Improving forage productivity for increased livestock production using biochar and green manure amendments

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Abstract
The rapid population growth in West African cities resulted in rising demand for animal source foods. However, this high demand for animal source food is rarely met by domestic production in Benin due to several factors, including low feed availability and poor animal nutrition, especially during the dry months, and degraded soils. To overcome this situation, the effects of maize (*Zea mays*) cob biochar and green manure from *Gliricidia sepium* and *Mucuna pruriens* (2 t/ha each) and their combination (1 t/ha each) were tested on *Brachiaria brizantha cv. Xaraés* agronomic performance over three months. The combination of biochar and green manure performed best with plant height increased by 57% (103.8 ± 17.12 cm) when compared to the un-amended control plots and each treatment alone two-month after planting. In addition, the number of leaves (22.9 ± 5.82) and the biomass determined (20.3 ± 5.64 t dry matter/ha) were highest with the combined treatment than the un-amended control plots three-months after planting. *B. brizantha cv. Xaraés*, fertilized with locally available biochar and green manure, could contribute significantly to increasing feed availability at farm level and boost meat and milk production.
Keywords. *Gliricidia sepium*, livestock production, *Mucuna pruriens*, organic amendments, Benin.

Introduction
In Benin, animal production represents the second most important economic activity after agriculture, particularly in the Alibori and Borgou departments (Saka et al. 1991; De Haan, 1997; Djenontin, 2011). However, due to the deterioration of the environment, the dairy sector remains fragile and fails to meet the increasing population demand, resulting in a short-term response of imports of powdered milk at high prices (SOS Faim, 2015). Despite frequent climatic and food crises, the national livestock herd is constantly growing. This increase is due to a strong demand for milk and meat, following rising incomes, population growth and increasing urbanization (SOS Faim, 2015). According to Hamadou et al. (2005), *Brachiaria* grasses are important forage that boosts ruminants' milk and meat productions. In Benin, fodder shortage usually occurs during the dry season when transhumant herds move into the country from the Sahelian regions. To satisfy the needs of the herders and increase forage availability for animal production, the present study aimed to evaluate the performance of *Brachiaria brizantha cv. Xaraés*, a very palatable plant to ruminants as affected by the (i) biochar treatment alone; (i) green manure of *Gliricidia sepium* and *Mucuna pruriens,* and the (3) combined effect of biochar and green manure amendments.

Materials and methods
Study environment
The trial was set-up at the Faculty of Agronomy, University of Parakou (Benin Republic, West Africa) located at 9°21' latitude north and 2°36'east longitude and at 350 m above sea level. Parakou is neighbored in the north by the municipality of N'Dali, in the south, east and west by the municipality of Tchaourou and covers an area of 441 km² (Monograph Parakou, 2006). The climate is tropical sub-humid with an average annual precipitation of about 1200 mm (Akoègninou et al. 2006).

Plant materials used
Mucuna puriens var *utilis,* a perennial legume of the Fabaceae family that protects and retains soil moisture through its mulching capacity (ProSol, 2017) and *Gliricidia sepium,* a shrub legume belonging to the Papilionaceae (Figures 1a, b) family were used. Their biomass (leaves plus twigs less than 5 cm) were used as green manure solely or in combination.

Brachiaria brizantha cv. Xaraés is a perennial C_4 herbaceous grasses of the Poaceae family, originating from Africa. This cultivar was released by Embrapa in 2003 after 15 years evaluation in Brazil. It is a 1.5 m height grass with high biomass production, fast regrowth and late flowering (Embrapa, 2004). According to Husson et al. (2008), *Brachiaria* grasses produce a high biomass (quality fodder, Figure 1c), and can suppress weeds through their powerful and deep rooting system. They have a great ability to sequester and accumulate large amounts of soil organic carbon through their large shoots and roots biomass (Peters et al., 2012) and thus important for livestock feed production and soil improvement (Gichangi et al. 2017).

(a) *Mucuna pruriens* *(b) Gliricidia sepium* *(c) Brachiaria brizantha cv. Xaraés*

Figure 1. The green legume biomass used (a and b) and applied to *Brachiaria brizantha cv. Xaraés* plots (c). Source: Photo by *Nambima A. (2020).*

Biochar treatment

Biochar is the by-product of artisanal or industrial pyrolysis of plant biomass. It has a porous structure which confirms its water absorption and retention properties (Brodowski et al. 2006; Liang et al. 2006). Biochar increases soil porosity, allowing oxygen supply to the soil (Yanai et al. 2007). The biochar used in the trial was produced from corn cobs' biomass at 350°C for 5 hours (Figure 2).

Figure 2. Biochar from *Zea mays* cobs' biomass.
Source: Photo by *Diogo RVC. (2019).*

Experimental design

The set-up was a randomized complete block design consisting of three blocks, each containing eight experimental units as follows:

T0: Plots of *Brachiaria brizantha cv. Xaraés* with no amendment; T1: Plots of *Brachiaria* amended with biomass of *Mucuna* at 2 t dry matter (DM/ha); T2: Plots of *Brachiaria* amended with biomass of *Gliricidia* 2 t DM/ha, T3: Plots of *Brachiaria* amended with mixture of biomass at 2 t DM/ha (1 t/ha *Mucuna* + 1 t/ha *Gliricidia*); T4: Plots of *Brachiaria* amended with biochar at 300 kg DM/ha; T5: Plots of *Brachiaria* amended with biochar at 60 kg DM / ha + 2 t DM/ha *Mucuna;* T6: Plots of *Brachiaria* amended with biochar 60 kg DM/ha + 2 t DM/ha *Gliricidia;* T7: Plots of *Brachiaria* amended with biochar 60 kg DM/ha + 2 t DM/ha mixture of biomass (1 t/ha *Mucuna* + 1 t/ha *Gliricidia*). The biomass was incorporated into the soil 15 days after sowing.

The seeds of *B. brizantha cv. Xaraés* were installed on the experimental plots of 3.6 m² according to sowing patterns of 20 by 20cm. The average number of seeds per pocket was five. The first germination started on the fourth day after sowing. The biomass of *M. puriens* and *G. sepium* were incorporated at 2 t DM/ ha on plots that received each of the treatment alone, and at 1 t DM/ha on the plots that received the combined biomasses. Biochar was applied at 300 kg DM/ha alone, but the rate of 60 kg DM/ha referring to 20% sole biochar treatment was used when combined with any of the biomass used for its effectiveness as suggested by Schmidt (2017). It was introduced at 5 cm soil depth near the *B. brizantha cv. Xaraés* plant roots. Each treatment was replicated three times, totaling 24 experimental units.

Data collection

Five plants of *B. brizantha cv. Xaraés* were chosen randomly to assess plant growth per treatment. The height of the plants from the crown to the flag leaf tips was measured using a tape and the number of leaves counted every 15 days for two months. The biomass was cut at two and three months after application of the treatments in a 1 m² net plot to avoid border effects. Samples of fresh biomass were put in an oven at 105°C for 2-3 days to determine DM.

Data analysis

Data collected were checked for homogeneity and normality assumption before F-test was performed using one-way ANOVA. The statistical analysis was performed using the R programming software.

Results

Effect of treatments on B. brizantha cv. Xaraés growth and biomass

Plots that received green biomass plus biochar grew more than plots with sole green biomass and biochar treatment alone. The greatest plant height obtained was with T7 (biochar plus biomass of legumes) compared to the other treatments (Table 1, $P<0.05$). Likewise, the number of leaves determined increased significantly with biochar and legume treatments, Table 1, $P<0.05$). With regard to biomass, no significant difference was obtained between the treatment at the first pruning two months after sowing (MAS). At the second cut (3MAS), the treatment T7 performed best with significantly higher biomass compared to the other treatments (Table 1). Moreover, the treatments T3, T5 and T6 produced greater biomass compared to the control ($P>0.05$).

Table 1. Effect of treatments on growth parameters (2-month after sowing, MAS) and on total biomass of *Brachiaria brizantha cv. Xaraés* 3MAS

Treatment	Height (cm)	Number of leaves	1st cut (t DM / ha, 2MAS)	2nd cut (t DM / ha, 3MAS)	Total biomass (t DM / ha)
T0	47.1 ± 17.71^{d}	13.3 ± 4.69^{b}	2.4 ± 1.71^{a}	1.8 ± 0.46^{d}	3.9 ± 1.80^{c}
T1	57.1 ± 8.58^{cd}	15.6 ± 5.64^{b}	2.3 ± 0.93^{a}	6.4 ± 0.76^{bcd}	7.1 ± 2.15^{bc}
T2	69.5 ± 10.30^{c}	16.9 ± 4.77^{b}	2.9 ± 1.40^{a}	3.8 ± 0.24^{cd}	6.7 ± 1.41^{bc}
T3	86.3 ± 8.70^{b}	18.3 ± 5.08^{ab}	4.4 ± 2.84^{a}	8.2 ± 0.75^{bc}	13.6 ± 1.80^{ab}
T4	60.9 ± 11.50^{c}	15.5 ± 4.67^{b}	2.5 ± 1.3^{a}	4.6 ± 0.89^{bcd}	8.4 ± 0.21^{bc}
T5	79.3 ± 14.25^{b}	16.5 ± 4.21^{b}	2.5 ± 0.44^{a}	9.1 ± 0.93^{b}	11.6 ± 0.79^{b}
T6	82.7 ± 13.13^{b}	17.5 ± 4.70^{ab}	5.0 ± 2.98^{a}	7.9 ± 1.60^{bc}	12.1 ± 1.86^{b}
T7	103.8 ± 17.12^{a}	22.9 ± 5.82^{a}	6.0 ± 1.55^{a}	14.3 ± 4.14^{a}	20.3 ± 5.65^{a}

Means in the same column followed by different letters differ significantly at 5% level.

T0: Plots of *Brachiaria* brizantha cv. Xaraés with no amendment; T1: Plots of *Brachiaria* amended with biomass of *Mucuna* at 2 t dry matter (DM / ha); T2: Plots of *Brachiaria* amended with biomass of *Gliricidia* 2 t DM/ ha, T3: Plots of *Brachiaria* amended with mixture of biomass at 2 t DM / ha (1 t / ha *Mucuna* + 1 t / ha *Gliricidia*); T4: Plots of *Brachiaria* amended with biochar at 300 kg DM / ha; T5: Plots of *Brachiaria* amended with biochar at 60 kg DM / ha + 2 t DM / ha *Mucuna*; T6: Plots of *Brachiaria* amended with biochar 60 kg DM / ha + 2 t DM/ ha *Gliricidia*; T7: Plots of *Brachiaria* amended with biochar 60 kg DM / ha + 2 t DM/ ha mixture of biomass (1 t / ha *Mucuna* + 1 t / ha *Gliricidia*).

Discussion

The different growth parameters and biomass production show that the combined application of biochar and legume biomass of *G. sepium* and *M. pruriens* significantly improve the growth of *Brachiaria brizantha cv. Xaraés* plants. The supply of biochar in the soil generally increases the retention of water and nutrients, through the cation exchange capacity of the soil-biochar system, the permeability, the penetration of the roots deeper without counting its indirect effects on biological and chemical properties in the soil (Lehmann and Joseph, 2009; Sohi et al. 2010). The biomass produced under different treatments showed a marked difference between the amended plots and the control plots. This is explained by the nutrient content of the legume plants used which were favoured by the biochar amendment to create favourable environment for the nutrient uptake by the *B. brizantha cv. Xaraés* plant. Therefore, the combination of biochar plus biomass of *G. sepium* and *M. pruriens* is recommended to improve the performance of *B. brizantha cv. Xaraés* fodder availability for animals. These results corroborate the findings by Sohi (2012); Kanouo (2017); Oguntunde et al. (2004) and Crane-Droesch et al. (2013) who showed that incorporating charcoal into the soil improves crop yields. However, the charcoal is not a biochar as their production processes are different. Nonetheless, they play similar role. Beyond serving as forage, our findings confirm the importance of *G. sepium and M. pruriens* in the restoration and protection of soil (ProSol, 2017) and could be promoted as green amendment.

Conclusion

The present study investigating the effect of biochar and green manure amendments of *Mucuna pruriens* and *Gliricidium sepium* shows that the green biomass of these legumes could be combined with biochar to conserve their nutrient to improve *Brachiaria brizantha cv. Xaraés* forage production and soil restoration through fertility improvement. Our findings could be useful to several actors working in the field of food intensification and animal production. This approach could be used to increase forage production that maximizes milk and meat production in Benin.

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