

Phosphate Organomineral Fertilizer Usage Compared to Mineral Phosphate in Corn Cultivation

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Abstract

Corn has great relevance for agribusiness as it is used in human and animal food, besides the energy matrix. The objective of this study was to assess the leaf content of macro and micronutrient, accumulation of primary macronutrients, production components and productivity with the application of pelleted organomineral fertilizer in different doses compared to mineral fertilization, in two soils of different textures in the corn crop. Two trials were conducted in the municipality of Uberlândia-MG-Brazil: one located near the highway BR 452 km 141, at the coordinate 18°55'26"S, 48°09'36"W, clay soil. The other at km 640 of BR 365, at coordinate 18°54'05"S, 48°25'20"W, sandy soil. A randomized block design with five replications was used, with five doses of organomineral fertilizer (40, 60, 80, 100 and 120% of the recommended dose of P₂O₅ for corn) and an additional with 100% of the recommendation of mineral P₂O₅, total of six treatments and 30 plots. The results showed that, with the exception of phosphorus leaf content, yield in the sandy texture and the number of grains per row in the clay texture, there was no difference between the doses of phosphate organomineral and did not differ from the mineral. Thus, phosphate organomineral is as efficient as mineral for phosphorus supply.

Keywords: organic fertilizer, *Zea mays*, phosphorus

1. Introduction

Fertilizers play an important role in crop productivity, especially corn (*Zea mays*), and are among the main limitations of agricultural production in the country. Among the difficulties for greater efficiency, is finding the best time to fertilize and the appropriate amount. The correct fertilization provides nutrients efficiently to plants, improving growth and positively impacting the harvest of superior quality. The correct use of fertilizers makes it possible to increase production and correct soil and crop limitations.

The consumption of phosphorus in Brazil and the excessive cost of phosphate fertilizers require alternatives in the choice of management techniques to enhance the agronomic and economic yield (Martins, 2018). The use of organic matter aims to increase the content of phosphorus in the soil and its availability to plants (Teixeira, 2013). However, the conversion, both biological and physical, of organic waste and the mixture of mineral nutrients, can make viable the use of pelleted organomineral fertilizers with high phosphorus concentration, to be used in grain production (Benites et al., 2010). Thus increasing soil fertility and reducing the amount of chemical fertilizers, bringing a set of benefits to agriculture (Teixeira, 2013).

The study of organomineral fertilizers has provided high expectations for better efficiency, economy and sustainability (Kulikowska & Gusiatin, 2015; Liang et al., 2016). The effectiveness of organominerals is associated with the dynamics of nutrients in different soil classes. Phosphate-rich organomineral fertilizers are shown to be superior in fertilizer efficiency compared to mineral, as the presence of organic compounds can minimize the binding of phosphorus to colloids in the soil, making it almost unavailable (Gatiboni et al., 2008; Santos et al., 2008).

Thus, studies by Correa et al. (2016) emphasize that organomineral fertilizers in solid form showed greater benefits to soil properties than chemical fertilizers. Including the increase in crop yields when compared to

mineral fertilizers. However, organominerals pelletized are of a recent technology that is being progressively studied in different cultures and environments.

Teixeira et al. (2011) found an increase of 20% in the production of dry matter in corn plants, when they used organomineral fertilizer compared to a mineral source, results that corroborate those observed by Grohskopf et al. (2011). The authors related the high agronomic efficiency of organominerals to the benefits that organic matter plays in reducing the phosphorus retention capacity in the soil, due to the competition for mineral adsorption sites, thus increasing the availability and use of this nutrient.

Dania et al. (2012), report the increase in corn productivity when organomineral fertilizer was used. Comparing two sources of phosphorus, mineral and organomineral, Lana et al. (2014), found that none of the sources influenced the components of production and grain productivity in corn. Teixeira et al. (2014), reported greater agronomic efficiency when using organomineral compared to mineral. These conclusions are in line with Kiehl (2008), who highlights the beneficial effect of organomineral fertilizer on soil attributes and yields of agricultural crops. Still, little research has compared the efficiency of mineral fertilizers with pelleted organominerals. According to Morais and Gatiboni (2015), the two categories of fertilizers take approximately thirty days to supply plants with the phosphorus present in their chemical composition.

In the composition of the organic fraction of the organominerals, several raw materials are used, such as filter cake, poultry litter, cattle manure, cultural remains, industrial waste, sewage sludge, among others. This causes these materials, normally discarded, to be taken to utilization destinations, minimizing the damage caused to the environment. Therefore, Schmidt Filho et al. (2016) report several problems caused by the inappropriate destination of solid urban, agricultural and industrial waste on the environment, causing numerous economic, social and environmental losses. Therefore, there is no doubt that the agricultural use of organic waste is an economically viable, environmentally correct and socially just practice.

Research regarding chemical changes in the properties of soil fertilized with organomineral fertilizers and its influence on corn production, until then, is modest. Considering the implications of the benefits generated from organic matter on the soil, as well as the contribution to plant growth and development, the use of organomineral fertilizers appears to constitute a relevant mechanism aimed at improving fertility and consequently increasing the productivity of agricultural crops.

Given the above, the objective of this study was to evaluate the application of pelleted organomineral phosphate fertilizer in different doses compared to mineral fertilization, in two soils of different textures in the corn crop.

2. Method

2.1 Experiments

Two tests were carried out in the city of Uberlândia-MG, one being implanted at the Syngenta experimental station, located on the BR 452 highway, km 141, at coordinate 18°55'26"S, 48°09'36"W. The soil is classified as a red dystrophic Oxisol, with a clayey texture, with 23.7% coarse sand, 24.1% fine sand, 19.1% silt and 33.1% clay, according to the EMBRAPA classification (2018). The other experiment was carried out at the Juliagro experimental station, located at BR 365, km 640, at coordinate 18°54'05"S, 48°25'20"W. The soil is classified as a red latosol with a sandy texture, with 27, 7% coarse sand, 52.5% fine sand, 7.6% silt and 12.2% clay according to the EMBRAPA (2013) classification. The results obtained in the soil analysis are shown in Table 1.

Table 1. Chemical characterization of soil samples from experimental areas

Textura	pH/H ₂ O(1:2.5)	P me ^{h-1}	K ⁺	S-SO ₄	K ⁺	Ca ⁺²	Mg ⁺²	Al ⁺³	H+AL	SB	t	T
		mg dm ³				cmol dm ³						
Arenosa	6.8	3.8	64	7	0.16	1.60	0.7	0.0	1.30	2.46	2.46	3.76
Argilosa	5.8	29.1	148	14	0.38	3.0	1.3	0.0	3.10	4.68	4.68	7.78
	V	M		M.O.	C.O			B	Cu	Fe	Mn	Zn
	%			dag kg ⁻¹				mg dm ³				
Arenosa	65	0		1.4	0.8			0.27	0.4	15	2.7	0.8
Argilosa	60	0		2.2	1.3			0.17	0.8	24	1.9	4.1

The design used in both experiments was randomized blocks, with five replications, five doses of the organomineral fertilizer (40, 60, 80, 100 and 120% of the recommended dose of P₂O₅ for corn) and an additional 100% recommendation of mineral P₂O₅. The fertilization recommendation was made according to Alves et al. (1999) for productivity above 8000 kg ha⁻¹ of grains.

The nutrients nitrogen and potassium were balanced to provide the same amount of these in each treatment, using urea (25%) and potassium chloride (30%) as the organomineral source.

The cover fertilization was carried out fifteen days after sowing when the plants were in stage V₃, using nitrogen and potassium from mineral source, urea 45% N and potassium chloride 60% K₂O. The characterization of organomineral fertilizers are shown in Table 2.

The experimental plot consisted of six lines five meters long and 0.5 m spacing between lines, totaling 15 m². The plot's useful area was composed of the two central lines, discarding one meter from each end, making the plot's area equal to 3 m².

Sowing was carried out in the first half of November of the year 2017, using the seed of hybrid corn Syngenta STATUS VIP3, aiming at a population of 68,000 plants ha⁻¹. Grooves of 0.1 m depth were made where the sowing was carried out. Cultural treatments were carried out preventively to control weeds, pests and diseases, with the use of phytosanitary products, insecticides, fungicides and herbicides.

Table 2. Chemical composition of the organomineral fertilizer (dry basis at 65 °C of temperature)

Fertilizer	N-P-K	Urea	KCl
	04-20-05	25-00-00	00-00-30
	----- % -----		
N	4	25	-
P ₂ O ₅	20	-	-
K ₂ O	5	-	30
Ca	3.20	3.80	4.10
Mg	0.72	0.85	0.93
S	1.15	1.37	1.48
B	0.009	0.010	0.011
Cu	0.013	0.015	0.016
Fe	0.501	0.597	0.648
Mn	0.180	0.214	0.233
Zn	0.020	0.023	0.025
M.O.	18.91	22.535	24.49
C/N	2/1	2/1	2/1
CTC	200	238	259
pH	5.2	-	-

Note. The macronutrients N, P and K are expressed as a percentage and the micronutrients in mg kg⁻¹. N-[N Total] = Sulfuric digestion, B = Incineration, Dt. Azomethine. P, K, Ca, Mg, S, Na, Cu, Fe, Mn, Zn = Perchloric Nitro Digestion, Atomic Absorption.

2.2 The Tests

The tests were carried out on six plants per plot, within the useful area, in the flowering stage (VT). The following were tested: Spad Index using the sheet below and opposite to the ear, Stem diameter, Plant height, leaf area suggested by Sangoi et al. (2007), corn cob of ear insertion. Leaf analysis: leaves were collected below and opposite the ear for the determination of macro and micronutrient contents, Fresh mass and dry mass, Accumulation of primary macronutrients in the entire plant, the determination of macro and micronutrients was carried out according to the methodology described by Silva (2009).

At harvest time, the following parameters were tested: ear length, number of grains per row and number of rows per ear, weight of 1000 grains and total productivity, with the grain moisture being corrected to 13%.

2.3 Statistical Analysis

Tests of assumptions of ANOVA regarding the normality of residues, homogeneity of variances and additivity of blocks at 1% were carried out by IBM SPSS Statistics version 20.0 (Marôco, 2011). Once the assumptions were accepted, the data were submitted to analysis of variance (ANOVA), with the F test at 5% probability. The doses of the organomineral were compared with the mineral by Dunnett's test at 0.05 significance out by IBM SPSS Statistics version 20.0 (Marôco, 2011). The regression analyzes were performed using the computer program SISVAR (Ferreira, 2008).

3. Results and Discussion

The levels of leaf macro and micronutrients were not influenced by the doses of organomineral phosphate fertilizer when compared to the application of super triple, both in clayey and sandy soils (Table 3). For the phosphorus content, in the sandy texture, there was a difference between organomineral and mineral. The doses of 40 and 60% were higher than the mineral with contents of 1.40 and 1.42 g kg⁻¹ respectively, while the additional treatment, with mineral fertilization, obtained 1.16 g kg⁻¹. However, these levels are below those recommended as ideal for maize (Martinez et al., 1999).

Table 3. Content of macronutrients and leaf micronutrients

Organomineral (%)	Macro (g kg ⁻¹)						Micro (mg kg ⁻¹)			
	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
<i>Clayey</i>										
40	25.3	1.74	30.5	2.22	1.48	1.10	8.48	111.7	30.1	16.22
60	24.8	1.60	29.2	2.08	1.36	0.88	9.06	103.0	31.9	15.49
80	24.8	1.62	30.2	2.02	1.50	0.86	11.87	129.7	30.9	16.56
100	25.2	1.62	30.1	1.84	1.42	0.80	10.59	139.1	27.3	17.71
120	25.3	1.50	29.7	2.16	1.54	0.84	8.16	112.6	29.5	14.71
Ad100(*)	25.6	1.36	30.0	2.20	1.54	0.88	9.50	89.2	24.6	15.06
C.V. %	5.4	16.2	5.2	10.6	6.6	24.8	28.2	36.4	45.1	12.6
SW	0.034	0.050	0.194	0.854	0.439	0.050	0.004	0.310	0.565	0.784
LV	0.466	0.466	0.046	0.349	0.192	0.007	0.136	0.060	0.902	0.282
F'	0.689	0.346	0.271	0.918	0.533	0.144	0.533	0.087	0.530	0.755
<i>Sandy</i>										
40	21.42	1.40*	24.80	2.32	1.96	1.16	7.76	116.9	79.25	25.16
60	21.84	1.42*	24.50	2.66	2.16	1.06	8.06	122.2	64.37	25.79
80	21.56	1.22	23.00	2.56	1.96	1.14	8.40	150.4	63.44	23.24
100	21.56	1.14	23.30	2.96	2.40	1.12	7.55	122.9	82.56	22.30
120	20.86	1.30	24.50	2.80	2.20	1.08	7.93	125.6	65.35	26.44
Ad100(*)	20.72	1.16	23.40	2.52	2.18	1.18	8.50	92.6	71.47	25.16
C.V. %	4.66	10.54	5.69	15.09	11.92	11.91	19.08	31.58	18.30	18.22
SW	0.114	0.768	0.873	0.046	0.208	0.544	0.965	0.700	0.725	0.440
LV	0.333	0.418	0.640	0.13	0.720	0.310	0.683	0.579	0.789	0.246
F'	0.847	0.143	0.137	0.06	0.361	0.439	0.589	0.387	0.442	0.162

Note. *Averages in the column differ from the 100% mineral SFT control by the Dunnett test at the level of 5% probability. SW, F, F': assumptions of the Shapiro-Wilk, Levene e Block Additivity tests, values in bold indicate residues with normal distribution, homogeneous variances and additive effects.

Supposedly, this fact is related to the protection that organic matter provided to the nutrient in the organomineral fertilizer. Gazola et al. (2013) recommends the coating of phosphates to attenuate and limit adsorption, since the coating can reduce the contact of the phosphate fertilizer with iron and aluminum oxides present in the clay fraction of the soil. However, the corn hybrid was also efficient in absorbing phosphorus from organomineral fertilizer at doses of 40 and 60% compared to mineral, a peculiar characteristic that can be directly related to phosphorus absorption. However, Pereira (2018) studying the corn culture observed that there were no phosphorus is the nutrient least demanded in quantity by corn, compared to nitrogen and potassium (Castro et al., 2016). However, it is indispensable for production, where approximately 85% of the total absorbed is exported to grains (Resende et al., 2006).

However, Pereira (2018) studying a reduced maize crop that there were no differences between combinations of super triple and organic fertilizer composted in the foliar content of phosphorus, which presented 1.50 g kg⁻¹. This content was below that considered adequate, which is 2.0 to 4.0 g kg⁻¹ of phosphorus for corn (Raj et al., 1997), supposedly, the low concentrations of leaf content are due to the levels phosphorus in the soil, which were around 2 mg dm⁻³. Another factor to be considered was the rapid vegetative development of the cultivated hybrid, positively affecting phosphorus absorption in this short period of time (Pereira, 2018).

Tiritan et al. (2010) found phosphorus content in the aerial part of corn of 3.6 g kg⁻¹ of phosphorus in dry matter, with the presence of organic fertilizer, demonstrating that the use of organic matter associated with mineral

fertilizer generated benefit with a higher concentration of this nutrient. These authors demonstrated that the adequate supply of organic matter allowed for an improvement in the efficiency of mineral fertilization.

The other macros and micronutrients are within the sufficiency range for the corn crop (Martinez et al., 1999; Büll, 1993), which indicates similar efficiency of fertilizers on macro and micronutrient levels. The reduction in the doses of organomineral phosphorus in the sowing fertilization did not interfere in the content of the other leaf macro and micronutrients. Grohskopf et al. (2019) found no differences in leaf phosphorus content in corn submitted to doses of phosphate mineral and organomineral fertilizers, with values ranging from 2.6 to 3.3 g kg⁻¹, within the range of 2.0 to 4.0 g kg⁻¹, which is considered suitable for culture, according to Silva et al. (2016). The foliar phosphorus content determined in all treatments, including the control without phosphate fertilization, is considered adequate. In this way, it is attributed to the good initial content of phosphorus available in the soil, which has allowed a high yield, even when no phosphate fertilizer was applied.

Phosphorus is the least required nutrient in terms of corn, compared to nitrogen and potassium (Castro et al., 2016). However, it is indispensable for production, where approximately 85% of the total absorbed is exported to grains (Resende et al., 2006).

The accumulation of nitrogen, phosphorus and potassium in the aerial part of the corn plants and in the grains did not differ with the increase in phosphorous organomineral doses, nor did they differ from the application of mineral phosphorus, both in clayey and sandy soil (Table 4). The grains obtained greater accumulation of phosphorus in the clayey texture in relation to the sandy. These results may indicate that phosphorus accumulation occurred due to the greater natural fertility of the clayey soil.

Table 4. Accumulation of nitrogen (N), phosphorus (P) and potassium (K), in the flowering phase and in corn kernels

Organomineral (%)	Plant			Grains		
	N	P	K	N	P	K
	----- Kg ha ⁻¹ -----					
<i>Clayey</i>						
40	161.7	4.2	256.7	174.9	47.9	58.1
60	167.3	6.2	283.4	190.4	48.9	59.3
80	173.5	7.5	299.0	193.6	52.7	69.5
100	170.5	5.8	286.8	194.7	51.7	68.9
120	159.2	7.4	283.1	203.2	49.6	65.1
Ad100 (*)	172.6	5.8	278.6	208.4	49.6	68.7
C.V. %	9.85	35.97	10.43	4.9	15.9	10.8
SW	0.499	0.097	0.513	0.262	0.653	0.786
LV	0.521	0.277	0.376	0.286	0.306	0.480
F'	0.780	0.321	0.544	0.631	0.313	0.734
<i>Sandy</i>						
40	101.8	7.9	162.8	134.2	17.8	42.7
60	108.9	7.8	161.6	137.9	16.5	38.4
80	96.0	6.2	137.6	135.2	18.6	42.1
100	98.1	7.6	154.1	134.4	16.5	38.1
120	100.3	7.5	158.7	141.4	19.0	43.1
Ad100 (*)	96.4	6.6	151.4	126.5	15.7	37.6
C.V. %	9.33	22.89	11.61	14.6	27.2	19.0
SW	0.740	0.725	0.821	0.742	0.193	0.138
LV	0.804	0.899	0.197	0.559	0.873	0.323
F'	0.317	0.931	0.878	0.259	0.245	0.259

Note. *Averages in the column differ from the 100% mineral SFT control by the Dunnett test at the level of 5% probability. SW, F, F': assumptions of the Shapiro-Wilk, Levene e Block Additivity tests, values in bold indicate residues with normal distribution, homogeneous variances and additive effects.

Through the application of doses of mineral and organomineral phosphorus in corn, Ferreira (2014) observed a greater accumulation of phosphorus in the plant when mineral fertilizer was applied, while the organomineral

was the one with the lowest accumulated content in the plant. Thus, he concluded that the greater accumulation of phosphorus is related to the greater availability of the nutrient in the soil, as the solubility of mineral fertilizers is high and the nutrient is readily available to plants, which led to a greater increase in the root system, thus inducing greater efficiency of the roots in absorbing phosphorus from the soil.

Although there are numerous advantages with the use of organomineral fertilizers over environmental liabilities, there are few publications that discuss the interaction of organic and inorganic fertilizers and their effects on the production of agricultural crops. The results of this study point to an efficiency of organomineral fertilizer similar to mineral in corn culture in sandy and clayey soil under the conditions that were carried out in this research.

The variables spad, plant height and stem diameter were not influenced by the doses of phosphate organomineral when applied to clayey or sandy soil. There was also no significant difference between the doses of organomineral with the additional super triple treatment (Table 5). Probably the phosphorus content in both soils, added to the seeding fertilization, may have been sufficient for the satisfactory development of the crop, making the corn plants to develop properly. It should be noted that the averages in the clayey soil probably occurred higher than the sand in response to greater natural fertility or that at the time of planting. Studying two sources of monoammonium phosphate (MAP) in corn, in the first and second harvest, Gazola et al. (2013) found no difference for the variables spad, stem diameter and plant height with averages of 58.96, 21.07 and 2.64 respectively in the first harvest.

Table 5. Spad averages, plant height (P.H.) and stem diameter (S.D.)

Organomineral (%)	Spad	P.H. (m)	S.D. (mm)
<i>Clayey</i>			
40	57.2	2.63	22.9
60	56.6	2.62	22.4
80	57.8	2.64	23.6
100	56.0	2.64	22.9
120	57.0	2.65	22.3
Ad 100% (*)	55.9	2.58	23.6
C.V. %	2.76	2.85	5.61
SW	0.536	0.148	0.197
LV	0.683	0.345	0.085
F ²	0.426	0.284	0.215
<i>Sandy</i>			
40	55.1	2.38	20.6
60	54.3	2.41	21.1
80	56.0	2.42	20.8
100	55.4	2.30	20.3
120	55.2	2.40	21.3
Ad 100% (*)	55.3	2.28	21.0
C.V. %	2.64	5.22	3.69
SW	0.011	0.574	0.898
LV	0.854	0.678	0.372
F ²	0.066	0.676	0.594

Note. *Averages in the column differ from the 100% mineral SFT control by the Dunnett test at the level of 5% probability. SW, F, F²: assumptions of the Shapiro-Wilk, Levene and Block Additivity tests, values in bold indicate residues with normal distribution, homogeneous variances and additive effects.

They report that there was no gradual release of phosphorus by granules covered with three different polymers, the ineffectiveness of the polymers is associated with the accelerated degradation favored by climatic conditions, especially at high temperatures. The values found by these authors are similar to the averages found in this study for the doses of organomineral and additional mineral in the two classes of soil texture (Table 5). It is evident, however, the need for the soil to be adequately supplied with phosphorus to meet the needs of the plant throughout the cycle. In this case, theoretically, there may have been a luxury consumption of phosphorus by the corn plants, so the higher doses did not promote effects on these variables.

These results seem to show that the doses of organomineral and super triple additional, added to the pre-existing content in the soil, met the need for corn, showing no differences between treatments for the spad, plant height and stem diameter variables.

The diameter and number of rows per ear in the clayey texture showed no difference between the doses of organomineral in relation to the mineral source (Table 6). Ear length and number of grains per row at a 40% dose was lower than the mineral control, obtaining an average of 15.5 cm and 30.3, respectively, in clayey soil. This result can be explained by considering the lower amount of phosphorus supplied by the organomineral, thus demonstrating that the reduction of phosphorus implies a limitation in the length of the ear and the number of grains per row.

Table 6. Averages of ear diameter (E.D.), ear length (E.L.), grains per row (G.R.) and row per ear (R.E.)

Organomineral (%)	E.D. (mm)	E.L. (cm)	G.R.	R.E.
<i>Clayey</i>				
40	51.3	15.5*	30.3*	16.6
60	51.9	15.8	31.3	17.1
80	52.2	16.0	32.3	16.8
100	52.4	15.9	31.6	16.7
120	52.1	16.1	32.6	16.6
Ad100 (*)	53.2	16.8	33.2	17.5
C.V. %	1.74	4.07	5.13	3.30
KW	0.301	0.208	0.604	0.890
LV	0.226	0.035	0.092	0.757
F'	0.852	0.671	0.583	0.765
<i>Sandy</i>				
40	47.1	15.0	28.7	17.0
60	47.5	15.3	29.6	17.1
80	48.1	15.4	30.8	16.8
100	47.3	15.0	29.5	16.8
120	48.6	15.3	30.2	17.0
Ad 100% (*)	49.6	15.8	30.5	16.9
C.V. %	3.44	4.90	5.09	3.92
SW	0.238	0.447	0.253	0.268
LV	0.215	0.045	0.065	0.288
F'	0.090	0.478	0.859	0.899

Note. *Averages in the column differ from the 100% mineral SFT control by the Dunnett test at the level of 5% probability. SW, F, F': assumptions of the Shapiro-Wilk, Levene e Block Additivity tests, values in bold indicate residues with normal distribution, homogeneous variances and additive effects.

While the mineral source had an ear length of 16.81 cm and 33.2 grains per row in the clay soil. Mineral fertilizer was more efficient in relation to the 40% organomineral dose. Lana et al. (2014) studying two sources of organomineral and mineral phosphorus found no difference in the average length of the ear and in the number of grains per row, demonstrating that the organomineral exhibited efficiency compatible with the mineral.

These results may indicate that, probably, in systems where organic matter is introduced, it favors the availability of phosphorus for plants. This is also how Nardi et al. (2002), noting that organic matter stimulates greater root growth. This may explain the lack of differences between the lower doses of the phosphate organomineral compared to the mineral in this study. Tiritan et al. (2010) reported that the organomineral was expressed as a viable organic option to replace mineral fertilization.

There were no statistical differences for variations in leaf area, ear insertion height, fresh weight, dry weight, weight of a thousand grains and productivity (Table 7). For these variables, the doses of phosphate organomineral fertilizer were as efficient as the dose of the mineral in providing phosphorus. The phosphorus content in the soil added to the applied doses seems to have supplied the demand of the plants without interfering in the responses of these variables.

Table 7. Leaf area (F.A), Height of ear insertion (E.I.), fresh weight (F.W.), dry weight (D.W.), weight of a thousand grains (W.T.G.) and productivity (Prod)

Organomineral (%)	F.A. (cm ²)	E.I. (m)	F.W. (kg h ⁻¹)	D.W. (kg h ⁻¹)	WTG (g)	Prod. (Kg ha ⁻¹)
<i>Clayey</i>						
40	8445.2	1.43	61900.4	7660.0	334.6	12364.8*
60	8441.6	1.43	64906.0	8261.3	337.5	12949.4
80	8051.3	1.44	63019.0	8434.5	342.5	13061.8
100	8085.7	1.48*	65467.0	8608.6	349.6	13266.4
120	8205.7	1.47*	62713.0	8089.5	345.4	13559.7
Ad100 (*)	8258.0	1.37	62322.0	8111.2	343.6	14058.1
C.V. %	4.0	3.4	7.4	9.4	3.9	5.36
SW	0.404	0.197	0.674	0.264	0.502	0.137
LV	0.298	0.504	0.002	0.025	0.703	0.605
F'	0.390	0.294	0.835	0.519	0.868	0.900
<i>Sandy</i>						
40	7296.5	1.32	45696.0	5786.0	280.1	10197.1
60	7024.8	1.31	46756.8	5882.4	276.7	9993.5
80	6845.2	1.28	45791.2	5337.3	276.8	9928.0
100	7294.3	1.34	46648.0	5717.6	285.9	9979.4
120	7502.7	1.30	49966.4	6294.4	288.7	10491.8
Ad100 (*)	7045.7	1.28	44458.4	5540.8	274.6	10032.5
C.V. %	6.81	3.82	6.86	7.56	6.09	11.58
SW	0.211	0.951	0.625	0.360	0.569	0.162
LV	0.685	0.219	0.658	0.961	0.685	0.441
F'	0.503	0.444	0.918	0.151	0.285	0.744

Note. *Averages in the column differ from the 100% mineral SFT control by the Dunnett test at the level of 5% probability. SW, F, F': assumptions of the Shapiro-Wilk, Levene and Block Additivity tests, values in bold indicate residues with normal distribution, homogeneous variances and additive effects.

In the clayey texture, it was observed that the insertion of the ear, in the doses of 100 and 120% of organomineral, obtained 1.48 and 1.47 m, respectively, while the 100% mineral dose reached 1.37 m. However, Possamai et al. (2001), report advantages over the greater height of the ear insertion, because less losses and improvement in the purity of the grains occur in the mechanized harvest. Castoldi et al. (2011) studying three fertilizers in the corn crop found values of 1,002, 0.98 and 1.008 m for mineral, organic and organomineral fertilizer respectively. These heights were lower than those found in this study, both for organomineral and mineral.

Thus, the doses of pelleted organomineral fertilizer and the super triple additional had the same capacity to supply phosphorus to the corn plants. In the period of conducting the study, the rainfall conditions provided a good development of the culture. Phosphorus in the soil is a nutrient displaced mainly by diffusion. Diffusion is the most expressive mechanism of phosphorus transport in the soil and depends on several factors. One is the amount of water present in the soil (Costa et al., 2006).

In this way, the doses of pelleted organomineral fertilizer and the super triple additional have been shown to have the same ability to supply phosphorus to corn plants. In the period during which the study was being conducted, the pluviometric conditions favored the good development of the culture, facilitating the diffusion of phosphorus, as explained above.

The productivity with the 40% organomineral dose was lower than the mineral control, in the clayey texture (Table 7). Mineral phosphorus with the 100% recommendation was more efficient in productivity. It is worth mentioning that the dose of 40% of the organomineral is 60% lower than the recommended dose of P₂O₅ for corn. This shows that 40% of the organomineral does not produce the same amount of grains as the mineral source. On the other hand, Lana et al. (2014) studying two sources of phosphorus, organomineral and mineral, found average yields of 11,610 and 11,850 kg ha⁻¹ respectively. The lack of response can be explained due to the content of 13.65 mg dm⁻³ of phosphorus available in the soil, which is above the sufficiency level for corn, which is 6 mg dm⁻³ of phosphorus (Malavolta et al., 1997). In this study, the dose of 40% of the organomineral phosphate in the clayey soil produced 12,364 kg ha⁻¹. The content of 29.1 mg dm⁻³ of phosphorus in the clayey texture is considered high (Alves et al., 1999), this content added to a dose of 40 kg ha⁻¹ of phosphorus from the

pelleted organomineral fertilizer theoretically supplied the plant's demands satisfactorily. Note that this productivity is above the national average, which is 5,322 kg ha⁻¹ (CONAB, 2019). Apparently, the pelletized organomineral phosphate fertilizer has the potential to supply the requirements of the corn crop as it can also increase productivity when compared to the national average. Phosphate organomineral fertilizers generally show to be more efficient than mineral phosphate fertilizer, since the presence of organic compounds can minimize the binding of phosphorus to soil colloids, making it more available (Gatiboni et al., 2008; Santos et al., 2008). Therefore, the use of phosphate organomineral has a promising possibility in the fertilization of corn.

According to Tiritan et al. (2010) when mineral phosphorus is used together with an organic source, there is a decrease in phosphorus adhesion by mineral compounds in the soil, thus increasing availability for plants, as organic carriers they improve the solubility of phosphorus compounds in the soil after the application of the fertilizer, thus gradually releasing the phosphorus, which may not occur with the application without the association with organic matter. Probably, the pelleted and super triple organomineral fertilizers added to the contents of phosphorus in the clayey and sandy texture supplied the demand of the corn plants, thus reaching high productivity. Phosphorus deficiency in the soil causes a reduction in the appearance, development and longevity of the leaves, minimizing the leaf area index and the interception of solar radiation.

Thus, grain yield is limited (Fletcher et al., 2008). The sandy texture soil has a low buffering power of nutrients due to low fertility. In this sense, when applying fertilizers, there will quickly be intense availability and absorption of nutrients by plants. However, with a very low phosphorus content in the soil, plants will be affected in their development, thus limiting growth (Ghiberto et al., 2015). In tropical regions, adequate organic matter in the soil is essential for preserving the balance of nutrients. Organomineral fertilizer has the fraction from organic matter in its composition, thus favoring the maintenance of nutrients in the soil. The clayey soil has a higher buffering power of nutrients. Thus, Goldemberg et al. (2008), point out that greater soil fertility is efficient to adequately ensure the development of plants without the need to add fertilizers. Thus, to maintain buffering power, it is suggested to replace the soil's nutritional content with organic and organomineral fertilizers (Kirkels et al., 2014).

The solubility attributes between the sources of phosphorus have great relevance in terms of their efficiency. Phosphate fertilizers with greater solubility make the nutrient more readily available and thus favor the absorption and utilization of the nutrient, especially for short-cycle plants. However, the accelerated release of phosphorus can favor the process of adsorption and precipitation of soluble forms by soil components, forming phosphate compounds of low solubility and leaving the nutrient unavailable. This can occur on soils with a higher clay content. In this way, fertilizers that have low reactivity, by making phosphorus available more slowly, decrease the fixation processes and can favor the best efficiency of the use of the nutrient by the plants (Novais & Smyth, 1999).

Within this context, the organomineral fertilizer behaved similarly to low reactivity fertilizers, thus making phosphorus available gradually, making it impossible for phosphorus to be limited to corn plants. According to Silva and Lana (2018), the main advantages of organominerals are the lower rate of leaching, gradual release of nutrients and less fixation of phosphorus.

The use of phosphate organomineral, even in the lowest doses, was sufficient to achieve satisfactory productivity. This result indicates that the use of phosphated organomineral provided greater availability of phosphorus for plants, especially in those doses lower than the mineral source exclusively. However, it can be inferred that the plasticity of the corn hybrid used, together with the genotypic efficiency with phosphorus, also cooperated for a uniformity and leveling of the responses to the different doses of phosphorus. According to Faria (2014), genetic improvement techniques are making available increasingly productive hybrids. Apparently, further studies on the efficiency of the use of phosphorus in maize breeding programs should be carried out, since this nutrient is directly linked to the productivity of crops such as corn. In general, it was found that the fertilization with the organomineral fertilizer was efficient in this study, in the two soil textures and independent of the initial fertility level of the experimental area.

In soils with high phosphorus adsorption, organomineral fertilizers can generate superior benefits when compared to minerals. Supposedly this behavior is related to the efficiency of the use of phosphorus by plants due to the presence of organic compounds that can minimize the fixation of phosphorus during the mineral phase of the soil and increase the availability of the nutrient for the plants, especially in their initial growth stages (Fernandes et al., 2015). Improving the efficiency in the use of phosphorus in agriculture is a factor to be researched, in order to better understand the use of higher doses of this nutrient as well as to have an

understanding of the best practices for soil, crop and fertilizer management, thus verifying the dynamics phosphorus availability over time (Rowe et al., 2015).

Currently, fertilizers are being targeted by the development of new technologies that, mainly, make it possible to reduce nutrient losses. Among these are organomineral fertilizers that have specific characteristics, which allows nitrogen, phosphorus, potassium and micronutrients to be combined in the same pellet together with bio-stabilized organic matter, ensuring the applicability of the mineral and organic fraction together, in a homogeneous, effective and gradual manner. This makes it permissible to infer about the accumulation, extraction, macro and micronutrient contents in plant tissue and soil, in the phytotechnical variables and productivity. Thus making possible the best understanding of this fertilizer innovation in the corn crop.

4. Conclusions

With the exceptions of the foliar content of phosphorus, the productivity in the sandy texture and the number of grains per row in the clay texture, there was no difference between the doses of phosphate organomineral, as well, these did not differ from the treatment with supply of mineral fertilizer.

The average grain yield in the two textural classes of soil was not influenced by the doses of pelleted organomineral. In the clayey texture, the dose of 40% of the organomineral was lower than the control with mineral fertilizer.

The use of phosphate organomineral is as efficient as the mineral for supplying phosphorus.

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