh *et al.* 2004) and 200 kg ha^{-1} N (Neeraja *et al.*, 2001).

Similar results were found for production of waste (non-commercial bulbs), in which significant effect was found only for doses of N (Figure 2). A gradual reduction IN the production of non-commercial bulbs was found when doses of N were increased. The lowest production of waste was estimated with the dose of 147.0 kg ha^{-1} N (1.30 t ha^{-1}). These results show the responsiveness of the onion to nitrogen application and confirm the statements of different authors, who report that the element contributes markedly to greater yield of this crop, especially in the production of larger bulbs. Ghaffoor *et al*. (2003) reported lower yields of waste with the increase in NPK fertilization. Lee *et al*. (2003) and Mandira & Khan (2003) also reported that these elements contribute markedly to better crop productivity, especially in the production of larger bulbs

Concerning to bulb fresh mass, an effect was found only for the levels of N (Figure 3). The increase in the levels of the fertilizers caused a linear increase in fresh mass of the bulbs. These results display the positive effects of N in increasing the fresh mass of the bulb, and they agree with the statements of different authors that the element contributes markedly to produce larger bulbs (Hussaini *et al.*, 2000; Lee *et al.*, 2003; Mandira & Khan, 2003).

The classification of commercial onion bulbs was influenced by the interaction of the evaluated factors (N x K) for the different classes (Table 1). As for the bulbs of smaller size (greater than 35 to 50 mm in diameter) it was found a linear reduction in total class 2 bulbs 2 in the lack potassium fertilization, given by the negative angular coefficient (-a) of the linear equation (Y=ax+b). That is, in these cases, the higher the nitrogen fertilization, the fewer the Class 2 bulbs. Similar results were obtained for the 180 kg ha^{-1} K2O, for which it was found 55.2% of class 2 bulbs against 24.8% with the highest dose (180 kg N ha^{-1}) for the lack of N. For the level of 90 kg ha^{-1} K_2O, a quadratic effect with the point of minimum production with 127.6 kg N ha^{-1} (20.3% of small bulbs) was found, obtaining the value of 25.9% for the maximum

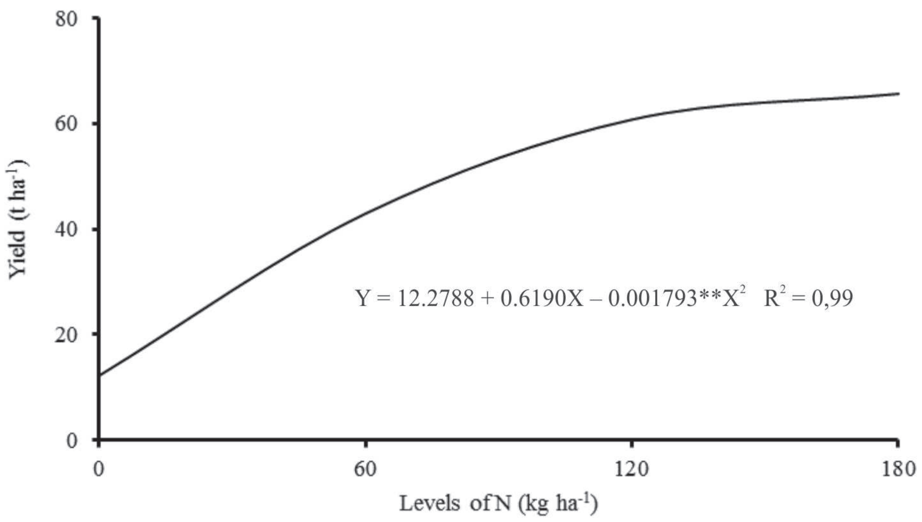

Figure 1. Onion bulbs yields according to N levels. Petrolina-PE, Embrapa Semiárido, 2009.

dose of N, 180 kg ha^{-1} of K_2O and 50.8% for the control, considered as small bulbs. Due to the figures presented, it is inferred that the level of 90 kg ha^{-1} K_2O is the most economical and with the lowest percentage of smaller bulbs, in the presence of N, compared with the highest dose of potassium applied (180 kg ha^{-1} of K_2O).

For Class 3, bulbs that are intermediate in size (greater than 50 to 70 mm in diameter), a positive linear effect was found when zero potassium was applied. The maximum production of intermediate bulbs for 90 kg ha^{-1} K_2O occurred by applying 120.0 kg ha^{-1} N (63.4%), that is, by increasing the levels of nitrogen, higher percentages of larger size bulbs was achieved, compared with those obtained with the lack of K fertilization, which reached 39.6% (Table 1). A quadratic effect was also found when 180 kg ha^{-1} K_2O was applied; however, at the point of minimum production at the dose of 50.0 kg ha^{-1} N (31.1%) but when the maximum dose of N (180 kg N ha^{-1}) was used, 63.8% was achieved, a result similar to that found with the intermediate dose of 90 kg ha^{-1} of K_2O, so the most appropriate for production of bulbs of that class.

As for larger caliber bulbs, (class 4), linear effects were found when zero potassium fertilizer was used. For 90 kg ha^{-1} K_2O, results similar to those obtained with increasing doses of N were found, for which 30.4% of bulbs of that class was obtained when the highest dose (180 kg ha^{-1}N) was applied. When the highest dose of 180 kg ha^{-1} K_2O was applied, the dose of 92.8 kg ha^{-1} was estimated as the one that would promote the highest yield of bulbs of that class (35.4%), that is, higher nitrogen doses would promote lower percentage of bulbs of that caliber at the highest level of K, which are values slightly higher than those found when the intermediate level of potassium (90 kg ha^{-1} K_2O) was used. By analyzing the results obtained in the three classes of bulbs, it can be inferred that the dose of 90 kg ha^{-1} of K_2O provided the best responses in interaction with nitrogen fertilization.

When such results are evaluated, what can be found in relation to the diameter of the bulbs, in the different classes, is that the N x K interaction provides, depending on the combination of these nutrients, in general, larger and intermediate caliber bulbs (classes 3 and 4), with a

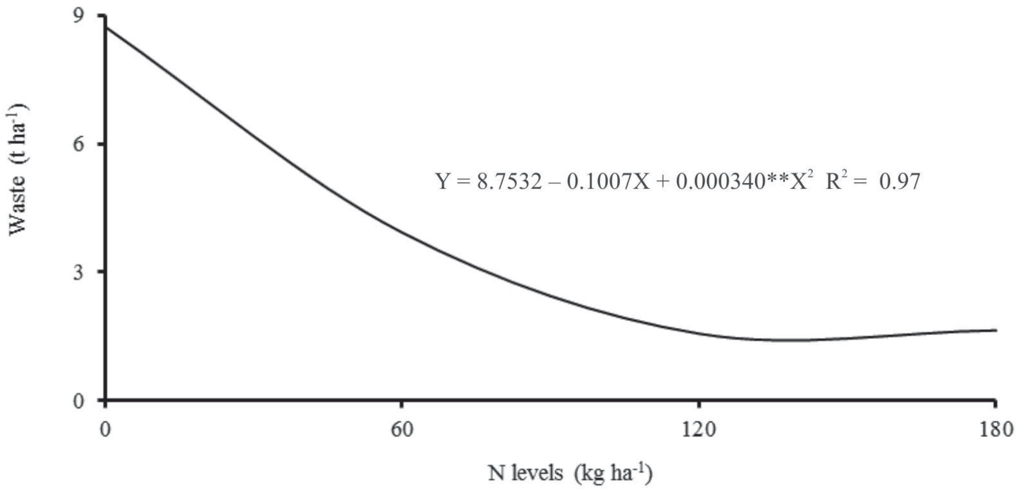

Figure 2. Waste (non-commercial yield) of onion bulbs according to N levels. Petrolina-PE, Embrapa Semiárido, 2009.

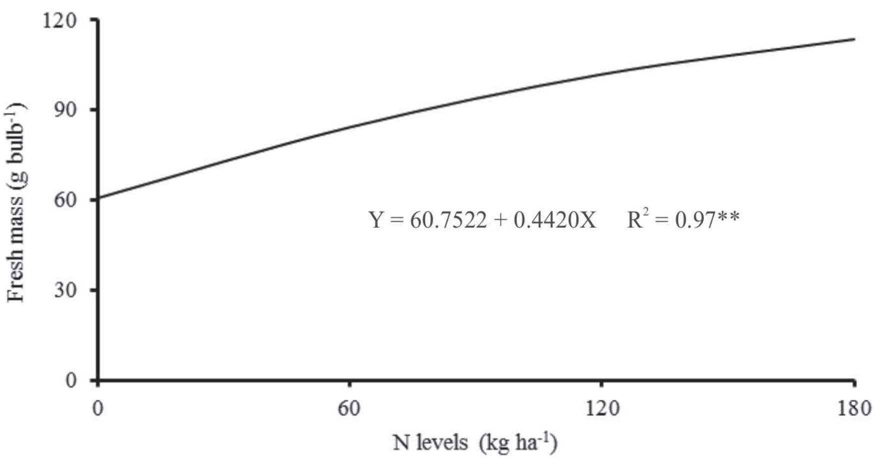

Figure 3. Onion bulbs fresh mass according to N levels. Petrolina-PE, Embrapa Semiárido, 2009.

Table 1. Classification (potassium (K) level classes, %), according to cross diameter of onion bulbs in function of the N levels (N). Petrolina - PE, Embrapa Semiárido, 2009

Characteristic	Regression equations	R^2
Class 2	N : K (0) $Y = 47.8641 – 0.1194^{**}X$	0.75
	N : K (90) $Y = 50.8193 – 0.4686X + 0.001836^{**}X^2$	0.99
	N : K (180) $Y = 55.2595 – 0.1691^{*}X$	0.76
Class 3	N : K (0) $Y = 40.6697 + 0.0770^{**}X$	0.65
	N : K (90) $Y = 39.6007 + 0.3970X – 0.001655^{**}X^2$	0.97
	N : K (180) $Y = 32.9212 – 0.1162 + 0.001600^{**}X^2$	0.79
Class 4	N : K (0) $Y = 6.5520 + 0.1180^{**}X$	0.68
	N : K (90) $Y = 3.3228 + 0.0947^{*}X$	0.80
	N : K (180) $Y = 5.2611 + 0.6493X – 0.003498^{**}X^2$	0.73

** * Significant at 1 and 5% probability by the F test and Non-significant.

consequent reduction in the production of smaller size bulbs (class 2). Such result is well evidenced when positive or negative linear effects were achieved. The literature reports an antagonism between these elements; however, the results suggest an additional response, in which N is the main factor that positively affects the production of larger diameter bulbs. These results corroborate the statements of May *et al*. (2007), who concluded that a more expressive application of nitrogen, in terms of relevance to the response to the application of potassium fertilization, probably due to their different metabolic functions.

The positive results obtained with nitrogen and potassium fertilization on onion crop can be justified by the fact that nitrogen is absorbed in large amounts, surpassed only by potassium (Porto *et al*., 2007, May *et al*., 2008) and it can be found in organic compounds such as amino acids and nucleic acids and takes place in diverse vital physiological processes to plants - ion absorption, photosynthesis, respiration, and cell differentiation and multiplication and inheritance (Epstein & Bloom, 2004). Moreover, because potassium integrates different biochemical functions in the physiological processes, whether in translocation of sugars (translocation and storage of photosynthesis assimilates), in the respiration, in the opening and closing of stomata in osmotic regulation (maintaining the osmotic potential and ionic balance) or as activator of more than 60 enzymes related to these processes (Malavolta, 2006; Epstein & Bloom, 2006).

Because of the positive results in commercial and non-commercial (waste) productivity, fresh mass and classification of bulbs (diameter) the doses, in interaction, of 172.6 kg ha^{-1} N (which promoted greater yields) and 90 kg ha^{-1} K_2O (which provided better responses in terms of classification of commercial bulbs) are suggested as a way to unify a recommendation for fertilization of Vale Ouro IPA-11 cultivar. Such recommendation is the most suitable for cultivation under conditions in the São Francisco Valley.

CONCLUSION

The increase in the levels of nitrogen increased fresh mass yield of of bulbs and reduced the yields of non-commercial bulbs (waste).

The N x K interaction provided the highest yield of intermediate diameter and larger caliber bulbs and the reduction of smaller bulbs.

Levels of 172.6 kg ha^{-1} of N and 90 kg ha^{-1} of K_2O, in function of the different characteristics evaluated, may be indicated as those that provided the best responses to the crop under the conditions found in the São Francisco Valley.

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