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DOLOMITE, PHOSPHORUS AND NITROGEN FERTILIZATION AFFECT BIOMASS PRODUCTION AND SEED QUALITY OF FODDER SPECIES *BRACHIARIA RUZIZIENSIS* GERM. & EVRARD, *STYLOSANTHES HAMATA* (L.) AND *STYLOSANTHES GUIANENSIS* (AUBL.)

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ABSTRACT

Seed production of forage species in the natural rangelands reflects its ability to reseed and enrich the rangeland. This study aims to evaluate the effect of dolomite and phospho-nitrogen fertilization on the biomass production and seed quality of *Brachiaria ruziziensis*, *Stylosanthes hamata*, and *Stylosanthes guianensis* in Burkina Faso. Thus, two split plots experimental setups were established in the Farako-Bâ, Burkina Faso. The first block without dolomite was composed of nine treatments in four repetitions. The experiment involved the cultivation of *Brachiaria ruziziensis* (Ruzi, Congo grass) on elementary plots of 30 m^2, with treatments consisting of two doses of dolomite (0 and 400 kg. ha^{-1}), three doses of nitrogen (N) (0; 50; and 100 kg N. ha^{-1}) and three doses of phosphorus (P) (0; 50 and 100 kg P_2O_5.ha^{-1}). In the second experiment design, two varieties of *Stylosanthes* were grown, with treatments including two doses of dolomite (0 and 400 kg. ha^{-1}) and three doses of P (0; 50; and 100 kg P_2O_5.ha^{-1}). Each elementary treatment was repeated 4 times in the experimental design. The results showed that the application of dolomite, P and N significantly influenced the biomass of *Brachiaria ruziziensis*. The plot treated with dolomite and fertilized at doses of 50 P/ha and 100 N. ha^{-1} provided a biomass (7403 kg DM. ha^{-1}) ten times greater than that treated with dolomite and fertilized at doses of 100 kg P. $ha^{-1}$and 100 N. ha^{-1} (734 kg DM. ha^{-1}). For seed quality, N influenced the rate and germination speed of *Brachiaria ruziziensis*. In addition, the contribution of dolomite to the variety of *Stylosanthes hamata* influenced grain yield and 1000-grain weight respectively ($P<0.05$). *S. hamata* variety showed better performance with grain yield of 191 kg. $ha^{-1}$and 3.81 g/1000 seeds. Based on these results, phospho-nitrogen fertilization seems necessary to increase the biomass production and the grain yield of *Brachiaria ruziziensis*. This implies that a combination of P and N fertilizers with dolomite would be beneficial for enhancing the productivity of this species.

Keywords: Biomass, *Brachiaria ruziziensis,* Fertilizers, Fodder, Grasses, Legumes, *Stylosanthes hamata, Stylosanthes guianensis.*

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INTRODUCTION

In Sahelian countries, livestock farming employs more than 86% of the active population. It contributes approximately 10 to 20% of the gross domestic product. Livestock farming is the main source of income for rural households (Ouedraogo *et al.* 2019). It also provides various products (meat, milk, hides and skins, manure, labor). Some of these aforementioned products are sold to meet household needs.

Nowadays, livestock farming in the Sahel is facing enormous problems such as the conversion of natural rangelands into agricultural land, the degradation of pastures due to animal overload. This situation has negatively impacted the quantity and quality of fodder. The pastoral system based essentially on livestock mobility in search of available biomass in natural rangelands is encountering difficulties (Vall and Diallo, 2009; Sanou *et al*. 2023). This situation creates environmental problems. This results in high agricultural and pastoral pressure on natural resources combined with the perverse effects of accentuated climate change.

This calls for exploring innovative solutions to improve soil productivity for crops and fodder. Thus, Tarawali (1998) and Nacro *et al*., (2010) have proposed different solutions.

For example, Tarawali (1998) demonstrates that the effects of manure and artificial fertilizer application on sorghum crops in Burkina Faso showed that the application of chemical fertilizers on tropical soils leads to stagnation of crop yields but that a combination of manure and NPK resulted in sustainable increases in crop yields. Nacro *et al*. (2010) applied organic manure, P and N which improve soil fertility and grain and biomass yield of maize and cotton.

The adoption of innovative technologies such as crop-livestock integration could allow the preservation of natural resources and ensure sustainable development.
In the western region of Burkina Faso, *Brachiaria ruziziensis*, *Stylosanthes hamata* and *S. guianensis* appear to be the forage species best adapted to the existing agroclimatic conditions. Several research studies have also proven that these species have good nutritional value and are highly palatable to animals (Koffi, 1992; Pamo and Yonkeu, 1987; Pamo *et al*., 2007; Ouedraogo *et al*., 2024; Sanou *et al*., 2023).

The adoption of forage crops has advantages both in terms of livestock feed and in terms of soil rehabilitation and protection (Sanou *et al*. 2024). However, one of the major constraints to the success of forage crops is the decline in soil fertility and the high price of seeds in Burkina Faso. This situation does not allow for high production of forage biomass and seeds of quality and quantity for their restoration in order to enrich natural pastures. However, it is recognized that soil fertility affects their ability to produce under current growing conditions and to optimize crop yield and seed quality obtained. Therefore, soil fertilization for good crop yield and seed quality becomes imperative, especially in forage cultivation.

This present study is part of a contribution to a better recommendation for the fertilization of these mentioned species, for a more profitable production of forage biomass and seed quantity.
This study aims to evaluate the effect of dolomitic and phospho-nitrogen fertilization on the yield and quality of seeds of *Brachiaria ruziziensis*, *Stylosanthes hamata* and *Stylosanthes guianensis* in Burkina Faso. We tested the effect of dolomite and phospho-nitrogen fertilization on the yield and seed quality of *Brachiaria ruziziensis*; *Stylosanthes hamata* and *Stylosanthes guianensis*. We hypothesized that the addition of dolomite and phospho-nitrogen fertilization improves biomass production, grain yield and seed quality of *Brachiaria ruziziensis, Stylosanthes hamata* and *Stylosanthes guianensis*. The results of this study could contribute to the formulation of one of the best formulas for forage production in Burkina Faso in a context of overload of natural pastures.

MATERIALS AND METHODS

Description of the study site: This study was carried out at the Farako-Bâ, located in the Sudanian zone of Burkina Faso (4°20'W; 11°06'N; Alt. 405 m). According to Fontès and Guinko (1995), the climate of Farako-Bâ is dominated by a Sudanian tropical climate.

Based on data collected from an in situ mini-weather station at Farako-Bâ Research Station for the recent decade (2012-2022), the mean annual precipitation varies between 900 and 1,000 mm. The mean annual precipitation was 1065 mm ± 158.73 and the mean number of rainy days was 90 ± 7 (Table 1). Mean daily minimum and maximum temperatures ranged from 16 to 32 °C in January (the coldest month) and from 26 to 40 °C in April (the hottest month). The vegetation of Farako-Bâ is characterized by shrubland and woodland, open forest and gallery forest. *Parkia biglobosa, Detarium microcarpa, Vittelaria paradoxa, Gmelina arborea, Mangifera indica, Khaya senegalensis* and *Tamarindus indica* are the dominant species of the woody layer. The herbaceous layers are dominated by *Andropogon gayanus, Andropogon pseudapricus, Andropogon fastigiatus, Loudetia togoensis, Eragrostis tremula, Digitaria horizontalis* etc. (Ouédraogo *et al*. 2019). The encountering ferruginous soils are leached or poorly leached and on sandy, sandy clay and clay-sandy materials. These soils are poor in clay, organic matter, calcium, potassium and P, explaining their low cation exchange capacity. They have also poor structure and are susceptible to be eroded. Their average depth remains an important asset in a country where the soils are mostly superficial, ranging from 40 to 100 cm deep (Sanou *et al*., 2023).

Table 1: Wheater data at the experiment site between 2012-2022.

Climatic parameters	Values
Monthly average temperature	26±15°C
Rainfall (mm)	1065± 158.73
mean number of rainy days	90 ± 7
Relative humidity	82%

Species studied: *Stylosanthes hamata* and *Stylosanthes guianensis* are legumes with a lifespan of approximately 3 years. They have slow and heterogeneous germination during the first months. They dominate weeds through their perennial trait and their high biomass production (Husson *et al*., 2008).

Brachiaria ruziziensis is a perennial herb of tropical regions, and makes excellent fodder. *B. ruziziensis* is diploid and has a high rate of self-pollination. *B. ruziziensis* a fodder production of around

5-6 t DM. $ha^{-1}$and with a seed production of up to 50-100 kg. ha^{-1} (Ouedraogo *et al*., 2023).

Experimental design: Two experimental designs were used. The first split-split-plot design for the grass *B. ruziziensis* was composed of the following treatments:

(1) main treatment: Addition of dolomite at 0 kg. ha^{-1} (D0) and 400 kg. ha^{-1} (D400);

(2) secondary treatment: N application at 0 kg. ha^{-1} (N0), 50 kg/ha (N50), 100 kg. ha^{-1} (N100);

(3) tertiary treatment: P application at 0 kg. ha^{-1} (P0), 50 kg/ha (P50), 100 kg. ha^{-1} (P100).

The first block without dolomite was composed of nine treatments in four (04) repetitions: D0P0N0, D0P0N50, D0P0N100, D0P50N0, D0P50N50, D0P50N100, D0P100N0, D0P100N50, D0P100N100. The second block with dolomite also included nine treatments in four (04) repetitions: D400P0N0, D400P0N50, D400P0N100, D400P50N0, D400P50N50, D400P50N100, D400P100N0, D400P100N50, D400P100N100. 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.

The second experimental design which was also a split-split plot for the two legumes is composed as follows:

(1) main treatment: Stylosanthes species (*S. guianensis* and *S. hamata*);

(2) secondary treatment: Addition of dolomite at 0 kg. ha^{-1} (D0) and 400 kg. ha^{-1} (D400);

(3) tertiary treatment: P application at 0 kg. ha^{-1} (P0), 50 kg/ha (P50), 100 kg. ha^{-1} (P100).

The variety of the species constitutes the qualitative factor for this experimental design, and forms a block. The dolomite-free block was composed as follows: D0P0 D0P50 D0P100. Finally, the block with dolomite was composed of D400P0, D400P50, D400P100. Each elementary treatment was repeated 4 times in the design. Each elementary plot was 24 m² (6 m x 4 m). Sowing was carried out in continuous lines with spacings between the sowing lines of 80 cm. Thus, sowing of Brachiaria and Stylosanthes was done on 1st Jully 2022 and the harvest date for the both studies specie was 30th October 2022.

Data collection and statistical analyzes

Biomass assessment: The evaluation of the biomass was made according to the different levels of fertilization and the different cuts. Thus, we measured the biomass of *Brachiaria ruziziensis* at 70 and 86 days after sowing. For *Stylosanthes guianensis* and *Stylosanthes hamata,* we measured their biomass at 80 and 96 days after sowing.
This biomass was weighed using a balance to determine the fresh mass (FM) of the samples from each plot. Then, the biomass from the 4 replicates was pooled and carefully mixed to obtain a composite sample. From this composite sample, two 100 g samples were taken for each species to be dried in an oven at 105°C. Another 500 g sample was taken and then dried in an oven at 65°C for 48 hours. This sample was ground using a 0.25 mm mesh grinder, and stored in biodegradable envelopes for the various chemical analyses. The production of dry matter biomass was determined by the following formula:

$$Biomass\ (kg\ DM) = \frac{\text{Fresh biomass (g)}\ x\ \%\ DM\ x\ 10000\ m^2}{\text{mown area (m}^2\text{)}\ x\ 1000}$$

Where mown area = 0.8 m^2

Evaluation of seed production: Determination of seed production permits the estimation of the seed production capacity of the species. At the end of the vegetative cycle, seed production of *B. ruziziensis* was evaluated using the inflorescence bagging method. According to Klein *et al.* (2014), bagging is done in bags allowing air to pass through (jute or perforated plastic). In the case of our study, the mosquito net bags were used to cover and tie the inflorescences of the plant just before their full maturity characterized by dehiscence of spikelets. Four bags were placed over a length of 0.5 m on the three central lines in each elementary plot. Once cut, the inflorescences covered by the bags were exposed to the open air in the sun for drying before being sorted and weighed. Grain yield was determined from seed samples obtained per bag. For the Stylosanthes, once maturity was reached, the harvest was made on an area of 1 m^2 twice in each elementary plot. These collected samples were dried and then processed to obtain the seeds of each variety of Stylosanthes. The formula used to calculate the grain yield was as follows:

$$Grain\ yield\ (kg/ha) = \frac{weight\ grain\ (g)\ x\ 10000\ m^2}{harvested\ area\ (m^2)\ x\ 1000}$$

Where harvested area: 1 m^2

Estimated 1000-grain weight of seeds: The evaluation of 1000-grain weight seeds was carried out on 72 samples of *Brachiaria ruziziensis* and 48 samples for *Stylosanthes hamata* and *Stylosanthes guianensis*. These samples were counted using a grain counter (Nimugral, DIMO's Labstronics, Canada). Through its universal bowl and the adjustment screw, the device allows you to automatically count seeds or seeds. Then the weight of these 1000 seeds was determined using an electronic balance with a sensitivity of around 0.1 mg.

Germinative characteristic of seeds: The aim was to determine the maximum germination potential of the seeds in order to assess their quality and estimate their value before sowing. The germination test was done 8 months after harvest. In total, 04 batches of 100 seeds per treatment were taken randomly from the seed stock created for this purpose. There were 72 samples for

Brachiaria ruziziensis and 48 samples for Stylosanthes. The tests were carried out in petri dishes placed in germinators maintained at a temperature of 20°/35°C day/night temperature. The substrate used was blotting paper soaked in distilled water and placed in each petri dish. An additional supply of distilled water was made if necessary, during the counting of germinations. Lasting 21 days, germination was monitored daily, at a fixed time, 24 hours from installation. The number of seeds germinated per treatment was recorded on a germination monitoring sheet. After each count, the germinated seeds were placed aside in the petri dish. A seed is considered germinated if the radicle appears visibly. The germination rate and germination speed were calculated according to the following mathematical equations:

$$Germination\ rate\ (\%) = 100\ x\ \frac{\text{Number of germinated seeds after 21 days}}{\text{Total number of seeds to germinate}}$$

$$\text{Germinated speed} = 100\ x \sum_{i=1}^{j=21} \frac{Number\ of\ germinated\ seeds\ at\ day\ i}{Number\ of\ days\ after\ the\ sowing\ ij}$$

Data analysis: The collected data allow to calculate the germination rate, germinated speed, grain yield, biomass. The calculated parameters such as biomass, grain weight, seed quality of the studied species were first analyzed with a nested ANOVA considering vegetable as a random factor and phosphorus application as a fixed factor nested within vegetables. The models were fitted using the function 'aov' from the 'stats' package from in R software. When a significant difference was detected, a pair-wise comparison was made using Tukey's test at the 5% level of significance. The biomass, grain weight, seed quality of fodder vegetables (studied species) were analyzed using the generalized linear model (GLM) to detect the effect of treatments [studied species] and dolomite application on these parameters mentioned above. Vegetable and dolomite application were considered as explanatory variables in the GLM. GLM was performed using the stats package in R statistical software. Prior to analysis, data exploration was performed following the protocol described by Zurr *et al.* (2010).

RESULTS

Variation in forage biomass of *Brachiaria ruziziensis* depending on the treatments: At the first assessment date, it was observed that addition of dolomite, P and N significantly influenced the production of fodder biomass of *B. ruziziensis* (P<0.05). Treatments with dolomite provided high amounts of forage biomass as compared to treatments without dolomite (Table 2). The highest quantity of biomass was obtained at the D400P50N100 treatment (7.403 kg DM. ha^{-1}) and the lowest production was recorded by the D400P100N100 treatment (734 kg DM. ha^{-1}). However, this trend changed on the second evaluation date. Only dolomite and P had a significant effect on biomass production (P<0.05). The D400P50N50 treatment (6,530 kg DM. ha^{-1}) made it possible to obtain biomass production four times higher than that of the control treatment D0P0N0 (1.324 kg DM. ha^{-1}). The results also showed the beneficial effect between N and P on *Brachiaria biomass* production during the two evaluations carried out (P<0.0001). However, the dolomite, P, N interaction had a significant effect on biomass production at both biomass assessment dates.

Variation in forage biomass of *Stylosanthes guianensis* and *Stylosanthes hamata* (in kg DM/ha) depending on the treatments: The results showed that the contribution of dolomite and P had no significant effect on the biomass production of the two forage legumes (*Stylosanthes hamata* and *S. guianensis*) (Table 3). However, by comparing the averages of the biomass produced at the first evaluation date as well as at the second evaluation, it appears that the treatments having received dolomite produced a higher biomass than the treatments without dolomite. This production varied between 186 and 334 kg DM. $ha^{-1}$for the species *S. hamata*. It is 174 to 304 kg DM. ha^{-1} in the species *S. guianensis*. Furthermore, biomass production more than double during the second assessment. At the level of the species *S. hamata*, the biomass varied between 317 and 973 kg DM. ha^{-1} while in the species *S. guianensis*, it more than doubled (612.25 and 1454.31 kg DM. ha^{-1}).

Variation in grain yield and 1000-grain weight of *Brachiaria ruziziensis* depending on the treatments: Statistical analysis revealed a significant difference in grain yield. This difference came from the contribution of N and P respectively P<0.008 and P<0.0001. The best grain yield treatment was recorded by the D400P50N50 treatment (905 kg. ha^{-1}), while the lowest yield was recorded by the D400P100N100 treatment with 228 kg. ha^{-1} (Table 4). In terms of *Brachiaria* seed production, there is, therefore, a rational dose of phospho-N fertilization to which the plant responds effectively. No significant difference was noted in the 1000-grain weight of *Brachiaria*. However, an average variation of 4.05 to 6 grams in the 1000-grain weight of the crop was observed. Comparing the averages, the D0P100N50 treatment produced the highest 1000-grain weight of 6 g, while the lowest 1000-grain weight is recorded by the D0P50N100 treatment with 4.05 g. No interaction had a significant effect on grain yield and 1000-grain weight of *Brachiaria ruziziensis*.

Table 2: **Variation in forage biomass of *Brachiaria ruziziensis* depending on the treatments**.

Dolomite	P	N	70 DAS (day)	86 DAS (day)
			Mean	Mean
D0	P0	N0	1160±194[n]	1.324±784[n]
		N50	3.862±1.633[efghijk]	3.451±1.086[hijklm]
		N100	2.420±605[ijklmn]	3.612±953[ghijl]
	P50	N0	2.211±623[klmn]	3.722±1.505[fghijkl]
		N50	2.340±886[jklmn]	3.898±2.013[efghilk]
		N100	4.581±1.334[defgh]	5.307±1.286[bcdefg]
	P100	N0	1.118±544[n]	5.496±2.564[bcdef]
		N50	2.354±1.549[jklmn]	2.365±401[ijklmn]
		N100	922±342[n]	2.038±243[lmn]
D400	P0	N0	1.718±378[mn]	2.479±752[ijklmn]
		N50	7.028±1.198[ab]	3.504±361[ghijklm]
		N100	5.854±2.911[abcd]	5.562±774[bcde]
	P50	N0	4.762±1.998[cdefgh]	4.889±119[cdefgh]
		N50	4.457±1.908[defgh]	6.530±1251[abc]
		N100	7.403±641[a]	4.864±948[cdefgh]
	P100	N0	4.396±3.256[defgh]	4.085±459[defghij]
		N50	2.023±1.062[lmn]	4.178±643[defghi]
		N100	734±278[n]	2.361±389[ijklmn]
Effects of factors	Df		Pr > F	Pr > F
Dolomite	1		0.0001	0.003
P	2		0.0001	0.0001
N	2		0.0151	0.542
Dolomite×P	2		0.1250	0.318
Dolomite×N	2		0.8392	0.161
P×N	4		0.0001	0.0001
Dolomite×P×N	4		0,0233	0.008

In the same column, averages marked with the same letter do not differ significantly (P> 0.05).
DAS: day after sowing

Table 3: Variation in forage biomass of *Stylosanthes guianensis* and *Stylosanthes hamata* (in kg DM. ha^{-1}**) depending on the treatments**

Species	Dolomite	P	80 DAS	96 DAS
			Mean	Mean
Stylosanthes guianensis	D0	P0	174±109	795±447
		P50	302±120	612±323
		P100	195±158	1.112±281
	D400	P0	294±114	696±336
		P50	304±104	1.233 ±306
		P100	284±62	1.454±266
Stylosanthes hamata	D0	P0	272±49	396±212
		P50	285±168	656±456
		P100	186±149	317±86
	D400	P0	275±89	539±203
		P50	315±39	556±128
		P100	334±230	973±373
Effects of factors	Df		Pr > F	Pr > F
Culture	1		0.609	0.509
Dolomite	1		0.083	0.127
P	2		0.452	0.507
Culture×Dolomite	1		0.891	0.704
Culture×P	2		0.898	0.835
Dolomite×P	2		0.530	0.474
Culture×Dolomite×P	2		0.587	0.339

DAS: day after sowing

Table 4: Variation in grain yield and 1000 grain weight of *Brachiaria ruziziensis* depending on the treatments

Dolomite	P	N	Grain yield (kg.ha^{-1})	Weight1000 grains (g)
			Mean	Mean
D0	P0	N0	297±194[ef]	4.5±2.5[a]
		N50	396±1633[abcde]	4.3±1.1[a]
		N100	415±605[abcde]	4.7±1.4[a]
	P50	N0	365±623[cdef]	4.5±2.2[a]
		N50	533±886[ab]	5.5±0.7[a]
		N100	355±1334[cdef]	4.1±1.0[a]
	P100	N0	395±544[abcde]	5.1±1.8[a]
		N50	476±1549[abcd]	6±0.4[a]
		N100	281±342[ef]	5.4±1.7[a]
D400	P0	N0	389±378[bcde]	4.6±1.7[a]
		N50	476±1198[abcd]	5.2±2.0[a]
		N100	377±2911[cde]	4.1±1.6[a]
	P50	N0	539±1998[ab]	4.3±0.4[a]
		N50	905±1908[a]	5.4±1.2[a]
		N100	459±641[abcde]	4.1±1.3[a]
	P100	N0	330±3256[def]	4.6±1.3[a]
		N50	474±1062[abcd]	5.2±1.7[a]
		N100	228±278[f]	5.0±0.7[a]
Effect of factors	ddl		Pr > F	Pr > F
Dolomite	1		0.248	0.581
P	2		0.008	0.287
N	2		0.000	0.166
Dolomite×P	2		0.126	0.703
Dolomite×N	2		0.538	0.936
P×N	4		0.121	0.816
Dolomite×P×N	4		0.280	0.908

In the same column, averages marked with the same letter do not differ significantly (P> 0.05).

Variation in grain yield and 1000-grain weight of *Stylosanthes guianensis* and *Stylosanthes hamata* depending on the treatments: It appears from the analysis of the data that only dolomite had a significant effect (P>0.019) on the grain yield of legumes. Thus, for the *S. guianensis* variety, plots without dolomite made it possible to obtain the best yields (127 to 165 kg. ha^{-1}) unlike the yields of plots with dolomite (57 to 93 kg. ha^{-1}; Table 5). In terms of the *S. hamata* variety, the best yields were obtained in plots without dolomite (149 to 167 kg. ha^{-1}) while plots with dolomite gave yields varying between 97.81 to 191 kg. ha^{-1}. Regarding 1000-grain weight, it was significantly influenced by the variety of legumes (P<0.0001). For this purpose, the best weights of 1000 grains were recorded by the *S. hamata* variety varying from 3.57 g with the D400P50 treatment to 3.81 g with the D0P0 treatment while at the level of the *S. guianensis* variety the variation was from 2.7 g for D0P100 to 3.08 g for D400P50. However, the interaction between variety and dolomite significantly (P<0.05) influenced the 1000-grain weight of both legumes.

Variation in seed quality of *Brachiaria ruziziensis* depending on treatments: These results revealed that N significantly affected the germination rate of *B. ruziziensis* (P= 0.028). The best germination rates were obtained with treatments D400P100N0 (24.5%) and D0P100N0 (18.75%), while treatments D100P100N100 and D0P100N100 gave the lowest germination rates which were 2.25% and 2%, respectively (Table 6). It was found that when the dose of P was high, any addition of N led to a reduction in the germination rate of the grass. Regarding the speed of germination, the addition of dolomite and N produced a significant effect with respective probability values of P = 0.021 and P = 0.014. The highest germination speeds were obtained respectively with treatments D400P100N0 (4.65) and D400P50N100 (3.32). The treatments with the lowest germination rates were D400P100N100 (0.31) and D0P100N100 (0.21). However, it was noted that the treatments having the lowest germination rates also had the lowest daily seed germination rates. It showed that the daily germination speed was correlated with the germination rate. Thus, these two parameters were affected by the same variations depending on N fertilization which produced a significant effect. In all cases, the interaction of P and N significantly influenced the parameters for demonstrating the quality of *Brachiaria ruziziensis* seeds.

Table 5: Variation in grain yield and 1000 grain weight of *Stylosanthes guianensis* and *Stylosanthes hamata* depending on the treatments

Studied species	Dolomite	P	Grain yield (kg.ha^{-1})	Weight 1000 grains (g)
			Mean	Mean
Stylosanthes guianensis	D400	P0	80±47^{bc}	2.8±0.4^{bc}
		P50	93 ±55^{bc}	3.1±0.2^{b}
		P100	57±24^{c}	2. 9±0.3^{bc}
	D0	P0	127± 42^{abc}	2.9±0.2^{bc}
		P50	165±21^{ab}	2.7±0.3^{c}
		P100	140±66^{abc}	2.7±0.3^{c}
Stylosanthes hamata	D400	P0	98±56.42^{bc}	3.8±0.1^{a}
		P50	191±78^{a}	3.6±0.2^{a}
		P100	116±64^{abc}	3.7±0.1^{a}
	D0	P0	149±82^{abc}	3.8±0.1^{a}
		P50	167±109^{ab}	3.8±0.1^{a}
		P100	162±78^{ab}	3. 7±0.1^{a}
Effects of factors	Df		Pr > F	Pr > F
Culture	1		0.058	0.0001
Dolomite	1		0.019	0.543
P	2		0.172	0.518
Culture× Dolomite	1		0.256	0.048
Culture×P	2		0.797	0.507
Dolomite×P	2		0.672	0.592
Culture×Dolomite×P	2		0.557	0.216

In the same colon, averages marked with the same letter do not differ significantly (P> 0.05).

Table 6: Variation in seed quality of *Brachiaria ruziziensis* depending on treatments

Dolomite	P	N	Germination rate	Germination speed	Daily germination rate
			Mean	Mean	Mean
D0	P0	N0	12.25±3.77^{bcde}	1.72±1.08	0.58±0.18
		N100	7.25±7.27^{cde}	0.87±0.89	0.35±0.35
		N50	5.75±^{de}	0.80±0.20	0.27±0.07
	P100	N0	18.75±9.00^{ab}	2.21±1.21	0.89±0.43
		N100	2.00±1.83^{e}	0.21±0.22	0.10±0.09
		N50	15.75±6.08^{abcd}	2.14±0.90	0.75±0.29
	P50	N0	13.75±6.65^{abcd}	2.56±1.39	0.65±0.32
		N100	5.50±4.36^{ed}	0.76±0.69	0.26±0.21
		N50	10.25±7.23^{bcde}	1.211.20	0.49±0.34
D400	P0	N0	8.50±4.20^{bcde}	1.24±0.80	0.40±0.20
		N100	17.25±11.62^{abc}	2.01±1.14	0.82±0.55
		N50	15.50±10.41^{abcd}	2.63±1.94	0.74±0.50
	P100	N0	24.5±15.80^{a}	4.65±3.29	1.17±0.75
		N100	2.25±1.26^{e}	0.31±0.26	0.11±0.06
		N50	10.75±5.68^{bcde}	1.93±1.36	0.51±0.27
	P50	N0	12.50±12.71^{bcde}	2.63±2.79	0.60±0.61
		N100	18.50±8.89^{ab}	3.32±1.90	0.88±0.42
		N50	8.50±5.97^{bcde}	1.08±0.62	0.40±0.28
Effects of factor	df		Pr > F	Pr > F	Pr > F
Dolomite	1		0.114	0.021	0.114
P	2		0.857	0.600	0.857
N	2		0.028	0.014	0.028
Dolomite×P	2		0.549	0.997	0.549
Dolomite×N	2		0.204	0.637	0.204
P×N	4		0.003	0.014	0.003
Dolomite×P×N	4		0.152	0.056	0.152

Variation in seed quality of *Stylosanthes hamata* and *Stylosanthes guianensis* depending on treatments: Dolomite and P did not have a significant effect on the germination rate of the two legumes (Table 7). On the other hand, a significant difference in the variety appeared in the germination rate and the daily germination speed with probability P = 0.001 for these two parameters. Thus, the best germination rates varied from 39% for the D0P0 treatment to 54.25% for the D0P100 treatment, were obtained with the *S. hamata* variety. The variety of *S. guianensis* gave the lowest germination rates. This rate is 22.5% for treatment D0P100 and 44.5% for D0P0. This trend is repeated at the daily germination rate parameter. There is, therefore, a correlation between the P application and the germination rate. The legume variety and P interaction remained the only one that influenced the three germination parameters.

Table 7: Variation in seed quality of *Stylosanthes hamata* and *Stylosanthes guianensis* depending on treatments.

Culture	Dolomite	P	Rate of germination	Germination speed	daily germination rate
			Mean	Mean	Mean
Stylosanthes guianensis	D400	P0	38±8.64	7.09±1.57	1.81±0.41
		P100	29.75±4.86	5.15±0.79	1.42±0.23
		P50	32±7.07	5.38±1.59	1.52±0.34
	D0	P0	44.5±24.24	8.52±4.51	2.12±1.15
		P100	22.5±4.43	4.43±0.80	1.07±0.21
		P50	28±15.90	5.15±3.35	1.33±0.76
Stylosanthes hamata	D400	P0	43.75±12.18	7.01±2.46	2.08±0.58
		P100	40.5±6.40	5.92±0.94	1.93±0.30
		P50	39.75±6.34	6.20±0.81	1.89±0.30
	D0	P0	39±7.16	5.00±1.11	1.86±0.34
		P100	54.25±10.69	7.54±2.19	2.58±0.51
		P50	46.5±4.80	6.56±1.58	2.21±0.23
Effects of factors	Df		Pr > F	Pr > F	Pr > F
Variety	1		0.001	0.499	0.001
Dolomite	1		0.564	0.907	0.564
P	2		0.387	0.242	0.387
Variety	1		0.285	0.888	0.285
Variety ×P	2		0.031	0.043	0.031
Variety ×P	2		0.949	0.884	0.949
Variety ×Dolomite×P	2		0.116	0.156	0.116

Df : degree of freedom

DISCUSSION

Impacts of dolomite, P and N on the biomass of *Brachiaria ruziziensis*: The results showed that the treatments having received dolomite then fertilized at doses (50 P/ha, 100 N. ha^{-1}), (0 P. ha^{-1}, 50 N/ha) and (0 P. ha^{-1}, 50 N. ha^{-1}), allowed to have high biomass yields of *B. ruziziensis* at the first assessment. The combined contribution of dolomite, P and N made it possible to improve the production of fodder biomass. This result can be attributed to the effect of N which constitutes the main stimulant of plant growth (Mandret *et al.*, 1990). This also justify that *B. ruziziensis* gave a strong response to N fertilization (Husson, 2008, Jiope Azangue *et al.,* 2019). This result corroborates those obtained by other authors (Obulbiga and Kabore-Zoungrana, 2007; Pamo *et al.*, 2007 Tendonkeng *et al.*, 2009. These authors showed that the biomass of forage species was influenced by N fertilization. However, the results of the study of Veilleux (2018) showed that N and phosphate fertilization significantly affected forage yield. At the second evaluation, the addition of dolomite and P had a significant effect on the production of forage biomass. Thus, the highest biomass was obtained by the treatment having received dolomite with 50 kg. ha^{-1} of P and 50 kg. ha^{-1} of N, four times higher than the control treatment. This could be explained by the fact that the Calco-magnesium amendments by correcting the pH of the soil, also contribute to higher biomass production due to the nutrients they make available in the soil for the benefit of crops. This result corroborates those of Alrashidi *et al.* (2022), who found that calcium and magnesium play an equally important role, both in crops growing and higher yields.

Impacts of dolomite and P on the biomass of *Stylosanthes hamata* and *Stylosanthes guianensis*: The absence of significant difference in the biomass production of *S. hamata* and *S. guianensis* crops despite the addition of dolomite and P could be explained by the findings of Afkairin *et al.* (2024). According to these authors, legumes are efficient in P acquisition and, therefore, could be used to develop new technologies to improve soil P bioavailability. Here, we studied different species and varieties of legumes and their rhizosphere microbiome responses to low-P stress. Some varieties of common beans, cowpeas, and peas displayed a similar biomass with and without P fertilization. The rhizosphere microbiome of those varieties grown without P was composed of unique microbes displaying different levels of P solubilization and mineralization.

Indeed, according to authors such as (Caddel *et al*., 2017; Kebede *et al.* 2016), legumes have a slower growth rate which limits the production of biomass; Husson (2008) narrated that legumes had the capacity to efficiently recycle leached nutrients, thus acting as a biological pump. This particularity allowed the two varieties to have practically the same biomass production during the two evaluations. Under conditions with similar rainfall, the production of fodder biomass in this study is low compared to the potential production of its varieties, which varies from 2 to 4 $t.ha^{-1}$for *S. hamata* and 5 to 15 $t.ha^{-1}$for *S. guanensis* (Cesar *et al.*, 2004). This low productivity could be justified by the fact that in forage legumes, plant development is slow in the establishment phase of the crop (Schneider and Huyghe 2015). However, the analysis of the results showed that the treatments having received the addition of dolomite had a significantly improved production of forage biomass than the treatments without dolomite. This observation is identical in the two varieties hamata and guianensis. This result corroborates that of Bado (2002) who found that dolomite increased the biomass and symbiotic N fixation of legumes. This could be explained by a better use of P, which contributes to the growth of legumes when phosphate fertilization is combined with an addition of dolomite. Our results corroborate those of Devau *et al.* (2009), who showed that a modification of the pH in the rhizosphere is a powerful lever for the availability of P by modifying the absorption of phosphate ions. Similar studies have shown that dolomite, by correcting the acidity of the soil, makes the P in the soil usable by the plant (Lerot, 2006).

Impacts of dolomite, P and N on grain yield and 1000-grain weight of *Brachiaria ruziziensis*: The optimal P and N rates is the difference between the P and N demand of the crop and the P and N supplies from different sources. In this study, the plots that received the dose 50 kg of N. ha^{-1} and 50 kg of P. ha^{-1} provided a better grain yield than those fertilized at doses of more or less. We can argue that these doses are optimal for *B. ruziziensis* seed production. Lompo (2009) reported that a plant well supplied with P uses water and soil N more efficiently, but also, the existence of a critical level of nutrients in plants. Mandret and Noirot (1999) had made a similar observation according to which the plant makes better use of N when it is well balanced by phosphate fertilizer. The best plot (D400P50N50) gave a grain production of 905 kg. ha^{-1} indicating dolomite supply in addition to P50N50 increase grain production near by 100%. This value is significantly higher than the potential yield proposed by Husson *et al.* (2008) of the same species. Furthermore, similar studies conducted by Adjolohoun *et al.* (2013) on the spacing and N fertilization of *B. ruziziensis*, showed that plots fertilized at a dose of 50 kg of N. ha^{-1}gave the best results in seed production in the first year of cultivation. Mandret and Noirot (1999) made the same observation showing that a high dose of N fertilization reduces the lifespan of inflorescences and the weight of seeds. Compared to 1000-grain weight, the dose of 100 kg of N. ha^{-1}, P combined with 50 N. $ha^{-1}$of N produced better results (6 g). The same value was obtained by Adjolohoun *et al.*, (2013) with plots fertilized at a dose of 50 N. ha^{-1}. These values are significantly higher than those obtained by Husson *et al.* (2008). However, grass yields remained low despite the amendments and fertilizations carried out. This result could be justified by a miscalculation of the bagging date. According to Mandret and Noirot (1999), when panicles are bagged before their anthesis, this can lead to poor (or absence) seed filling. The same authors found that in the grass *P. maximum*, a week or more of delay in bagging leads to a drop-in yield of 50%, due to spontaneous ginning.

Impacts of dolomite and P on grain yield and 1000-grain weight of *Stylosanthes guianensis* and *Stylosanthes hamata*: According to Xu *et al.* (2014) dolomite showed a stronger capacity for immobilizing phosphorus than does calcite. Dolomite therefore serves as a better phosphorus sink than calcite in calcareous soil environments. In our case**,** the addition of dolomite significantly influenced the grain yield of the two varieties of Stylosanthes. The results showed that the best grain yields recorded came from treatments without dolomite. The addition of dolomite combined with P would negatively influence the grain yield of the forage legume Stylosanthes. There would undoubtedly be an interaction between the phosphoric ions of the TSP and the Ca^{2+} and Mg^{2+} cations. Given that it plays an important role in filling the grains of plants, these low yields are justified by the fact that it can precipitate with calcium and magnesium from dolomite in the soil (Plassard *et al.*, 2015). In addition, according to the same authors, the availability of P is very sensitive to soil pH. To optimize phosphate fertilization in the context of seed production of the Stylosanthes species, it is necessary to know the pH level of the soil before adding dolomite. This would make it possible to avoid a basic soil pH through the double effect of legumes and dolomite which neutralize the acidity of the soil. However, the seed yield produced by the guianensis variety (57 to 165 kg. ha^{-1}) does not exceed that obtained by Koffi (1992) in Korhogo in Ivory Coast, between 150 to 200 kg. ha^{-1}. Our results also showed that the potential grain yield of the hamata variety (1,901 kg. ha^{-1}) was higher than that of *S. guianensis* (165 kg. ha^{-1}) in this ecological zone. Regarding the weight of 1000 grains, the control treatment (without dolomite and 0 kg. $ha^{-1}$of P) with the *S. hamata* variety produced the best weight (3.81g), twice as high as that obtained by Sanfo (2008) who found 1.89 g despite phosphate fertilization. Hamata seed production would depend on several factors in addition to fertilization. Indeed, according to Mandret and Noirot (1999), the seed production of forage plants depends on the vegetative phase, the period between floral induction and heading, the panicle heading phase and the seeding phase.

Impacts of dolomite, P and N on the seed quality of *Brachiaria ruziziensis:* The results showed that when P was added at a dose of 100 kg. ha^{-1}, the grass germination rate was improved in this study. This would allow the demonstration of the role of P in seed germination. Indeed, P is an element that accumulates in seeds and plays a very important role during germination (White and Veneklass, 2012). According to Lompo (2009), when it is in excess in the soil solution, it is accumulated in the vacuoles of plants then in the form of phytates in the seeds. Concomitantly with the effect of P, this improvement in the germination rate declined as the N dose increased. Thus, it was observed a significant difference in N on the germination rate. These results corroborate those of Adjolohoun *et al.* (2013), who showed that N fertilization doses significantly influenced the germination of *Brachiaria ruziziensis*. In our study, we could deduce that for better germination of seeds of *B. ruziziensis*, phosphate fertilization should be maximized rather than N fertilization. Indeed, insufficient P affects the uptake of other nutrients like nitrogen (N), potassium (K) and calcium (Ca) by plants, altering their architecture, leading to things such as reduced stem elongation and the production of shorter and thicker stems (Tariq *et al.,* 2023). P deficiency delays flowering and fruiting, reduces seed production and alters plant architecture. Arabidopsis thaliana responds to low P availability with phenological delay, allowing for increased P acquisition and utilization, resulting in higher reproductive biomass production (Nord *et al*.,2008).

In wheat crops, P deficiency primarily affects above-ground biomass, radiation interception, grain yield and spike biomass, leading to reductions in the grain number per square meter (Sandaña *et al.,* 2011).
However, the best germination rates did not reach 50%, whatever the doses of phospho-nitrogen fertilization. Indeed, the harvest period is a main factor in the yield and quality of seeds. This would justify these low germination rates in the context of our study. Furthermore, the dormancy factor of *B. ruziziensis* seeds could confirm these results. According to Long *et al.* (2012) and Husson *et al. (*2008), seed dormancy can range from 6 to 9 months and this under good storage conditions (low temperature, low humidity).

Impacts of dolomite and P on the seed quality of *Stylosanthes hamata* and *S. guianensis:* Statistical analysis of the data showed that dolomite and P had no significant effect on seed quality parameters of studied legumes. This is also true because there would be an interaction between phosphoric ions and the divalent cations of dolomite. This situation would prevent the assimilation of P, which plays an important role in seed filling and germination.

According to Afkairin *et al.* (2024). Some legumes did not respond to phosphorus shortage for their development. Consequently, phosphorus supply may impact less their seed quality.

Low germination rates were obtained with the guianensis variety, as compared to the hamata variety. This is due to the different genetic and intrinsic criteria of the two varieties of the crop. These results corroborated with those of Pamo *et al.* (1997), who showed that the germination rate of the guianensis variety can be low because of the very hard seed coat which surrounds the seed. Furthermore, high germination rates were obtained with treatments having a dose of 100 P. ha^{-1}a. We could then affirm that P stimulated germination of forage legumes. Furthermore, P supply favor seed maturation as reported by Lompo (2009). Also, in Ivory Coast, Koutouan *et al.* (2017) also found that P positively influenced germination rates of *Cajanus cajan*.

Conclusion: The control of production systems and the introduction of high-yielding forage species may serve to fuel operational and sustainable solutions and ultimately improve productivity. It may reduce conflicts between breeders and farmers. It would, therefore, be appropriate to develop information and advice strategies to ensure good assimilation of the technology by producers, without forgetting the multiple advantages of these plants on soil fertility. This practice, if it is popularized and practiced, would constitute a solution for the stabilization of breeders.

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