

YIELD OF POTATO CULTIVARS AS A FUNCTION OF NITROGEN RATES¹

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ABSTRACT - The use of fertilizers at appropriate doses positively impacts the production and the environment. Therefore, we aimed to evaluate the influence of nitrogen (N) rates on the crop yields of the potato cultivars, Ágata and Atlantic in Unai, Minas Gerais (MG), and Ágata in Mucugê, Bahia (BA), Brazil. The cultivation of Ágata and Atlantic was conducted in MG from May to August and June to September 2014, respectively. In BA, Ágata was cultivated between September and December 2014. A random block experimental design was used with treatment rates of 0, 30, 70, 120, and 280 kg ha⁻¹ of N. The macro and micronutrient concentrations in potato leaves were evaluated. At the end of the growth cycle, the production of tubers was also evaluated. In the absence of N application, it was observed that P, K, S, and B were below the adequate levels in Atlantic-MG, the S and Zn levels were lower than the adequate levels in Ágata-MG, and the N, K, Mg, and S levels were less than the adequate levels in Ágata-BA. The other nutrients met the needs of the potato, with the N increase being favorable to the levels of most nutrients in all experiments. The maximum rates of N varied between 138 and 194 kg ha⁻¹ in the high and low cationic exchange capacity (CEC) regions, respectively. The knowledge of the interaction among soil attributes, climate conditions and crop specificities allows for the improved prediction of the dosage of N and a reduction in the optimum amount without affecting yields.

Keywords: *Solanum tuberosum* L.. Urea. Nitrogen levels.

PRODUTIVIDADE DE CULTIVARES DE BATATA EM FUNÇÃO DE DOSES DE NITROGÊNIO

RESUMO - A utilização de fertilizantes em doses adequadas promovem impactos positivos na produção e no meio ambiente. Portanto, objetivou-se avaliar a influência de doses de nitrogênio na produtividade da batata cultivares Ágata e Atlantic em Unai-MG e Ágata em Mucuge-BA. O cultivo de Ágata e Atlantic foi conduzido em Minas Gerais (Unai), entre maio a agosto e junho a setembro de 2014, respectivamente. Já na Bahia (Mucugê), Ágata foi cultivada entre setembro a dezembro de 2014. O delineamento experimental utilizado foi o de blocos ao acaso. Foram avaliadas as doses de 0, 30, 70, 120 e 280 kg ha⁻¹ de N. Na fase de desenvolvimento foram avaliados os teores de macro e micronutrientes em folhas de batateira. No final do ciclo foi avaliada a produção de tubérculos. Na ausência de aplicação de N, observou-se que o P, K, S e B apresentaram teores inferiores ao adequado em Atlantic-MG, os teores de S e Zn foram inferiores ao adequado em Ágata-MG e os teores de N, K, Mg e S foram inferiores ao adequado em Ágata-BA. Os demais nutrientes atenderam as necessidades da batateira, sendo o incremento de N favoráveis ao aumento dos teores da maioria dos nutrientes, em todos os experimentos. As doses máximas de N variam entre 138 e 194 kg ha⁻¹, em região de CTC alta e baixa, respectivamente. O conhecimento da interação entre atributos do solo, condições climáticas e especificidades das cultivares permite aprimorar a previsão de dosagem e redução na quantidade ótima, sem afetar os rendimentos.

Palavras-chave: *Solanum tuberosum* L. Ureia. Níveis de nitrogênio.

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INTRODUCTION

The potato (*Solanum tuberosum* L.) is an important food source due to its high energy and nutritional contents (SHEN et al., 2019). Under favorable conditions of climate, cultivar, and advanced technology, the productivity of the crop can reach 60 t ha⁻¹. However, the characteristics that increase the cost of production, in association with market price fluctuations, may configure a financial risk to the producer (STÜRMER et al., 2014).

The low availability of N in the arable soil layer, in addition to the high demand for the nutrient by plants, means that this essential nutrient is one of the most limiting factors in the productivity of potato crops (BRAUN et al., 2013).

The plants adapt to nutrient fluctuations around the roots by means of the coordinated adjustment of root morphology and gene expression. This happens through the regulation of the rate of absorption by the roots, which decreases with deprivation and increases with the availability of N (ISHIKAWA-SAKURAI; HAYASHI; MURAI-HATANO, 2014). Thus, the supply of N synergistically or antagonistically alters the absorption and use of other nutrients present in the soil, with the genetically controlled absorption of nutrients affected by the genotype-environment-management interaction (MA et al., 2016; MALTAS; DUPUIS; SINAJ, 2018).

Low rates of N results in lower potato production, smaller tubers, early senescence, accumulation of carbohydrates in the leaves, and higher level of carbon allocated to the root (MOKRANI; HAMDI; TARCHOUN, 2018). To avoid this, it is possible to apply excessive quantities of N fertilizers to ensure desirable yields since the cost of this fertilizer is relatively low as compared to the total cost of production. The reason why farmers use large amounts of N fertilizer is related to the attempt to achieve the amount of N supply required for high crop productivity without a proper study of the soil, compensating for this with the excessive N application, and the lack of precise methods to help nutritional management (KONG et al., 2013).

A disparity between the optimum fertilizer amount recommended by the literature and that used by producers, associated with the lack of technical information on the subject (QUEIROZ et al., 2013), justifies the need to research this area. The results should guide the consistent, conscientious use of fertilizers, and ensure a sustainable relationship between the environment and the economy by reducing the cost of production (AYYUB et al., 2019).

The optimization of the use of N, increased potato yield, and reduced nutrient loss depend on the correct selection of the N source, dose, and time of application (CAMBOURIS et al., 2016, SOUZA et al., 2019; MILROY; WANG; SADRAS, 2019) along with the interaction with the genotype, soil moisture level, and soil type (SARAVIA et al., 2016). The development of strategies for aligning agricultural practices to ensure the availability of N in the soil, which is compatible with potato N demand, is considered challenging by researchers and producers (RENS et al., 2018; SOUZA et al., 2020).

Nutritional management is dynamic and affects external factors and internal factors within a crop, in which adequate rates reflect an increased balance of the system. Thus, the aim of this study was to evaluate the influence of rates of N fertilizer on the yield of Ágata and Atlantic potato cultivars.

MATERIALS AND METHODS

The cultivation of Ágata and Atlantic potato cultivars was carried out in Unai, Minas Gerais (MG; 6°21'27" S and 46°54'22" W, 640 m altitude, Aw climate in the Köppen climate classification, and with a clay-textured soil classified as Dystrophic Red Latosol), Brazil, from May to August and June to September in 2014, respectively. The maximum and minimum temperatures from May to August varied between 29–37°C and 9–14°C, respectively, and from June to September varied between 29–40°C and 9–17°C, respectively. The relative humidity ranged from 51–68% and 52–64% in the period from May to August and June to September, respectively. The total rainfall was 50 mm and 57 mm from May to August and June to September, respectively.

In Mucugê, Bahia [BA; 13°00'19" S and 41°22'15" W, 986 m altitude, Cfb climate according to the Köppen classification, and soils of a medium texture that are classified as Red-Yellow Latosol (TEIXIERA et al., 2017)], an experiment was conducted with the Ágata cultivar from September to December in 2014. The maximum and minimum temperatures during the study period ranged from 25–29°C and 12–16°C, respectively. The relative humidity ranged from 62–80%, and the total rainfall over the study period was 350 mm.

All experiments were conducted in fields used for potato production. Before planting, soil sampling was carried out in the 0–20 cm layer, and the sample was chemically analyzed in accordance with the method described by Teixeira et al. (2017). The values are in Table 1.

Table 1. Chemical characterization of soils in the experimental areas for different potato cultivars (in parentheses) before planting and fertilizer addition.

Soil characteristics	Bahia (Ágata)	Minas Gerais (Ágata)	Minas Gerais (Atlantic)
pH water	5.7	5.2	5.3
P (mg dm ⁻³)	11.7	14.5	17.0
K (mg dm ⁻³)	84	84.4	89
Ca (cmolc dm ⁻³)	1.3	2.9	3.2
Mg (cmolc dm ⁻³)	0.4	1.1	0.9
H+Al (cmolc dm ⁻³)	1.8	3.5	3.6
CEC (cmolc dm ⁻³)	3.7	7.7	7.9
V (%)	51.9	54.6	54.4

P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; H+Al: exchangeable soil aluminium; CEC: cationic exchange capacity; V: base saturation.

A random block experimental design was used with five rates of nitrogen application (0, 30, 70, 120, and 280 kg ha⁻¹ of N) and four replicates per N treatment. Each experimental unit consisted of six rows of 6 m in length, with rows spaced 0.8 m apart and plants spaced 0.30 m apart, totaling 28.8 m² per plot. The evaluations were carried out on the two central lines, with the assessed area of each experimental unit totaling 8 m².

A standard dose of the nutrients, P and K, fixed at 480 kg ha⁻¹ of P₂O₅ and 220 kg ha⁻¹ of K₂O, was applied following the recommendations of the Commission of Fertility of the Soils of Minas Gerais (RIBEIRO; GUIMARÃES; ALVAREZ, 1999) and based on the soil analysis results. The sources of N, P, and K used were urea (45% N), triple superphosphate (41% P₂O₅), and potassium chloride (60% K₂O), respectively. At the time of planting, micronutrients were applied: 2.2 kg ha⁻¹ of B and Cu and 5.4 kg ha⁻¹ of Mn and Zn in the plots in Unaí-MG and 2.5 kg ha⁻¹ of B, Cu, and Zn and 5 kg ha⁻¹ of Mn in Mucugê-BA.

Three months before planting, liming was carried out with dolomitic limestone (total relative neutralizing power: 90%) at a dose of 1 and 0.9 t ha⁻¹ for Ágata and Atlantic in Unaí, respectively, and 0.6 t ha⁻¹ for Ágata in Mucugê. After the ground was prepared with plowing, grating, and opening of the grooves, the application of fertilizers was carried out along with the treatment rates of N. The fertilizers were distributed manually to the planting furrow and were incorporated into the soil with the aid of a hoe.

Of the total N and K applied, 60% was applied during planting, and the remaining 40% was applied in coverage at 27 days after planting (DAP), at which time it was piled up.

The potato crops were irrigated by a pivot system with a sufficient water supply for the full development of the potatoes in the growing period (around 500 mm). In general, the irrigation rates in

both areas were 6 mm every 2 days until plant emergence, 10 mm every 2 days in the vegetative development phase, and 12 mm every 3 days in the stolonization and tuberization phases. Phytosanitary care was carried out when needed based on monitoring of pests, diseases, and weeds using products registered for the potato crop and at rates recommended by the manufacturers.

At 35 DAP in each cultivar and location, 20 complete sheets were collected from the third, fully-developed trifoliolate leaves of each plot (RIBEIRO; GUIMARÃES; ALVAREZ, 1999). The leaves, packed in paper bags, were taken to the laboratory for the foliar analysis of nutrients.

The leaf samples were washed and then placed to dry in an oven with a forced circulation of air (65°C ± 5°C). After drying, the leaves were ground and the foliar macronutrient concentrations (N, P, K, Ca, Mg, and S) and micronutrient concentrations (B, Cu, Fe, Mn, and Zn) were determined according to the methodology of Möller et al. (1997).

At the end of the experiments (112 and 115 DAP for Ágata and Atlantic in MG, respectively, and 106 DAP for Ágata in BA), the tubers produced in the assessed areas of the plots (disregarding 0.5 m at each end) were manually harvested, classified, and weighed on an electronic scale. From these results, the potato yields were estimated in t ha⁻¹.

The tubers were classified by diameter as: Special (> 5 cm), 1X (4–5 cm), and 2X (< 4 cm). The total commercial yield was estimated by ratings and the tuber production of all assessed tubers.

The data were submitted to an analysis of variance to determine significant differences among treatments. For the comparison of the means, the F test and a polynomial regression analysis were applied to identify differences that were significant. All statistical analyses were carried out in the SISVAR statistical program (FERREIRA, 2014).

RESULTS AND DISCUSSION

Foliar content of macro and micronutrients

The polynomial equations that were suitable for the experimental N treatment rates for the macronutrients (N, P, K, Mg, and S) and micronutrients (Cu, Mn, and B) are presented in Tables 2 and 3.

Nitrogen fertilization mostly influenced the foliar nutrient concentrations in Ágata-BA, where

only Ca and Fe were not different among the N rates. On the other hand, the application of N in Ágata-MG did not significantly affect the Zn concentration and all macronutrients except N. The concentrations found in Ágata-MG of P, K, S, and Mg were 2.9–3.2, 42.8–43.6, 1.2–1.3, 6.2–6.5 g kg⁻¹ dry mass (MS) and 30.2–35.7 mg kg⁻¹ MS for Zn. Of these, only S was below the appropriate level suggested by Lorenzi et al. (1997), whereas the others were within the range indicated for potatoes (Tables 2 and 3).

Table 2. Polynomial equations adjusted for macronutrient foliar concentrations in Atlantic and Ágata potato cultivars grown in Unai, Minas Gerais (MG) and Ágata grown in Mucugê, Bahia (BA) under different N rates. The rate of N (Xmax) required to reach a higher foliar nutrient concentration (Ymax) in the respective potato cultivar is given, and the interval for the appropriate foliar concentration for potatoes was determined according to Lorenzi et al. (1997).

Nutrient	Cultivar and location	Equation	R2	Xmax kg ha ⁻¹	Ymax g kg ⁻¹	Adequate interval
N	Atlantic MG	$y = 0.0412x + 41.964$	83.45	280.00	53.5	
	Ágata MG	$y = -0.0002x^2 + 0.0599x + 45.104$	88.88	149.75	49.59	40–50
	Ágata BA	$y = 0.0504x + 36.566$	79.32	280.00	50.68	
P	Atlantic MG	$y = -0.00005x^2 + 0.0202x + 1.5424$	84.31	202.00	3.58	
	Ágata MG	--	-	-	-	2.5–5
	Ágata BA	$y = -0.00002x^2 + 0.0057x + 3.5651$	60.58	142.50	3.97	
K	Atlantic MG	$y = -0.0002x^2 + 0.1038x + 35.573$	71.63	259.50	49.04	
	Ágata MG	--	-	-	-	40–65
	Ágata BA	$y = -0.0001x^2 + 0.0299x + 35.102$	70.70	149.50	37.34	
Mg	Atlantic MG	--	-	-	-	
	Ágata MG	--	-	-	-	3.5–5
	Ágata BA	$y = -0.000006x^2 + 0.003x + 2.9685$	49.57	250.00	3.34	
S	Atlantic MG	$y = -0.0006x + 1.4533$	38.34	280.00	1.29	
	Ágata MG	--	-	-	-	2.5–5
	Ágata BA	$y = -0.0006x + 1.2242$	55.58	280.00	1.22	

¹-- not significant according to the F test at 0.05 probability. N: nitrogen; P: phosphorus; K: potassium; Mg: magnesium; S: sulfur.

Table 3. Micronutrient levels in Atlantic and Ágata potatoes grown in Unai, Minas Gerais (MG) and Ágata grown in Mucugê, Bahia (BA) under different N rates. The dose of N (Xmax) required to reach a higher foliar nutrient concentration (Ymax) in the respective potato cultivar is given, and the interval for the appropriate foliar concentrations for potatoes was determined according to Lorenzi et al. (1997).

Nutrient	Cultivar and location	Equation	R2	Xmax kg ha ⁻¹	Ymax mg kg ⁻¹	Adequate interval Lorenzi et al. 1997
Cu	Atlantic MG	--	-	-	-	
	Ágata MG	$y = -0.0168x + 36.919$	48.81	280.0	32.2	7–20
	Ágata BA	$y = -0.0001x^2 + 0.0313x + 18.001$	99.82	156.5	20.4	
Mn	Atlantic MG	$y = -0.0007x^2 + 0.3517x + 36.757$	93.30	251.2	80.9	
	Ágata MG	$y = 0.1126x + 91.031$	91.67	280.0	122.5	30–250
	Ágata BA	$y = -0.0833x + 248$	71.41	280.0	347.2	
B	Atlantic MG	--	-	-	-	
	Ágata MG	$y = -0.0323x + 43.508$	93.17	280.0	34.4	25–50
	Ágata BA	$y = -0.0288x + 62.666$	74.91	280.0	54.5	

¹-- not significant according to the F test at 0.05 probability. Cu: copper; Mn: manganese; B: boron.

The highest response to N rates in the foliar levels of macro and micronutrients in Ágata-BA probably related to the characteristics of soil, especially the soil texture. In the soil of BA, there were greater dynamics among the nutrients because it is sandy with a larger amount of free nutrients in the soil solution and, therefore, more available to plants and also to leaching processes.

The dynamics that occur in the soil are influenced by climatic conditions; in particular, the temperature x precipitation/irrigation of the sites interferes with the soil microbial activity, which can affect nutrients by mineralization-immobilization (CHEN et al., 2013). This highlights the importance of considering these regional factors when recommending fertilizer application rates.

Calcium concentrations were not significantly affected by N doses in any cultivar or location. The concentrations ranged from 15.7–17.7, 15.5–17.2, and 12.6–13.5 g kg⁻¹ MS for Atlantic-MG, Ágata-MG, and Ágata-BA, respectively (Table 1), which were all within the appropriate range recommended by Lorenzi et al. (1997) of 10–20 g kg⁻¹ MS.

The increasing dose of N promoted a linear increase in the concentration of N in Atlantic-MG and Ágata-BA. In Ágata-MG, rates over 149 kg ha⁻¹ reduced the concentration of N. The Atlantic-MG cultivar was the least responsive to variations of the N rate in terms of foliar concentrations of nutrients, as the N rate did not affect the Mg, Fe, Cu, Zn, and B concentrations, which were 67–80, 254.2–335, 49–73, 65.7–76, and 17–21.2 mg kg⁻¹ MS, respectively (Tables 1 and 2). Only B was below the appropriate level suggested by Lorenzi et al. (1997).

The P and K concentrations at low rates of N (0 and 30 kg ha⁻¹) were below the appropriate range recommended by Lorenzi et al. (1997) in Atlantic-MG. The maximum concentrations of P and K (3.6 and 49 g kg⁻¹, respectively) were at N rates of 202 and 259.5 kg ha⁻¹ in Atlantic-MG. In Ágata-BA, the maximum concentrations of P and K (3.9 and 37.3 g kg⁻¹, respectively) were at the N rates of 142.5 and 149.5 kg ha⁻¹ (Table 1).

Increasing the N rate promoted an increased in the Cu concentration in Ágata-MG. At the maximum evaluated N rate (280 kg ha⁻¹), the estimated maximum concentration of Cu was 32.2 g kg⁻¹ MS. The Mn concentration also increased in response to the increased N rate in Ágata-MG and Ágata-BA, as did B concentrations, with maximum concentrations in Ágata-MG of 122.5 and 34.4 g kg⁻¹ for Mn and B, respectively, and in Ágata-BA of 347.2 and 54.5 g kg⁻¹ for Mn and B, respectively (Table 2).

There was quadratic adjustment for the Cu concentrations in Ágata-BA (maximum concentration of 20.4 g kg⁻¹ MS at the N rate of 156.5 kg ha⁻¹) and Mn in Atlantic-MG (maximum concentration of 80.9 g kg⁻¹ MS at the N rate of 251.2 kg ha⁻¹) (Table 2).

In Ágata-BA at all N rates, the K was below adequate concentrations, including at the maximum rate. This may have occurred because the rate of absorption of cations and anions was unequal, with the presence of the available nutrients in the solution of no guarantee of absorption and translocation (MENGEL; KIRKBY, 1987).

The S concentration was below the appropriate range in all locations and cultivars, with levels below 2 g kg⁻¹ MS. This indicated a reduced concentration of S in the soils of MG and BA, making it necessary to apply some fertilizer containing S or perform plastering, which is a way to increase the concentrations of S and low-cost Ca in the soil.

The concentrations of the micronutrients Cu, Fe, Mn, and Zn fit into the appropriate potato crop range (Lorenzi et al., 1997) (Table 2) in all the cultivars and sites evaluated. Boron was below the range in Atlantic-MG, within the range in Ágata-MG, and above the range for Ágata-BA. This may be related to differences in the dynamics, absorption efficiency, and translocation between the two cultivars in MG and between the MG and BA soil types.

In a study of the extraction and export of nutrients in different potato cultivars by Fernandes, Soratto and Silva (2011) and Soratto, Fernandes and Souza-Schlick (2011), the foliar concentrations of N, P, K, Mg, S, Cu, Fe, Mn, Zn, and B were higher than those found in this study for Ágata and Atlantic. It is worth noting that the differences between the regions of cultivation, the N rate applied, and general crop management were also responsible for the different responses of the cultivars to the absorption of nutrients between experiments.

When examining the lower limits of the levels recommended by Lorenzi et al. (1997) and the levels found in populations where there was no application of N fertilizer, it was observed that P, K, S, and B presented levels 32.8, 6.3, 36.8, and 15.1%, respectively, lower than the appropriate concentrations in Atlantic-MG, the S and Zn levels were 50.8 and 27.6%, respectively, lower than adequate in Ágata-MG, and the concentrations of N, K, Mg, and S were 6.5, 13.1, 14.2, and 50.8%, respectively, lower than adequate in Ágata-BA.

All other nutrients met the needs of the potato, in accordance with Lorenzi et al. (1997). Luz, Queiroz and Oliveira (2014) also found adequate value of N in the absence of N fertilizer application, stating that the levels contained in the soil were sufficient for the needs of the cultivar.

The levels of nutrients applied along with those contained in the soil were sufficient to ensure good yield in the absence of N application, even above the national average yield (30.5 t ha⁻¹) at 7.8, 53, and 15.6% for Atlantic-MG, Ágata-MG, and Ágata-BA, respectively.

Yield of potato tubers

The potato cultivars responded in a quadratic manner to the application of N fertilizer in the production of tubers of Special class and total

classes. The rate -estimated maximums of N in Atlantic-MG, Ágata-MG, and Ágata-BA were, respectively, 141.50, 140, and 192.14 kg ha⁻¹ for a yield of 34.27, 42.87, and 52.9 t ha⁻¹ of tubers classified as Special (Figure 1).

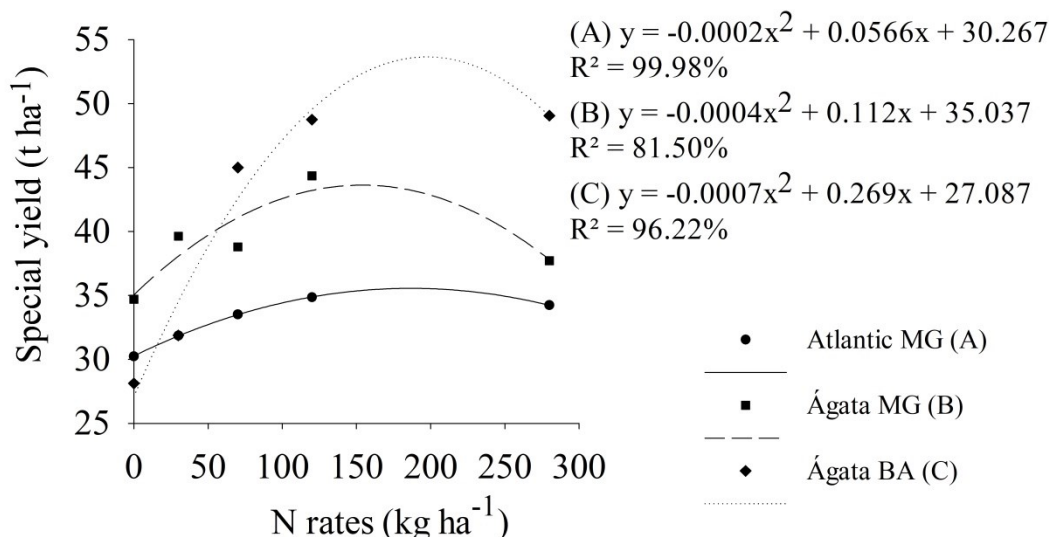


Figure 1. Yield of potato tubers in the Special Class (> 45 mm) for cultivars (A) Atlantic and (B) Ágata grown in Unai, Minas Gerais, and (C) Ágata grown in Mucugê, Bahia, under different N rates.

According to the regression equation, it was inferred that a reduction of 50% of the maximum estimated N rate would reduce the yield by 3, 4.5, and 12.1% in Atlantic-MG, Ágata-MG, and Ágata-BA cultivars, respectively. Therefore, it was observed that responses for the maximum yield of Special Class tubers of different cultivars grown in the same region were similar, whereas the same cultivar in different regions showed greater changes in yield and responses to N fertilizer application.

Ágata-BA required an N fertilization rate 27.1% higher than that of Ágata-MG; however, its yield was 18.9% higher. The climate conditions for Ágata-BA are ideal for growing potatoes; this, combined with the high technological level of the region's producers, contributed to the high yield observed in BA.

On the other hand side, a 20% reduction in the maximum N rate generated a decrease of only 0.4, 0.6, and 1.6% in the production of Special Class tubers of Atlantic-MG, Ágata-MG, and Ágata-BA, respectively. In this sense, producers should pay attention to their production conditions, consistently

analyzing the cost of production and trends in the market price of potatoes to decide how much fertilizer applications can be reduced without affecting the final estimated profit. These calculations are especially important when considering the Special Class tuber, in view of the potato size being the most desired characteristic by consumers.

As for 1X Class tubers, only Ágata-MG responded to the application of N (Figure 2B), with a minor decrease in the production of this class as the rate increased. The minimum yield of 5.77 t ha⁻¹ was observed at the maximum N rate. For Atlantic-MG and Ágata-BA tubers, the yield of 1X Class tubers varied from 2–2.8 t ha⁻¹ and 3.7–9 t ha⁻¹, respectively (Figure 2A and 2C).

For 2X Class tubers, the response to N differed between cultivars and growing regions. Atlantic-MG showed production levels between 0.3 and 0.6 t ha⁻¹. The smallest yield (4.05 t ha⁻¹) and the largest yield (1.55 t ha⁻¹) were in Ágata-MG and Ágata-BA, respectively, and occurred at the maximum rate of N (280 kg ha⁻¹) (Figure 3).

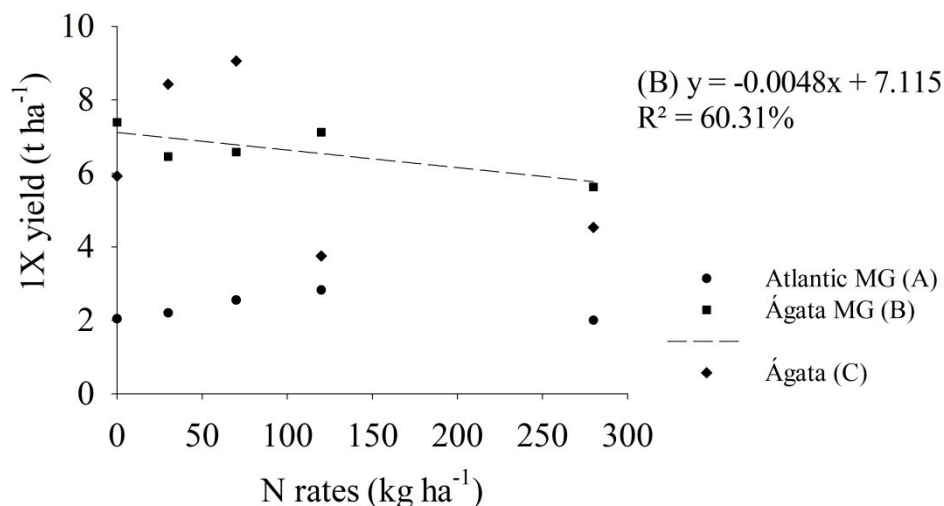


Figure 2. Yield of 1X Class potato tubers (33–45 mm diameter) for cultivars (A) Atlantic and (B) Ágata grown in Unai, Minas Gerais, and (C) Ágata grown in Mucugê, Bahia, under different N rates.

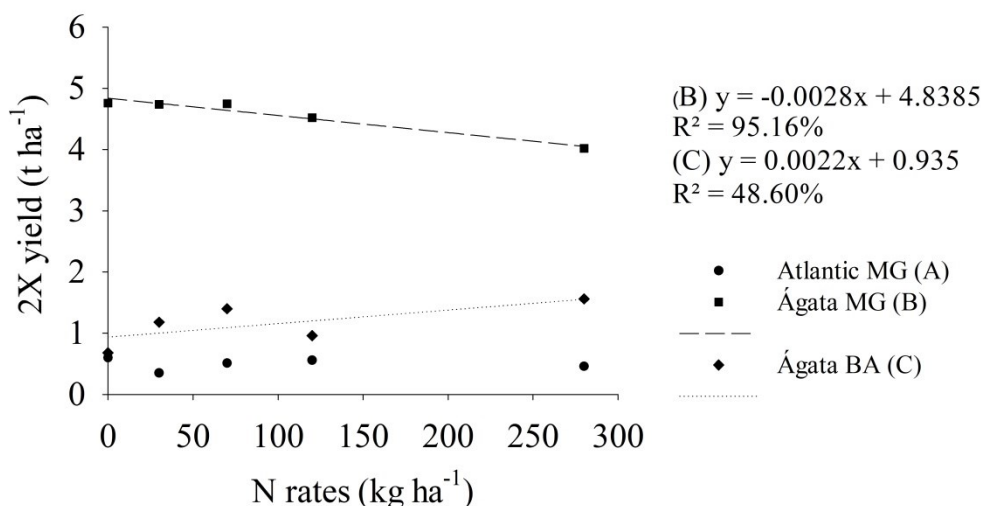


Figure 3. Yield of 2X Class potato tubers (< 33 mm diameter) for cultivars (A) Atlantic and (B) Ágata grown in Unai, Minas Gerais, and (C) Ágata grown in Mucugê, Bahia, under different N rates.

The 2X Class tubers have a low market value; therefore, growing conditions that do not favor this class should be employed by producers. Although the Ágata-BA cultivar showed greater variation in 2X Class potato yields between the extreme rates (0 and 280 kg ha⁻¹ of N), it produced half the quantity of this tuber class produced by Ágata-MG.

Bangemann, Sieling and Kage (2014) reported that N fertilization has significantly influenced the classification of potato tubers across several years and favors the formation of tubers with larger diameters; in contrast, it does not alter the production of tubers with smaller diameter.

The estimated maximum N rates for total yield in Atlantic-MG, Ágata-MG, and Ágata-BA were, respectively, 170.75, 138.37, and 194.56 kg ha⁻¹ of N to achieve total yield of 38.58, 54.45, and 65.88 t ha⁻¹ (Figure 4).

With regard to the regression equations, a 50% reduction of the maximum estimated N rate (i.e., applications of 85.4, 69.2, and 97.3 kg ha⁻¹ of N for Atlantic-MG, Ágata-MG, and Ágata-BA, respectively) reduced the total yield by 3.8, 3.5, and 11.5% for Atlantic-MG, Ágata-MG, and Ágata-BA, respectively. In the literature, 50% reduction of the N rate reduces potato production by 7.6–10.4% (QUEIROZ et al., 2013; LUZ; QUEIROZ; OLIVEIRA, 2014).

The decreased yield in the three experiments as a function of the high N rate can be attributed to the physiological role of N in photosynthesis. The N absorbed by plants can result in vigorous vegetative growth, but this does not necessarily translate into high yield (LIU et al., 2017).

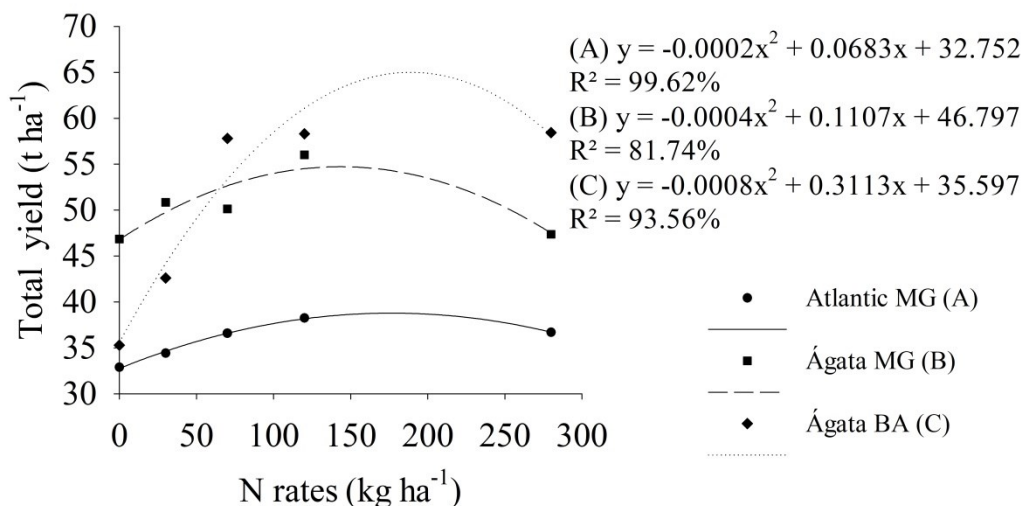


Figure 4. Total yield of potato tubers of cultivars (A) Atlantic and (B) Ágata (B) grown in Unai, Minas Gerais, and (C) Ágata grown in Mucugê, Bahia, under different N rates.

The difference between the dosages of the two areas can be justified by the characteristics of the soil, which was sandier in BA than in MG and meant that the nutrients in the BA soil were less attached to colloids, facilitating nutrient loss through leaching. This was expected because the soil analysis of the sites showed MG had higher CEC than that of BA. Thus, correctly interpreting the soil analysis can allow the producer to manage fertilization rates sensibly.

Studies proved that good fertilizer management practices have the potential to minimize future impacts and maximize resource use efficiency (HERATH et al., 2014). This is particularly true for areas with sandier soils that are more prone to leaching, such as BA.

The N level required for the maximum yield is reduced with the reduction in the irrigation rate (AHMADI et al., 2016). A moderate irrigation rate (40–50%) and moderate N (135–150 kg ha⁻¹ N) were shown to achieve yields that tripled the national average yield in the northwest of China; this demonstrates how appropriate management can result in the production of top quality potatoes and the preservation of irrigation water (YANG et al., 2017).

The mild climate of Mucugê-BA greatly favored the development of the Ágata-BA potato, with production 21% higher than that of Ágata-MG with a hotter climate. This is because higher temperatures can impact the efficiency of N use in plants. Thus, during a season when the temperature is higher, less N fertilizer should be provided (ZHOU et al., 2017).

In addition, the discrepancies between N rates and observed yield may be related to the influence of other factors such as agronomics and producer management (LUZ; QUEIROZ; OLIVEIRA, 2014). Regarding management aspects, it was shown that some potato cultivars used for processing required

about 150% more N and K than that of table potatoes (DAS et al., 2015). Similarly, we observed that the Atlantic-MG cultivar (used for processing) needed higher N inputs than that of Ágata-MG (by 23.7%) in order to achieve high yield; nonetheless, the Atlantic-MG cultivar showed lower yield.

In Brazil, the fertilization rates with N are variable and can be between 120 and 200 kg ha⁻¹ (RIBEIRO; GUIMARÃES; ALVAREZ, 1999). The results of the current experiment fell within this broad range of recommended N application, but the focus of our work was to emphasize that cultivars respond to N application with higher yields at N rates below the maximum recommendation.

In the literature, it is apparent that there are variations between the optimal N rates in potatoes grown under different management strategies, technological levels, and in different locations. It was found that the yield of the BRS Ana cultivar did not respond to N rates greater than 100 kg ha⁻¹, which suggested that the recommended rate according to the soil analysis (120 kg ha⁻¹) could be reduced by up to 17% (SILVA et al., 2014).

Silva et al. (2007) recommended rates of 163–171 kg ha⁻¹ of N, depending on whether the scenario is favorable or unfavorable to the price of the potato. Kawakami (2015) reported that 120 kg ha⁻¹ of N, with half applied at planting and half in coverage, results in high yield.

Banjare, Sharma and Verma (2014) also highlighted the importance of parceling N applications for more sustainable management. Splitting the application of N fertilizer can reduce leaching and more efficiently use space and time because plants only need a low input of nutrients at the beginning of their development (HERATH et al., 2014). This management practice is particularly essential in regions with medium to sandy soil textures, such as BA.

CONCLUSIONS

The yield of the Special Class and total potato tubers responded to N rates in all cultivars and locations. The maximum N rates for the total yield varied between 138 and 194 kg ha⁻¹ of N in regions of high and low CEC, respectively.

Nitrogen fertilization should be oriented towards the potato production context, with the soil attributes and the dynamics of the soil's constituents (texture and fertility), climatic conditions (precipitation and temperature), specificities of the cultivar (genetic control of absorption and formation of the root system), and a cost analysis (economic and environmental) considered. Focusing attention on the interactions among such factors over many years will make it possible to improve the prediction of the required N dosage by reducing the optimum amount of N applied without affecting the market value of the potato crop, which requires site-specific management strategies.

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