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Original Article

Organic fertilization in soybean cultivation and forage grown in succession

Adubação orgânica na cultura da soja e de forrageira cultivada em sucessão

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Abstract

Organic fertilization can significantly increase productivity in crop-livestock integration systems, by improving soil quality. To investigate this, the study evaluated the effects of organic sources on Urochloa hybrid 'BRS Ipyporã' grown after soybeans in an air-conditioned greenhouse. Using a randomized block design, 10 treatments were established in a factorial scheme (2x5). The first factor consisted of two types of soil, with and without a history of application of swine manure, incorporated into five types of substrates: mineral fertilizer, Uberlândia compost, Rio Verde compost, poultry litter, and swine manure, with five replications. While soybean plants exhibited no treatment effects on plant height, leaf number, photosynthetic rate, transpiration rate, stomatal conductance, ratio between internal and external CO_2 concentrations, instantaneous water use efficiency, intrinsic water use efficiency, chlorophyll *a* and chlorophyll *b*, those grown in manure-historied soils treated with Rio Verde compost produced higher dry mass of leaves, stems, and total biomass. Conversely, forage plants thrived in soils without a history of manure application, demonstrating greater stem, root, and total dry mass. Soils with a history of swine manure application exhibited higher concentrations of phosphorus, copper, and zinc. Additionally, the enzymes arylsulfatase, β-glucosidase, and acid phosphatase concentrations in the soil were significantly enhanced by the continuous application of swine manure over time.

Keywords: *Glycine max*, *Brachiaria*, forage yield, swine manure.

Resumo

A adubação orgânica pode aumentar significativamente a produtividade das culturas em sistemas de integração lavoura-pecuária, pela melhoria da qualidade do solo. Para investigar isso, foram avaliados neste trabalho os efeitos de fontes orgânicas no cultivo do híbrido Urochloa 'BRS Ipyporã' cultivada após a soja em casa-de-vegetação climatizada. O ensaio foi delineado em blocos casualizados e dez tratamentos foram arranjados em esquema fatorial (2x5). O primeiro fator foi composto por dois tipos de solo, com e sem histórico de aplicação de dejetos suínos, incorporados em cinco tipos de substratos: adubo mineral, composto de Uberlândia, composto de Rio Verde, cama de frango e dejeto de suínos, com cinco repetições. Embora as plantas de soja não tenham apresentado efeitos de tratamento na altura da planta, número de folhas, taxa fotossintética, taxa de transpiração, condutância estomática, razão entre concentrações internas e externas de CO_2, eficiência instantânea do uso da água, eficiência intrínseca do uso da água, clorofila *a* e clorofila *b*, aquelas cultivadas em solos com histórico de esterco tratados com composto Rio Verde produziram maior massa seca de folhas, caules e biomassa total. Por outro lado, as plantas forrageiras produziram maior massa seca de caule, raiz e total em solos sem histórico de aplicação de esterco. Solos com histórico de aplicação de dejetos suínos apresentaram maiores concentrações de fósforo, cobre e zinco. Além disso, as concentrações das enzimas arilsulfatase, β-glicosidase e fosfatase ácida no solo foram significativamente aumentadas pela aplicação contínua de dejetos suínos ao longo do tempo.

Palavras-chave: *Glycine m*ax, *Brachiaria*, rendimento de forragem, dejeto suíno.

1. Introduction

The growing demand for food, coupled with the expansion of agricultural areas, highlights the importance of proper soil and crop management. In this context, investigating sustainable practices for economically important crops, such as soybeans and forage used in cultivated pastures, becomes crucial, considering aspects such as photosynthesis, and the chemical and microbiological parameters of the soil (Skorupa and Manzatto, 2019).

Soybean cultivation plays a crucial role in the Brazilian agricultural landscape and represent the main commodity in integrated production systems, with an estimated

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production of 166.33 million tons of grains for the 2024/25 harvest (Brasil, 2025). Similarly, the beef market generated more than 7 million direct and indirect jobs and exported 2.29 million tons in 2023 (ABIEC, 2024). Integrating the two commodities is a significant strategy and can be optimized by early sowing of pastures with soybeans still in the field (Borghi et al., 2017).

In Brazil, the expansion and continued use of conservation management systems, such as no-tillage and crop-livestock integration, considering crops and forage grasses intercropped or crop rotation systems, was a fundamental milestone in the construction of a more biologically active and healthy soil environment (Mendes et al., 2020). Regarding the soil, the primary source of fertilization is mineral fertilizers, which are derived from non-renewable sources and are expensive. This presents the challenge of developing alternative and innovative technologies, such as the use of organic fertilizers.

In this context, the study evaluated the effects of organic sources on *Urochloa* hybrid 'BRS Ipyporã' grown after soybeans in an air-conditioned greenhouse.

2. Material and Methods

The experiment was conducted in a climate-controlled greenhouse at the Federal Institute of Goiás, Rio Verde Campus (IF Goiano - Campus Rio Verde), located in the municipality of Rio Verde-GO. The geographic coordinates of the site are 17° 49' 10.83" S latitude, 49° 12' 13.46" W longitude, and altitude of 901 m. The experiment was established with soybean cultivation followed by the cultivation of the forage crop *Urochloa* hybrid cv. BRS Ipyporã.

The treatments were arranged in a randomized block design with a 2 × 5 factorial scheme. The first factor consisted of two types of soil, with and without a history of swine manure application, combined with five types of substrates (Mineral fertilizer = MF; Uberlândia compost = UbC; Rio Verde compost = RVC; Poultry litter = PL; Swine manure = SM), with five replicates.

The soils were collected from the 0-20 cm layer of a Red Oxisols (USDA, 2022). The samples were taken from two adjacent plots from an agribusiness in the municipality of Rio Verde-GO, one with a history of swine manure application for over 10 years for corn production (geographic coordinates: 17° 36' 2" S latitude and 50° 51' 37" W longitude) and another without any history of animal manure application (geographic coordinates: 17° 36' 04" S latitude and 50° 51' 41" W longitude). After collection, the soil samples were broken up, sieved, weighed, and separated into plastic containers. A chemical analysis of the two soil types was conducted following the methodologies described in Teixeira et al. (2017) (Table 1).

Soil correction was performed to raise the base saturation (V%) to 70% for soybean cultivation. For that purpose, 3.37 g of nanoparticulate limestone was applied to the soil with a history of animal manure application, and 4.22 g of limestone was applied to the soil without a history of application. After liming, the samples were moistened and incubated for 20 days.

For the treatments, four sources of organic residue were used in both soil types: two raw sources (poultry litter and solid swine manure) and two composted sources (Uberlândia compost and Rio Verde compost). The composition of the organic fertilizers was as follows: Swine manure composed of 40% feces, 60% urine, residual water, leftover feed, and other materials; Poultry litter composed of wood shavings, rice husk, sawdust, feathers, excreta, and other materials; Rio Verde compost made from eggshells, ashes, sludge, restaurant waste, sugarcane bagasse or soybean husk, viscera, and poultry litter applied after 50 days of composting; and Uberlândia compost made from sludge, wood chips, poultry litter, restaurant waste, and swine manure.

For the control treatment, chemical fertilizer based on NPK was used, applying 80 kg of P_2O_5 and 80 kg of K_2O per hectare, equivalent to 0.666 g of K_2O and 1.904 g of superphosphate (P_2O_5) per pot. Plastic pots of 15 kg were used, with a standardized quantity of 10 kg of soil per pot. The spacing between pots was approximately 40 × 40 cm.

For the chemical analyses and enzyme activity measurements of arylsulfatase, β-glucosidase, and acid phosphatase, soil samples were collected on the day of soybean sowing (January 27, 2023) and at the end of the experiment, after the forage was cut (May 31, 2023). Soil samples of 200 g were collected for chemical analysis and 300 g for enzyme analysis. The soil was removed using a spatula and a knife. The samples were weighed on an analytical balance and stored in pre-labeled plastic bags. This procedure was the same on both dates.

Soil enzyme activity associated with the sulfur cycle (arylsulfatase), carbon cycle (β-glucosidase), and phosphorus cycle (acid phosphatase) were determined using the methods described by Tabatabai and Bremner (1970) and Eivazi and Tabatabai (1990). These methods are based on the colorimetric determination of p-nitrophenol released after incubating the soil with the specific substrate at 37 °C for 1 hour.

In the samples for chemical analysis, the following were quantified: pH in $CaCl_2$, cation exchange capacity (CEC), H + Al, base saturation (V%), calcium (Ca), magnesium (Mg), phosphorus (P), and the micronutrients: copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). These variables were determined using the methodology specified by Silva and Silva (2009).

The soybean cultivar used was CZ 37B43 IPRO - BASF AGRO, with indeterminate growth habit, medium cycle, high yield potential, and wide geographical adaptability. On the day of soybean planting, the seeds were inoculated and sown (six seeds per pot). After germination, thinning was performed, leaving two plants per pot. Soybean seed germination occurred five days after sowing, on February 1, 2023. At 21 and 56 days after emergence (DAE), plant height (PH) and the number of leaves (NL) per soybean plant were evaluated.

To control pests and diseases, fungicides and insecticides were applied to all treatments, using the following products and doses: 200 mL of water; 0.4 mL of Score Flexi® (propiconazole + difenoconazole); 0.4 mL of Privilege® (acetamiprid + pyriproxyfen); 0.15 mL of Intrepid® Edge

Table 1. Chemical attributes of the soils used in the experiment.

Soil	pH	OM	P	K	Ca	Mg	H + Al	SB	CEC	BS	Clay	Silt	Sand
		....g dm^{-3}.....		...............cmolc dm^{-3}.........................						%	......dag kg^{-1}.......		
MTS	5.4	26.4	26.05	34.0	1.92	0.82	1.52	2.83	4.35	65.1	24	8	68
US	5.0	27.8	6.03	59.0	1.34	0.73	1.57	2.22	3.79	58.6	18	8	74

MTS - Manure Treated Soil; US - Untreated Soil; pH - Hydrogen potential; OM - Organic matter; P - Phosphorus; K - Potassium; Ca - Calcium; Mg - Magnesium; H + Al - Potential acidity; SB - Sum of bases; CEC - Cation exchange capacity; BS - Base saturation.

(methoxyfenozide + spinetoram); 0.6 mL of Bio-imune® (Bacillus subtilis BV02, minimum of 3×10^9 CFU mL^{-1}). Manual control of caterpillars was also performed. Additionally, fertilizers were applied as a top dressing to all plants, consisting of a mixture containing: nitrogen (15%), phosphorus (5%), potassium (5%), calcium (2%), magnesium (2%), sulfur (8%), boron (0.1%), copper (0.1%), iron (0.3%), manganese (0.1%), molybdenum (0.005%), and zinc (0.2%) at a dose of 150 g m^{-2}. Throughout the crop cycle, the pots were irrigated to maintain moisture near field capacity.

At the onset of flowering, on March 3, 2023, assessments related to gas exchange were carried out. The evaluations obtained by analyzing the central leaflet of the youngest fully expanded leaf were carried out between 8 am and 11 am, without the presence of clouds, using an infrared gas analyzer (IRGA; LI6800xt, Li-Cor, Lincoln, NE, USA) under density constant photosynthetic photon flux (1500 µmol m^{-2} s^{-1}), CO_2 concentration in the chamber 400 µmol CO_2 mol^{-1} air, vapor pressure deficit of approximately 1.0 kPa, constant temperature (25 °C) and constant relative humidity (50%). Stomatal opening was maximized using irradiance of 1000 µmol photons m^{-2} s^{-1} with 10% blue light. Gas exchange was evaluated to obtain the photosynthetic rate (A - µmol CO_2 m^{-2} s^{-1}), transpiration rate (E - mmol H_2O mol m^{-2} s^{-1}), stomatal conductance (g_{sw} - mol H_2O m^{-2} s^{-1}) anda ratio between internal and external CO_2 concentrations (Ci/Ca ratio). The values of A, E and gs were used to calculate the instantaneous (A/E) and intrinsic (A/gs) water use efficiency (WUE). A ClorofiLOG CFL1030 was used to obtain chlorophyll a and chlorophyll b. Chlorophyll was confirmed in the same leaf where gas exchange was determined. The same physiological evaluations were repeated at soybean harvest, at 56 days after emergence.

On March 29, 2023, when the soybeans were at the grain-filling stage, following physiological, PH, and NL evaluations, harvesting was conducted. The following were evaluated per plant of: (i) leaf dry mass (LDM); (ii) pod dry mass (PDM); (iii) stem dry mass (SDM); and (iv) total dry mass (TDM) of soybean plants. For dry mass evaluation, the samples were placed in an oven at 65 °C until constant mass was reached, approximately 72 hours, and then weighed on an analytical balance.

The forage used was the hybrid BRS RB331 Ipyporã, a cultivar of *Urochloa* resulting from a cross between *U. ruziziensis* and *U. brizantha*. This forage is an alternative for diversifying areas and is adapted to soils of medium fertility. BRS Ipyporã was planted on March 31, 2023, in the same pot previously cultivated with soybeans, with the soybean root system still present. The forage emerged from April 7, 2023. Fifteen seeds were planted per pot, with thinning between the first and second tillers, leaving one plant per pot.

Fertilizers were applied to all pots, the same as those applied to soybeans, with the addition of nitrogen at a dose of 0.454 g of N per pot, applied as urea. Throughout the cycle, the pots were irrigated daily.

Sixty days after sowing, the same physiological evaluations mentioned earlier for soybeans were performed. On the same date, the forage had an average height of over 40 cm, and cutting was carried out. On the day of cutting, the following evaluations were performed: (i) plant height (PH), (ii) number of tillers (NT), (iii) number of leaves (NL), (iv) leaf dry mass (LDM); (v) stem dry mass (SDM); (vi) root dry mass (RDM); and (vii) total dry mass (TDM). For dry mass evaluation, the samples were placed in an oven at 65 °C until constant mass was reached, approximately 72 hours, and then weighed on an analytical balance.

The data obtained were subjected to analysis of variance using the F-test and Tukey's test. The level of significance used in the tests was 5%. For the variables arylsulfatase, β-glucosidase, and acid phosphatase, the data were transformed using the square root (x) for analysis. The statistical program used was SISVAR (Ferreira, 2019).

3. Results and Discussion

The values of PH, NL and PDM for soybean plants are presented in Table 2. No effects were observed for interaction or isolated factors in the evaluations conducted at 28 and 56 DAE (Table 2). However, these results differ from Pacheco et al. (2024), who evaluating the productive capacity of *Crambe abyssinica* in response to fertilization levels and soil correction in a medium-textured Yellow Oxisols, observed higher values for plant height, number of leaves, and fresh shoot mass of the cambre plants, when fertilized with organic manure.

LDM, SDM, and TDM showed differences ($p \leq 0.05$) for the interaction between the historical factors of manure application (Table 3). In the soil with swine manure application, the UbC compound showed lower LDM. In soil without a history of swine manure application, the RVC compound showed lower LDM, SDM and TDM values. Higher values in soils with manure application may be a result of the levels of nutrients present in soils

Table 2. Plant height (PH) and number of leaves (NL) at 28 and 56 days after emergence (DAE) and pod dry mass (PDM) per plant, at 56 DAE of soybeans grown in a greenhouse, as a function of each treatment.

Treatments[1]	PH (cm)		NL		PDM
	28 DAE	56 DAE	28 DAE	56 DAE	(g)
			Soil with a history of swine manure application		
MF	37.00^{ns}	56.20^{ns}	8.10^{ns}	15.30^{ns}	8.68^{ns}
UbC	34.70	52.90	7.50	16.20	6.97
RVC	42.30	60.40	9.90	19.20	9.77
PL	38.30	61.00	8.50	18.80	8.32
SM	36.00	53.00	8.40	15.90	6.55
			Soil without a history of swine manure application		
MF	37.70^{ns}	53.90^{ns}	8.10^{ns}	16.00^{ns}	6.18^{ns}
UbC	36.10	59.80	7.20	17.00	7.39
RVC	36.70	53.30	7.30	13.70	6.02
PL	38.40	59.90	9.80	18.50	7.69
SM	34.10	54.60	7.20	17.40	5.99
CV (%)	13.45	15.01	19.83	19.79	28.27

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - Poultry litter; SM - Swine manure; ns - no significance (p > 0.05); CV - Coefficient of variation.

with swine manure application, as well as their gradual availability, including nitrogen, which is one of the most essential macronutrients for leaf growth, fundamental in the formation of chlorophyll, proteins and various biomolecules (Miflin and Lea, 1976).

Regarding the types of fertilizers, it is possible to observe that mineral fertilizer did not differ from organic fertilizers. In the SDM and TDM variables, the UbC compound and swine manure showed lower results when compared to the RVC compound, in soils with swine manure application. In soils without application, there were no differences between the types of fertilizers. These results are in agreement with a study carried out by Macedo et al. (2020), in which, with the objective of analyzing the initial growth of corn under different fertilization managements in a greenhouse using a clay-textured Red-Yellow Latosol, it was found that organomineral management resulted in higher plant height and shoot dry mass at 42 and 57 days after sowing and higher root dry mass at 57 days after sowing. In this study, the pelleted organomineral source (80% of the P_2O_5 dose) had the same efficiency as mineral fertilizer in the initial phase of corn cultivation.

Regarding the physiological variables evaluated in soybean plants and the forage crop, no differences were observed for the interaction of the tested factors or isolated factors. The average values found in soybean plants were: photosynthetic rate (A) = 23.18 µmol CO_2 m^{-2} s^{-1}; transpiration rate (E) = 13.67 mmol H_2O m^{-2} s^{-1}; stomatal conductance (g_{sw}) = 0.96 mol H_2O m^{-2} s^{-1}; ratio of internal to external CO_2 concentrations (Ci/Ca) = 0.85; instantaneous water use efficiency (A/E) = 1.71 [(µmol m^{-2} s^{-1})(mmol m^{-2} s^{-1})$^{-1}$]; intrinsic water use efficiency (A/g_s) = 24.66 [(µmol m^{-2} s^{-1}) (mol m^{-2} s^{-1})$^{-1}$]; chlorophyll *a* = 25.33; chlorophyll *b* = 5.97 at 30 DAE; and

Table 3. Leaf dry mass (LDM), stem dry mass (SDM), and total dry mass (TDM) per plant, at 56 DAE of soybeans grown in a greenhouse, as a function of each treatment.

Treatments[1]	LDM	SDM	TDM
	(g)	(g)	(g)
		with swine manure application	
MF	12.75 aA	7.96 abA	29.34 abA
UbC	9.78 aB	6.37 bA	23.12 bA
RVC	14.77 aA	12.11 aA	36.65 aA
PL	12.43 aA	7.42 abA	28.17 abA
SM	9.07 aA	5.82 bA	21.44 bA
		Soil without swine manure application	
MF	10.20 aA	5.74 aA	22.13 aA
UbC	14.63 aA	9.49 aA	31.51 aA
RVC	8.51 aB	5.67 aB	20.21 aB
PL	13.78 aA	9.11 aA	30.59 aA
SM	11.93 aA	7.39 aA	25.30 aA
CV %	30.27	19.32	27.30

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; VC - Rio Verde Compost; PL - Poultry litter; SM - Swine manure. Averages followed by the same uppercase letters are statistically similar for the swine manure application history factor, while those followed by the same lowercase letters are statistically similar for fertilization types, by Tukey's test (p ≤0.05); CV - Coefficient of variation.

photosynthetic rate (A) = 22.53 µmol CO_2 m^{-2} s^{-1}; transpiration rate (E) = 10.81 mmol H_2O mol m^{-2} s^{-1}; stomatal conductance (g_{sw}) = 0.77 mol H_2O m^{-2} s^{-1}; ratio of internal to external

CO_2 concentrations (Ci/Ca) = 0.84; instantaneous water use efficiency (A/E) = 2.10 [(μmol m^{-2} s^{-1}) (mmol m^{-2} s^{-1})$^{-1}$]; intrinsic water use efficiency (A/g_s) = 29.93 [(μmol m^{-2} s^{-1}) (mol m^{-2} s^{-1})$^{-1}$]; chlorophyll *a* = 32.20; chlorophyll *b* = 12.24 at 56 DAE.

For *Urochloa* BRS Ipyporã, the average values found were: photosynthetic rate (A) = 24.57 μmol CO_{22} m^{-2} s^{-1}; transpiration rate (E) = 3.97 mmol H_2O; the ratio of internal to external CO_2 concentrations (Ci/Ca) = 0.43; instantaneous water use efficiency (A/E) = 6.48 [(μmol m^{-2} s^{-1}) (mmol m^{-2} s^{-1})$^{-1}$]; intrinsic water use efficiency (A/g_s) = 18.12 [(μmol m^{-2} s^{-1}) (mol m^{-2} s^{-1})$^{-1}$]; chlorophyll *a* = 31.05; chlorophyll *b* = 10.65. According to Gondim et al. (2015), the transpiration rate, stomatal conductance, and intercellular CO_2 concentration are correlated parameters that help diagnose physiological changes in plants when subjected to adverse conditions such as low and high nutrient levels.

Table 4 presents the results of PH, NT, NL, LDM, SDM, RDM, and TDM for BRS Ipyporã forage plants. No effects were observed for the interaction between manure application history and types of fertilization, nor isolated fertilization types, but only for manure application history. Higher SDM, RDM, and TDM values were observed in forage plants established after soybeans in soil without a history of swine manure application. For the other variables, the average values found were PH of 43.08 cm; NT of 21.29; NL of 62.57; and LDM of 15.78 g.

In a study by Lopes et al. (2023) evaluating the development and production of the grasses *Urochloa brizantha* cv. Marandu and *Panicum maximum* cv. Massai under organic fertilizer sources in a shaded environment in pots, no differences were observed for any treatment in terms of dry mass. In this study, the authors found that poultry and sheep manure provided greater plant height compared to no organic fertilizer application. Additionally, concerning root length, the authors observed that poultry manure resulted in higher averages compared to sheep manure and the control, with increases of 14.7 and 28.6%, respectively.

Melo et al. (2021), evaluating the productive performance of *Urochloa brizantha* cultivars subjected to organic fertilization in pots with clay-textured Dystroferric Red Latosol, found that increasing the dose of poultry litter increased dry mass productivity in the studied cultivars. They concluded that poultry litter can be used as an alternative fertilization source for tropical pasture in the Cerrado regions due to significant increases in forage mass production, with maximum dry mass productivity obtained with 9.8 t ha^{-1} of poultry litter for cv. Marandu and 15 t ha^{-1} of poultry litter for cvs. BRS Paiaguás and Xaraés.

Regarding the chemical characterization of soil samples before soybean cultivation, the results showed differences in the interaction between manure application history and types of fertilization for CEC, P, Cu, Mn, and Zn, and an effect of the historical application factor for H + Al (Table 5). P, Cu, and Zn levels (mg dm^{-3}) were higher in soil with a history of manure application. These higher values in the scenario with a history of application are justified by the fact that this soil received one or more annual applications of swine manure-based compost for at least 10 years, a material that is a significant source of these three nutrients.

In this condition, among the types of fertilization, RC showed the highest values for P, Cu, and Zn compared to the other types of fertilization. On the other hand, in soil without a history of manure application, there were no differences between fertilization types for P, Cu, Mn, and Zn. In soil with a history of manure fertilization, Mn levels were lower compared to soil without a history of manure fertilization when treated with MF, UC, and SM (Table 4). The highest Mn levels were observed with RC and non-composted sources of PL and SM.

These differences between soils with and without a history of manure application were repeated in the evaluation after forage cultivation, with P, Cu, and Zn levels increasing in the soil (Table 6). In the manure application history scenario, it was observed that the use of MF increased P, Cu, and Zn levels. Mineral fertilization showed comparable results to organic fertilization in both periods analyzed, indicating that it is feasible to use both sources (in natura - composted, and inorganic) for fertilizing crops. Rhoden et al. (2024) highlights that the use of liquid swine manure as biofertilizers in pasture areas promotes positive results in forage production, potentially replacing mineral fertilization. Compared to the interpretation ranges presented by Ribeiro et al. (1999), in soil with a history of manure application, the levels are low for H + Al, medium for pH, and high/good for Ca, Mg, CEC, V%, P, Zn, Mn, Fe, Cu. In soil without a history of manure application, the levels are low for H + Al, medium for pH, P, Zn, Cu, and high/good for Ca, Mg, CEC, V%, Mn, and Fe in both analyses.

The evaluation of the enzymes arylsulfatase and β-glucosidase as indicators of soil biological functioning is based on the inability of changes in chemical properties, particularly soil organic matter (SOM) levels, to fully reflect the impacts of adopting conservation management systems, such as no-tillage, crop-livestock integration, and crop-livestock-forestry integration (Mendes et al., 2020). According to Silva Aragão et al. (2020), microbiological indicators, such as enzyme activity, can quickly show constant changes in soil conditions, as they are extremely sensitive to management changes.

The results of arylsulfatase, β-glucosidase, and acid phosphatase enzyme activities evaluated before soybean sowing and after cutting the BRS Ipyporã forage are presented in Tables 7 and 8, respectively. In Table 7, it can be observed that there were no interaction effects between factors, only an isolated effect of manure application history, with higher activity of β-glucosidase and acid phosphatase enzymes in soils treated with swine manure for a long time. Higher results for both enzymes and arylsulfatase were also observed in the soil continuously treated with swine manure in the evaluation conducted after the forage was cut (Table 8).

Regarding the microbiological variables evaluated, both in the initial and final analyses, there was no effect of the diverse types of fertilization. Compared to the initial characterization conducted before soybean sowing, it is interesting to note that there was reduction in arylsulfatase enzyme activity, maintenance of β-glucosidase enzyme values, and increase in acid phosphatase activity in the evaluation conducted after the forage was cut. Compared to the interpretation ranges presented by Lopes et al. (2018), it can be said that the values of β-glucosidase and acid phosphatase are low, and arylsulfatase is moderate.

Table 4. Plant height (PH), number of tillers (NT) and leaves (NL), as well as leaf dry mass (LDM), stem dry mass (SDM), root dry mass (RDM) and total dry mass (TDM) of BRS Ipyporã forage plants as a function of the treatments.

Treatment[1]	**PH (cm)**	**NT**	**NL**	**LDM**	**SDM**	**RDM**	**TDM**
					------------ g per plant ------------		
			Soil with swine manure application				
MF	41.80^{ns}	22.75^{ns}	62.50^{ns}	13.83^{ns}	14.37^{ns}	6.79^{ns}	34.99^{ns}
UbC	41.80	24.40	66.00	16.89	18.62	8.63	44.15
RVC	39.80	22.80	70.80	16.59	16.91	9.28	42.78
PL	42.00	21.20	61.80	16.58	15.70	8.45	40.72
SM	45.60	17.00	50.80	11.49	10.39	6.03	27.91
			Soil without swine manure application				
MF	44.80^{ns}	21.20^{ns}	67.60^{ns}	15.66^{ns}	19.79^{ns}	12.97^{ns}	48.42^{ns}
UbC	44.00	18.60	65.40	15.07	16.55	9.42	41.04
RVC	44.80	22.00	61.80	16.76	18.86	11.11	46.73
PL	44.20	22.00	63.60	18.10	19.64	12.96	50.70
SM	42.00	21.00	55.40	16.86	16.86	11.36	45.08
CV %	11.56	24.33	18.44	17.29	25.48	30.88	21.63

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - poultry litter; SM - Swine manure; ns - no significance ($p > 0.05$); CV - Coefficient of variation.

Table 5. Chemical attributes of the soil as a function of the treatments assessed before planting of soybean cultivar CZ 37B43 IPRO - BASF AGRO.

Treatment[1]	**[2]pH $CaCl_2$**	**CEC**	**Ca**	**Mg**	**H + Al**	**P (Mehlich^{-1})**	**Cu**	**Fe**	**Mn**	**Zn**	**V**
		-----------cmolc dm^{-3}---------				------------------------mg dm^{-3}---------------------					%
					Soil with a history of swine manure application						
MF	5.40^{ns}	6.76 aA	2.99^{ns}	1.22^{ns}	2.38^{ns}	52.32 bA	2.58 bA	35.24^{ns}	24.64 bB	19.70 bA	64.34^{ns}
UbC	5.22	6.58 aA	2.68	0.89	2.82	36.78 bA	1.34 bA	56.20	23.24 bB	10.12 cA	56.60
RVC	5.38	7.56 aA	3.26	1.33	2.80	86.9 aA	4.36 aA	48.32	33.18 abA	31.12 aA	62.84
PL	5.50	6.62 aA	2.98	1.21	2.20	49.06 bA	2.58 bA	74.62	39.16 aA	16.14 bcA	67.30
SM	5.46	6.5 aA	2.97	1.26	2.14	43.44 bA	2.02 bA	56.36	34.22 abB	17.10 bcA	66.42
					Soil without a history of swine manure application						
MF	5.30^{ns}	6.36 aA	2.40^{ns}	1.07^{ns}	2.58^{ns}	6.98 aB	0.88 aB	62.54^{ns}	40.30 aA	0.92 aB	58.78^{ns}
UbC	5.46	6.02 aA	2.69	1.08	2.02	7.22 aB	0.68 aA	79.44	40.46 aA	1.32 aB	66.30
RVC	5.60	5.92 aB	2.78	1.21	1.62	11.94 aB	0.64 aB	70.78	37.50 aA	1.4 aB	72.26
PL	5.60	6.68 aA	3.21	1.30	1.84	10.88 aB	0.78 aB	44.54	35.58 aA	1.50 aB	71.70
SM	5.54	6.60 aA	2.90	1.34	2.14	7.48 aB	0.66 aB	76.56	45.66 aA	1.04 aB	68.08
CV %	3.79	8.95	18.69	23.89	25.96	43.25	44.48	56.93	19.24	47.74	13.80

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - Poultry litter; SM - Swine manure; [2]pH ($CaCl_2$) – pH Calcium Chloride; CEC - Cation Exchange Capacity; Ca - Calcium; Mg - Magnesium; H + Al - Hydrogen + Aluminum; P - Phosphorus; Cu - Copper; Fe - Iron; Mn - Manganese; Zn - Zinc; V - Base Saturation. Averages followed by the same uppercase letters are statistically similar for the swine manure application history factor, while those followed by the same lowercase letters are statistically similar for fertilization types, by Tukey's test ($p \leq 0.05$). ns - no significance ($p > 0.05$); CV - Coefficient of variation.

Table 6. Chemical attributes of the soil as a function of the treatments assessed after cutting of BRS Ipyporã forage grass.

Treatment[1]	[2]pH $CaCl_2$	CEC	Ca	Mg	H + Al	P (Mehlich^{-1})	Cu	Fe	Mn	Zn	V
		----------cmolc dm^{-3}-----------				-------------------------mg dm^{-3}----------------------------					%
Soil with a history of swine manure application											
MF	5.44^{ns}	7.18^{ns}	3.30^{ns}	1.36^{ns}	2.48^{ns}	62.38 bA	3.10 abA	37.68^{ns}	30.16 abB	23.22 abA	65.68^{ns}
UbC	5.30	6.46	2.78	1.01	2.62	37.94 bA	1.68 bA	57.44	26.10 bB	12.92 cA	59.10
RVC	5.38	7.22	3.25	1.29	2.64	87.68 aA	4.34 aA	46.76	33.28 abB	31.62 aA	63.52
PL	5.46	6.72	3.08	1.25	2.34	49.80 bA	2.92 abA	75.14	40.14 aA	19.06 bcA	65.18
SM	5.50	6.86	3.26	1.37	2.20	47.22 bA	2.40 bA	62.06	37.94 abA	20.32 bcA	67.50
Soil without a history of swine manure application											
MF	5.34^{ns}	5.74^{ns}	2.32^{ns}	1.10^{ns}	2.26^{ns}	9.66 aB	1.04 aB	67.64^{ns}	43.00 aA	3.64 aB	59.90^{ns}
UbC	5.54	6.06	2.96	1.16	1.88	8.88 aB	0.88 aA	77.48	41.00 aA	3.70 aB	69.14
RVC	5.64	6.10	3.17	1.25	1.64	13.04 aB	0.92 aB	83.60	50.10 aA	3.76 aB	73.08
PL	5.60	6.42	3.20	1.34	1.82	11.16 aB	0.96 aB	47.54	37.98 aA	3.96 aB	71.18
SM	5.58	6.46	3.15	1.41	1.88	10.24 aB	1.08 aB	71.16	44.24 aA	4.32 aB	71.36
CV %	3.73	8.89	15.97	18.64	27.43	41.10	43.46	55.58	18.39	38.19	12.80

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - Poultry litter; SM - Swine manure; [2]pH ($CaCl_2$) - pH Calcium Chloride; CEC - Cation Exchange Capacity; Ca - Calcium; Mg - Magnesium; H + Al - Hydrogen + Aluminum; P - Phosphorus; Cu - Copper; Fe - Iron; Mn - Manganese; Zn - Zinc; V - Base Saturation. Averages followed by the same uppercase letters are statistically similar for the swine manure application history factor, while those followed by the same lowercase letters are statistically similar for fertilization types, by Tukey's test ($p \leq 0.05$). ns - no significance ($p > 0.05$); CV - Coefficient of variation.

Table 7. Soil microbiological activity related to the enzymes arylsulfatase, β-glucosidase and acid phosphatase as a function of treatments evaluated before soybean sowing.

Treatment[1]	Arylsulfatase	β-glucosidase	Acid phosphatase
		μg of p-nitrophenol g^{-1} of soil	
History			
With swine manure	165.70 a	35.77 a	173.27 a
Without swine manure	143.61 a	24.76 b	97.21 b
Types of fertilizers			
MF	163.86^{ns}	31.63^{ns}	143.78^{ns}
UbC	137.44	29.71	124.92
RVC	165.90	30.79	129.48
PL	142.48	29.42	130.91
SM	163.59	29.81	147.11
CV (%)	17.18	17.39	28.25

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - poultry litter; SM - Swine manure. Averages followed by the same uppercase letters are statistically similar by Tukey's test ($p \leq 0.05$). ns - no significance ($p > 0.05$); CV - Coefficient of variation.

Table 8. Soil microbiological activity related to the enzymes arylsulfatase, β-glucosidase, and acid phosphatase as a function of treatments evaluated after cutting the BRS Ipyporã forage in a greenhouse.

Treatment[1]	Arylsulfatase	β-glucosidase	Acid phosphatase
		μg of p-nitrophenol g^{-1} of soil	
History			
With swine manure	83.66 a	36.90 a	451.01 a
Without swine manure	64.99 b	22.61 b	110.00 b
Types of fertilizers			
MF	80.84^{ns}	28.34^{ns}	281.04^{ns}
UbC	88.06	31.01	348.90
RVC	77.71	29.94	238.04
PL	64.43	28.00	262.66
SM	60.55	31.47	271.87
CV (%)	23.02	12.31	47.65

[1]Treatment MF - Mineral fertilization; UbC - Uberlândia Compost; RVC - Rio Verde Compost; PL - Poultry litter; SM - Swine manure. Averages followed by the same letters are statistically similar by Tukey's test ($p \leq 0.05$). ns - no significance ($p > 0.05$); CV - Coefficient of variation.

4. Conclusion

Soil with a history of swine manure application, combined with the Rio Verde compost substrate, contributes to higher dry mass production in soybean plants. The *Urochloa* hybrid BRS Ipyporã forage cultivated in soils without a history of manure application is more productive, regardless of whether composted, non-composted organic sources or mineral fertilizer is added.

Soils with over ten years of swine manure application history and treated with CRV have higher amounts of nutrients P, Cu, and Zn. Mn concentrations in the soil are higher in soils without a history of manure application, particularly when fertilized with mineral fertilization and Uberlândia compost.

Soil enzyme activity is enhanced with the continuous addition of swine manure over time.

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