Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"

ISSN 1980-0827 – Volume 20, Number 3, Year 2024

Cultivation of *Urochloa brizantha* cv. Marandu in relation to the use of organic residues, biochars, and nitrogen fertilization

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ABSTRACT
The objective of this study was to evaluate whether applications of organic residues and biochars, either individually or combined with nitrogen fertilization (NF), affect the development of *Urochloa brizantha* cv. Marandu. An experiment was set up in a completely randomized design (CRD), with a 7x4 factorial arrangement and 5 repetitions, consisting of: control soil (CS); soil + 300g of pure biosolids (PB); soil + 100g of pure sugarcane bagasse (PSB); soil + 150g of pure biosolids + 50g of pure sugarcane bagasse (PB+PSB); soil + 300g of biosolids biochar (BB); soil + 100g of sugarcane bagasse biochar (SBB); soil + 150g of biosolids biochar + 50g of sugarcane bagasse biochar (BB+SBB); and 4 levels of mineral nitrogen fertilization: 0; 12.5; 25; and 50 mg dm-3. Four harvests were conducted at 60, 88, 116, and 144 days after planting *Urochloa brizantha* cv. Marandu. Subsequently, the development of Marandu grass and the chemical attributes of the soil, after cultivation, were evaluated. Variance analysis (SISVAR software), mean comparison (Scott-Knott test $p<0.05$), Pearson correlation (t-test $p<0.05$), and a principal component multivariate analysis of soil chemical variables (R software) were performed. Regarding the productivity of *Urochloa brizantha* cv. Marandu, soil with the addition of PB at the corresponding dose of 100 kg of N per hectare showed higher values. Soil with the addition of PB and BB, individually or combined with NF, led to an increase in pH, CEC, and base saturation. The highest content of organic matter and organic carbon was obtained in soil with the addition of PSB, individually or combined with NF.

Keywords: Biosolids, Sugarcane Bagasse, Pyrolysis, Biochar, Soil Fertility.

1 INTRODUCTION

Through the application of organic waste in agricultural soils, the use of soil conditioners—products that can improve the chemical, physical, or biological attributes of the soil (ALMEIDA, 2008)—has become an attractive strategic management method. This is because it can partially replace the use of chemical fertilizers, such as phosphate and nitrogen fertilizers, thereby reducing costs and energy expenditure (YAGMUR et al., 2017; MELO et al., 2018; DHANKER et al., 2021). Although these chemical fertilizers provide nutrients readily available to plants, increasing their productivity, they can also deteriorate soil health if used over a long period (HERNANDEZ et al., 2016).

According to a study coordinated by the Food and Agriculture Organization of the United Nations (FAO, 2015), about 30% of the world's soils are degraded. Soil degradation implies a reduction in productive capacity, particularly in agricultural soils, mainly due to improper management of this resource.

Some urban and agro-industrial wastes are used as soil conditioners in an attempt to maximize recycling, minimize improper disposal, and provide a sustainable end-use. In this context, there is sugarcane bagasse, an agro-industrial waste produced in large quantities, and sewage sludge, a solid urban waste produced in large quantities at Sewage Treatment Plants (STPs), generated in the sewage treatment process through primary, biological, or chemical sedimentation (BRAZIL, 2020). When treated and processed, sludge is called biosolids (BARBOSA; SON, 2006). In Brazil, biosolid production reaches about 150 to 220 thousand tons of dry matter per year (MANCA et al., 2020).

The use of biosolids in soils is an environmentally appropriate option and aligns with the principles of waste recycling under Law No. 12.305 of 2010 (BRAZIL, 2020). It is an organic material rich in nutrients such as nitrogen and organic carbon and also contains phosphorus and elements like iron, copper, manganese, and zinc (LOBO et al., 2013). These elements are important for plant growth; therefore, when used for soil conditioning purposes, it can improve soil fertility and enhance its physical, chemical, and biological attributes (SCOTTI et al., 2016). It can also contribute to the formation of stable soil aggregates, improve soil aeration, water exploitation, and cation exchange capacity (ALVARENGA et al., 2017; DHANKER et al., 2021). Thus, the incorporation of biosolids into the soil constitutes a practice for the development of a sustainable agricultural system.

However, according to the Federal Resolution of the National Environment Council - CONAMA No. 498 of 2020, there are limitations for the use of biosolids in agricultural soils. Therefore, transforming this waste into biochar, a carbon-rich byproduct, through the thermochemical conversion process, pyrolysis—where biomass is degraded in the partial or total absence of oxygen (LEHMANN et al., 2011; OK et al., 2015)—becomes a good management option. This process transforms the biosolid into a material free of pathogenic organisms, rich in nutrients such as nitrogen, phosphorus, calcium, and zinc (PAZ-FERREIRO et al., 2018; FACHINI; FIGUEIREDO, 2022).

The application of biochar can modify acidic soils and reduce nitrogen loss (CLOUGH; CONDRON, 2010; LAN et al., 2017; HOU et al., 2021). It can also improve the attributes of degraded and low-fertility soils, increasing crop productivity (EL-NAGGAR et al., 2019). According to Trazzi et al. (2018), biochar in soil can increase pH, cation exchange capacity, and organic carbon, provide refuge for microbiota, increase nutrient availability through changes in soil biota, and improve soil structure. In this sense, the present study aimed to assess whether applications of organic residues and biochars, individually or combined with nitrogen fertilization, affect the chemical attributes of the soil and the development of *Urochloa brizantha* cv. Marandu.

2 MATERIALS AND METHODS

2.1 Location of the experiment

The experiment was conducted in an open greenhouse, located at 22°06'57.7" South latitude and 51°27'03.6" West longitude, from December 2019 to September 2020. According to the Köppen classification, the climate of the region is CWA with a wet summer and dry winter, featuring two defined seasons: a warmer summer-autumn period (average maximum temperatures between 27 °C and 29 °C) and very rainy (between 150 and 200 mm monthly), and mild winters (average minimum temperatures between 16 °C and 18 °C) with less humidity (monthly rainfall between 20 and 50 mm).

2.2 Acquisition of organic residues, production, and characterization of biochars

The biosolids used in the experiment were provided by the Basic Sanitation Company of the State of São Paulo – SABESP, Presidente Prudente unit, SP. It is obtained through the activated sludge treatment process and is subsequently subjected to thermal drying of the residue to reduce pathogens. The sugarcane bagasse came from a mill located in Pontal do Paranapanema. The biochars were produced separately from the biosolids and sugarcane bagasse through the process of slow pyrolysis at 350°C for 30 minutes, in a fixed bed laboratory reactor at the Chemistry Laboratory of the Universidade do Oeste Paulista (SOUZA et al., 2021).

For the characterization of the residues and biochars, chemical analyses were performed. The pH and electrical conductivity were determined according to the methodology proposed by Rajkovich et al. (2012). The cation exchange capacity followed the method of the Ministry of Agriculture, Livestock and Supply – MAPA (BRAZIL, 2007). The organic matter content was determined by the muffle method, and the organic carbon was estimated from the organic matter content. Nutrient contents, except nitrogen (Kjeldahl method), were determined according to the methods described by Malavolta, Vitti & Oliveira (1997), using atomic absorption spectrometry, UV-visible spectrometer at 420nm, and flame photometer at the Plant Tissue Laboratory of the Universidade do Oeste Paulista (Table 1).

Table 1 – Characterization of organic residues and biochars prior to the experiment setup

	pH	**C.E**	**MO**	**C.Org**	**N**	**C/N**	**CTC**
		µS	**------- g dm^{-3} -------**		**g kg^{-1}**		**mmol$_c$ kg^{-1}**
Biosolids (BP)	12,02	1498,60	460,54	255,86	36,62	7,00	865,93
Sugarcane Bagasse (BCP)	6,10	266,48	925,92	514,40	2,32	221,72	112,39
Biosolids Biochar (BB)	9,64	1036,00	327,52	181,96	27,52	6,61	725,14
Sugarcane Bagasse Biochar (BBC)	8,11	291,40	864,75	480,40	4,92	97,64	52,00

	P	**K**	**Ca**	**Mg**	**S**	**Cu**	**Fe**	**Mn**	**Zn**
	--------------- g kg^{-1} ---------------					**-------------- mg kg^{-1} --------------**			
Biosolids (BP)	5,16	1,78	13,94	6,52	3,66	129,66	5.775,47	85,94	370,22
Sugarcane Bagasse (BCP)	0,38	2,24	0,50	0,46	0,50	10,38	878,12	36,84	31,06
Biosolids Biochar (BB)	5,69	1,90	14,58	6,82	3,50	157,16	5.315,18	108,10	386,10
Sugarcane Bagasse Biochar (BBC)	0,62	5,46	0,64	1,60	0,70	17,44	1.478,24	87,03	51,44

Source: The Authors, 2023

Legend: pH (Hydrogen potential); EC (Electrical Conductivity); OM (Organic Matter); Org.C (Organic Carbon); N (Nitrogen); C/N (carbon/nitrogen ratio); CEC (Cation Exchange Capacity); P (Phosphorus); K (Potassium); Ca (Calcium); Fe (Iron); Mn (Manganese); Zn (Zinc).

2.3 Collection and physicochemical characterization of soil

The soil used in the experiment was of the type known as riverbank soil, collected from the 0-20 cm depth layer. Soil samples underwent particle size analysis (EMBRAPA, 1997) and chemical analysis according to Raij et al. (2001). Based on the results of the physical analysis, the soil had 80.95% sand, 5.2% silt, and 13.85% clay, classifying it as sandy loam. Regarding the chemical parameters of the soil, it was observed that the pH was 5.6 (CaCl2), with organic matter and total organic carbon presenting values of 12.3 and 7.2 g dm-3, respectively. Phosphorus and sulfate content were 20.3 and 0.1 mg dm-3, respectively, while potential acidity, potassium, calcium, and magnesium levels were 19.6, 2.1, 10.3, and 6.1 mmolc dm-3, respectively. The calculated parameters of Base Sum, Cation Exchange Capacity, and Base Saturation were 18.5 and 38.1 mmolc dm-3, and 48.6%, respectively.

The determination of the amount of residues to be used was based on the soil volume of the pot (10 dm3), where the level of biosolids and their respective biochar corresponded to 3%. The sugarcane bagasse and its biochar amounted to 1%. And the mixes of residues and biochars to 2% of the pot's soil volume. For the calculation of the nitrogen fertilization applied to the pots, the amount of nitrogen recommended for the brachiaria crop was used as a reference (RAIJ et al., 1997).

2.4 Experimental Design

A completely randomized design (CRD) was utilized, in a 7x4 factorial scheme with 5 repetitions, consisting of: control soil (CS); soil + 300 g of pure biosolids (BP); soil + 100 g of pure sugarcane bagasse (BCP); soil + 150 g of pure biosolids + 50 g of pure sugarcane bagasse (BP+BCP); soil + 300 g of biosolids biochar (BB); soil + 100 g of sugarcane bagasse biochar (BBC); soil + 150 g of biosolids biochar + 50 g of sugarcane bagasse biochar (BB+BBC); and 4 levels of mineral nitrogen fertilization (NF): 0; 12.5; 25, and 50 mg dm-3, corresponding to 0, 25, 50, and 100 kg of N ha^{-1} per simulated grazing cycle.

For the preparation of the pots, PVC containers with a capacity of 15 L were used, which were filled with 10 dm3 of soil. Following the results of the soil chemical analysis, 1 g of dolomitic lime was applied and incorporated to raise the base saturation to 70%. After liming, the pots were moistened and covered with black bags, where they remained incubated for 90 days. After 90 days, the materials were incorporated into the soil, according to the design previously described, and the incubation process was repeated for another 60 days before proceeding to sow *Urochloa brizantha* cv. Marandu at a density of 15 seeds per pot. Approximately 15 days after plant germination, thinning was carried out, leaving only the five most vigorous and well-distributed plants per pot.

At the time of planting, fertilization with phosphorus (180 mg dm-3), potassium (150 mg dm-3), boron (1.4 mg dm-3), and zinc (1.7 mg dm-3) was also performed. The sources used were, respectively, single superphosphate (2,290 mg dm-3), potassium chloride (302 mg dm-3), boric acid (8 mg dm-3), and zinc sulfate (8.5 mg dm-3), which were diluted in 1,000 mL of water and applied to the pots. The nitrogen fertilization at the tested doses (0; 12.5; 25, and 50 mg dm-3 of N) was applied using urea (0; 27.75; 55.5, and 111 mg dm-3 of urea) as the source, diluted in 1,000 mL of water and applied to the pots after thinning. All applications were made in a single dose, except for the 111 mg dm-3 dose, which was divided into two applications, with 50% applied along with the others, and the remaining 50% applied 15 days after the previous application to avoid the toxic effect on the plants due to excess N.

Germination occurred 10 days after sowing *Urochloa brizantha* cv. Marandu. As for plant cutting, a first uniformity cut was performed 45 days after thinning. Subsequently, three more cuts (simulated grazing cycle) were made with an interval of 28 days between each, i.e., the 1st cut at 28 days, the 2nd cut at 56 days, and the 3rd cut at 84 days after the uniformity cut, all at 5 cm from the soil surface. After the leveling cut and the 1st and 2nd cuts, the nitrogen fertilizations were repeated at the already stipulated doses, following the same application criteria as previously described. To ensure optimal growth conditions, the plants were irrigated three times a week, with 600 mL of water each time, totaling 1,800 mL of water per week (calculation based on a field capacity of 60%).

At the end of the experiment, leaf and root samples were collected for dry mass analysis, and soil samples were taken from depths of 0-10 cm for soil fertility analysis. The samples were sent to the Plant Tissue Analysis Laboratory and the Physico-Chemical Soil Analysis Laboratory at UNOESTE.

2.5 Experiment Evaluation Parameters

Soil fertility analysis (determination of pH, organic matter, organic carbon, phosphorus, sulfur, potassium, calcium, magnesium, aluminum, hydrogen plus aluminum, boron, copper, iron, manganese, and zinc) was performed according to the methodology described by Raij et al. (2001) at the UNOESTE Physicochemical Analysis Laboratory. Before starting the chemical analyses, the soil was disintegrated and sieved (2 mm). At the end of each simulated grazing cycle, the aerial part of the plants was cut, and the green mass of the material contained in each pot was determined using a precision electronic scale. Subsequently, the samples were washed and air-dried for 24 hours, then placed in paper bags to be sent to a forced air circulation oven at 65°C until a constant mass was achieved, and weighed to determine the dry mass. The same procedure was followed for the root part of *Urochloa brizantha* cv. Marandu.

2.6 Statistical Analysis

The data obtained from the experiments were subjected to variance analysis using the SISVAR software. For mean comparison, the Scott-Knott test was used at a 5% probability level ($p<0.05$). In the Pearson correlation analysis (R software) and linear regression, the t-test was used at a 5% probability level ($p<0.05$). A multivariate principal component analysis of the soil chemical variables was also performed using the R software.

3 RESULTS AND DISCUSSION

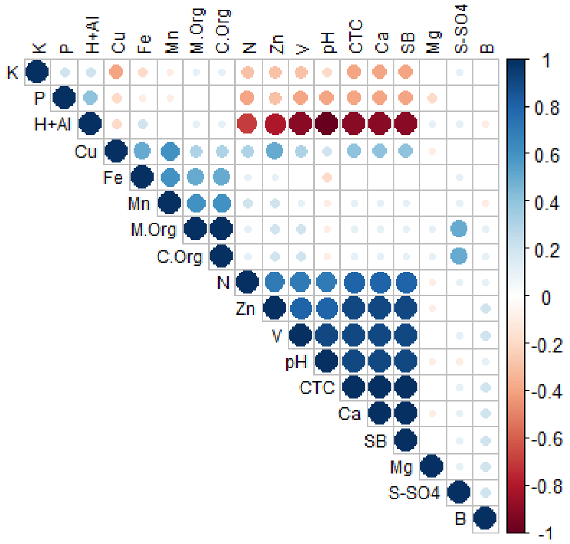
3.1 Correlation of soil chemical attributes with the addition of organic residues and biochars under nitrogen fertilization doses

Pearson correlation is a measure of the degree of linear relationship between quantitative variables (FIGUEIREDO FILHO et al., 2014). Figure 3 displays the soil chemical variables in a Pearson correlation matrix, revealing that potential acidity showed a strong negative correlation with pH ($r = -1$), Ca, SB, CTC, V ($r = -0.9$), N ($r = -0.7$), and Zn ($r = -0.8$). This means that as the content of these elements increases, there is a reduction in soil potential acidity. This parameter also showed a low positive correlation, ranging from 0.1 to 0.4 with P, K, Fe, Mg, sulfate content, organic matter, and organic carbon, and a weak negative correlation with Cu and B, ranging from -0.1 to -0.2.

Potassium and phosphorus also showed a negative correlation with pH, N, Ca, CTC, V, Fe, Cu, and Mn, with variations from -0.2 to -0.4. P also had a weak negative correlation with Mg. The sum of bases showed a weak negative correlation with K ($r = -0.4$) and a positive correlation with Ca ($r = 1$). Magnesium did not show significance ($p<0.05$). K ($r = -0.4$) and Mg ($r = -0.1$) had a negative correlation with Ca. Calcium, on the other hand, had a strong positive correlation with CTC, pH, V, N, and Zn. It can be said that calcium was the element that most influenced the cation exchange capacity of the soil. This was evidenced in the treatments, as the application of biosolids and their respective biochar significantly increased the CTC and base saturation.

For sulfate, iron, manganese, and copper, it was observed that they had a higher positive correlation with organic matter and carbon compared to other parameters. Organic matter and carbon showed a positive correlation with almost all parameters, except for pH (r = -0.1), and it did not show significance ($p<0.05$) in relation to phosphorus. The micronutrients, Fe, Cu, Mn, and Zn showed a positive correlation among themselves, while boron had a low positive correlation with Zn, and a negative correlation of -0.1 with manganese.

Figure 1 – Pearson correlation matrix of soil chemical attributes with the addition of organic residues and biochars under nitrogen fertilization doses.



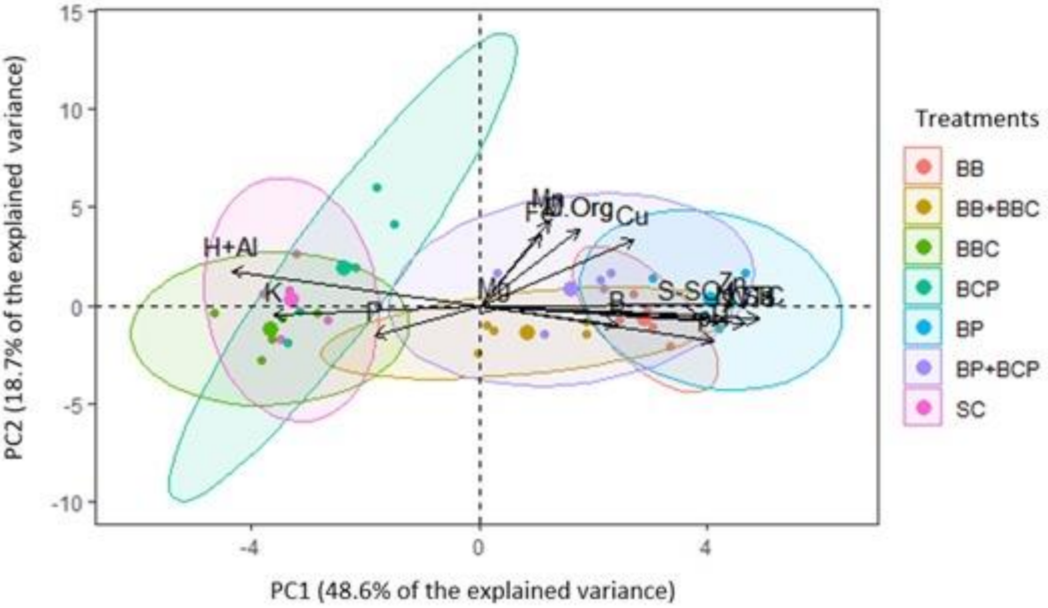
Source: The Authors, 2023.
Legend: pH (Hydrogen potential); Org.M (Organic matter); Org.C (Organic carbon); N (Total nitrogen); P (Phosphorus); S-SO4^2- (Sulfate content); H+Al (Potential acidity); K (Potassium); Ca (Calcium); Mg (Magnesium); SB (Sum of bases); CTC (Cation exchange capacity); V (Base saturation); B (Boron); Cu (Copper); Fe (Iron); Mn (Manganese); Zn (Zinc). Blue and red colors indicate positive and negative correlations, respectively. Empty spaces indicate that correlations are not statistically significant at $p<0.05$, t-test.

3.2 Principal component analysis of soil chemical attributes with the addition of organic residues and biochars

Hongyu, Sandanielo, and Oliveira Junior (2015, cited by JOHNSON; WICHERN, 1998) mention that PCA (Principal Component Analysis) is a multivariate statistical technique that involves transforming a set of original variables into another set of the same dimension called principal components. Each principal component is a linear combination of all the original variables, being independent from each other and estimated with the purpose of retaining, in order of estimation, the maximum information in terms of the total variation contained in the data. This analysis is useful for exploratory data analysis, allowing for a better visualization of the variation present in a dataset with many variables. It identifies which samples are similar or different from each other. Through PCA, groups of similar samples are identified, and it is also checked which variables make one group different from another. It can also be used for generating indices and clustering individuals. Thus, PCA groups individuals according to their variation (HONGYU; SANDANIELO; OLIVEIRA JUNIOR, 2015).

Figure 4 shows the soil chemical variables under the influence of organic residues and biochars. PC1 accounted for 48.6% of the explained variance, while PC2 accounted for 18.7%. It can be said that the treatments affect the soil chemistry differently. The blue circle, which represents the set of soil samples with the addition of biosolids, is indicated by the eigenvectors to have higher levels of Ca, SB, CTC, V, pH, N, Zn, and Cu compared to other treatments. The pink circle, which represents the control treatment, shows a higher content of potential acidity, though the BCP and BBC also showed higher levels compared to the others. The treatment that received the addition of BBC showed a higher phosphorus content. Higher contents of organic matter and carbon were observed in the BCP and BP+BCP. In the latter, a higher content of Mg was also observed. Higher contents of sulfate and boron were noted in the BB and BP .

Figure 2 – Principal component analysis of soil chemical variables under the influence of organic residues and biochars without nitrogen fertilization

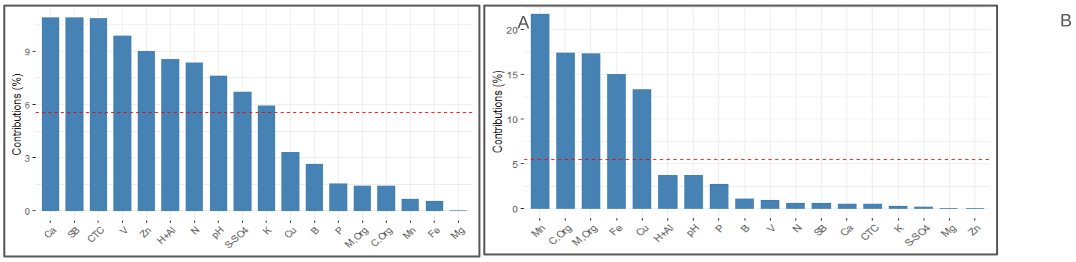


Source: The Authors, 2023.

Legend: SC (Control Soil); BP (Biosolids); BCP (Sugarcane Bagasse); BP+BCP (Biosolids + Sugarcane Bagasse); BB (Biosolids Biochar); BBC (Sugarcane Bagasse Biochar); BB+BBC (Biosolids Biochar + Sugarcane Bagasse Biochar).

The variables Ca, SB, CTC, V, Zn, H+Al, N, pH, sulfate content, and K made the largest contributions to PC1 (Figure 3A). For PC2, the parameters that contributed the most were Mn, total organic carbon, organic matter, Fe, and Cu (Figure 3B). It is also noted that B, P, and Mg had little contribution in dimensions 1 and 2.

Figure 3 – Contribution charts of soil chemical variables across dimensions



Source: The Authors, 2023.

Legend: A (Dimension 1); B (Dimension 2).

3.3 Productivity of *Urochloa brizantha* cv. Marandu

Table 2 presents the values of green mass and dry mass of *Urochloa brizantha* cv. Marandu. In the results related to the first cut, analyzing only the treatments at zero dose of nitrogen fertilization, it is noted that BP showed the highest value, followed by BB and BP+BCP, where both showed significance among themselves and from the other treatments. The lowest values of green mass production were in treatments with the insertion of sugarcane bagasse, sugarcane bagasse biochar, and in the control. The same occurred for the production of dry mass, however, the treatment with biosolids biochar and BP+BCP did not differ.

In the second cut, for green mass, BP achieved the highest value and showed significance, in relation to treatments without nitrogen fertilizer. It was observed that BB was comparable to BP+BCP. The mixture of biochars had a higher value only in relation to SC, BBC, and BCP. For dry mass, the lowest values were obtained in the mixtures of biochars, in the control soil, in BBC, and BCP.

Still analyzing only the treatments at zero dose of nitrogen fertilization, BP also showed higher values of green and dry mass in the third cut, presenting significance in relation to the others. While the treatments with BBC, SC, and BCP obtained lower values. In the treatment with sugarcane bagasse, in this last cut, it was not possible to quantify the production of green and dry mass, due to the biomass of the plant being greatly reduced.

It is known that biosolids are a residue rich, especially, in nitrogen and contains some essential nutrients for plants. Having a low C/N ratio (Table 1) may indicate easy mineralization of nitrogen by soil microorganisms. It is assumed that N and some nutrients became more available in the soil and, thus, there may have been a greater nutrient uptake by the plant.

In this study, there was greater production of green and dry mass in treatments with BP. BP, without NF, in the 1st cut, showed higher production values of I cv. Marandu, compared to the control treatment (SC) at the doses corresponding to 25, 50, and 100 kg of N ha^{-1}. That is, just the insertion of this residue in the soil can increase the productivity of this crop, as it brought significant results for the production of green and dry mass similar to Campos and Alves (2008) who also found greater production of green and dry matter of brachiaria in treatments with the insertion of sewage sludge.

Similarly, Trannin, Siqueira, and Moreira (2005) showed a significant increase analyzing corn productivity in soil that received the incorporation of 10 mg ha^{-1} of sewage sludge on a dry basis, supplemented with K2O and 30% of the requirement in P2O5, comparing with the corn productivity obtained with complete mineral fertilization. For biosolids biochar, Gwenzi et al. (2016) mention that its application to soil improves fertility properties and increases growth and biomass production of corn.

Now, analyzing the treatments in general, without and with the application of mineral fertilization dosages 0, 12.5, 25, and 50 mg dm-3 corresponding to 0, 25, 50, and 100 kg of N ha^{-1} (Table 2). In terms of green mass, it can be observed that the treatment with biosolids at the dose corresponding to 100 kg of N ha^{-1} showed the highest value and significance in relation to the other treatments, this in the 1st and 2nd cut of *Urochloa brizantha* cv. Marandu. It was also noted that there was a significant increase in the production of green mass in this treatment, comparing the 1st and 2nd, where the first obtained 72 g and the second 98.49 g. In the third cut, despite showing the highest value, BP100 had no significance in relation to BP+BCP100, BB100, BBC100, BCP100, SC100, and BB+BBC100.

In the 1st cut, it is observed that the treatments that previously had no increase in productivity, such as SC, BBC, and BP, after the addition of NF at the dose of 50 mg dm^{-3} corresponding to 100 kg of N ha^{-1}, began to have green mass production values closer to those found in the treatment only with the addition of biosolids. While in the 2nd and 3rd cut, these treatments surpassed the values of green mass production present in the treatment with the insertion of biosolids without the addition of urea.

In general, the treatments BP100, BP+BCP100, and BB100 showed higher values in the three cuts of *Urochloa brizantha* cv. Marandu. While the lowest values for the production of green mass of the aerial part for the first cut were found in BB+BBC, BCP50, BCP25, SC, BBC, and BCP. In the 2nd cut were the treatments SC, BBC, and BCP, and in the 3rd cut were SC and BCP.

In this study, when the dose of 50 mg dm^{-3} of mineral fertilization was applied, a significant increase was noted in relation to the treatments with the insertion of biosolids and their respective biochar, which before the insertion of NF doses already showed higher values than the control treatment without NF. BP100 showed an increase in the production of green mass, in the first cut, of 10.46 times and, in the second cut of 16.37 compared to the treatments that obtained the lowest values. This may have occurred due to a greater supply of nutrients, via the decomposition of the biosolids and via nitrogen fertilization, by the plant. It is assumed that there may have been greater absorption of these elements by the plant, in the treatment with BP100, and as a result, there was a greater production of leaf mass. Since, forages are excellent extractors of nitrogen from the soil (CANTARELLA et al., 2003; COSTA et al., 2008), preferably in the form of NH^{4+} and NO^{3-}.

There is a greater response of crops when there is a joint application of biochar with nitrogen fertilizer (BIEDERMAN; HARPOLE, 2013). This was observed in treatments that had biochars in conjunction with NF, as they showed an increase in the production of green mass, especially the BB100. The sugarcane bagasse biochar, at the dose corresponding to 100 kg of N ha^{-1}, in the results of the first and second cut, obtained values higher than SC100.

In Figure 4, in general, it was verified that there was statistical significance ($p<0.01$ and $p<0.05$) of productivity as a function of N doses. Where nitrogen fertilization caused an increase in dry mass production, especially at the dose of 50 mg dm-3. Comparing the productivity values as a function of nitrogen fertilization doses, it is noted that in the third cut there was greater productivity compared to the 1st and 2nd cut.

Figures 4B, 4P, 4Q, and 4R showed greater linearity ($R^2= 0.99$) and evidenced significance ($p<0.01$) of productivity as a function of nitrogen fertilization doses.

Trat.	**Doses de N (kg ha^{-1})**	**1°Corte**		**2°Corte**		**3°Corte**	
		MVPA	**MSPA**	**MVPA**	**MSPA**	**MVPA**	**MSPA**
		------------------------------------ g ------------------------------					
SC	0	5,37 f	2,09 d	7,10 g	1,67 g	21,69 d	17,81 e
	25	16,41 e	5,10 c	26,57 e	5,91 f	42,81 c	23,74 c
	50	19,60 e	5,12 c	40,98 d	9,19 e	60,44 c	29,26 b
	100	41,44 c	10,97 b	67,37 c	16,12 c	88,13 a	34,31 a
BP	0	50,81 b	13,63 a	56,84 c	13,98 d	68,23 b	30,54 b
	25	50,25 b	13,68 a	65,42 c	16,82 c	83,27 b	34,22 a
	50	49,03 b	14,30 a	69,12 c	18,11 c	80,33 b	33,77 a
	100	72,00 a	15,86 a	98,49 a	25,37 a	99,87 a	38,79 a
BCP	0	2,39 f	0,71 d	3,92 g	1,02 g	-	-
	25	6,16 f	2,11 d	12,43 f	2,89 g	35,44 d	21,44 d
	50	8,74 f	2,73 d	21,66 f	5,22 f	53,91 c	26,40 c
	100	36,69 c	9,79 b	66,93 c	16,05 c	90,46 a	36,03 a
BP+BCP	0	22,47 e	6,78 c	27,98 e	7,07 f	49,34 c	24,68 c
	25	29,85 d	8,72 c	43,48 d	9,89 e	75,21 b	30,54 b
	50	31,07 d	8,74 c	61,20 c	13,83 d	74,50 b	31,94 b
	100	53,35 b	14,45 a	86,51 b	20,30 b	99,59 a	37,67 a
BB	0	29,96 d	7,35 c	28,25 e	6,91 f	45,99 c	24,56 c
	25	27,49 d	7,55 c	36,51 d	8,19 e	57,31 c	26,42 c
	50	31,98 d	8,14 c	55,43 c	12,31 d	72,86 b	27,58 b
	100	56,10 b	13,91 a	85,20 b	20,04 b	97,22 a	37,15 a
BBC	0	5,13 f	1,39 d	5,99 g	1,37 g	24,24 d	18,94 d
	25	17,79 e	4,75 c	26,05 e	6,07 f	48,40 c	24,71 c
	50	26,40 d	7,72 c	46,12 d	10,37 e	71,46 b	28,70 b
	100	45,89 b	14,84 a	79,60 b	19,50 b	95,10 a	37,00 a
BB+BBC	0	9,88 f	3,62 d	15,33 f	3,27 g	35,15 d	21,65 d
	25	20,80 e	6,95 c	35,19 d	8,62 e	56,68 c	26,75 c
	50	22,86 e	7,24 c	44,52 d	10,22 e	71,78 b	31,14 b
	100	39,67 c	12,17 b	69,47 c	17,62 c	86,92 a	35,58 a
CV (%)		22,05	26,89	19,03	18,07	13,05	7,33

Table 2 – Values of green mass and dry mass of the aerial part from the 1st, 2nd, and 3rd cut of *Urochloa brizantha* cv. Marandu

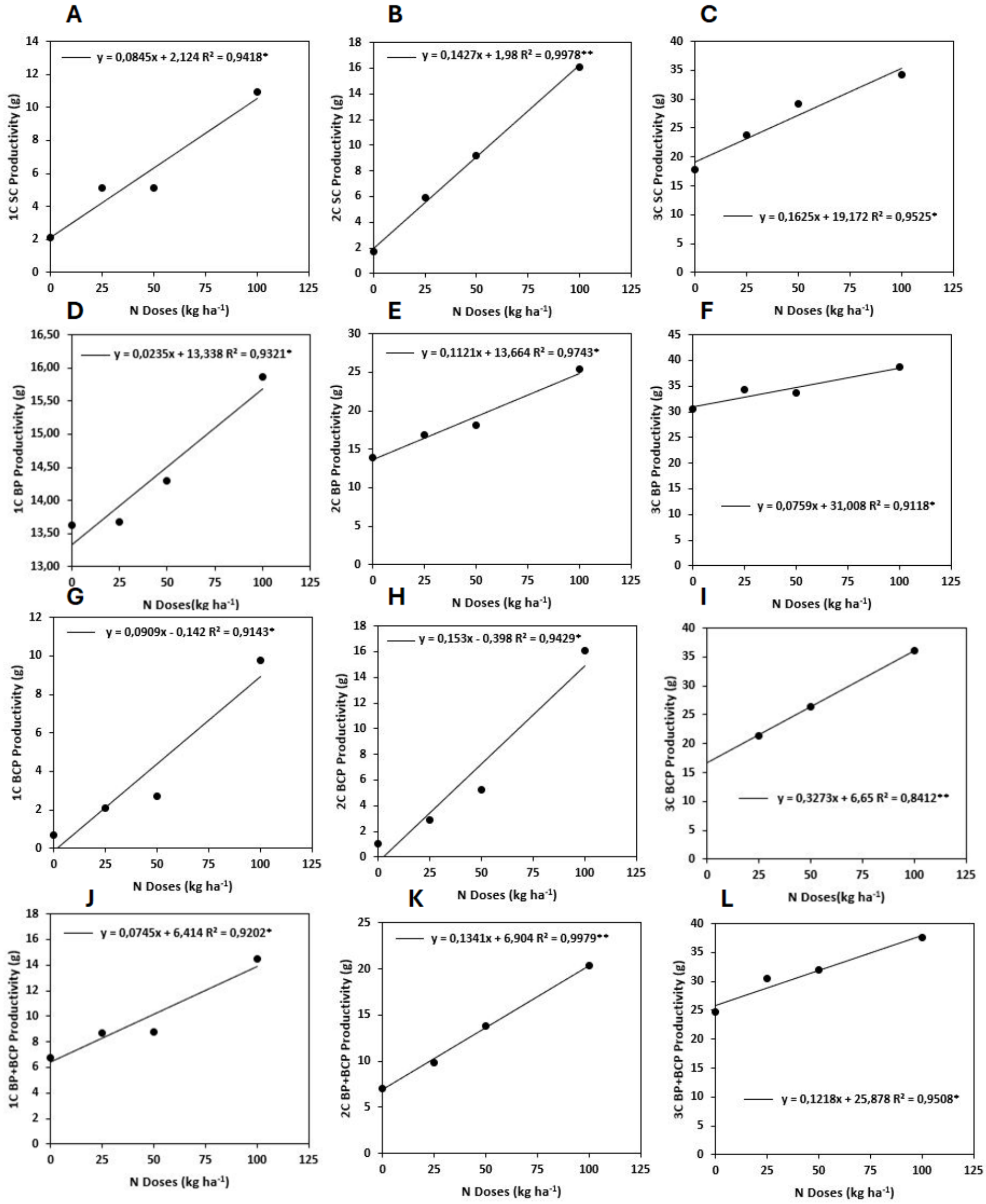
Source: The Authors, 2023.

Legend: Treat. (Treatment); SC (Control Soil); BP (Biosolids); BCP (Sugarcane Bagasse); BP+BCP (Biosolids + Sugarcane Bagasse); BB (Biosolids Biochar); BBC (Sugarcane Bagasse Biochar); BB+BBC (Biosolids Biochar + Sugarcane Bagasse Biochar). AGM (Aerial Green Mass of the plant); ADM (Aerial Dry Mass of the plant). Means followed by the same letter do not differ significantly by the Scott-Knott test at 5% probability ($p<0.05$).

The treatment with the addition of biosolids showed higher values, in both cuts ($p<0.05$), of productivity at the dose corresponding to 100 kg of N ha^{-1} (Figures 4D, 4E, and 4F). Araujo, Gil, and Tiritan (2009) found greater production of leaf dry mass due to the application of sewage sludge. The same was observed for treatments with biosolids biochar (Figures 4M, 4N, and 4O), although it was not significant in the 1st cut, it showed 5% significance in the 2nd and 3rd cuts. Albuquerque et al. (2014), Rosa et al. (2014), and Hossain et al. (2010) found positive effects on the production of plant dry mass due to the application of biochar, corroborating the present study.

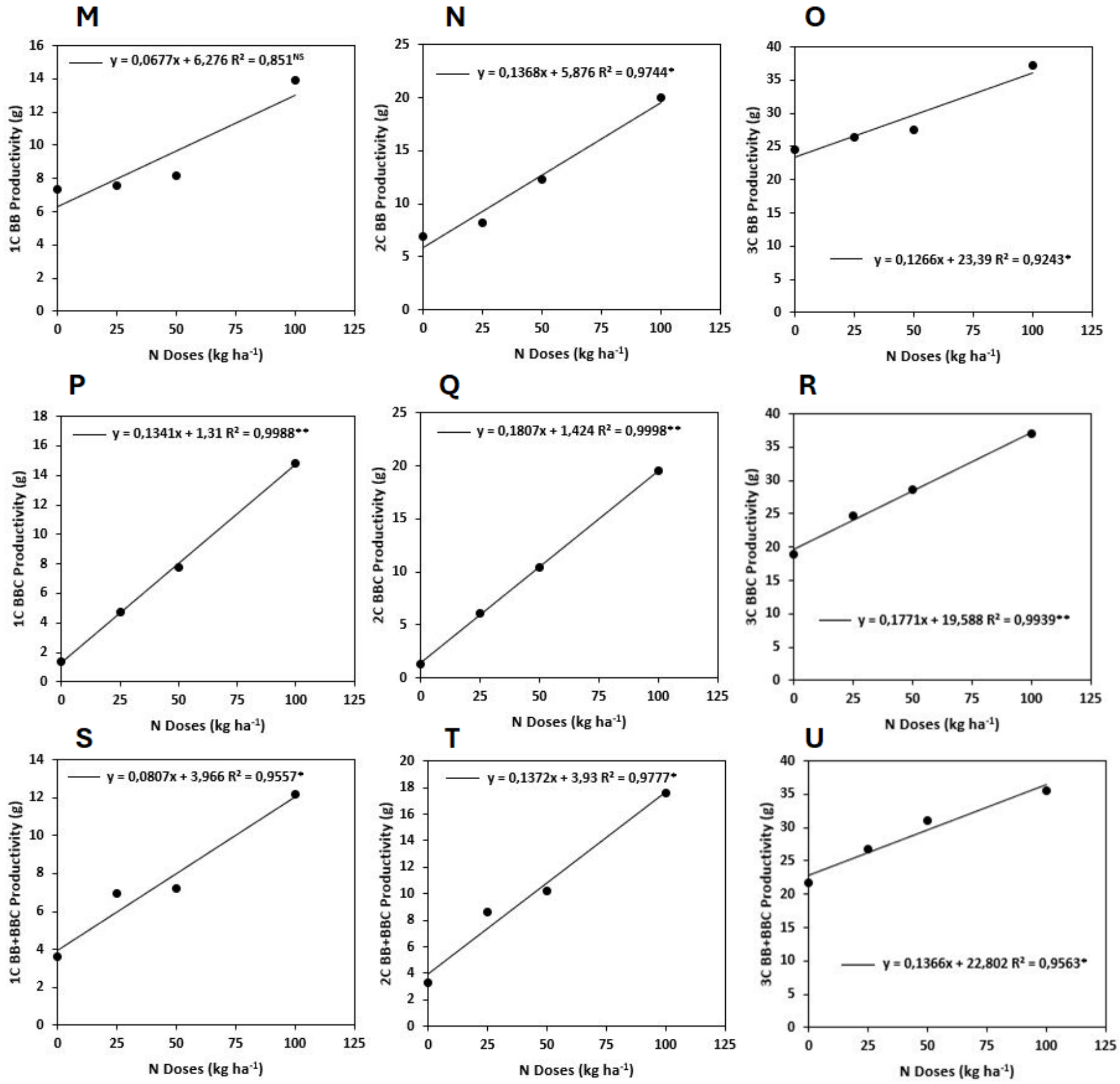
BP+BCP (Figures 4J, 4K, and 4L) and BBC (Figures 4P, 4Q, and 4R) also showed higher productivity due to the higher dose of NF. There is an increase in dry mass production as a function of N doses (SANTOS et al., 2013). Hurtado et al. (2010) in their study on different soils, showed increasing results for leaf dry mass with nitrogen doses, as obtained in the present study. Another factor that should be considered in relation to plant mass production in the 1st, 2nd, and 3rd cuts may also be related to phytotechnical, climatic, and temporal factors.

Figure 4 – Linear regression between the dry mass productivity of the aerial part from the 1st, 2nd, and 3rd cut of *Urochloa brizantha* cv. Marandu and nitrogen doses (Continued...)



(Continued...)

Figure 4 – Linear regression between the dry mass productivity of the aerial part from the 1st, 2nd, and 3rd cut of *Urochloa brizantha* cv. Marandu and nitrogen doses.



Source: The Authors, 2023.

Legend: SC (Control Soil); BP (Biosolids); BCP (Sugarcane Bagasse); BP+BCP (Biosolids + Sugarcane Bagasse); BB (Biosolids Biochar); BBC (Sugarcane Bagasse Biochar); BB+BBC (Biosolids Biochar + Sugarcane Bagasse Biochar). ** and * significant at 1% and 5%, respectively, by the t-test.

4 CONCLUSION

Biosolids at the dose corresponding to 100 kg of N ha^{-1} showed the highest dry mass production in all cuts. The incorporation of BP, BB, BP+BCP, and BB+BBC in the soil, individually or combined with NF, resulted in an increase in pH, Ca, CEC, and V. Biosolids and their respective biochar can act as soil amendments, providing the liming effect with limestone. Sugarcane bagasse, without NF, did not show positive effects on the productivity of Marandu grass, being comparable to control soil. Treatments with only sugarcane bagasse, individually or combined, presented higher levels of organic matter and carbon in the soil.

In this context, the research's contribution to the Western Paulista region, characterized by sandy soils with limitations such as low natural fertility, high acidity, and low organic matter content, represents an opportunity to utilize residues through agricultural recycling, which can result in economic, social, and environmental benefits.

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