International Journal of Recycling of Organic Waste in Agriculture (2022) 11: 355-362
Doi: 10.30486/IJROWA.2021.1918036.1172

ORIGINAL RESEARCH

Organic fertilizer produced from chicken carcasses on soybean production

Willian Silva Melo[1], Natalia Pereira[2*], Edna Aparecida de Andrade[1], Reginaldo Ferreira Santos[1], Luiz Antônio Zanão Júnior[3]

Received: 16 December 2020 / Accepted: 05 October 2021 / Published online: 14 June 2022

Abstract

Purpose The objective of this study was to evaluate soybean production and nutrient availability in the soil using doses of organic fertilizer formed from chicken carcasses, compared to the use of mineral fertilizer.

Method The evaluated treatments, produced from chicken carcasses, were calculated to provide 0, 30, 60, 90, 120 kg ha^{-1} of P_2O_5, that is, 0; 3.37; 6.71; 10.11 and 13.48 t ha^{-1}, respectively. We also evaluated an additional treatment, in which 60 kg ha^{-1} of P_2O_5 were applied, through 400 kg ha^{-1} of NPK 10-15-15; this was carried out in a rural area located in the municipality of Ubiratã, Western Paraná. After harvest, the plant production components of soybean were evaluated, as well as the P content in the soil. The data were submitted to analysis of variance (ANOVA). The effect of the organic compost doses was evaluated by regression analysis and the additional treatment was compared by contrast analysis.

Results The use of organic compost doses based on chicken carcass in soybean cultivation resulted in linear increase in plant height, number of pods per plant, thousand grain weight productivity and oil content in the grains. It was also efficient in increasing P levels of the soil. Compared to mineral fertilizer, the use of organic compost resulted in greater amount of P available in the soil but had a lower productivity.

Conclusion Organic fertilizer from chicken carcass was able to increase the production components of soybean as well as to increase the soil P availability.

Keywords Phosphorus availability, Organic waste, Poultry farms, *Glycine max*

Introduction

Soybean (*Glycine max* (L.) Merrill) is one of the most important cultivated oilseeds in the world, and one of the leading agricultural commodities of Brazil. In the 2018/19 crop, it presented average productivity of 3168 kg ha^{-1}, with a production of more than 113 million tons. Soybeans are such a relevant crop in the country due to the level of technology involved in production, with emphasis on soil management and fertilization. Cultivated practically throughout the national territory, the Brazilian soybean presents, in some regions such as Western Paraná, higher averages than those obtained by its North American counterpart. According to the National Supply Company (CONAB) (2019), Paraná state is the second largest producer of soybeans in Brazil with 11.8 million tons of grains with productivity averages of 3200 kg ha^{1} (CONAB 2019).

To ensure maximum productivity of soybeans, it is essential to properly supply the nutrients during cultivation, through soil fertilization, which is usually done with mineral fertilizers. However, in recent decades, with the scarcity of these non-renewable resources plus the increase in fertilizers cost, alternatives have become necessary.

In addition to the high cost, one of the great limitations of mineral fertilizer use in tropical soils is the low efficiency in providing phosphorus (P), due to

✉ Natalia Pereira
pe.nataliaa@gmail.com

[1] Western Paraná State University, Department of Energy Engineering in Agriculture, Cascavel, Paraná, Brazil
[2] Western Paraná State University, Department of Agricultural Engineering, Cascavel, Paraná, Brazil
[3] Rural Development Institute of Paraná, Department of Soil Science, Santa Teresa do Oeste, Paraná, Brazil

the high absorption of this element into the soil matrix. An organic source of nutrients is an alternative to mineral fertilizers, as the addition of organic compost in the soil, to prevent P fixation and increase its solubility by biocycling organic phosphates (Santos et al. 2008).

Organic fertilizers are an option mainly in regions with high production of poultry and pigs, where it is possible to take advantage of both manure and carcasses, as well as for their value in relation to mineral fertilizer. Moreover, the use of organic compost allows the correct disposal of this waste, avoiding environmental impacts (Liégui et al. 2021).

Brazil generates more than 13 million tons of chicken carcass annually; the state of Paraná leads the ranking of chicken slaughter, with 31.7% of the national share (IBGE 2018). The composting of animal carcasses is not only an efficient practice for soybean fertilization, but also represents an environmentally safe destination.

Correct conducted composting does not cause air or water pollution, allowing management to avoid the formation of odors, destroying agents that cause diseases, and providing as a final product an organic compost that can be used in the soil. This way, it is possible to reinsert this residue in the agro-industrial production chain in a fair competition with any other carcass disposal system that seeks effectiveness (Paiva et al. 2012).

Its use as fertilizer can increase the organic matter content of the soil, potentially improving its physicochemical properties and increasing crop productivity (Orrico Júnior et al. 2010; Cestonaro et al. 2014; Yang et al. 2017). In addition, by incorporating organic elements into the soil, greater efficiency is obtained in the use of phosphorus, as well as prevention of nitrogen losses through the volatilization of ammonia.

However, it is necessary to respect agronomic criteria that ensure good agricultural productivity and soil preservation. Thus, the use of this compost in the soil needs to be studied, to recommend the appropriate dose of chicken carcass to the different production systems. To date, little information is documented on the efficiency of this compost in affecting nutrient availability in the soil and large crops productivity.

Therefore, the objective of this study was to evaluate the soybean production and the nutrient availability in the soil using doses of organic fertilizer formed from chicken carcasses, compared to the use of mineral fertilizer.

Material and methods

The experiment was conducted in the rural area located in the municipality of Ubiratã, Paraná state, in the crop of the agricultural year 2018/2019. Geographical coordinates are 24°27’17.00” S and 53°3’28.34” W and 415 m of altitude. The soil of the area is classified as distroferric Red Latosol (dfRL) (Santos et al. 2014) equivalent to the Rhodic Hapludox of the USDA soil classification (Soil Survey Staff 2010) of clayey texture.

Prior to experiment conduction, the area had been cultivated for at least 10 years with the succession of soybeans followed by corn as the second crop in no-tillage system and using mineral fertilizers as the main source of P for the plants. Before the soybean implantation, soil samples were collected at a depth of 0-20 cm and sent for chemical analysis. The results are presented in Table 1.

Table 1 Initial soil chemical analysis of the area in which the experiment was conducted collected in 2019

pH	P	C	K	Ca	Mg	Al	H+Al	V
$CaCl_2$	mg dm^{-3}	g dm^{-3}	---------------------- $cmol_c$ dm^{-3} -------------------------					%
4.80	6.39	25.65	0.75	6.31	1.19	0.05	6.21	57

Extrator: P and K (HCl 0.05 mol L^{-1} + H_2SO_4 mol L^{-1}); Al, Ca, Mg = (KCl 1 mol L^{-1})

The evaluated treatments consisted of five doses of fertilizer produced from chicken carcasses, calculated to provide 0, 30, 60, 90, 120 kg ha^{-1} of P_2O_5, that is, 0; 3.37; 6.71; 10.11; and 13.48 t ha^{-1}, respectively. An additional treatment was also evaluated in which 60 kg ha^{-1} of P_2O_5 were applied, through 400 kg ha^{-1} of the mineral fertilizer NPK 10-15-15. Table 2 shows the quantities of fertilizers applied (treatments) and the quantity of P_2O_5 provided in each of them.

The experimental design was carried out based on randomized blocks, with five replications. Each plot had 46 m^2 (4.6 × 10 m) and a space between the blocks of 4 m.

Table 2 Description of the treatments evaluated, doses applied and quantities of P_2O_5 provided in each plot. Ubiratã - PR, 2019

Treatment	Dose ($t\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)
	0	0
	3.37	30
Chicken carcass	6.74	60
	10.11	90
	13.48	120
NPK 10-15-15	400 $kg\ ha^{-1}$	60

The organic fertilizer used in the experiment was obtained from composting carcasses of chickens routinely slaughtered in the property's aviaries. The chicken carcasses were grinded in compost accelerator equipment in order to facilitate decomposition. For every 15 kg of chicken, 18 L of sawdust were also added so that the equipment conducted the mixing and homogenization. The organic fertilizer was used after 60 days of composting. Right after coming out of the compost accelerator, it was chemically analyzed, as Table 3 shows.

Table 3 Results of the chemical analysis of the organic compost produced from chicken carcasses in the compost accelerator used in the experiment

Element	Content
…………..$g\ kg^{-1}$…………	
Nitrogen	24.10
Phosphorus	3.69
Potassium	6.00
Calcium	6.85
Magnesium	0.65
Sulphur	2.74
Organic carbon	561.00
Organic matter	965.00
……………$mg\ kg^{-1}$……………..	
Copper	13.00
Zinc	38.00
Iron	1480.00
Manganese	56.50
Boron	6.97
Humidity	% 13.98
pH	6.70

The treatments with chicken carcass compost were applied by spreading over the soil before seeding, only once, 30 days before sowing. The mineral fertilizing with NPK was applied to the sowing furrow.

The planting date was in August 2019, the desiccation of the area was carried out, followed by the sowing with a seeder of 9 traction lines, with a spacing of 0.45m and an amount of 330 thousand plants per hectare. The selected cultivar was NA-5909 RG, of early cycle and indeterminate growth habit, which is one of the most cultivated in Western Paraná.

When the plants were in the R8 phenological stage, ten plants were randomly selected in each plot for height measuring, with a graduated ruler, from the soil to the pointer, and determination of pod count per plant.

The soybeans present in the usable area of each parcel were harvested on January 20, 2020. The considered usable area were the two central lines of 5 m in each plot. The harvested plants were manually screened and stored in bags.

Then the pods were threshed for grain separation, which had their mass quantified to calculate grain yield, in $kg\ ha^{-1}$, with humidity corrected to 13%. One thousand grain mass was determined on a precision digital scale of 0.01g, with water content of the grains corrected to 13% and four repetitions per experimental unit.

The oil content analysis in the soybeans was carried out at the Federal University of Paraná (UFPR) by nuclear magnetic resonance (NMR). For the analysis of the oil content by NMR, a 100 g grain sample was evaluated, taken at random from the total produced in a plot. An average of 20% oil in the soybean seeds was considered by the Ascend 600 MHz (14.1 T) NMR Spectrometer.

Three soil sub-samples were collected between the soybean lines, after harvesting, in the usable area of the plots, to form a composite sample. The soil samples were collected at a depth of 0-20cm. After collection, the samples were sent to the laboratory for determination of P-levels, with Mehlich-1 extractor, according to the methodology described by the Brazilian Agricultural Research Corporation (Embrapa) (2011).

The data were submitted to analysis of variance (ANOVA). The effect of the organic compost doses was evaluated by regression analysis, being selected the mathematical models that presented better significance level and higher coefficient of determination (R^2). The effect of the additional treatment was compared by contrast analysis with the 6.74 $t\ ha^{-1}$ dose of compost since both provided 60 $kg\ ha^{-1}$ of P_2O_5 for the plants. Statistical analyses were performed using the Assistat software (SILVA and Azevedo 2016).

Results and Discussion

The variables plant height, number of pods per plant, one thousand grain weight, grain yield, oil content, and P content in soybeans obtained significant results as a linear regression response, as a function of the chicken carcasses compost doses applied to the soil (Fig. 1).

The P content in the soil increased in a positive linear way with the increase of compost doses, ending between 11 and 19 mg dm^{-3} (Fig. 1A). Studies have shown that the addition of animal residues to the soil has been efficient in increasing its P content (Diacono and Montemurro 2010; Faria et al. 2020).

Phosphorus is the second macronutrient that most limits the development of crops, in addition to being the least mobile nutrient in the rhizosphere (Gassner and Schnug 2020). Despite being present in high amounts in the soil, much of it is unavailable for absorption by plants since it forms insoluble complexes with cations in acidic and alkaline conditions. As a result, a large amount of inorganic phosphate fertilizers have been applied to sustain agricultural production systems (Ali et al. 2019).

Organic fertilization, in addition to being efficient in increasing the readily available P content in the soil, is the most sustainable way to recover soil fertility (Scotti et al. 2015a). This practice is related to increased fertility, as it increases the CEC values and organic carbon content, in addition to increasing the solubility of P, which becomes available in greater quantities to plants (Scotti et al. 2015b).

According to the Manual of Fertilizing and Liming for the State of Paraná, P levels between 10 and 24 mg dm^{-3} are considered high in clayey soils (NEPAR-SBCS 2017), such as the soil of this study. Levels of P higher than 24 mg dm^{-3} are considered very high, but only levels higher than 60 mg dm^{-3} represent a condition to avoid (NEPAR-SBCS 2017). However, despite high capacity of clay soils for P fixation – such as the Oxisol, mainly due to its weathering , when there is an increase of this element, the colloids absorption capacity can be exceeded, leaving part of it available in the soil solution (Bedin et al. 2003).

For the variable plant height, the fertilization with chicken carcass organic compost in the soil provided a difference between the doses used. Doses higher than 12 t ha^{-1} resulted in higher plants, adjusting to the linear regression model (Fig. 1B), reaching a 68.8 cm average value with the highest dose. Doses between 6 and 12 t ha^{-1} presented similar heights (around 63 cm).

The absence of nutrients in the soil can reduce the height of plants, with pod formation occurring very close to the soil, thus harming mechanized harvesting. Plants with heights between 60 and 120 cm are considered suitable for this process (Ribeiro et al. 2017). Therefore, increasing doses of chicken carcass compost resulted in positive effect for plant height.

The linear increase observed in plant height in response to the application of increasing doses of organic compost is due to the increase in nutrients availability in the soil, notably P. This behavior was similar to that found by Siavoshi et al. (2010) using organic compost in rice cultivation.

Usually the greater P and N availability for soybean plants promote greater growth and formation of new vegetative parts (Xu et al. 2020), which is also reflected in the greater production of pods per plant.

It was found as an effect of organic compost doses for the number of pods. This variable was significantly affected by the compost doses, increasing linearly with the addition of doses (Fig. 1C). This result indicates that the compost had a significant positive effect and the highest dose used resulted in 58 pods per plant, on average. Onyenali et al. (2020) also obtained a higher number of pods per plant in soybean cultivation with organic fertilizer from animal waste.

The supply of adequate doses of phosphorus, from the beginning of plant development, stimulates root development, is important for the formation of the early reproductive parts, is essential for the good formation of fruits and, in general, increases production in crops such as soybean (Malhotra et al. 2018).

In legumes, nutrient deficiency, especially of P, reduces yield potential by resulting in lower flower and pod production and lower seed production (Ventimiglia et al. 1999; Zucareli et al. 2006). It was observed that the plants responded better to the elements present in the chicken carcasses compost by assimilating the nutrients derived from it and stimulating the formation of pods. Soybean production is associated with the variation in the number of seeds as a function of the number of pods per plant. There is a highly positive and significant association between the number of pods per plant and grain productivity (Ikeogu and Nwofia 2013).

Grain yield increased linearly with increasing compost doses (Fig. 1D). The highest dose provided an average yield of 4092 kg ha^{-1}. According to Lana et al. (2003), there is a direct relationship between soil fertility and soybean productivity, being directly dependent on the available concentration of P in the soil solution. Therefore, the organic compost was efficient in providing the primordial nutrients for soybean production, thus resulting in high grain productivity.

In a work conducted in the Cerrado biome, during three soybean harvests, Leite et al. (2017) found that increasing doses of phosphorus positively influenced grain productivity. They also verified that in periods of water deficit, only the height of plants responds to P doses, a fact not corroborated by our study.

Global productivity depends on a healthy and fertile soil and most soils in the world do not have the capacity to provide sufficient P, often leading to low grain productivity (Ali et al. 2019). Thus, using organic fertilizers brings several benefits for the improvement of soil quality and, consequently, for the development and productivity of crops.

Regarding the one thousand grain mass, we also verified the effect of organic compost doses. This variable was significantly affected, as it was linearly higher as doses increased (Fig. 1E). The increase of this parameter followed by the application of organic compost in the soil has been reported for soybeans in several research (Onyenali et al. 2020; Yagoub et al. 2012). The good development of soybeans in the treated plots may be due to the supply and availability of nutrients necessary for the assimilate partitioning for the various structural plant components.

Increasing doses of organic compost affected the oil content in soybeans in a positive and linear way (Fig. 1F). Soybean seed quality is greatly influenced by nutrient availability, with P having a positive impact on the oil content of the grains (Win et al. 2010). Significant effects on oil content were observed with different levels of P in soybean cultivation (Malik et al. 2006). In this sense, the necessary supply of P for a good production of oil in soybeans can be supplied with the contribution of chicken carcass organic compost.

Comparisons were made, by contrast analysis, between the additional treatment in which 60 kg ha^{-1} of P_2O_5 were provided, through 400 kg ha^{-1} of the formulated NPK mineral 10-15-15, with the treatment in which the same amount of P_2O_5 was provided through 6.74 t ha^{-1} of chicken carcass based organic compost. Table 4 shows the results.

Phosphorus supply in the soil, via organic compost, resulted in taller plants and greater number of pods per plant. The organic compost also resulted in a higher P content in the soil compared to the use of mineral fertilizer. However, higher grain yield was observed with the use of mineral fertilizer. There was no significant difference between the oil content of the grains and the thousand grain mass between the treatments. But even no difference was observed for these variables, the use of chicken carcass can make available more P in soil and turn the production system more sustainable.

Nevertheless, it is important to mention that excessive levels of P in soils can cause an antagonisms effect for boron (B) and zinc (B), both essential micronutrients to the crops (Aboyeji et al. 2020) and could damage the soil fertility and soybean production. However, this effect was not verified, since the higher P content observed in this study was below to the critic level (> 60 mg dm^{-3}) that should be avoided (NEPAR-SBCS 2017).

Agricultural soils usually have limited amount of organic matter; and the application of organic fertilizer stimulates the growth of microorganisms that increase the amount of P in the soil; this, along with carbon and nitrogen, serves as the main energy source for microbial mineralization (Demoling et al. 2007).

In this study, the application of phosphorus from organic compost probably provided readily available substrate for the microbial community, which acts on

Table 4 Plant height, pods per plant, productivity, thousand grain mass and oil content in soybeans (NA-5909 RG) and P content in the soil as a function of the sources of fertilization

Measured parameters	t ha^{-1} compost 6.74	kg ha^{-1} of NPK 10-15-15 400
Height of plants, cm	a 66.00	b 56.83
Pods per plant	a 44.50	b 34.16
Productivity, kg ha^{-1}	b 3108	a 3900
Thousand grain mass, g	a 125.8	a 125.4
% ,Oil content	a 20.45	a 20.85
P content in the soil, mg dm^{-3}	a 27.27	b 15.12

Equal letters on the lines do not differ significantly by the T-test at 5% significance.

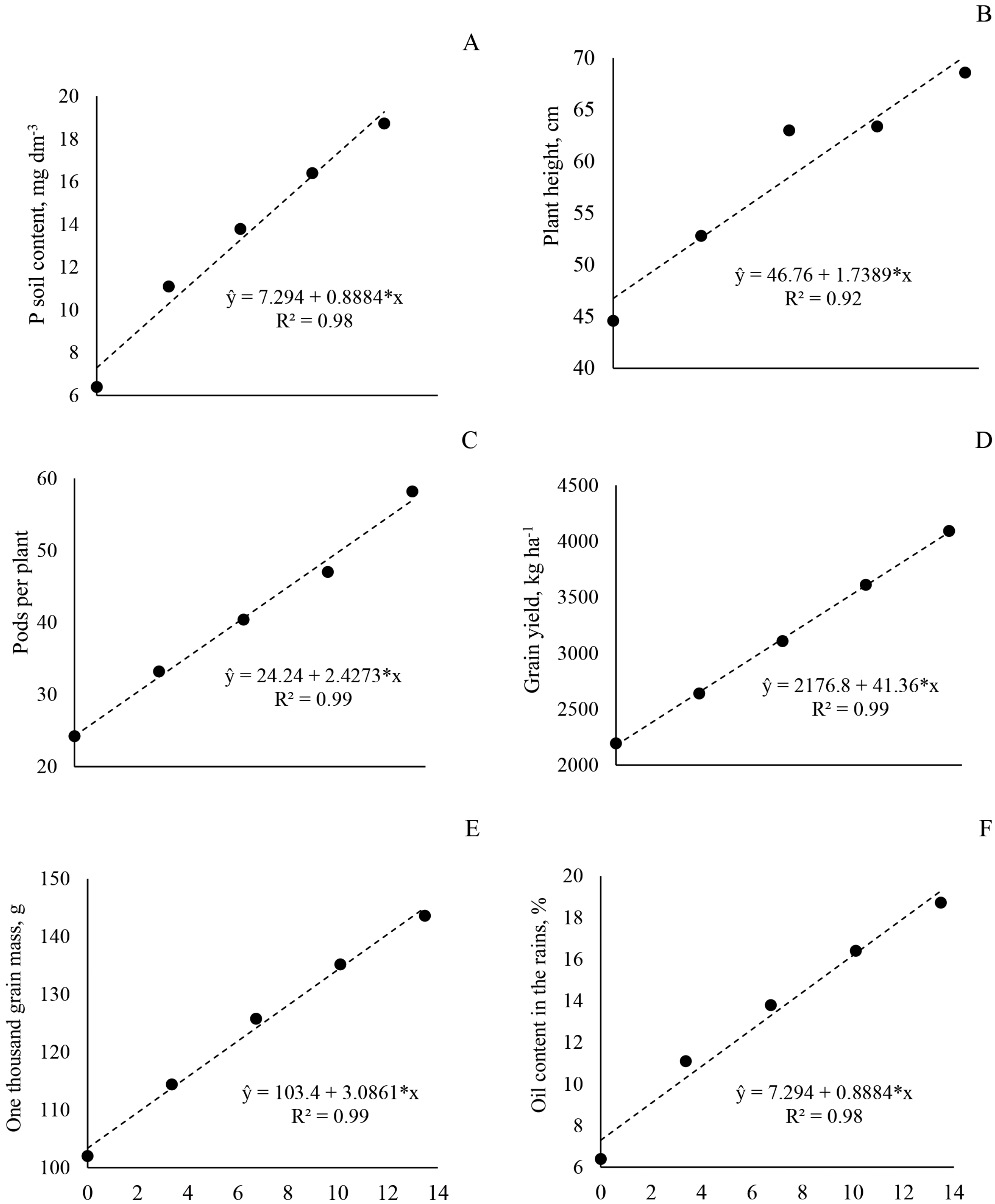

Fig. 1 Phosphorus content in the soil (A); plant height (B), number of pods per plant (C), grain yield (D), one thousand grain mass (E) and oil content in the grains (F) of the soybean crop
(NA-5909 RG) as a function of the chicken carcasses compost doses. * = significant to 5 % by F test.

phosphorus solubilization. The application of inorganic phosphate may have resulted in its fixation in colloids, with only part of it available in the soil solution.

Although the organic compost at the dose of 6.74 t ha^{-1} resulted in taller plants and greater number of pods, the higher productivity was achieved with the application of mineral fertilizer. However, higher yields can be achieved with higher doses of the compost (10.11 and 13.48 t ha^{-1}), without losses to other plant components.

Conclusion

The use of chicken carcass based organic compost at a dose of 6,74 t ha^{-1} in soybean cultivation resulted in increases for plant height, number of pods per plant, thousand grain mass, productivity, and oil content in the grains. It was also efficient in increasing soil P levels. Compared to mineral fertilizer, the use of organic compost to provide the same P amount resulted in greater content of P available in the soil, but 20% lower productivity.

Compliance with ethical standards Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

References

Aboyeji CM, Dunsin O, Adekiya AO, Suleiman KO, Chinedum C, Okunlola FO, Joseph A, S. Ejue SW, Adesola OO, Olofintoye TAJ, Owolabi IO (2020) Synergistic and antagonistic effects of soil applied P and Zn fertilizers on the performance, minerals and heavy metal composition of groundnut. Open AgI 5(1):1-9

Ali W, Nadeem M, Ashiq W, Zaeem M, Gilani S, Rajabi-khamseh S, Pham TH, Kavanagh V, Thomas R, Cheema R (2019) The effects of organic and inorganic phosphorus amendments on the biochemical attributes and active microbial population of agriculture podzols following silage corn cultivation in boreal climate. Scient Rep 9:17297. https://doi.org/10.1038/s41598-019-53906-8

Bedin I, Resende AV, Furtini Neto AE, Mendonça LA, Vilela LCS (2003) Phosphorus sources and maize growth in soils under differents phosphate buffer capacity. Cienc Agrotec 1:1522-1531

Cestonaro T, Abreu PG, Abreu VMN, Lopes LS, Coldebella A (2014) Poultry carcass decomposition and physicochemical analysis of compounds in different Composter types. Eng Agr 34:617-625. https://doi.org/10.1590/S0100-69162014000400002

CONAB–National Supply Company (2018/2019) Crop. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

Demoling F, Figueroa D, Bååth E (2007) Comparison of factors limiting bacterial growth in different soils. Soil Biol Biochem 39:2485–2495. https://doi.org/10.1016/j.soilbio.2007.05.002

Diacono M, Montemurro F (2010) Long-term effects of organic amendments on soil fertility. A review. Agron Sustain Dev 30:401-422. https://doi.org/10.1051/agro/2009040

EMBRAPA – Brazilian Agricultural Research Corporation (2011) Soil analyses methods guide. 2.ed. Rio de Janeiro: Embrapa Solos

Faria MR, Guimarães RA, Pinto FAMF, Siqueira CS, Silva CA, Medeiros FHV, Bettiol W (2020) Contribution of organic amendments to soil properties and survival of *Stenocarpella* on maize stalk. Sci Agric 77:e20180289. https://doi.org/10.1590/1678-992x-2018-0289

Gassner A, Schnug E (2020) Agricultural soils: Phosphorus. Managing soils and terrestrial systems. (2nd ed., p. 7). London: CRC Press

IBGE–Brazilian Institute of Geography and Statistics. IBGE Indicators: Livestock production statistics. https://biblioteca.ibge.gov.br/visualizacao/periodicos/2380/epp_2018_4tri.pdf

Ikeogu UN, Nwofia GE (2013) Yield parameters and stability of soybean [*Glycine max*. (L.) Merril] as influenced by phosphorus fertilizer rates in two ultisols. J Plant Breed Crop Sci 5:54-63

Lana RMQ, Vilela Filho CE, Zanão Júnior LA, Pereira HS, Lana AMQ (2003) Adubação superficial com fósforo e potássio para a soja em diferentes épocas em pré-semeadura na instalação do sistema de plantio direto. Sci Agr 4:53-60. http://dx.doi.org/10.5380/rsa.v4i1.1066

Leite RC, Carneiro JSS, Freitas GA, Casali ME, Silva RR (2017) Phosphate fertilization in soybean during three consecutive harvests in the new Brazilian agricultural frontier. Sci Agr 18:28-35. http://dx.doi.org/10.5380/rsa.v18i4.50310

Liégui GS, Cognet S, Djumyom GVW, Atabong PA, Fankem NJP, Chamedjeu RR, Temegne CN, Noumsi Kengne IM (2021) An effective organic waste recycling through vermicomposting technology for sustainable agriculture in tropics. Int J Recycl Org Waste Agric 10:203-214. http://dx.doi.org/10.30486/ijrowa.2021.1894997.1080

Malhotra H, Vandana SS, Pandey R (2018) Phosphorus nutrition: Plant growth in response to deficiency and excess. In Hasanuzzaman M, Fujita M, Oku H, Nahar K, Hawrylak-Nowak B (eds) Plant Nutrients and Abiotic Stress Tolerance. Springer, Singapore. https://doi.org/10.1007/978-981-10-9044-8_7

Malik MFN, Qureshi AS, Ashraf M, Ghafoor A (2006) Genetic variability of the main yield related characters in soybean. Inter J Agri Biol 8:815-819

NEPAR-SBCS. Brazilian Society of Soil Science – Paraná State Nucleus (2017) Fertilization and liming manual for the state of Paraná. Curitiba: NEPAR-SBCS

Onyenali T, Olowe V, Fabunmi T, Soretire A (2020) Organic fertilizers improve the growth, seed quality and yield of newly released soybean (*Glycine max* (L.) Merrill) varieties in the tropics. Org Agr 10:155-170. https://doi.org/10.1007/s13165-019-00258-2

Orrico Júnior MAP, Orrico ACA, Lucas Júnior J (2010) Waste composting of poultry production: Poultry litter and carcass. Eng Agr 30:538-545.

http://dx.doi.org/10.1590/S0100-69162010000300017

Paiva ER, Matos AT, Azevedo MA, Barros RTP, Costa TDR (2012) Assessment of the composting of poultry carcasses by bin methods and aerated static piles. Eng Agr 32:961-970. http://dx.doi.org/10.1590/S0100-69162012000500015

Ribeiro ABM, Bruzi AT, Zuffo AM, Zambiazzi EV, Soares IO, Vilela NJD, Pereira JLAR, Moreira AG (2017) Productive performance of soybean cultivars grown in different plant densities. Ciênc Rural 47:e20160928. http://dx.doi.org/10.1590/0103-8478cr20160928

Santos DR, Gatiboni LC, Kaminski J (2008) Factors affecting the phosphorus availability and the fertilization management in no-tillage system. Ciênc Rural 38:576-586. https://doi.org/10.1590/S0103-84782008000200049

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lubreras JF, Coelho MR, Almeida JA, Araujo Filho JC, Cunha TJF, Oliveira JB (2014) Brazilian soil classification system (4th ed., p. 376). Brasília: Embrapa

Scotti R, Bonanomi G, Scelza R, Zoina A, Rao MA (2015a) Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. J Soil Sci Plant Nutr 15:333-352. http://dx.doi.org/10.4067/S0718-95162015005000003

Scotti R, D'ascoli R, Gonzalez Caceres M, Bonanomi G, Sultana S, Cozzolino L, Scelza R, Zoina A, Rao MA (2015b) Combined use of compost and wood scraps to increase carbon stock and improve soil quality in intensive farming systems. Euro J Soil Sci 66:463-475. https://doi.org/10.1111/ejss.12248

Siavoshi M, Nasiri A, Lawre S (2010) Effect of organic fertilizer on growth and yield components in Rice (*Oryza sativa* L.). The J Agri Sci 3:217-224. http://dx.doi.org/10.5539/jas.v3n3p217

Silva FAS, Azevedo CAV (2016) The Assistat Software version 7.7 and its use the analysis of experimental data. African J Agri Res 11:3733-3740. http://dx.doi.org/10.5897/AJAR2016.11522

Soil Survey Staff (2010) Keys to soil taxonomy (11th ed., p. 338). Washington,DC:USDA/NRCS

Ventimiglia LA, Costa JÁ, Thomas AL, Pires JLF (1999) Soybean yield potential influenced by soil phosphorus content and row spacing. Pesq Agropec Bras 34:195199. https://doi.org/10.1590/S0100-204X1999000200007

Win M, Nakasathien S, Sarobol E (2010) Effects of phosphorus on seed oil and protein contents and phosphorus use efficiency in some soybean varieties. Kasetsart J Nat Sci 44:1-9

Xu F, Chu C, Xu Z (2020) Effects of different fertilizer formulas on the growth of loquat rootstocks and stem lignification. Sci Rep 10:1033. https://doi.org/10.1038/s41598-019-57270-5

Yagoub SO, Ahmed WMA, Mariod AA (2012) Effect of urea, NPK and compost on growth and yield of soybean (*Glycine max* L.), in semi-arid region of Sudan. ISRN Agron 2012:678124. https://doi.org/10.5402/2012/678124

Yang X, Lu K, Mcgrouther K, Che L, Hu G, Wang Q, Liu X, Shen L, Huang H, Ye Z, Wang H (2017) Bioavailability of Cd and Zn in soils treated with biochars derived from tobacco stalk and dead pigs. J Soil Sed 17:751-762. https://doi.org/10.1007/s11368-015-1326-9

Zucareli C, Ramos Junior EU, Barreiro AP, Nakagawa J, Cavariani C (2006) Phosphorus fertilization, production components, productivity and seed physiological quality in common beans seeds. Rev Bras Sementes 28:915. https://doi.org/10.1590/S0101-31222006000100002