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Effects of phosphorus, calcium and magnesium on biomass production of *Stylosanthes hamata* (L.) Taub., *Stylosanthes guianensis* (Aubl.) Sw., *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf) and *Brachiaria ruziziensis* Germ. & C.M. Evrard in Burkina Faso

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ABSTRACT

Legumes and grasses play an important role in livestock production and sustainable agriculture. In semi-arid regions like Burkina Faso, most of the natural rangelands are degraded with the low quantity and quality of forage. Thus, it is imperative to explore the strategies that could improve the biomass production of palatable legumes and grasses. In this study, the effects of nitrogen, phosphorus, calcium and magnesium on the quality and quantity of biomass of *Stylosanthes hamata, Stylosanthes guianensis, Brachiaria brizantha* and *Brachiaria ruziziensis* was evaluated in the experimental designs. The results showed that the best biomass production of *B. brizantha* and *B. ruziziensis* was: 2.3 t DM/ha for a dose of P0D0N50 and 0.9 t DM/ha for a dose of P50D0N0 in June; 2.6 t DM/ha for the dose of P0D400N50 and 1.734 t DM/ha for a dose of P0D0N0 in July; 3.9 t DM/ha for a dose of P100D400N50 and 2.4 t DM/ha for a dose of P0D400N0 in August. The highest biomass values of *S. hamata* and *S. guianensis* were: 1.9 t DM/ha for a D0P50 dose and 2.2 t DM/ ha for the D0P100 dose in June; 4.4 t DM/ha for the D400P100 dose and 5.4 t DM/ha for the D0P50 dose in July; 6.1 t DM/ha for the D0P100 dose and 9.5 t DM/ha for the D0P50 dose in August. From the results it can be seen that, fertilizers improved the biomass production of forage species, which is an advantage in meeting the feed needs of livestock.

Keywords: Biomass, Dolomite, Phosphorus, Nitrogen, *Brachiaria, Stylosanthes*, Burkina Faso.

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INTRODUCTION

In sub-Saharan Africa, livestock feed mainly depends on natural rangelands. However, these natural rangelands do not meet the maintenance needs of livestock throughout the year (Ouedraogo et al., 2019; Sanou et al., 2023). There is a considerable reduction in livestock productivity due to the fodder shortage either in quality and quantity for part of the year (Ouedraogo et al., 2022). Also, the anthropic pressure on natural resources due to rapid demographic growth and the increase in livestock, leads to a restriction of pastoral space on the one hand and its overexploitation on the other (Sanou, 2020; Zida et al., 2020, Ouattara et al., 2021). Consequently, competition for its exploitation leads to its degradation and conflicts (Kodio et al., 2001; Jeder et Sghaier, 2010).

It is admitted that feed is the main constraint to livestock production in a semi-arid environment especially in dry season (Sanou et al. 2023). But, primary productivity is restricted by the deficiency of assimilable phosphorus and nitrogen in soils which are very poor in organic matter (Hiernaux and Le Houerou, 2006). In rural Burkina Faso, livestock farming is essentially pastoral and faces a lack of natural rangelands. It is therefore imperative that solutions be explored for both qualitative and quantitative improvement of pastoral resources. To learn more about the behavior of forage species in the presence of fertilizing elements, the present study was initiated. It aimed at contributing to the improvement of the production of biomass and seeds of fodder grasses and legumes.

MATERIALS AND METHODS

Description of study site

The experiment was carried out at the Institute of Environment and Agricultural Research located at Farako-Bâ (11°06 N, 04°20 W, 405 m at sea level). Phytogeographically, the study site is situated in the southern sudanian zone of Burkina Faso with a mean annual rainfall varying between 900 mm and 1000 mm (Fontès and Guinko, 1995). The site has a unimodal rainy season, which lasts for about 7 months each year from May to November. The mean annual rainfall for the last decades was 1272±124 mm, and the number of rainy days per annum was 71±6. Mean daily minimum and maximum temperatures ranged from 14°C to 32°C in January (the coldest month) and from 25°C to 41°C in April (the hottest month). Soil types are mostly the tropical ferruginous to ferrallitic (Driessen et al., 2001), characterized by a sandy-loan texture with, pH 5.2 to 5.4, average organic matter content of 0.95 to 1.03% and low phosphorus content (41 to 85 mg/kg) (Sedogo et al., 1991). The natural pastures are dominated by woody species such as *Danielia olivieri*, *Afzelia africana, Isoberlinia doka, Pterocarpus erinaceus, Prosopis africana, Parkia biglobosa, Burkea africana* and *Albizzia chevalier* and some characteristic herbaceous species such as *Andropogon ascinodis, Andropogon gayanus, Aristida kerstingii, Ctenium newtonii, Loudetia togoensis, Monocymbium cereciforme, Pennisetum pedicellatum Schizachyrium sanguineum*, etc (Ouedraogo et al., 2019). Legumes species are rare in the vegetation of the study site. However, the legume *Indigofera* sp., which is mostly non palatable, occasionally has invaded some of these natural pastures. Aside from agriculture, which is the occupation of 80% of the area's active population, livestock breeding is the most second important activity for household income generation.

Species studied

Native to Africa, *Brachiaria brizantha* (Hochst. ex A. Rich.) and *Brachiaria ruziziensis* Germ. & Evrard are perennial herbaceous plants belonging to the

Poaceae family, to the Brachiaria genus which has around 100 species (Keller-Grein et al., 1996). The species*B. brizantha*, with a height between 0.8 m and 2 m, has a semi-erect to erect port (Seiffert, 1980). It has leaves that are 1.5 to 2 cm wide and 100 cm long, spreading with thickened and partially wavy edges, with parallel veins (Jacques-Félix, 1962; Husson et al., 2008b). They are dark green, glabrous or slightly hairy (Antandroy, 2010; Husson et al., 2008b). *B. ruziziensis* with a height between 1 and 1.5 m, has a semi-erect to creeping port (Husson et al., 2008b). Its leaves are 1 to 1.5 cm wide and 25 cm long; they are tender green and hairy (Husson et al., 2008b). *Brachiaria brizantha* and *B. ruziziensis* have a fasciculated root system which is composed of numerous roots, dense and capable of developing to a depth of more than 1.8 m. It is also capable of soil decompaction, restructuring them, injecting carbon at depth and effectively recycling leached nutrients (Husson et al., 2008b). *Brachiaria ruziziensis* is a photoperiodic plant, which flowers when the days shorten, while *B. brizantha* is non-photoperiodic (Husson et al., 2008b). Both grow in a wide variety of soils, but prefer fertile, well-drained soils. They have a high biomass production (quality fodder), and are capable of suppressing weeds. Globally, they adapt well to acidic soils; nevertheless, differences can be observed between species.

Native to South America, *Stylosanthes hamata* (L.) Taub., *Stylosanthes guianensis* (Aubl.) Sw., are perennial herbaceous plants belonging to the Fabaceae family, and the Stylosanthes genus. They have an average lifespan of 3 to 4 years (Cesar and Gouro, 2002). *S. guianensis* has an erect to semi-erect, non-twining port. It has a height of between 1 and 1.8 meters (Husson et al., 2008a). Its leaves are trifoliate, lanceolate, tender green to dark green in color, 0.5 to 5 cm long. It can grow on soils with a pH between 4 and 6 and shows very good tolerance to aluminum and manganese. However, very basic soils with a pH greater than 8.3 should be avoided (Husson et al., 2008a). It develops best between rainfall periods which vary from 600 to more than 3,000 mm/year (Husson et al., 2008a). *S. hamata* has a semi-erect to prostrate port with a height of approximately 1 m (Kabore, 2014). With a rainfall of 800 mm, *S. hamata* tends to behave like an annual and does not tolerate competition from local species. It has the advantage of re-seeding spontaneously and escaping the aging phenomenon which characterizes many other legumes (Cesar and Zoumana, 1998). *S. hamata* has alternate, trifoliate leaves of 16 to 26 mm long. Its inflorescences are small spikes of 315 flowers with trifoliate floral bracts (Kabore, 2014). *S. hamata* has fruits in the form of pods, each formed of two reticulated articles of 2 to 2.5 mm long, bearing a hook-shaped beak at the terminal. It has an average fertility rate of 71%, a viability rate of 36% and a germination rate of around 10 to 40% (Zampaligre, 2007; Sanfo, 2008). The particularity of *S. hamata* is its resistance to drought and anthracnose. Furthermore, it supports rainfall ranging from 400 to 1200 mm/year (Coulibaly, 1996). *S. guianensis* and *S. hamata* have a powerful root system which gradually improves the structure of compacted soils even at depth (although less quickly than grasses). The particularity of the root system of *S. guianensis* is that it can go down to more than 1.5 m for the main pivots and has no rhizomes or stolons. It can take root from stems lying on the ground which emit roots (Husson et al., 2008a). They are both excellent forage plants with very similar characteristics of 100-200 g/kg of digestible protein, 0.6-0.8 milk fodder units/kg, 52-60% digestibility, 30- 38% fiber, and 0.6-1.6%

calcium. Excellent fodder in green and at the young stage, *Stylosanthes* lignifies as it ages and its stems become unpalatable to animals (Husson et al., 2008a).

Experimental design

The study was carried out on a Split-Split-Split-Split-plots design for the *Brachiaria* test with the following treatments:

- Main treatment: Addition of dolomite at 0 kg/ha and 400 kg/ha;
- Secondary treatment: Nitrogen application at 0 kg/ha, 50 kg/ha, 100 kg/ha;
- Tertiary treatment: Phosphorus application at 0 kg/ha, 50 kg/ha, 100 kg/ha;
- Quaternary treatment: *Brachiaria* species with *B. brizantha* and *B. ruziziensis*.

Each elementary treatment was repeated four (04) times. The total number of plots for the device with *B. brizantha* and *B. ruriziensis* was 144. The spacing between the plots and each repetition was 1 m; and that between the different blocks was 2 m. The size of the plots was 30 m2 (6 m x 5 m). Sowing was carried out in continuous lines with spacings between the sowing lines of 80 cm. For the *Stylosanthes* test, the device was a Split-Split-Split-plots (Figure 5) with the following treatments:

- Main treatment: *Stylosanthes* species (*S. guianensis* and *S. hamata*);
- Secondary treatment: addition of dolomite at 0 kg/ha and 400 kg/ha
- Tertiary treatment: Phosphorus contribution at 0 kg/ha, 50 kg/ha, 100 kg/ha.

Each elementary treatment was repeated 4 times in the design. In total, this system included 48 elementary plots. Each elementary plot was 24 m^2 (6 m x 4 m). Sowing was carried out in continuous lines with spacings between the sowing lines of 80 cm.

Conduct of the test

Dolomite was added at a dose of 400 kg/ha 3 days before sowing. Triple super phosphate was also added 3 days before sowing at different doses from 0; 50; and 100 kg/ha. Urea was added 15 days after sowing at a dose of 0; 50; and 100 kg/ha. A weeding operation took place upon request. In each elementary plot, three lines were identified taking into account the borders to be mowed every month from the end of June. The first mowing was carried out at the end of June, the second at the end of July and the third at the end of August. At each mowing, the *Brachiaria* and *Stylosanthes* biomasses were mowed over one (1) linear meter of seedlings, which represents a plot of 0.80 m^2.

Data collection and analysis

The quantitative evaluation of the biomass was made according to the different treatments. The biomass obtained after mowing was packaged in polyethylene bags, labeled and transported to be weighed in the laboratory using a RADWAG brand electronic balance with a capacity of 6 kg and precision of 0.1 g to obtain the total fresh weight. Fresh weights were recorded on previously established data collection sheets. After weighing, the biomass of all the elementary plots of the same treatment was carefully mixed, then a sample of approximately 500 g was taken and then dried in a RAYPA brand oven at 65°C for 48 hours for analysis in the laboratory. Then two other samples of 100 g were taken and dried in a RAYPA brand oven at 105°C for 24 hours to determine the dry matter content (% DM). All data were submitted to anova analysis after normality test. Then, means separation was done when anova shows significant difference using Fisher LSD-test at 5%.

RESULTS

Evolution of *B. brizantha* and *B. ruziziensis* biomass production depending on the treatments

The highest biomass observed at the end of June was achieved by *B. brizantha* with 2.3 t DM/ha under the P0D0N50 treatment (Table 1). Next came the productions obtained by the same species in treatments P50D0N0 and P100D0N0 with respectively 2.1 t DM/ha and 2.0 t DM/ha. Generally speaking, the addition of 400 kg/ha of dolomite (D400) did not seem to improve the biomass production of *B. brizantha* at this period. At the end of July, the highest biomass production was obtained by *B. brizantha* with 2.6 t DM/ha corresponding to the P0D400N50 treatment. It was followed by treatments P50D400N50, P100D400N100 and P0D400N100 with biomass productions of 2.6 t DM/ha, 2.5 t DM/ha and 2.5 t DM/ha respectively. At this evaluation date, the addition of 400 kg/ha of dolomite seems to have had more effect on the biomass production of *B. brizantha*. At the end of August, the highest biomass production of 3.9 t DM/ha was observed with still *B. brizantha* on the P100xD400xN50 treatment. The improving effect of the addition of dolomite on biomass production seems to be maintained. From the start of the rainy season to August, the biomass production obtained with the different treatments was greater for *B. brizantha* compared to *B. ruziziensis*. For this second *Brachiaria* species, the highest biomass production in June was 0.9 t DM/ha corresponding to the P50D0N0 treatment. In July, the highest biomass was 1.7 t DM/ha for the P0D0N0 treatment while in August, the highest biomass was 2.4 t DM/ha for the P0D400N0 treatment.

We observe that the *Brachiaria* species factor had a very highly significant effect ($P<0.0001$) on biomass production at all evaluation periods (Table 2). Phosphorus intake had a highly significant effect ($P<0.003$) at the end of July assessment. The nitrogen supply factor had a very highly significant effect ($P<0.0001$) on the assessment of biomass at the end of June. As for the dolomite treatment, its effect was very highly significant ($P<0.0001$) at the evaluations at the end of June and the end of July and highly significant ($P=0.0004$) at the end of August.

The effects of the interactions varied widely. For simple interactions, species, phosphorus and dolomite interactions had no significant effect ($P>0.05$) on biomass production at any assessment period. Species and nitrogen interaction was very highly significant ($P<0.0001$) at the assessments at the end of June and July and significant ($P<0.05$) at the assessment at the end of the month of August. The species and dolomite interaction was highly significant ($P<0.0001$) at the evaluation at the end of July and not significant for those at the end of June and the end of August. Phosphorus and nitrogen interaction had a very significant effect ($P<0.0001$) at the end of June evaluation, highly significant ($P<0.01$) at the end of July evaluation and not significant ($P>0.05$) to that of the end of August. The nitrogen and dolomite interaction had a highly significant ($P=0.01$), significant ($P<0.05$) and non-significant ($P>0.05$) effect respectively at the end of June, July and August. For third level interactions, those species, phosphorus and nitrogen; species, phosphorus and dolomite; phosphorus, nitrogen and dolomite had highly significant effects ($P<0.001$ and $P<0.01$) respectively at the end of the June assessment. Interaction of all treatments had a significant effect at the end of the June evaluation ($P<0.01$). Given the very highly significant effect ($P<0.0001$) of the *Brachiaria* variety on biomass production, a variety by variety analysis of the effect of the other studied factors is necessary for better understanding.

Evolution of the biomass production of *B. brizantha* depending on the treatment

Separate analysis of the effects of studied treatments on biomass production of *B. brizantha* is presented in Table 3.

Evolution of *B. ruziziensis* biomass production depending on the treatments

The evaluation of the biomass of *B. ruziziensis* depending on the treatments (supply of P, Dolomite and N) is presented in Table 4. The biomass of this species was ranged from 300 to 900 kg DM/ha at the end of June. It increased up to 1,700 kg DM/ha at the end of July. At the end of August, this biomass production was of the order of 1,000 to 2,400 kg DM/ha, a fairly significant increase. The factors studied (contribution of dolomite, phosphorus and nitrogen) and their interactions had no significant effect ($P>0.05$) on the production of this biomass. On the other hand, during the cutting at the end of July, the effect of nitrogen supply as well as the interaction of nitrogen and dolomite was very highly significant ($P<0.0001$) and significant ($P<0.05$). At the cutting at the end of August, the additions of dolomite and nitrogen had highly significant ($P<0.0005$) and significant ($P<0.01$) effects on the biomass production of this species. The addition of dolomite had a significant effect while the addition of nitrogen had a negative effect on this biomass production.

The best biomass production of *S. guianensis* in June was 2.2 t DM/ha with the D0P100 treatment. Coming in second place was the D0P0 treatment, the biomass production of which was 2.2 t DM/ha. Generally speaking, the block without addition of dolomite (D0) recorded higher biomass production than the block amended with 400 kg/ha of dolomite (D400). In July, the highest production was 5.4 t DM/ha and corresponded to the D0×P50 treatment. This biomass was approximately 3 times the highest production in June. For this second evaluation period again, block D0 recorded higher biomass production than block D400. At the end of August, the best biomass production was 9.5 t DM/ha with the D0P50 treatment. It made approximately 2 times the highest production in the month of July. For this third evaluation period also, block D0 had a higher biomass production than block D400. The highest *S. hamata* biomass production in June was 1.9 t DM/ha with the D0×P50 treatment, followed by the biomass of the D0×P0 treatment (1.6 t DM/ha) and D0P100. (1.4 t DM/ha). Block D0 had higher biomass production than block D400. In July, the best biomass production was 4.401 t DM/ha for the treatment of D400P100, approximately 2.4 times that of June. Block D400 had higher biomass production than block D0. In August, the highest production increased to 6.1 t DM/ha for the D0P100 treatment, approximately 1.4 times that of July. Block D0 had higher biomass production than block D400.

The analysis of the effect of the studied factors is presented in Table 5, showing a non-significant difference ($P> 0.05$) during the 3 months between *S. guianensis* and P; between *S. guianensis* and dolomite; and between *S. guianensis* plus P and dolomite. The analysis of the factors studied in Table 6 reveals a significant difference ($P < 0.05$) in the month of July between *S. hamata* and P. During the months of June and August, there was no difference significant ($P > 0.05$) between *S. hamata* and P. For the interactions between *S. hamata* and dolomite, and between *S. hamata* plus P and dolomite, there was no significant difference ($P > 0.05$) during the 3 months (Table 7).

Table 1: Biomass production of *B. brizantha* and *B. ruziziensis* depending on treatments (kg DM/ha; n = 4).

Species	Phosphorus.	Dolomite	Nitrogen	Period of cutting: End of June Mean	SD	End of July Mean	SD	End of August Mean	SD
B. brizantha	P0	D400	N0	722^{a}	107	$1,474^{g}$	159	$2,619^{f}$	908
			N50	$1,081^{f}$	306	$2,613^{m}$	410	$2,921^{h}$	751
			N100	685^{a}	204	$2,538^{m}$	254	$2,856^{h}$	302
		D0	N0	$1,064^{d}$	288	697^{b}	124	$2,553^{e}$	696
			N50	$2,331^{k}$	588	$1,397^{d}$	532	$2,900^{h}$	354
			N100	780^{a}	267	$1,456^{g}$	349	$2,973^{h}$	525
	P50	D400	N0	993^{e}	184	$1,445^{f}$	248	$3,703^{m}$	400
			N50	$1,337^{i}$	357	$2,562^{m}$	300	$2,681^{g}$	1,311
			N100	458^{a}	82	$1,726^{j}$	299	$3,531^{l}$	1,254
		D0	N0	$2,126^{k}$	743	$1,225^{c}$	646	$2,306^{d}$	701
			N50	$1,109^{f}$	800	$1,558^{h}$	686	$2,874^{h}$	750
			N100	651^{a}	190	$1,365^{e}$	486	$2,352^{d}$	111
	P100	D400	N0	$1,459^{j}$	884	$2,331^{l}$	672	$3,484^{l}$	580
			N50	$1,164^{g}$	322	$2,399^{l}$	571	$3,862^{n}$	946
			N100	493^{a}	193	$2,539^{m}$	953	$3,210^{j}$	677
		D0	N0	$2,016^{k}$	452	$1,701^{j}$	389	$3,346^{k}$	816
			N50	$1,234^{h}$	257	$1,607^{i}$	232	$3,083^{i}$	385
			N100	550^{a}	321	$1,933^{k}$	274	$2,676^{g}$	1,081
B. ruziziensis	P0	D400	N0	393^{a}	245	957^{a}	218	$2,434^{e}$	1,393
			N50	495^{a}	182	770^{a}	420	$1,426^{a}$	71
			N100	525^{a}	254	$1,000^{a}$	200	$1,776^{a}$	405
		D0	N0	809^{b}	131	$1,734^{h}$	493	$1,112^{a}$	420
			N50	593^{a}	416	693^{a}	321	975^{a}	474
			N100	502^{a}	180	$1,027^{b}$	377	$1,565^{a}$	682
	P50	D400	N0	482^{a}	146	$1,105^{b}$	450	$2,340^{d}$	641
			N50	447^{a}	51	901^{a}	217	$1,841^{a}$	655
			N100	483^{a}	309	900^{a}	198	$1,599^{a}$	699
		D0	N0	935^{c}	206	$1,331^{e}$	107	$1,685^{b}$	682
			N50	498^{a}	65	735^{a}	226	$1,132^{a}$	336
			N100	315^{a}	215	478^{a}	50	$1,093^{a}$	555
	P100	D400	N0	465^{a}	252	$1,703^{j}$	203	$2,144^{c}$	805
			N50	364^{a}	127	946^{a}	106	$1,509^{a}$	835
			N100	451^{a}	140	615^{a}	274	$1,674^{a}$	737
		D0	N0	689^{a}	527	$1,214^{d}$	81	$1,199^{a}$	423
			N50	344^{a}	183	879^{a}	439	$1,407^{a}$	333
			N100	740^{a}	300	730^{a}	76	$1,211^{a}$	425

Note : In the same column, means with the same letter are not significantly different (P> 0.05).

Table 2: Effects of the factors studied on biomass yield.

Sources of variation	DF	Period of evaluation					
		End of June		End of July		End of August	
		F	Pr > F	F	Pr > F	F	Pr> F
Variety of Brachiaria	1	107.17	< 0.0001	169.35	< 0.0001	128.26	< 0.0001
Phosphorus	2	0.05	0.9522	6.22	0.00277	1.32	0.27133
Nitrogen	2	23.70	< 0.0001	0.54	0.58562	3.03	0.05237
Dolomite	1	21.04	< 0.0001	30.26	< 0.0001	13.33	0.0004
Species×Phosphorus	2	0.24	0.78503	2.57	0.08087	1.81	0.16795
Species×Nitrogen	2	19.23	< 0.0001	24.60	< 0.0001	3.55	0.03212
Species×Dolomite	1	3.87	0.05185	28.30	< 0.0001	0.00	0.98676
Phosphorus×Nitrogen	4	6.94	< 0.0001	3.50	0.00996	0.80	0.52656
Phosphore×Dolomite	2	0.56	0.57456	0.12	0.88939	1.02	0.36406
Azote×Dolomite	2	5.05	0.00802	3.57	0.03166	0.29	0.74852
Species×Phosphorus×Nitrogen	4	4.79	**0.00135**	1.67	0.16283	0.77	0.54848
Species×Phosphorus× Dolomite	2	0.69	0.50283	2.50	0.08689	0.86	0.42787
Species×Nitrogen×Dolomite	2	0.40	0.66872	0.64	0.52677	0.22	0.80083
Phosphorus×Nitrogen× Dolomite	4	3.69	**0.00744**	1.81	0.13281	0.54	0.70314
Species×Phosphorus×Nitrogen× Dolomite	4	3.37	**0.01226**	0.62	0.64892	1.18	0.3243

Note: the valued of probability values in bold face are statistically significant (P<0.05).

Table 3: Effect of N, P, Ca and Mg on biomass production of *B. brizantha* (kg DM/ha; n = 4).

Treatments			Period of evaluation					
			End of June		End of July		End of August	
Phosphorus	Dolomite	Nitrogen	Mean	SD	Mean	SD	Mean	SD
P0	D400	N0	722[a]	107	1,474[g]	159	2,619[f]	908
		N50	1,081[f]	306	2,613[m]	410	2,921[h]	751
		N100	685[a]	204	2,538[m]	254	2,856[h]	302
	D0	N0	1,064[d]	288	697[b]	124	2,553[e]	696
		N50	2,331[k]	588	1,397[d]	532	2,900[h]	354
		N100	780[a]	267	1,456[g]	349	2,973[h]	525
P50	D400	N0	993[e]	184	1,445[f]	248	3,703[m]	400
		N50	1,337[i]	357	2,562[m]	300	2,681[g]	1,311
		N100	458[a]	82	1,726[j]	299	3,531[l]	1,254
	D0	N0	2,126[k]	743	1,225[c]	646	2,306[d]	701
		N50	1,109[f]	800	1,558[h]	686	2,874[h]	750
		N100	651[a]	190	1,365[e]	486	2,352[d]	111
P100	D400	N0	1,459[j]	884	2,331[l]	672	3,484[l]	580
		N50	1,164[g]	322	2,399[l]	571	3,862[n]	946
		N100	493[a]	193	2,539[m]	953	3,210[j]	677
	D0	N0	2,016[k]	452	1,701[j]	389	3,346[k]	816
		N50	1,234[h]	257	1,607[i]	232	3,083[i]	385
		N100	550[a]	321	1,933[k]	274	2,676[g]	1,081

Effects of studied factors							
Sources of variation	DF	F	Pr > F	F	Pr > F	F	Pr > F
Phosphorus	2	0.0657	0.9364	4.8599	0.0115	2.3045	0.1095
Nitrogen	2	27.1280	< 0.0001	5.4229	0.0071	0.1822	0.8339
Dolomite	1	14.9311	0.0003	33.7306	< 0.0001	4.9643	**0.0301**
Phosphorus×Nitrogen	4	6.2142	0.0003	1.9686	0.1124	0.6994	0.5957
Phosphorus×Dolomite	2	0.9920	0.3775	0.5704	0.5687	2.0900	0.1336
Nitrogen×Dolomite	2	2.7176	0.0751	2.5915	0.0842	0.3142	0.7317
Phosphorus×Nitrogen×Dolomite	4	3.7439	0.0093	0.6780	0.6102	1.3397	0.2672

Note: Means in the same column with the same letters are not significantly different (P>0.05).

Table 4: Biomass production of *B. ruziziensis* depending on treatments (kg DM/ha; n = 4).

Treatments			**Period of evaluation**					
			End of June		**End of July**		**End of August**	
Phosphorus	**Dolomite**	**Nitrogen**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
P0	D400	N0	393[a]	245	957[a]	218	2,434[e]	1.393
		N50	495[a]	182	770[a]	420	1,426[a]	71
		N100	525[a]	254	1,000[a]	200	1,776[a]	405
	D0	N0	809[b]	131	1,734[h]	493	1,112[a]	420
		N50	593[a]	416	693[a]	321	975[a]	474
		N100	502[a]	180	1,027[b]	377	1,565[a]	682
P50	D400	N0	482[a]	146	1,105[b]	450	2,340[d]	641
		N50	447[a]	51	901[a]	217	1,841[a]	655
		N100	483[a]	309	900[a]	198	1,599[a]	699
	D0	N0	935[c]	206	1,331[e]	107	1,685[b]	682
		N50	498[a]	65	735[a]	226	1,132[a]	336
		N100	315[a]	215	478[a]	50	1,093[a]	555
P100	D400	N0	465[a]	252	1,703[j]	203	2,144[c]	805
		N50	364[a]	127	946[a]	106	1,509[a]	835
		N100	451[a]	140	615[a]	274	1,674[a]	737
	D0	N0	689[a]	527	1,214[d]	81	1,199[a]	423
		N50	344[a]	183	879[a]	439	1,407[a]	333
		N100	740[a]	300	730[a]	76	1,211[a]	425
Effects of studied								
Sources of variation		DF	F	Pr > F	F	Pr > F	F	Pr > F
Phosphorus		2	0.1860	0.8308	1.0208	0.3672	0.0388	0.9620
Nitrogen		2	1.0034	0.3733	16.0215	< 0.0001	4.2198	0.0198
Dolomite		1	3.0317	0.0873	1.6490	0.2046	13.9542	0.0005
Phosphorus×Nitrogen		4	1.4393	0.2336	2.6160	0.0451	0.6339	0.6405
Phosphorus×dolomite		2	0.2694	0.7649	2.0938	0.1331	0.1627	0.8502
Nitrogen×dolomite		2	1.1129	0.3360	0.0207	0.9795	0.9875	0.3791
Phosphorus×Nitrogen×dolomite		4	1.0318	0.3993	2.9966	0.0263	0.3265	0.8590

Note:Means in the same column with the same letters are not significantly different (P>0.05).

Table 5: Biomass production (kg MS/ha; n = 4): S. *hamata* and *S. guianensis.*

Culture	Dolomite	Phosphorus	Period of cutting					
			End of June		End of July		End of August	
			Mean	SD	Mean	SD	Mean	SD
S. guianensis	D400	P0	1,111^{a}	464	3,819^{ab}	973	6,798^{bc}	2,379
		P50	1,041^{a}	546	4,750^{bc}	1,953	6,044^{abc}	2,896
		P100	1,189^{a}	701	4,148^{ab}	747	7,455^{abc}	1,027
	D0	P0	2,175^{b}	894	4,709^{bc}	963	7,775^{abc}	771
		P50	1,404^{ab}	717	5,408^{c}	2,775	9,548^{d}	2,623
		P100	2,197^{b}	1,012	4,994^{bc}	1,608	6,623^{c}	2,436
S. hamata	D400	P0	1,562^{a}	487	3,327^{abc}	649	4,481^{ab}	734
		P50	1,367^{ab}	317	3,029^{a}	968	×5,413^{ab}	850
		P100	1,057^{ab}	312	4,401^{ab}	847	4,863^{a}	2,514
	D0	P0	1,590^{ab}	212	3,087^{abc}	693	4,385^{abc}	1,263
		P50	1,857^{ab}	395	3,073^{a}	384	5,628^{abc}	1,185
		P100	1,384^{ab}	341	4,296^{a}	1,249	6,063^{a}	995
Effects of studied factors								
Source of variation		DF	F	Pr > F	F	Pr > F	F	Pr > F
Variety		1	0.09	0.7691	8.42	0.0063	17.95	**0.0002**
Phosphorus		2	0.48	0.6205	1.21	0.30903	0.76	0.473
Dolomite		1	10.50	**0.0026**	0.84	0.36462	2.46	0.1253
Culture×Phosphorus		2	2.18	0.1283	1.89	0.16644	0.49	0.6164
Culture×Dolomite		1	2.47	0.1247	1.40	0.24482	0.54	0.4664
Phosphore×Dolomite		2	0.17	0.8442	0.00	0.99887	0.98	0.3867
Culture×Phosphorus×Dolomite		2	1.04	0.363	0.04	0.96132	2.14	0.1325

Note: Means in the same column with the same letters are not significantly different (P>0.05)

Table 6: Biomass production of *S. guianensis* (kg DM/ha; n = 4).

Dolomite	Phosphorus	Period of cutting					
		End of June		End of July		End of August	
		Mean	SD	Mean	SD	Mean	SD
D400	P0	1,111^{a}	464	3,819^{ab}	973	6,798^{bc}	2,379
	P50	1,041^{a}	546	4,750^{bc}	1,953	6,044^{abc}	2,896
	P100	1,189^{a}	701	4,148^{ab}	747	7,455^{abc}	1,027
D0	P0	2,175^{b}	894	4,709^{bc}	963	7,775^{abc}	771
	P50	1,404^{ab}	717	5,408^{c}	2,775	9,548^{d}	2,623
	P100	2,197^{b}	1,012	4,994^{bc}	1,608	6,623^{c}	2,436
Effetcs of studied factors							
Sources of variation	DF	F	Pr > F	F	Pr > F	F	Pr > F
Phosphorus	2	0.958	0.402	0.492	0.619	0.251	0.781
Dolomite	1	7.095	0.016	1.388	0.254	1.868	0.188
Phosphorus×Dolomite	2	0.545	0.589	0.011	0.989	1.997	0.165

Table 7: Biomass production of *S. hamata* (kg DM/ha; n = 4).

Dolomite	Phosphorus	Period of cutting: End of June		End of July		End of August	
		Mean	SD	Mean	SD	Mean	SD
D400	P0	1,562[a]	487	3,327[abc]	649	4,481[ab]	734
	P50	1,367[ab]	317	3,029[a]	968	5,413[ab]	850
	P100	1,057[ab]	312	4,401[ab]	847	4,863[a]	2,514
D0	P0	1,590[ab]	212	3,087[abc]	693	4,385[abc]	1,263
	P50	1,857[ab]	395	3,073[a]	384	5,628[abc]	1,185
	P100	1,384[ab]	341	4,296[a]	1,249	6,063[a]	995
Effects of studied factors							
Sources of variation	DF	F	Pr > F	F	Pr > F	F	Pr > F
Phosphorus	2	2.979	0.076	5.650	**0.012**	1.554	0.238
Dolomite	1	3.788	0.067	0.085	0.774	0.601	0.448
Phosphorus×Dolomite	2	0.878	0.433	0.056	0.945	0.474	0.630

Means in the same column with the same letters are not significantly different (P>0.05).

DISCUSSION

Effect of phosphorus, calcium and magnesium on the biomass production of *B. brizantha* and *B. ruziziensis*

The results showed that the P0D0N50, P0D400N50 and P100D400N50 treatments achieved high yields of *B. brizantha* biomass. Nitrogen fertilization improve the biomass production of the grasses studied during the evaluation at the end of June. This result corroborates those of Lee et al. (2017) who found that the addition of N increases the biomass production of grasses. By combining this nitrogen supply with a supply of 400 kg/ha of dolomite, biomass production becomes higher. Therefore, dolomite has a positive effect on the biomass production of *B. brizantha*. This result corroborates those of Jacques and Pierre (2005) who found that calcium and magnesium play an equally important role, both for crop growth and obtaining yields.

Phosphorus at 100 kg/ha associated with the D400xN50 interaction gives better yields than the doses of 0 and 50 kg/ha of P associated with the D400N50 interaction. Thus, a high dose of P associated with the D400N50 interaction makes it possible to obtain excellent production; this result corroborates those of Faria et al. (2018) who demonstrate that a high P content increases the growth of *Brachiaria*. At the end of June, July and August the best biomass production of *B. ruziziensis* was obtained by the P50D0N0, P0D0N0 and P0D400N0 treatments. We noted that nitrogen had a negative effect on the biomass production of *B. ruziziensis*. However, it was only in June that phosphorus increased the biomass production of *B. ruziziensis*. Phosphorus at this period had a positive effect on the biomass production of *B. ruziziensis*; this result corroborates those of Faria et al. (2018) who showed that a high P content increases the growth of *Brachiaria*. Also, dolomite allowed the increase in biomass production of *B. ruziziensis*; this result corroborates those of Jacques and Pierre (2005) who proved that calcium and magnesium play an equally important role, both for the growth of crops and obtaining yields.

Effect of phosphorus, calcium and magnesium on the biomass production of *S. hamata* and *S. guianensis*

The results showed that the D0P100, D0P50 and D0P50 treatments provide better yields in the biomass production of *S. guianensis* during the months of June, July and August. We noted that dolomite negatively influenced the production of *S. guianensis* during these same periods. On the other hand, phosphorus made it possible to increase the biomass production of *S. guianensis*. This result corroborates those of Mitran et al. (2018) who demonstrated that phosphorus only slightly stimulates the biomass production of herbaceous legumes. The best biomass productions of *S. hamata* during the months of June, July and August were obtained by treatments D0P50, D400P100 and D0P100. During June and August, dolomite negatively influenced the biomass production of *S. hamata*. On the other hand, in July, it increased the biomass production of *S. hamata*. This result corroborates that of Bado (2002) who noted that dolomite increases the biomass of legumes. Phosphorus increased the biomass production of *S. guianensis*.

Conclusion

This study aimed to contribute for improving the production of biomass and seeds of grass and legume species through the provision of fertilizers. The addition of fertilizers such as dolomite, phosphorus and nitrogen allowed the increase in the biomass production of *B. brizantha* and *B. ruziziensis*. In the case of *Stylosanthes*, only the addition of phosphorus allowed an improvement in biomass production, thus confirming the ability of these two Stylosanthes to develop on acidic soils. Over time, the total nitrogen, phosphorus and calcium contents of the harvested forages decreased significantly with the aging of the forages. Fertilization contributed to improving the quality of the different forages studied. These results confirm the hypothesis according to which the addition of fertilizer improves the quality of *Brachiaria* and *Stylosanthes* forage.

In view of these results, the use of dolomite, phosphorus and nitrogen can be recommended as fertilizers capable of increasing the quantity of *Brachiaria* fodder. For *Stylosanthes*, only the addition of phosphorus can be recommended.

COMPETING INTERESTS

Authors declare that there is no competing interests.

AUTHORS' CONTRIBUTIONS

SO and LS conceived the idea of the research and make data analysis. SO and LS wrote the first draft with the contribution of BO and SK. SK corrected the final draft. SO, LS, BO and SK approved the submitted version.

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