Use of Organomineral at Fertilization of Beans in the Midwest Region of Brazil

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Abstract

This study aimed to evaluate the nutrition and yield of common bean according to the application of different doses of organomineral formulations (OMF), using filter cake as a basic organic compound in the presence and absence of nitrogen. The experiments was implemented and conducted in June "autumn/winter season" and November "rainy season" of the 2018 e 2018/2019 harvest, respectively. A randomized block design was used in a 6 x 2 factorial scheme, with four replications. The treatments were composed of six organomineral formulation doses: (0, 30, 60, 90, 120, and 150 kg ha^{-1}), with and without the addition of a nitrogen dose of 40 kg ha^{-1}, using urea as the mineral source. It was concluded that the organomineral fertilizer based on filter cake showed greater absorption of macronutrients N and K, an increase in the 100-grain weight, number of grains per pod, number of pods per plant, and grain yield in comparison with the absence of fertilization or mineral fertilizers, highlighting the doses of 90 and 150 kg ha^{-1}. The use of OMFs is a viable alternative with great potential for soil fertilization in agricultural production, besides the environmental sustainability generated by their inclusion in the production cycle of common bean.

1 Introduction

The common bean (*P. vulgaris* L.) is a legume of great importance for human consumption, considered the main source of vegetable protein, rich in iron, calcium, vitamins, carbohydrates, and fibers (Celmeli et al. 2018). The importance of its cultivation goes beyond the economic aspect due to its relevance as a cultural and food component being also considered as one of the of the world's poorest population diet pillars (Broughton et al. 2003), especially for Latin America, Caribbean and the African.

Due to the short cycle and shallow root system, beans stand out as a nutritionally demanding plant (Silva et al 2014; Nassary et al. 2020), among which nitrogen, potassium, calcium, magnesium, sulfur, and phosphorus represent the nutrients most required by the plant throughout its reproductive cycle (Soratto et al. 2013). The bean crop is very susceptible to the deficit nutritional at different development stages, especially between the beginning of flowering and grain filling (Ntukamazina et al. 2017).

Organic matter, when supplied together with mineral fertilizer, forms the OMFs, acting as a soil conditioner, retaining nutrients more efficiently, reducing losses by leaching or volatilization, in addition to improving the physical, chemical, and biological structure, providing greater efficiency in the plants' capacity to assimilate nutrients since they will be made available more gradually (Mahmood et al. 2017; Ukalska-Jaruga et al. 2020). This way, the supply for the plant's needs can be ensured throughout the cycle, improving the cation exchange capacity when compared to clay minerals, and presenting a chelating effect on nutrients (Mehrizi et al. 2015; Guimarães et al. 2016).

Growing beans has a strong dependence on mineral chemical fertilizers over the years in worldwide. Despite this reliance, the country underutilizes tons of nutrients in the form of organic waste from different sources (Kominko et al. 2017). The filter cake appears as an important alternative source for elaborating the OMFs, mainly due to this material action on the soil fertility maintenance (Prado et al. 2013; Mota et al. 2018). These products are also capable of increasing the availability of nitrogen, phosphorus, and calcium, increasing the cation exchange capacity (CEC), for reducing the contents of exchangeable Al in the soil (Corrêa et al. 2016, 2018; Soltangheis et al. 2019; Mumbach et al. 2020). As for the improvement of physical aspects, OMFs promote a reduction in soil density, providing an increase in the total soil porosity, thus increasing microbiological activity, diversifying the soil flora and microflora (Zhao et al. 2009; Watteau et al. 2012; Rauber et al. 2018).

The final disposal of filter cake in soils for cultivation is an alternative that allows for more sustainable agriculture since the management of these residues represents a high cost for the factories (Silva et al. 2020; Crusciol et al. 2020). Their use in agricultural practices can contribute to the economic and environmental efficiency of this process. In addition to providing an accessible fertilizer to producers, it promotes the reintegration of waste into the production cycle (Bueno et al. 2011). Besides the previously mentioned OMFs' advantages, Morales et al. (2016) and Moraes et al. (2018), still report benefits such as better root development of crops and water retention in the soil, the low propensity of the soil to erosion, less acidification, reduced use of limestone, recovery of microbial flora and lower operating cost with the joint application of organic product in relation to mineral fertilization. In addition, Gurgel et al. (2015), Silva et al. (2019) and Frazão et al. (2019) suggest that the use of OMFs can replace, partially or totally, the use of mineral fertilizer.

Given the bean crop's social and economic potential, studies that cover the knowledge of the productive processes are important to leverage their production. In this sense, the application of techniques to increase grain yield is essential, and the use of filter cake in the preparation of the organomineral formulations "OMFs" is characterized as a viable, inexpensive alternative with great potential for soil fertilization in agricultural production, besides the environmental sustainability generated by their inclusion in the production cycle (Kominko et al. 2017; Mota et al. 2018).

This study aimed to evaluate the development, nutrition, and grain yield of beans according to the application of different doses of organomineral formulations (OMF) using filter cake as a basic organic compound in the presence and absence of nitrogen.

2 Material And Methods

2.1 Description of the study area

The experiments were carried out in the "autumn/winter season" and "rainy season=waters" harvests of the agricultural years of 2018 and 2018/2019 (see Fig. 1), respectively, using the cultivar BRSMG Realce. They were deployed in the experimental area of the Goiás Agency for Technical Assistance, Rural Extension, and Agricultural Research – EMATER of Anápolis, GO, Brazil, whose geographical coordinates are: latitude 16°20'44.27" South, longitude 48°52'44.67" West. The maximum and minimum temperatures varied little over the crop cycle and were close to 38.5 and 13.8 ºC in the autumn/winter season, and 36.7 and 19.2 ºC in the rainy season.

The soil in the experimental area is classified as RED YELLOW LATOSOL distrofico (Distrofic Latosols). Soil samples were taken at a depth of 0 to 20 cm, and chemical-physical analyzes were performed, according to the Silva (2009), in season of autumn/winter: pH ($CaCl_2$): 5.1; Ca: 2.3 $cmol_c$ dm^{-3}; Mg: 0.7 $cmol_c$ dm^{-3}; Ca + Mg: 4.2 $cmol_c$ dm^{-3}; Al: 0.0 $cmol_c$ dm^{-3}; H + Al: 3.0 $cmol_c$ dm^{-3}; S: 7.9 mg dm^{-3}; P (Mehlich I): 7.4 mg dm^{-3}; K: 43 mg dm^{-3}; B: 0.3 mg dm^{-3}; Cu: 4.4 mg dm^{-3}; Fe: 111.8 mg dm^{-3}; Mn: 10.4 mg dm^{-3}; Zn: 4.0 mg dm^{-3}; Base saturation (V%): 51; Organic matter: 21 g dm^{-3}; Sand: 420 g kg^{-1}; Silt: 110 g kg^{-1}; Clay: 470 g kg^{-1}. In season of rainy=waters the results were: pH ($CaCl_2$): 4.8; Ca: 2.6 $cmol_c$ dm^{-3}; Mg: 0.9 $cmol_c$ dm^{-3}; Ca + Mg: 4.2 $cmol_c$ dm^{-3}; Al: 0.1 $cmol_c$ dm^{-3}; H + Al: 2.2 $cmol_c$ dm^{-3}; S: 7.9 mg dm^{-3}; P (Mehlich I): 17.5 mg dm^{-3}; K: 104.2 mg dm^{-3}; B: 0.1 mg dm^{-3}; Cu: 2.6 mg dm^{-3}; Fe: 20.5 mg dm^{-3}; Mn: 15.7 mg dm^{-3}; Zn: 8.6 mg dm^{-3}; Base saturation (V%): 63; Organic matter: 22 g dm^{-3}; Sand: 490 g kg^{-1}; Silt: 100 g kg^{-1}; Clay: 410 g kg^{-1}.

2.2 Origin and characterization of the organomineral

The organomineral formulation used in this experiment came from the Geiciclo Biotecnologia S/A company. It was transported to the study area in bags with a capacity of 50 kg. The chemical composition of the organomineral formulation was 4-16-16 (NPK).

2.3 Experimental design and treatments

The experiments were conducted in a randomized block design in a 6x2 factorial scheme, with four replications. Six doses of organomineral formulation: (0, 30, 60, 90, 120, and 150 kg ha^{-1}), with and without the addition of nitrogen at a dose of 40 kg ha^{-1}, based on crop requirements, were evaluated. Urea was used as a mineral source of nitrogen.

2.4 Experimental unit and crop treatments

The experimental area consisted of plots formed by eight rows 5 m long, spaced 0.5 m. In each experimental plot, the six central rows were taken as useful area, disregarding 0.5 m at the beginning and the end of the row. The three central rows were also used to evaluate agronomic traits; the other rows were used for destructive and development analysis. The population in each experimental plot was 15 plants per meter. Crop treatments were those commonly applied to bean crops, including weed control (Fusiflex), pests (Actara), and diseases (Cercobin).

2.5 Analyzes performed

At full bloom, the contents of macros and micronutrients in the leaves of beans were determined. For this, six random plants were collected in each experimental plot, and the samples were initially washed in distilled water. The material was first air-dried on a clean, shaded surface. Subsequently, packaged in labeled paper bags and placed to dry in an air-forced circulation oven at a temperature of ±70ºC for 48 hours. After ward, the grinding was carried out and passed through 2mm sieves. The analyzes of the leaf contents of N, P, K, Ca, Mg, S, Cu, Fe, Mn e Zn were carried out according to the methodology of Silva (2009).

At harvest time, the components, number of pods per plant, number of grains per pod, and 100-grain weight were determined based on data from 10 plants collected in each experimental unit's central useful area. The grain yield was estimated based on all plants collected in the useful area of the plot. The grains were weighed on a precision scale of 0.01g, the result extrapolated to kg ha^{-1}, with corrected water content to 13%.

2.6 Statistical analysis

The data regarding plant nutrition were subjected to descriptive analysis. Component and grain yield data were subjected to the analysis of variance. When significant, average values were compared using the Tukey test, and equations were adjusted by the regression analysis, both at 5% probability. When pertinent, their joint analysis was carried out. For the statistical analysis, the SISVAR 5.6 software was used (Ferreira 2011).

3 Results

3.1 Nutritional analysis

The average maximum contents of macronutrients in bean cv. BRS Realce (g kg^{-1}) in the autumn/winter season were: N = 54.1; P = 1.7; K = 36.2; Ca = 4.0; Mg = 2.1 and S = 1.6 (treatments without adding the urea as nitrogen source). The corresponding values found for treatments with addition of the urea as nitrogen source were N = 55.5; P = 1.8; K = 34.7; Ca = 4.3; Mg = 2.0 and S = 2.1 (Table 1). Some maximum average leaf contents of macronutrients in bean leaves (g kg^{-1}) in the rainy season were lower, N = 49.3; P = 2; K = 29.5; Ca = 4.9; Mg = 1.9 and S = 1.4 (treatments without urea as nitrogen source), and N = 50.3; P = 2; K = 31.6; Ca = 4.4; Mg = 2.2 and S = 1.2 (treatments with the urea as nitrogen source) (Table 2). The excessive rain season may have been one of the phenomena that contributed to reducing some macronutrient contents in the rainy season harvest, in which crops are more susceptible to leaching and erosion processes. This fact also explains the lower grain yield in this period.

According to Martinez et al. (1999), the adequate macronutrient contents found in bean leaves in full bloom are (g kg^{-1}) of: N = 30-35; P = 4-7; K = 27-35; Ca = 25-35; Mg = 3-6; S = 1.5-2. Thus, in general, it can be said that the leaf contents of macronutrients in bean cv. BRS Realce grown in two harvests and submitted to organomineral and organic fertilization presented values close to those considered adequate for the good development of bean.

The maximum levels of leaf N were obtained in the treatments, 90 kg ha^{-1} in the autumn/winter season and 90 kg ha^{-1} + 40 kg ha^{-1} in the rainy, 58.9 and 55.2, respectively, showing that the addition of urea did not promote an increase in the leaf N content together with the applied organomineral, in both seasons. For Raij (2011), the optimum range of N in leaves for beans is 30 to 50 g kg^{-1}, so all treatments submitted or not to the urea addition had N content within or close to this range in both seasons. In this context, the nitrogen levels in all treatments were higher than the reference. This result can be attributed to organic matter from the organomineral formulation, which favors soil bacteria, improving its nodulation, allowing greater supply and higher nitrogen absorption by the crop. According to Corrêa et al (2016, 2018) and Soltangheis et al. (2019), organic matter provides greater nutrient availability for plants.

The average maximum contents found for leaf P were obtained in treatments with 30 kg ha^{-1}, 90 kg ha^{-1}, and 90 kg ha^{-1} + 40 kg ha^{-1} in the rainy season, 2 g kg^{-1}. Mumbach et al. (2020), in the evaluation of P levels in the bean shoot, they obtained higher levels of P, with values of 2.0 and 2.5 g kg^{-1}, in the shoot of cultivated plants in the soil with the addition of OMF 100 (60% poultry litter, 40% monoammonium phosphate fertilizer and 100% NPK) and CA 100 (100% poultry litter and 100% NPK), respectively, compared to a mineral fertilizer 100% that was 3.4 g kg^{-1}, values close to those found in these experiments. These findings agree with Chien (2014), who considers the gradual release of this nutrient to plants over time when using organic phosphates. Also, phosphorus tends to be more available to the plant, reducing the fixation by aluminum and iron oxides (Rheinheimer et al. 2008).

The average maximum values for leaf K contents were obtained in the treatments with 90 kg ha^{-1} and 150 kg ha^{-1} + 40 kg ha^{-1} in the autumn/winter season and 120 kg ha^{-1} and 120 kg ha^{-1} + 40 kg ha^{-1} in the rainy season, 36.2, 34.7, 29.5 and 31.6, respectively, showing that the plants were nourished with K in both experiments, even showing a reduction from one experiment to the other. The accumulation of K may have been influenced by the addition of organic matter and its reduction in the water harvest due to the period's climatic conditions. These results are close to those found by Mumbach et al. (2020) in the evaluation of the agronomic efficiency of organomineral fertilizer based on poultry litter and monoammonium phosphate in corn crop, which found K contents of 25.4 g kg^{-1} in plants grown with the addition of OMF 100 (60% poultry litter, 40% monoammonium phosphate fertilizer and 100% NPK).

Doses of 30 kg ha^{-1} and 120 kg ha^{-1} + 40 kg ha^{-1} (autumn/winter harvest) provided the highest averages of Ca content among treatments with the organomineral formulation, 4.7 and 4.4 g kg^{-1}, respectively. Similar results were observed in the second harvest (waters harvest), where, in the treatments with 30 kg ha^{-1} + 40 kg ha^{-1}, 60 kg ha^{-1} + 40 kg ha^{-1}, 90 kg ha^{-1} + 40 kg ha^{-1}, 120 kg ha^{-1}, and 150 kg ha^{-1}, Ca contents between 4.4 and 4.9 g kg^{-1} were found. The same was observed by Gurgel et al. (2015), with 4.4 g kg^{-1} of Ca content, in treatments with BIOFOM formulated with sugarcane molasses vinasse (30%) + 50% of the mineral fertilizer dose (0.432 urea and 0.780 KCl).

At first, Mg demonstrated a behavior similar to Ca in leaf content, between autumn/winter season and rainy season, 2.1 g kg^{-1} for treatments with 30 kg ha^{-1} + 40 kg ha^{-1}, 90 kg ha^{-1}, 120 kg ha^{-1} + 40 kg ha^{-1}, 150 kg ha^{-1} + 40 kg ha^{-1}, and 2.2 g kg^{-1} for the treatment with 90 kg ha^{-1} + 40 kg ha^{-1}. For Epstein and Bloom (2005), this situation is expected; due to the increased availability of Ca, the plants` absorption of Mg decreases. Oliveira and Parra (2003) reported that the highest corn yields, grown in pots, were obtained with the Ca:Mg ratio of 3:1. In the Ca and Mg concentrations in the dry matter of bean shoot, obtained during flowering, an inversely proportional relationship was observed, reflecting the soil analysis results (Tables 1 and 2).

Doses of 90 kg ha^{-1} and 150 kg ha^{-1} + 40 kg ha^{-1} showed the highest averages of S, 2.1 and 1.8 g kg^{-1} (autumn/winter season), differently from the rainy season with average maximum values of 1.4 g kg^{-1} in treatments with 30 kg ha^{-1}, 90 kg ha^{-1} and 150 kg ha^{-1}, respectively. Despite being significantly lower than the value obtained by these authors, according to Martinez et al. (1999), the contents express that the plants in the full flowering were sufficiently supplied in sulfur, where they must contain between 1.5 to 2 g kg^{-1} of the macronutrient in the leaf dry matter.

Based on the reference information, it can be seen that, in general, the average nutrient leaf levels in beans except for Ca and Mg, which were lower than the reference data, are within or close to the limits considered adequate for good growth and development of the crop. Despite the lower contents of Ca and Mg presented above, visual symptoms for deficiency of these mentioned macronutrients are not evident. The values of the average contents of the micronutrients Cu, Fe, Mn, and Zn in the leaves of bean cv. BRS Realce remained practically similar, with small fluctuations not relevant regarding the increasing doses of the organomineral formulation.

According to Martinez et al. (1999), the adequate contents of nutrients found in bean leaves in full bloom for micronutrients (mg kg^{-1}) are: Cu = 8-10, Fe = 300-500, Mn = 200-300 and Zn = 45-55. Thus, observing the averages for both the autumn/winter season and rainy season, it appears that, according to the critical ranges proposed by the referred authors, only Zn presents itself with adequate levels, the levels of Cu and Fe are high, and Mn is deficient (Tables 3 and 4). However, in the present situation, no deficiency symptoms of these nutrients were observed in the bean plants.

Fe is essential for energy metabolism, acts on nitrogen fixation, and the stem and roots development. The Fe content in bean leaves, considered adequate for good development, ranges from 300 to 500 mg kg^{-1}; however, in the present study, the average levels were from 1506.2 to 1861.9 mg kg^{-1}. Although considered high, these Fe contents corroborate results presented by Silva et al. (2007) in tests evaluating root growth and micronutrient absorption by bean plants due to liming; they observed average Fe content for the cultivar Carioca of 1416.0 mg kg^{-1}.

Although some results differ from normal, the availability of micronutrients for plants can be influenced by the soil traits, such as texture and mineralogy, organic matter content, moisture, pH, oxy-reduction conditions, and interaction between nutrients (Marschner 2012). Specifically, Cu plays an important role in photosynthesis, respiration, reduction, and nitrogen fixation inside the nodules in the roots of legumes. According to Fageria et al. (2002), plants absorb Cu in the form of Cu^{+2}, and high P, Zn, and Mo concentrations decrease this nutrient absorption. The average values referring to the Cu content in the leaves of the cultivar BRS Realce was between 15.8 and 25 mg kg^{-1}. The high levels of Cu verified can be attributed to the fact that the nitrogen supplied increased the Cu content since N, especially the mineral, contributes to the increase in the soil's acidity, thus providing a greater quantity of Cu for the plants.

Fe in high concentrations can interfere in the absorption of mineral elements, such as Mn, through competition for transport systems; however, there was no symptom of Fe toxicity or deficiency, as well as its interaction with other nutrients in beans. On the other hand, Mn acts to synthesize chlorophyll and participate in energy metabolism, being absorbed by vegetables in the cationic form of Mn^{2+} (Marschner 2012). High concentrations of Cu, Zn, K, and Fe in the medium cause a decrease in Mn's absorption, a phenomenon called antagonism (Epstein and Bloom 2005). The adequate manganese content in bean leaves ranges from 200 to 300 mg kg^{-1} (Martinez et al. 1999). In the current study, average contents found for this micronutrient ranged from 45.9 to 113.9 mg kg^{-1} in the autumn/winter season and rainy season, respectively. In both cases, the average values were lower than the reference mentioned above.

Plants absorb Zn as Zn^{2+}; its absorption is reduced by the excess of Cu and Fe and acts as an enzyme activator (Marschner 2012). The Zn content in the leaf, considered adequate for the good development of beans, is in the range of 45 to 55 mg kg^{-1}. In this experiment, the Zn contents found were between 41.4 and 74.6 mg kg^{-1}, considered within the normal range. In a study by Silva et al. (2007), leaf samples of cultivar Peróla according to limestone doses, the authors verified a Zn value of 76.1 mg kg^{-1}, therefore close to the average of the nutrient verified in this study.

The high contents of micronutrients can be explained because, under conditions of high availability in the soil, where plants absorb quantities above their metabolic needs, the accumulation of nutrients in plant cell organelles such as chloroplasts, mitochondria and, especially vacuoles take place (Gommers et al. 2005). Thus, understanding the dynamics of micronutrients in different soil types and the requirements for crops, the doses definition, sources, and strategies for micronutrient supply appropriate to local conditions, are crucial steps towards higher grain yield of crops and more efficient use of inputs.

3.2 Agronomic analysis

The number of pods per plant increased linearly according to the increase in doses of the organomineral formulation. The maximum number of pods per plant was obtained with 150 kg ha^{-1}, followed by doses of 120 and 90 kg ha^{-1} of OMF, with an average of 10.1, 9.4, and 9.3 pods per plant (Fig. 2). It was also found that the control treatment of the 0.0 kg ha^{-1} of the organomineral produced 50% fewer pods, an average of 5.0 pods per plant. In agreement with the result of this experiment, Silva et al. (2019), when testing the efficiency of organomineral filter cake in the grain yield of bean, achieved increasing values up to the dose of 100% of the biofertilizer application of fertilizers average of 6,7 pods, and with the dose of 125% an average of 7,8 pods per plant.

It is observed that the crop seasons differed from each other ($p \leq 0.05$), highlighting the autumn/winter season with the highest average observed. It is worth mentioning that, in the present experiment, the number of pods showed little variation between the autumn/winter and rainy seasons, with an average of 8.9 and 7.7 pods per plant, respectively. Pereira et al. (2015) observed larger variations in the 2011 and 2012 harvests, with an average of 11.5 and 6.6 pods per plant, respectively.

For the number of grains per pod, as well as for the number of pods per plant, linear increments are verified as the doses of the organomineral formulations are increased. It is noteworthy that the doses of 150 and 120 kg ha^{-1} were responsible for the highest averages, 4.1 and 4.0 grains per pod (data not shown). The increase observed in the number of grains per pod, according to Araújo et al. (2012), may be associated with other production components, such as the number of pods per plant, which increased the number of grains produced, a behavior verified in this experiment. The data obtained in this study are near to those obtained by Toledo et al. (2017) in beans, whose average number was 5,0 grains per pod when applying 500 kg ha^{-1} of organomineral fertilizer.

For the 100-grain weight, a quadratic regression model is observed until applying the dose of 120 kg ha^{-1} of the formulated organomineral (data not shown). This dose is responsible for the maximum peak, indicating that higher doses of the organomineral formulation based on the sugar cane filter cake do not increase the 100-grain weight, showing a slight decrease in this variable. The average 100-grain weight obtained in the study was around 38 g. When developing and testing the same cultivar (BRSMG Realce), Melo et al. (2014) found a 100-grain weight around 35.0g, therefore close to the average obtained in this experiment. A distinct result was verified by Toledo et al. (2017) when applying the dose of 500 kg ha^{-1} of organomineral fertilizer and obtaining the low average, 25g in 100 grains of beans.

The bean of grain yield was influenced by the treatments, with adjustments of quadratic regression models for the two crop seasons, in which the doses of the organomineral formulation (Fig. 3 and Table 5) increased from the dose of 60 kg ha^{-1}, with emphasis on the dose of 150 kg ha^{-1} of the organomineral fertilizer. The highest average of 2.666 kg ha^{-1} was achieved in the first harvest (autumn/winter). Since then, a decreasing trend for this parameter indicates a drop in grain yield as the dose of organomineral formulation per ha^{-1} increases. The result of this experiment demonstrates a higher average of yield than that verified in a study by Melo et al. (2014), with means of 2.259 and 1.893 kg ha^{-1} for the cultivar BRSMG Realce in autumn-winter and rainy seasons, respectively. These results reveal that in soils with the same traits of the present experiment, the organomineral formulation based on the filter cake can partially replace the mineral fertilization.

According to data from Conab (2021), grain yield in the rainy season of 2019/2020 in Brazil was 1.209 kg ha^{-1}, while in autumn/winter season presented an average yield of 1.481 kg ha^{-1}, both lower than the highest productivity obtained in the present study - 2.666 kg ha^{-1}. In this way it can be concluded this superiority for the organomineral fertilizer concerning the chemical fertilizer, corroborating the research results to Gurgel et al. (2015), Silva et al. (2019) and Frazão et al. (2019), can be attributed to the adequate supply and slow availability of nutrients to plants.

4 Conclusion

Considering the conditions of the current experiment, it was possible to conclude that the formulated organomineral fertilizer based on the filter cake can replace mineral fertilization.

The organomineral fertilizer significantly contributed to the crop`s development, with greater absorption of macronutrients N and K, increase in the weight of 100 grains, number of grains per pod, number of pods per plant, and grain yield, in comparison to the absence of fertilization and the addition of nitrogen doses, highlighting the doses of OMFs of 90 and 150 kg ha^{-1}.

The formulated organomineral fertilizers based on filter cake can be a viable alternative with great potential for fertilizing the bean crop, besides the environmental sustainability generated by their inclusion in fertilization.

5 Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: The survey on which this study is based was anonymous. Participation in the survey was exclusively on a voluntary basis.

Availability of data and materials: The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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7 Tables

Table 1. Average, maximum, and minimum contents of macronutrients N, P, K, Ca, Mg, and S in the leaves of the bean cultivar BRS Realce in the autumn/winter season of 2018 harvest according to different doses of organomineral formulations, with and without the presence of nitrogenous fertilization.

Treatments	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
	g kg^{-1}											
	Fertilization 0 Without N						Fertilization 0 With N					
Maximum	27.0	1.0	15.2	1.4	0.4	0.6	30.3	1.0	19.2	1.7	0.7	0.7
Minimum	23.7	0.6	9.2	1.0	0.2	0.2	25.4	0.8	12.8	1.3	0.4	0.3
Average	25.0	0.8	12.5	1.3	0.3	0.4	27.8	0.9	16.7	1.6	0.5	0.5
CV%	5.7	12.3	20.0	13.9	35.4	45.5	7.3	10.3	16.5	11.2	21.9	39.3
	Fertilization 30 Without N						Fertilization 30 With N					
Maximum	57.6	1.2	39.6	2.6	2.1	1.6	1.8	38.0	2.5	2.3	2.5	2.5
Minimum	50.4	1.0	32.4	1.8	1.7	0.6	52.1	1.6	27.2	2.3	1.6	1.0
Average	53.3	1.2	35.2	2.2	2.0	1.1	55.0	1.7	33.0	2.4	2.0	1.5
CV%	6.6	8.6	8.9	17.3	8.3	39.5	4.2	4.4	13.8	4.5	15.3	45.3
	Fertilization 60 Without N						Fertilization 60 With N					
Maximum	56.0	1.8	39.6	3.5	2.3	1.8	1.8	39.6	3.3	2.5	1.5	1.5
Minimum	50.2	1.6	23.6	2.5	1.4	1.2	50.4	1.2	24.8	2.0	1.3	0.8
Average	54.0	1.7	33.0	3.1	1.7	1.6	54.2	1.6	34.2	2.6	1.9	1.1
CV%	4.9	7.0	20.3	13.2	23.0	14.6	5.4	15.5	20.2	20.9	27.8	28.0
	Fertilization 90 Without N						Fertilization 90 With N					
Maximum	58.9	2.2	39.6	3.6	2.5	1.3	2.1	37.6	4.4	2.5	2.3	2.3
Minimum	50.2	1.1	31.6	2.1	1.8	1.2	50.7	1.2	26.0	2.4	1.4	1.9
Average	54.1	1.7	36.2	2.8	2.1	1.3	54.1	1.5	30.8	3.1	1.9	2.1
CV%	7.3	25.3	9.3	24.8	14.0	3.7	5.9	27.1	18.7	27.4	23.7	9.4
	Fertilization 120 Without N						Fertilization 120 With N					
Maximum	53.5	1.8	38.8	2.9	2.4	2.1	55,1	2.1	37.6	5.6	2.5	1.6
Minimum	50.5	1.1	28.4	2.3	1.4	1.0	52.3	1.6	29.6	3.3	1.3	0.9
Average	51.8	1.5	34.0	2.7	2.0	1.4	53.7	1.8	32.7	4.4	2.0	1.2
CV%	2.7	20.7	12.6	10.4	20.2	36.5	2.1	11.2	10.4	21.5	27.5	21.8
	Fertilization 150 Without N						Fertilization 150 With N					
Maximum	57.3	2.1	36.4	3.3	2.5	1.5	2.2	39.2	5.8	2.5	2.0	2.0
Minimum	47.7	1.3	20.4	2.8	1.4	1.1	53.0	1.4	28.0	2.1	1.7	1.4
Average	51.7	1.6	30.5	3.1	1.8	1.4	55.5	1.8	34.7	3.6	2.1	1.8
CV%	7.8	23.0	23.5	7.1	23.9	11.5	4.6	21.4	15.3	25.1	15.8	14.4

Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulfur (S).

Table 2. Average, maximum, and minimum contents of macronutrients N, P, K, Ca, Mg, and S in the leaves of the bean cultivar BRS Realce in the rainy season of 2018/2019 harvest according to different doses of organomineral formulations, with and without the presence of nitrogenous fertilization.

Tratamentos	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
	.... g kg^{-1}											
	Fertilization 0 Without N						Fertilization 0 With N					
Maximum	25.9	0.8	18.0	1.9	0.7	0.9	30.9	1.0	18.0	1.9	0.9	1.0
Minimum	23.1	0.5	13.2	1.3	0.4	0.7	24.9	0.6	14,.0	1.4	0.4	0.6
Average	24.4	0.6	15.1	1.6	0.5	0.8	27.9	0.8	16.0	1.6	0.7	0.8
CV%	4.7	26.1	13.8	15.9	24.0	14.3	11.8	22.0	10.2	15.3	15.3	20.4
	Fertilization 30 Without N											
Maximum	52.9	2.1	28.8	5.7	1.9	1.9	51.4	1.7	28.0	1.9	1.0	1.0
Minimum	42.5	1.9	22.8	4.1	1.7	1.2	44.9	1.2	26.0	4.0	1.4	0.9
Average	48.8	2.0	27.0	4.7	1.7	1.4	48.0	1.4	27.2	4.4	1.6	0.9
CV%	9.2	3.9	10.4	16.2	4.7	24.8	5.6	12.4	3.2	6.3	12.1	5.1
	Fertilization 60 Without N						Fertilization 60 With N					
Maximum	50.7	1.8	30.8	4.4	1.9	1.1	53.3	1.9	30.0	2.0	1.4	1.4
Minimum	43.2	1.4	27.2	3.1	1.4	0.9	48.9	1.7	28.4	3.6	1.7	0.9
Average	47.7	1.6	28.7	3.9	1.6	1.0	50.3	1.8	29.0	4.4	1.9	1.2
CV%	4.90	10.2	5.7	14.9	12.7	8.1	3.9	5.0	2.4	15.4	6.6	18.0
	Fertilization 90 Without N						Fertilization 90 With N					
Maximum	48.3	2.5	29.6	3.9	2.0	1.7	52.2	2.0	31.2	2.7	1.2	1.2
Minimum	43.5	1.7	25.2	3.6	1.7	1.1	40.8	1.9	27.6	3.5	1.9	0.7
Average	45.8	2.0	28.1	3.7	1.9	1.4	47.0	2.0	29.1	4.4	2.2	0.9
CV%	5.4	16.4	7.4	3.4	7.1	18.1	12.9	2.01	5.3	18.1	16.0	21.0
	Fertilization 120 Without N						Fertilization 120 With N					
Maximum	52.4	1.9	30.8	4.7	2.3	1.5	50.5	34.8	4.4	2.3	0.8	0.8
Minimum	46.1	1.6	28.0	4.1	1.7	1.1	49.6	1.4	28.8	3.3	1.7	0.7
Average	49.3	1.7	29.5	4.4	1.9	1.3	50.1	1.6	31.6	3.9	2.0	0.8
CV%	5.5	7.4	4.0	4.9	16.0	12.3	0.8	10.1	7.8	11.3	17.6	6.8
	Fertilization 150 Without N						Fertilization 150 With N					
Maximum	50.3	2.0	30.4	6.0	1.5	1.6	51.6	1.9	32.4	1.9	0.8	0.8
Minimum	41.6	1.8	26.0	3.9	1.1	1.0	46.0	1.4	29.6	3.1	1.5	0.6
Average	47.1	1.9	27.9	4.9	1.3	1.4	48.5	1.7	31.1	3.6	1.8	0.7
CV%	8.3	3.3	7.4	18.2	15.9	19.6	6.0	12.9	3.7	16.0	9.10	14.4

Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulfur (S).

Table 3. Average, maximum, and minimum contents of micronutrients Cu, Fe, Mn, and Zn in the leaves of the bean cultivar BRS Realce in the autumn/winter season of 2018 harvest according to different doses of organomineral formulations, with and without the presence of nitrogen fertilization.

Trataments	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn
	.... mg kg^{-1}							
	Fertilization 0 Without N				Fertilization 0 With N			
Maximum	22,8	1889,0	58,9	78,3	23,8	1785,2	68,7	61,8
Minimum	20,1	1168,8	30,0	60,5	17,1	1529,0	27,7	47,2
Average	21,5	1642,6	40,8	69,4	20,4	1643,2	45,9	54,2
CV%	9,0	19,6	38,9	10,4	16,3	6,8	40,7	11,0
	Fertilization 30 Without N				Fertilization 30 With N			
Maximum	29,0	2054,5	57,2	62,8	23,9	1906,2	78,7	69,6
Minimum	19,3	1685,6	56,3	55,4	20,4	1458,6	47,0	50,4
Average	24,1	1861,9	56,7	59,4	21,8	1621,4	62,8	59,7
CV%	28,5	8,1	0,8	5,1	8,7	12,1	35,6	13,2
	Fertilization 60 Without N				Fertilization 60 With N			
Maximum	25,1	1684,7	73,4	74,8	28,3	1843,4	89,3	58,6
Minimum	18,1	1459,9	49,0	50,6	14,1	1515,7	54,8	50,0
Average	21,6	1566,3	57,9	63,2	20,8	1655,6	72,1	54,3
CV%	22,7	6,3	23,1	15,8	34,3	9,3	33,8	6,5
	Fertilization 90 Without N				Fertilization 90 With N			
Maximum	28,0	1842,7	67,1	87,0	21,6	1805,8	72,8	75,9
Minimum	20,5	1564,7	55,3	58,7	18,1	1189,4	41,8	63,5
Average	25,0	1679,6	62,8	74,6	20,1	1506,2	57,3	67,7
CV%	15,9	7,1	10,4	15,8	8,9	18,8	38,3	8,6
	Fertilization 120 Without N				Fertilization 120 With N			
Maximum	24,5	1724,4	88,6	64,8	22,0	1762,1	50,5	55,1
Minimum	18,2	1182,9	52,1	53,5	17,0	1340,7	48,4	53,2
Average	21,5	1529,6	70,4	57,4	19,5	1591,9	49,4	54,2
CV%	14,7	15,7	36,6	8,8	12,8	11,4	3,1	1,5
	Fertilization 150 Without N				Fertilization 150 With N			
Maximum	25,2	2170,9	77,2	74,4	26,7	1966,0	86,0	74,5
Minimum	17,5	1360,9	43,4	59,9	19,0	1554,0	53,9	58,6
Average	20,6	1703,7	60,2	64,4	23,3	1734,3	68,4	68,7
CV%	19,8	20,5	28,0	10,4	16,8	9,9	23,8	10,4

Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn).

Table 4. Average, maximum, and minimum contents of micronutrients Cu, Fe, Mn, and Zn in the leaves of the bean cultivar BRS Realce in the rainy season of 2018/2019 harvest according to different doses of organomineral formulations, with and without the presence of nitrogen fertilization.

Tratamentos	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn
	.... mg kg^{-1}							
	Fertilization 0 Without N				Fertilization 0 With N			
Maximum	27,7	1785,5	65,4	59,8	19,9	1912,7	64,0	73,0
Minimum	19,0	1715,0	41,2	46,3	17,0	1730,5	43,2	51,2
Average	23,4	1747,7	54,9	51,3	18,5	1816,6	56,2	57,3
CV%	18,4	2,0	22,6	11,8	11,0	4,7	20,1	18,4
	Fertilization 30 Without N				Fertilization 30 With N			
Maximum	28,7	1932,2	65,5	55,8	18,2	1987,2	118,9	62,4
Minimum	12,5	1600,8	50,5	39,4	16,3	1522,7	64,1	44,9
Average	20,3	1774,8	58,0	47,6	17,3	1745,5	91,5	51,3
CV%	39,9	8,4	18,3	14,5	7,8	14,1	42,4	16,0
	Fertilization 60 Without N				Fertilization 60 With N			
Maximum	25,1	1744,6	102,0	63,3	20,8	1763,3	75,2	59,8
Minimum	21,2	1421,4	53,6	45,8	16,9	1378,2	58,4	24,7
Average	23,1	1595,6	77,8	54,1	18,9	1584,1	67,2	46,2
CV%	12,1	10,1	44,0	17,4	14,6	11,6	12,5	32,6
	Fertilization 90 Without N				Fertilization 90 With N			
Maximum	28,4	1936,4	77,8	55,2	24,8	1826,9	130,8	52,6
Minimum	16,7	1336,3	70,7	24,8	14,4	1176,0	97,0	46,0
Average	22,5	1683,1	74,3	41,4	19,3	1531,1	113,9	48,5
CV%	36,7	15,6	6,8	30,5	22,7	19,2	21,0	7,4
	Fertilization 120 Without N				Fertilization 120 With N			
Maximum	28,1	1755,8	118,4	49,7	24,5	1877,4	108,8	51,8
Minimum	17,6	1564,6	79,3	45,2	15,8	1597,9	53,8	44,7
Average	22,9	1650,4	102,9	47,0	20,2	1766,6	82,9	48,3
CV%	32,5	4,8	20,2	5,1	30,3	6,7	33,4	7,4
	Fertilization 150 Without N				Fertilization 150 With N			
Maximum	19,2	2024,0	101,4	49,6	26,1	1884,5	130,3	49,4
Minimum	12,4	1367,7	72,5	38,2	20,9	1389,3	76,2	37,4
Average	15,8	1754,3	84,7	43,2	23,5	1645,7	103,3	44,2
CV%	30,3	15,8	17,6	12,5	15,4	13,9	37,0	11,5

Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn).

Table 5. Average variation in grain yield (kg ha^{-1}) of bean plants grown in two seasons according to fertilization with organomineral formulation.

Doses (kg ha^{-1})	Crop Seasons	
	I	II
0	772.900 b	1040.46 a
30	2068.22 a	1804.20 b
60	2166.11 a	2035.94 a
90	2433.57 a	2082.51 b
120	2511.90 a	2189.63 b
150	2665.97 a	2304.55 b

Lowercase letters in the lines compare the means of each season (I - "autumn/winter season; II - rainy season) for each dose of organomineral formulations. Means followed by the same lowercase letter in the lines do not differ by the Tukey test at 5% probability.

Figures

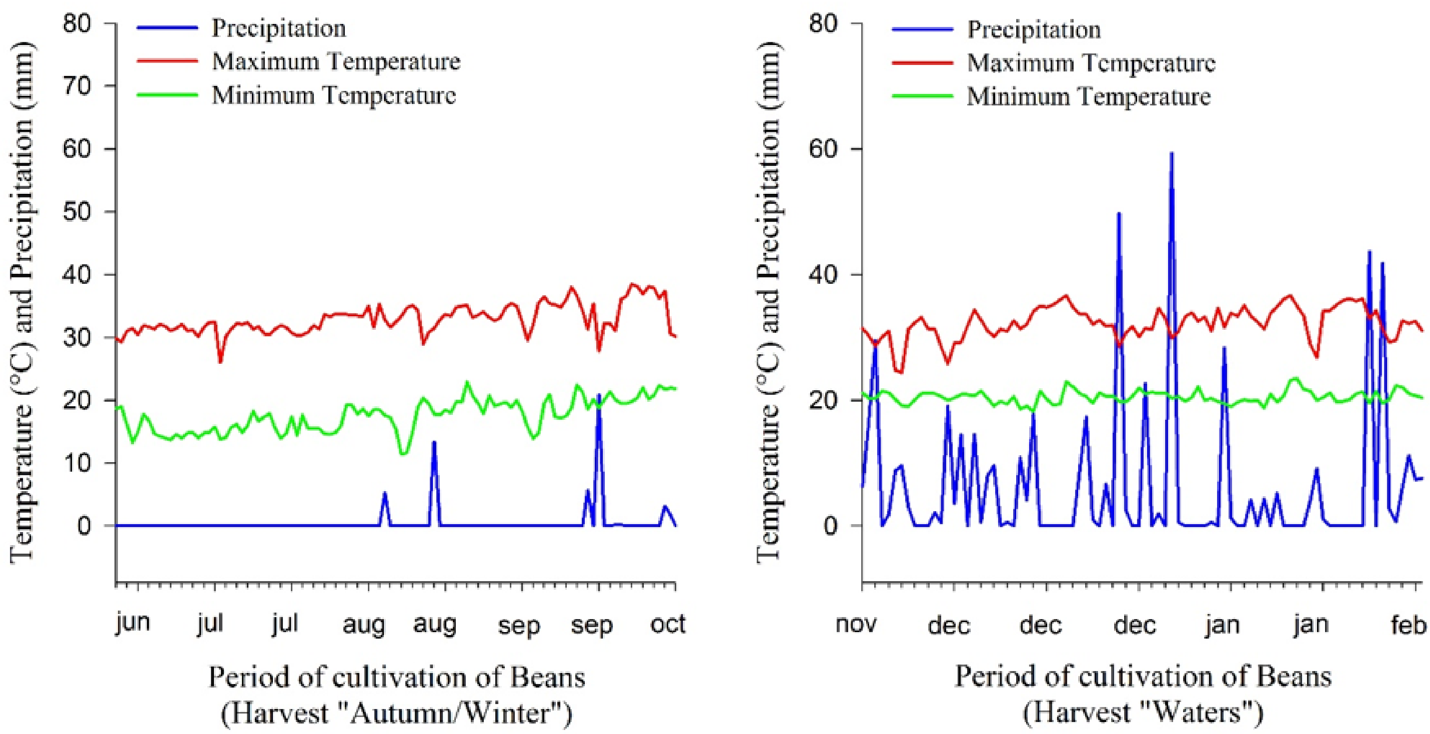

Figure 1

Meteorological data along the experiments. Anápolis/GO, Brazil, autumn/winter season of 2018 and rainy season=waters of 2018/2019. (INMET data).

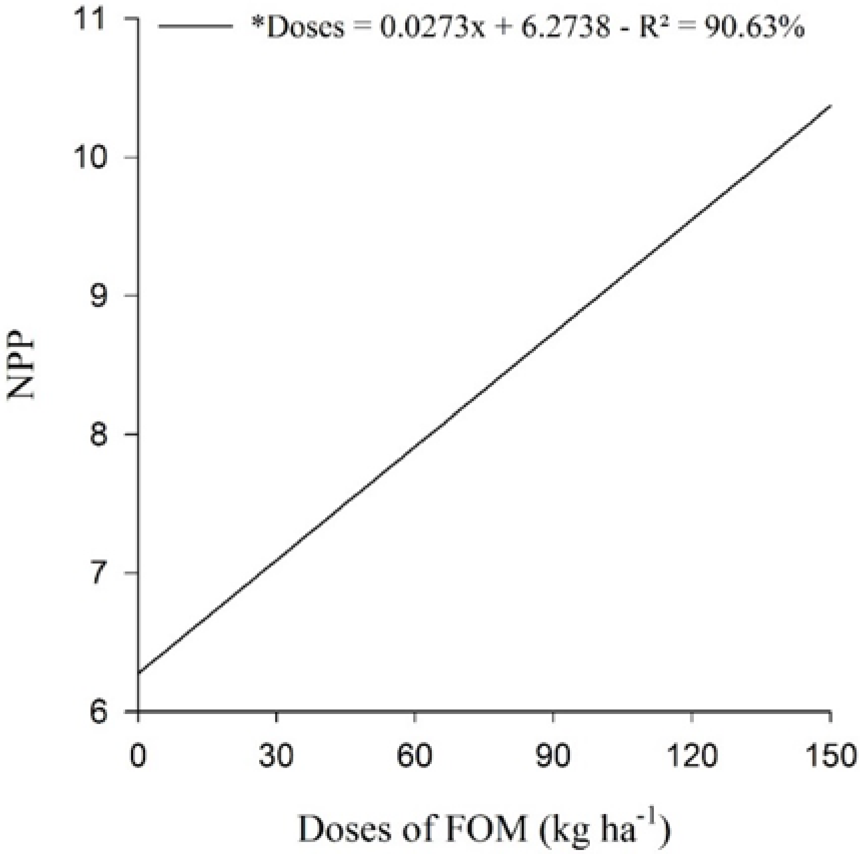

Figure 2

Number of pods per plant (NPP) of bean grown in the 2018/2019 crop according to the fertilization with organomineral formulation.

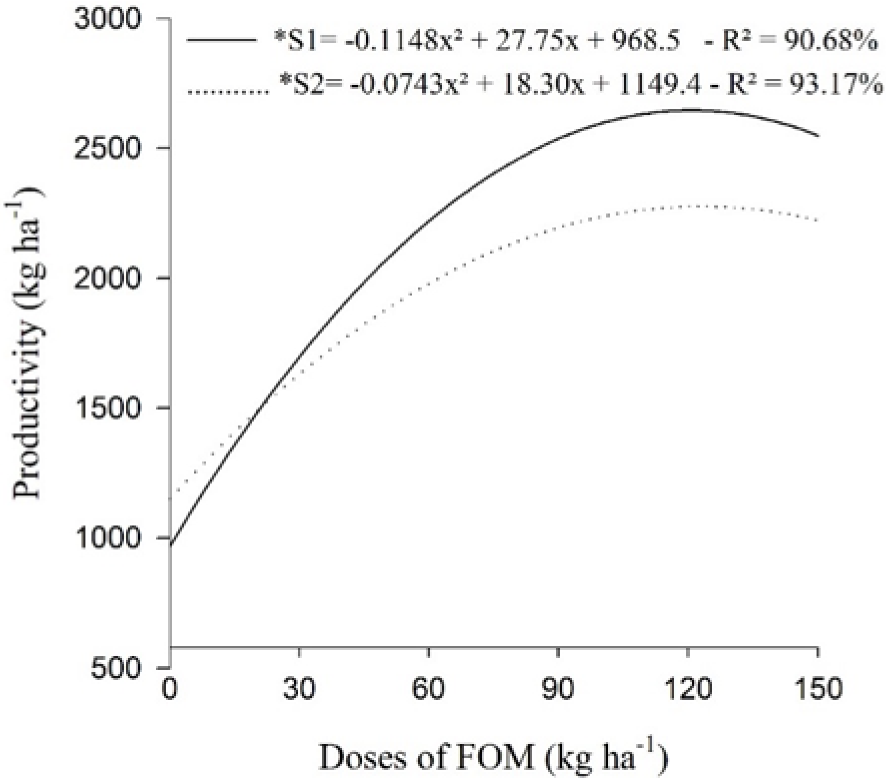

Figure 3

Grain yield (kg ha-1) of bean, grown in autumn/winter and rainy seasons according to fertilization with organomineral formulation. S1 = Autumn/winter season; S2 = Rainy season.