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Organomineral as a substitute for mineral fertilization in potato cultivation

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Abstract

Potato (*Solanum tuberosum,* L.) is one of the most responsive crops to fertilizer application, which drives the need to rationalize and make the most of nutritional resources in efficient and sustainable management. Based on the hypothesis that the organomineral is a great alternative to increase potato productivity (Ágata and Atlantic cultivars) and that it can be indicated as a substitute for mineral fertilizers, this study aims to evaluate the effect of organomineral doses applied in the planting furrow on potato productivity to identify the best level of mineral fertilizer replacement. A study was conducted in the city of Cristalina (state of Goiás, Brazil), evaluating the replacement of 40, 60, 80, and 100% of mineral fertilizer (standard) provided via organomineral fertilizer in two widely cultivated varieties. The total productivity and the productivity in classes were monitored, as well as the nutrient contents in the leaves. The results showed that the organomineral is a great alternative to increase potato productivity and can be indicated as a substitute for mineral fertilizers. For the cultivar Ágata, an organomineral dose of 80% is recommended concerning mineral fertilization. On the other hand, for the Atlantic cultivar, the same dose of mineral fertilizer is recommended. In both cultivars, there was an increase in tuber size with organomineral fertilization, which indicates greater efficiency in tuber productivity.

Keywords: Ágata; atlantic; organic matter; plant nutrition; *Solanum tuberosum* L.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops in the world, with an annual production of 380 million tons. When compared to corn, rice, and wheat starches, potato starch is the main carbohydrate used in the food industry due to its lower gelatinization temperature, higher transparency, and viscosity (Zhang et al., 2018). In addition to carbohydrates, potato tubers are rich sources of vitamins (C, B, A, K), minerals, and various macro and microelements (Nurmanov et al., 2019).

Mineral nutrition is crucial to determine the yield and quality of potatoes with a high nutrient demand, due to their short development cycle and high yield (Oliveira et al., 2021a). The final quality of the product and the nutrient content in the soil, always aiming to maximize profitability and reduce the risks of environmental contamination (Oliveira et al., 2021b). However, as this crop is very responsive to fertilization, excessive doses of mineral fertilizers applications can occur, which unnecessarily burdens production and can promote contamination of the environment via leaching (Luz et al., 2020). Studies that demonstrate the adequate source and dose of nutrients are important to ensure better use of available resources.

The use of organominerals as a source of nutrients for plants has become widespread due to the use of waste (urban and rural) that becomes a local problem when accumulated (Crusciol et al., 2020). Lopes et al. (2021) also demonstrated that composted residues and residues derived from the sugar and alcohol sector (ash and filter cake) promoted an increase in sugarcane productivity due to the increased availability of phosphorus in the soil. Pereira et al. (2020) showed that organominerals promote lower nutrient losses when compared to mineral fertilizers.

Organomineral fertilizer is defined as the product

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resulting from the physical mixture or combination of mineral fertilizers and residues, with at least: organic carbon: 8%; cation exchange capacity: 80 mmolc kg^{-1}; maximum humidity of 30%; 10% of primary macronutrients alone (nitrogen, phosphorus, and potassium) or in the mixture; 5% of secondary macronutrients (calcium, magnesium, and sulfur) and 1% of micronutrients (BRASIL, 2006).

The Brazilian production of fertilizers is insufficient to meet the Brazilian demand for these fertilizers, causing an external dependence on the fertilizer market (ANDA, 2017). The proper use of organomineral fertilizer achieves the principles of circular economy bringing harmony between the economy, environment, and society.

Based on the hypothesis that the organomineral is a great alternative to increase potato productivity (Ágata and Atlantic cultivars) and that it can be indicated as a substitute for mineral fertilizers, this study aims to evaluate the effect of organomineral doses applied in the planting furrow on potato productivity.

Material and Methods

Characterization of the study site

The experiment was installed in a commercial potato production area, located in Cristalina, Goiás, Brazil (latitude 16°46'07'' S, longitude 47°36'49'' W, and altitude of 1189 m). According to the Köppen classification, the region has an Aw climate with hot humid summers, cold and dry winters, average rainfall of 1426.3 mm, and an average temperature of 20.4 °C. The soil of the region was classified as Red Latosol in the Brazilian Classification of Soil Science (EMBRAPA, 2018).

The study was installed in an experimental design in randomized blocks with four doses of organomineral (100, 80, 60, and 40% of the recommended dose for planting the crop) and control (standard fertilization of the producer), using four replications. The organomineral was applied using a 03-35-06 formulation, referring to the amount of nitrogen, phosphorus, and potassium, respectively. The experimental plot consisted of four lines of six meters, spaced 0.30 m between plants and 0.8 m between lines, totaling 19.2 m^2 of total area per plot. In the harvest, four meters of the two central lines were used, discarding one meter on each side of these two lines for border edging.

The experiment was installed in June 2017. Soil preparation was carried out with plowing, followed by harrowing, crumbling, leveling, and subsequent opening of furrows for planting. The cultivars Ágata and Atlantic used were type 2 seed potatoes, treated with insecticide, fungicide, and nematicide, ensuring better health at planting. Previously, a soil sampling (layer 0 - 0.20; and 0.20 - 0.40 cm) was performed to monitor the availability of macro and micronutrients for fertilization recommendation (**Table 1**).

Organomineral fertilization was based on control fertilization (producer), using a dose of 2,300 kg ha^{-1} of the 3-35-06 formula to supply nitrogen, phosphorus, and potassium, respectively. The organomineral doses sought to replace 100, 80, 60, and 40% of the control, applying doses of 2300, 1840, 1380, and 920 kg ha^{-1}, respectively. A topdressing fertilization was conducted equally between treatments with the application of 350 kg ha^{-1} of the formulated 20-00-20 after 15 days after planting. Irrigation was performed by a central pivot providing, together with the rain, a total of 600 mm of water for the crop.

The phytosanitary treatments during the test period were recommended through the monitoring of pests and diseases, which, upon reaching the level of control, the products registered for the crop were applied, following the norms and instructions of the manufacturers.

Analyzed variables and statistical analysis

The tubers were harvested five months after planting with 118 days after planting. The tubers located in the central four meters of the two central lines of the plot were harvested. The tubers were classified according to their diameter and then weighed on an electronic scale. The classification adopted consisted of: Florão (> 70 mm), Special (42-70 mm), 1X (33-42 mm), 2X (28-33 mm), Diverse (up to 28 mm) and Discard (damaged tubers, non-commercial). Total productivity resulted from

Table 1. Chemical characterization of the soil used in the experiment

Layer	pH (H_2O)	P	K	S	K	Ca	Mg	Al
(cm)		mgdm^{-3}			-------------- cmolc dm^{-3}----------------------			
0-20	5.80	9.76	116.71	10.63	0.30	3.24	1.16	0.13
20-40	6.70	1.90	68.33	21.23	0.17	1.80	0.70	0.20

	B	Zn	Fe	Mn	Cu	Potential Acidity	CEC	V
			------------------ mg dm^{-3} ----------------			----cmolc dm^{-3}----		%
0-20	0.67	11.41	41.12	19.77	0.92	5.52	10.23	45.75
20-40	0.50	14.07	49.90	14.47	0.83	5.00	7.70	35.33

CEC: Cation Exchange Capacity; V: Base saturation.

the sum of all classes, except discard.

Leaves (third leaf from apical tuft) were collected 51 days after planting to monitor nutrient availability. A total of ten fully developed, competitive, disease-free, and damage-free leaves were selected per treatment. The nutrient content was monitored according to EMBRAPA (1997), classifying the results according to the critical level recommended by Martinez et al. (1999).

The critical level of the SPAD index (Soil Plant Analysis Development) in potato leaves was determined in four evaluations along the cultivar cycle in the field, using the SPAD-502 portable meter. The SPAD-502 is a device that allows obtaining a relative chlorophyll index (RCI), correlating the intensity of the green color of the leaves with the level of N in the leaf. The evaluations were carried out on the fourth leaf from the apex of ten plants chosen at random in the useful plot with two readings per plant being the readings performed on the terminal leaflet of the fourth leaf completely expanded from the apex of the plant at days 47, 61, 75 and 90 days after planting.

The quality of the dataset was monitored using a test for normality (Shapiro-Wilk test; $P < 0.05$) and homogeneity of variance (Bartlett test; $P < 0.05$). An analysis of variance (ANOVA) was used to test the hypotheses of the treatments using the F test ($P < 0.05$) and when there was a difference, the means were compared using the Tukey test ($P < 0.05$).

Results and discussion

Nutritional assessment

In the cultivar Ágata, the foliar contents of N, P, K, S, Zn, and B showed lower values than those recommended by Martinez (1999) for the potato crop. The Ca, Mg, Cu, Fe, and Mn contents were adequate or above the ideal range. In the cultivar Atlantic, the foliar contents of P, K, and S were also lower than those recommended in the literature, while N revealed high values for organomineral sources with doses of 80% and 60% (**Table 2**). Contents of Ca, Mg, Cu, Fe, Mn, and Zn showed values within or above the range considered ideal in all evaluated fertilizations (Martinez, 1999).

In addition, it was observed that, in both cultivars, there was an accumulation of absorbed Ca and Mg to the detriment of K, this is probably due to the correction used over the years of soil amendments to neutralize the acidity of Brazilian tropical soils, which increase the exchangeable bases Ca and Mg in the soil. K counterbalance is a fundamental factor to guarantee high production ceilings, especially because K is essential for plant water balance, plant growth, and synthesis processes (Amtmann & Rubio, 2012).

The S presented levels below the recommended and this has been recurring in Brazilian crops, where the replacement of supersimple by supertriple reduced the supply of S, which may generate future limitations of this nutrient. It is worth noting that organic matter from organominerals over the years determines the dynamics of exchangeable bases, which can alter the responses of cultures and promote a differential between the balances of nutrients available to plants. Thus, nutrition monitoring with the help of foliar analysis helps in decision making and consequently better rational use of resources.

According to the dynamics of mineralization of nutrients contained in soil organic matter, Pawlett et al. (2015) observed changes in nutrient availability and suggested that organominerals replenish the supply of nutrients used by plants and maintain nutrient levels in the soil. The excess of Fe found in leaf tissues is related to the soil mineralogy of the cultivated region, which is rich in iron and aluminum oxides and hydroxides. The excess of Cu is probably related to the frequent use of protective fungicides, which contain the Cu element in their composition.

SPAD Index

Ágata at 47 DAP, at doses of 80 and 40% (OM) presented an index lower than 100% (OM), and in the other fertilizations, the values were intermediate. In the last evaluation (90 DAP) of Atlantic, 100% (OM) presented an index 10% higher than 100% (M) (**Table 3**).

In the evaluations at 61 and 75 DAP, there was no statistical difference between the fertilizations. The concentration of chlorophyll in the leaves was reduced along with the evaluations, in the two cultivars analyzed. This fact corroborates with what was found by Cardoso (2011) and can be explained according to the metabolic changes that occurred in the potato cycle, with a change in the drain, from the leaves to the tubers, consequently, a good part of the nutrients is also diverted and accumulated in them.

Productivity

In the cultivar Ágata, the doses of 100% organomineral and mineral and 80% organomineral showed the highest yields with respective averages of 37.8, 39.5, and 38 Mg h^{-1} (**Figure 1**). Positive effects of organomineral use on soybean, potato, and bean yields are also mentioned in the literature by Machado et al. 2018, Cardoso, et al. (2015), and Kominko et al., (2017). Among the classifications, the highest productivity in the Special class was also obtained with nutrient

Table 2. Nutrient content in potato plants (Ágata and Atlantic cultivars) with the application of organomineral (100: 100/OM, 80, 60, and 40% of the recommended dose for planting the crop) and a control (100/M), at 51 days after planting

Organomineral doses(%)	Macronutrient contents in the leaf (g kg^{-1})						Micronutrient contents in the leaf (mg g^{-1})				
	N	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn	B
Ideal range*	45-60	2,9-5	93-115	2,5-5,0	7,6-10	1-1,2	7-20	50-100	30-250	45-250	25-50
					Ágata						
100/M	35.0	1.8	37.0	1.4	20.0	3.8	41	491	112	21	23
100/OM	37.8	2.0	42.5	1.4	28.0	4.7	40	493	111	25	22
80	37.8	2.2	42.5	2.2	29.0	5.3	30	438	136	26	20
60	37.1	2.3	37.0	2.2	29.0	5.1	34	472	90	23	22
40	41.3	2.2	40.0	4.3	24.0	5.2	25	197	100	24	22
					Atlantic						
100/M	42.0	0.8	47.0	1.4	21.0	4.0	109	486	185	73	31
100/OM	39.2	2.0	43.5	1.5	27.0	3.6	263	1008	239	129	28
80	51.8	2.7	51.0	1.8	28.0	4.8	268	529	223	107	29
60	51.1	1.1	48.0	1.8	23.0	2.9	275	106	206	101	35
40	39.9	1.9	47.0	1.7	27.0	3.0	302	112	236	87	34

*Recommend by Martinez et al. (1999).

Table 3. SPAD index in the fourth potato leaf (Ágata and Atlantic) with the application of organomineral (100: 100/OM, 80, 60, and 40% of the recommended dose for planting the crop) and a control (100/M)

Organomineral doses (%)	SPAD Index (Days after planting)			
	47	61	**75**	**90**
		Ágata		
100/M	52.771 ab*	49.532 a	50.000 a	47.803 a
100/OM	58.212 a	51.216 a	51.750 a	51.726 a
80	51.905 b	50.128 a	50.750 a	47.821 a
60	55.233 ab	50.282 a	49.750 a	48.443 a
40	52.215 b	49.848 a	49.500 a	46.945 a
		ANAVA		
Media	54.067	50.201	50.35	48.548
CV (%)	4.61	2.71	3.36	5.37
DMS	5.616	3.066	3.811	7.355
		Atlantic		
100/M	61.4 a	49.8 a	47.3 a	42.5 b
100/OM	55.9 a	52.2 a	49.0 a	46.8 a
80	55.3 a	51.6 a	48.9 a	46.3 ab
60	54.8 a	51.6 a	48.6 a	43.1 ab
40	54.1 a	51.2 a	47.5 a	43.3 ab
		ANAVA		
Media	56.3	51.321	48.3	44.463
CV (%)	9.25	2.8	5.37	3.1
DMS	11.752	3.241	5.853	3.89

*Means followed by the same letter do not differ from each other in the columns by Tukey's test ($p<0.05$); CV (%): coefficient of variation.

supplementation via fertilization with 100% Mineral and organomineral and 80% organomineral with production between 29.2 and 30.6 Mg ha^{-1} (Figure 1).

The diverse and total yields of tubers of the Florão class followed the same response as the Especial class. These results indicated that the application of the organomineral increased the amount of potato with a production of tubers with greater diameter. The 2X class did not differ between the fertilizations, while in the Diverse class, the replacement of 40% organomineral showed higher productivity (Figure 1). In this sense, if the option is made to use the organomineral for the Ágata cultivar, there is the possibility of reducing the dose to 80% of the organomineral.

Total productivity did not vary between organomineral doses for the Atlantic cultivar, with an average ranging from 43.7 to 50.7 Mg ha^{-1} (**Figure 2**). Among the Especial and 2X classes, it presented an average between 39.2 to 42.4 and 0.2 to 0.4 Mg ha^{-1}, respectively (Figure 2). For the Florão class, the productivity when the plants received the 100% OM fertilizer was 118% higher than the application via 100% M. This same relationship was also observed in relation to the productivity of the Diverse class.

The productivity of the class with the best economic value (Special) was similar between 100% OM and 100% M, respectively: 42.3 and 42.4 t ha^{-1}. Thus, it is observed that in terms of the amount of nutrients supplied, the potato response to the Atlantic cultivar was similar at the same dose (Figure 2). Codling (2014) reported that in

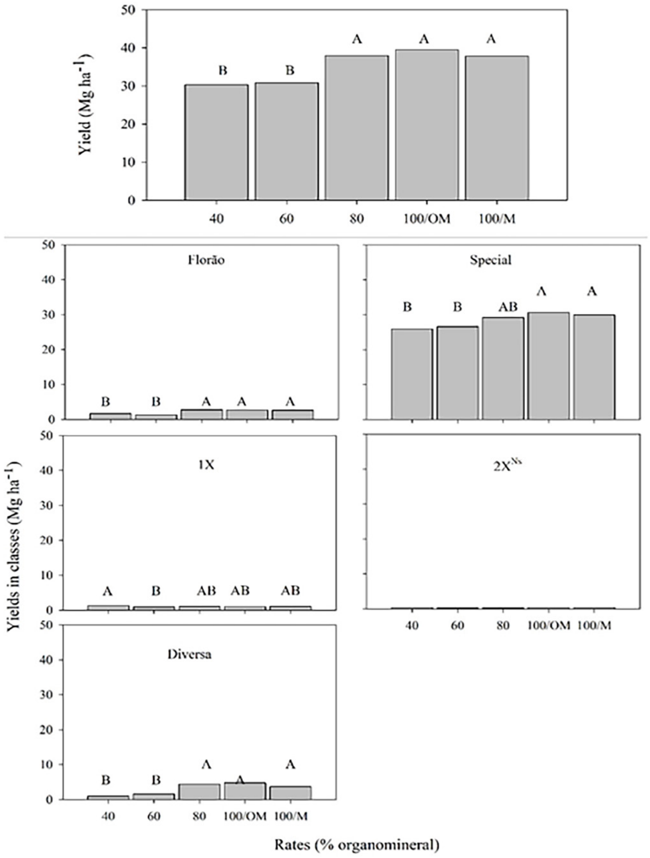

Figure 1. Productivity of potato tubers (Ágata cultivar) in Florão, Especial, 1X, 2X, Diverse and Total (Mg ha^{-1}) classes with organomineral application (100/OM, 80, 60, and 40% of the recommended dose for planting the crop) and a control (100/M). Means followed by the same letter do not differ in the columns by Tukey's test (p<0.05); CV (%): coefficient of variation.

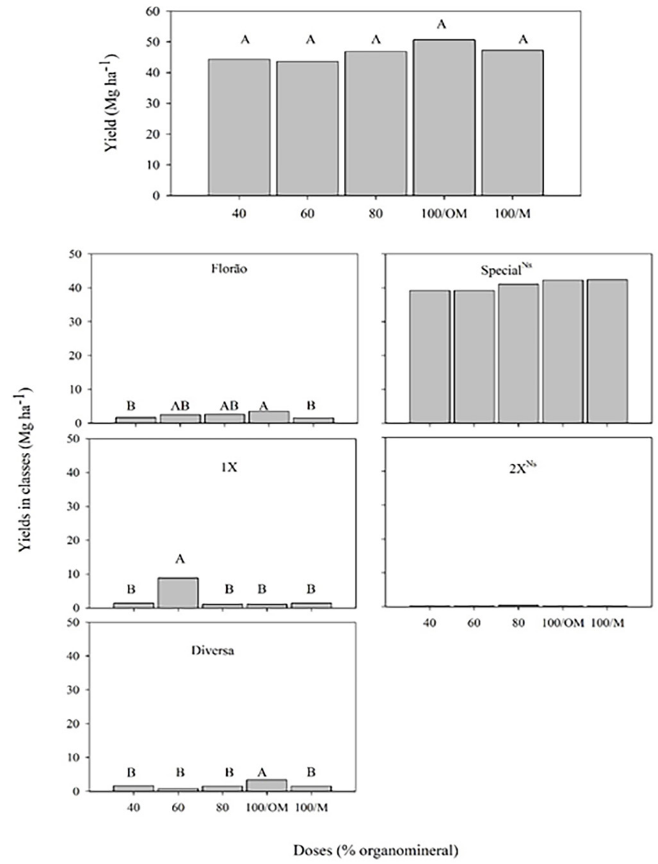

Figure 2. Productivity of potato tubers (Atlantic cultivar) in Florão, Especial, 1X, 2X, Diverse and Total (Mg ha-1) classes with organomineral application (100/OM, 80, 60, and 40% of the recommended dose for planting the crop) and a control (100/M). Means followed by the same letter do not differ in the columns by Tukey's test (p<0.05); CV (%): coefficient of variation.

a pot experiment to establish the use of soils that received biosolids for 16 to 24 years, it showed elevated levels of P, which determines a large residual effect that could be used as a nutritive resource.

Studies have shown that good fertilizer management practices are the potential to minimize future impacts and maximize resource use efficiency (Singh et al., 2015). The alteration of soil microbial biomass in plots where organominerals were used has also been discovered as a differential in the use of fertilizers with organic segments. This is due to the increase in the supply of substrates for microorganisms, and the magnitude of the change in the community varies with the season (Pawlett et al., 2015).

Fertilization with 100 and 80% OM showed the highest amount of Discard class tubers in both cultivars. Regarding the percentage of tubers of the Special class, the fertilizations with 60 and 40% OM provided the highest percentages. In Atlantic, 100% OM presented 6% fewer tubers of the Special class than 100% M, however, in the other OM dosages, these did not differ from 100% M (**Table 4**).

El-Sayed et al. (2015) also observed that the addition of organic compounds in potatoes is a favorable alternative to conventional production, without a significant reduction in yield. The authors also highlighted a better storage capacity of the tubers, which greatly favors the quality of the tubers.

Organic components of OM, such as humic substances (HSs) have, in addition to positive effects on soil attributes, a direct effect on plant physiology and growth, especially to stimulate root growth (Prado et al., 2016). Such conditions reflect high productivity, as observed in the present work. Hartz & Bottoms (2010) highlighted in their studies that the stage of development and the environment of the cultivated species interfere with the effect of the organic fractions of the OM, being the best results observed when the soils have a low content of organic matter and in plants under conditions of stress, whether nutritional or climatic.

Despite having been cultivated in the same soil and climate conditions (planting time), there was a different response between Ágata and Atlantic, which can be attributed to the marked physiological changes

Table 4. Productivity of potato tubers (Ágata and Atlantic) in the Discard classes and percentage of tubers in the Special class with the application of organomineral (100: 100/OM, 80, 60, and 40% of the recommended dose for planting the crop) and a control (100 / M)

Organomineral doses (%)	Discard	%Especial	Discard	%Especial
	--- Ágata ---		---Atlantic---	
100/M	0.8 b	77.4 c	0.4 bc	89.6 a
100/OM	1.7 a	79.2 bc	1.3 a	83.3 b
80%	1.3 ab	76.9 c	0.9 ab	87.7 a
60%	0.8 b	86.6 a	0.5 bc	89.7 a
40%	0.6 b	85.3 a	0.2 c	88.5 a
		ANAVA		
Media	1.1	81.1	0.6	87.7
CV (%)	27.2	3.7	42.6	1.9
DMS	0.6	6.8	0.6	3.9

Means followed by the same letter do not differ in the columns by Tukey's test ($p<0.05$); CV (%): coefficient of variation.

between the cultivars, with different capacity for dry mass accumulation, consequently, there was a difference in the uptake, use, and efficiency of nutrients obtained between the supply at different doses of OM.

Conclusion

The organomineral is a great alternative to increase potato productivity and can be indicated as a substitute for mineral fertilizers, under the conditions of Cristalina, Goiás. For the cultivar Ágata, an organomineral dose of 80% is recommended in relation to mineral fertilization. However, for the Atlantic cultivar, the same dose of mineral fertilization is recommended. In both cultivars, there was an increase in tuber size with the organomineral, indicating greater efficiency in tuber productivity.

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