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Productivity of three forage crops (*Vigna unguiculata* (L.) Walp., *Pennisetum purpureum* Schum. and *Hyparrhenia diplandra* (Hack.) Stapf.) introduced on the Essimbi ranch (Boundji, Republic of Congo)

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Abstract

The improvement of degraded pastures can be achieved by the introduction of forage crops. The objective of this study was to evaluate the herbaceous above-ground phytomass of three forage crops (*Vigna unguiculata* (L.) Walp., *Pennisetum purpuerum* Schum. and *Hyparrhenia diplandra* (Hack.) Stapf) introduced at Essimbi Ranch, with a view to improving degraded pastures. The introduction of these three forage species in pure and associated cultures was carried out after manual tillage. The herbaceous above-ground phytomass was measured by the harvesting method. The carrying capacity was calculated, taking into account the consumption of 1/3 of the phytomass. Normality and one-factor Student's t-tests were performed at the 5% significance level. The results showed that in pure culture, at two months after sowing, Vigna unguiculata, Pennisetum purpureum and Hyparrhenia diplandra had average phytomass of 2, 49 ± 0.27 t DM/ha, 7.01 ± 0.69 t DM/ha and 2.32 ± 0.005 t DM/ha respectively, with average carrying capacities of 0.36 ± 0.04 LU/ha/yr, 1.02 ± 0.1 LU/ha/yr and 0.33 ± 0.005 LU/ha/yr respectively. The association Vigna unguiculata - Pennisetum purpureum - Hyparrhenia diplandra showed the highest phytomass (10.15 ± 1.36 t DM/ha) with an average carrying capacity of 1.33 ± 0.29 LU/ha/yr. There is a highly significant effect of intercropping on phytomass and carrying capacity.

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Introduction

The savannahs of the Congo, like those elsewhere in the tropics, are exploited for agricultural and pastoral activities. They constitute real resources for agriculture and livestock (Yoka *et al.*, 2013) and play a major economic role as they provide food for herds in the extensive system (Rakotoarimanana *et al.*, 2008). Thus, savannahs constitute excellent pastures for cattle, sheep and goat breeding.

The feeding of livestock in extensive livestock farming relies on the excessive use of natural pastures, which constitute the basis and most often the totality of food resources (Rivière, 1991; Sinsin, 1993). Grazing lands are essential for many farming systems and for the expansion of global agricultural production (Baumont *et al.*, 2004). The livestock sector is central to agricultural development (Herrero *et al.*, 2015). Indeed, the increase in demand for animal-based food has come mainly from the rapidly expanding economies in developing countries. The products of domesticated herbivores are of major biological interest to humans (meat and milk are important sources of protein).

Fodder production is the main lever for improving herbivore feed and thus the productivity of the livestock systems concerned (Klein *et al.*, 2014). It also plays an essential role in the sustainability of mixed systems that combine crop and livestock production. Many current agro-ecological systems are based on the successful integration of fodder crops into these production systems. Fodder plants play a central role in feeding animals, producing organic manure and thus maintaining the fertility of cultivated land. Many fodder plants are also used to cover the soil and improve soil fertility.

The many agronomic, economic and environmental benefits of forage associations are now being rediscovered: the possibility of overproduction compared to monocultures (or pure crops), reduction of nitrogen fertilisation, which generates financial savings, less use of fossil energy and less negative environmental impact (greenhouse gas emissions, nitrate leaching), production of a forage balanced in terms of protein and energy, more regular production during the year (Finn *et al.*, 2013; Huyghe and Delaby, 2013; Protin *et al.*, 2016).

In Congo, savannahs cover 35% of the territory (UICN, 1990) and constitute potential grazing land. In the Congolese Cuvette, where the area of the present study is located, cattle breeding is beginning to take off thanks to the policy of sharecropping (Yoka *et al.*, 2011). These savannahs being on sandy, acidic soils, poor in organic matter and mineral elements are very fragile (Yoka *et al.*, 2010, Amboua, 2016). The low productivity of tropical cattle is attributable to several factors, including feeding, pathology and their low genetic potential (Akouango *et al.*, 2014; Mopoundza, 2014). The pastoral practices used and the volume of livestock are causing increasing and worrying degradation of vegetation cover (Nsibi *et al.*, 2006; Yoka *et al.*, 2011). Overgrazing leads to the disappearance of some of the most palatable species and the appearance of other species that are less palatable to livestock (Yoka *et al.*, 2011). In the Boundji area, the invasion of pastures by shrubs following the effects of grazing causes a decrease in herbaceous production (Yoka *et al.*, 2014; Amboua, 2016), which constitutes the fodder potential of pastures. This invasion of pastures by shrubs would characterise a state of pasture degradation. The production of domestic herbivores such as cattle, sheep and goats requires good quality pastures. Fodder intensification is essential to obtain the best yields from livestock in a sustainable way.

It is with this in mind that the present study was carried out. The general objective of this study was to evaluate the herbaceous above-ground phytomass of three forage crops (*Vigna unguiculata* (L.) Walp., *Pennisetum purpuerum* Schum. and *Hyparrhenia diplandra* (Hack.) Staapf) introduced at Essimbi Ranch, with a view to improving degraded pastures. Two specific objectives were selected: (i) to assess the herbaceous above-ground phytomass of pure crops; (ii) to assess the herbaceous above-ground phytomass of associated crops.

Materials and Methods

Study area

The study was carried out in the south-western part of the Congolese Cuvette in the north of the Republic of Congo, specifically at the Essimbi ranch in Boundji (Cuvette Department), located between 0° and 2° south latitude and between 15° and 16° east longitude. The climate of the study area is sub-equatorial (Samba-Kimbata, 1991).

The average annual temperature is 25.5°C. The average minimum is 19.9°C in July and the average maximum is 31.9°C in March.

The average annual rainfall in the study area is 1657 mm (Yoka, 2009). Rainfall is almost permanent. April and October are the wettest months of the year in the Congolese Cuvette. The maximum rainfall is recorded in October. There is no ecologically dry period; only a decrease in rainfall is noted in June-July-August and December-January. The average annual relative humidity in the study area is always high (98%).

The Congolese Cuvette has two geological formations, the Batéké sands and the alluvium (Bouka-Biona *et al.*, 2001). It is mainly ferralitic soils that are highly desaturated and impoverished.

These soils are generally very sandy (86-96% sand), rich in fine sand (62-73%), poor in organic matter (1.69-1.88%), clay (0-8.5%) and very permeable. The pH varies between 5.2 and 5.9 and the C/N ratio between 13 and 20 (Yoka *et al.*, 2010).

The study area is dominated by two vegetation formations, forests and savannas (IUCN, 1990). The savannahs are of four types: *Hyparrhenia diplandra* (Hack.) Stapf savannah, *Trachypogon spicatus* Stapf savannah, *Andropon schirensis* Hochst. savannah and *Loudetia simplex* C.E. Hubbard savannah.

As in the whole of the Congolese Cuvette, the forests in the Boundji area are also of several types: terra firma forests, swamp forests and flooded forests (IUCN, 1990).

Plant material

The plant material consists of cowpea seeds (*Vigna unguiculata* (L.) Walp.), *Pennisetum purpureum* Schum. stems and *Hyparrhenia diplandra* (Hack.) Stapf. stump chips.) Cowpea seeds are 'all-purpose'. The *Pennisetum purpureum* Schum. Stems were collected at the Agricongo experimental centre, south of Brazzaville. The stump chips of *Hyparrhenia diplandra* (Hack.) Stapf.), a local grass, were obtained two months after burning the savanna.

Experimental set-up

In open scrubby pasture with *Annona senegalensis* Pers. subsp *oulotricha* Le Thomas and *Elionurus brazzae* Kranch, four (4) experimental plots of 25 m × 25 m (i.e., 625 m^2) each were selected for a fodder crop trial with *Vigna unguiculata* (L.) Walp., *Pennisetum purpureum Schum*. and *Hyparrhenia diplandra* (Hack.) Stapf. in both pure and mixed cropping. Each plot is subdivided into two plots of 25 m × 12.5 m (312.5 m^2), each in which measurements were made after the establishment of the three forage crops. Therefore an area of 0.25 ha (i.e., 4 × 625 m^2 or 2500 m^2) was sampled.

Methods

Soil preparation

Soil preparation (August and September 2018) was done after having deseeded the shrubs, squared the plots and agronomic beds, avoiding large clods and surface residues. It was done manually during the dry season using machetes, spades, forks and rakes. Plots were made for sowing and cutting fodder crops. These planks are on average 10.25 m long and 1.5 m wide. The spacing between two plots is 0.5 m, between two plots 1 m and between two plots 3.5 m. Each plot, therefore, has 22 plots. Therefore a number of 88 plots were tested.

Implantation des cultures

Crop establishment by sowing or cuttings took place in November 2018 (rainy period) on beds with 50 cm x 50 cm spacing. For *Vigna unguiculata* (L.) Walp. sowing, three seeds were sown per stake (Yoka *et al.*, 2014).

Cutting is a technique that allows the stems to be cut to three or four nodes in length and implanted directly into the ground (Bigot *et al.*, 2002); this technique is well adapted to plants such as *Brachiaria*, *Cynodon,* or *Pennisetum*, which do not produce many seeds. For the establishment of Pennisetum purpureum Schum. young cuttings (cane 4-6 months old) are preferred at most, as beyond that, drier canes have a lower establishment capacity. The cuttings were cut into segments of 40-60 cm, so that each cutting had at least 4 nodes. The cuttings were planted in rows, 50 cm between each row of cuttings. In each row, the cuttings were planted every 50 cm.

A stump is a clump of leafy, rooted, mostly non-flowering herbaceous material (Bigot *et al.*, 2002). The technique consists of splitting it into tillers and planting these tillers on well-prepared land. It was used for the establishment of *Hyparrhenia diplandra* (Hack.) Stapf. At least two 45 cm long seedlings of *Hyparrhenia diplandra* (Hack.) Stapf. were planted in each pot. Planting was done manually in rows of 50 cm by 50 cm on boards.

Phytomass measurement

Samples for the measurement of phytomass were taken at ground level with pruning shears at 1, 2 and 3 months after the establishment of the crops (Fournier, 1994). These samples, consisting of stems and leaves, were weighed and then oven-dried at 70°C to constant weight. The average dry mass was calculated for each crop at each stage of the vegetation cycle.

Data processing

Calculation of carrying capacity

Herbaceous above-ground phytomass data were used to calculate the optimal carrying capacity. The method recommended by Boudet reported by Yoka (2009) and Yoka *et al.* (2021) was adopted: the potential production consumable by cattle weighing an average of 250 kg live weight was estimated as 1/3 of the total biomass. The results obtained are expressed in LU/ha/year (LU: Livestock Unit, cattle of 250 kg live weight) conducted under extensive conditions. It is determined by the following formula:

$$Cc = Ki \times \text{phytomass (t DM/ha)} \times 1000/C \times D$$

Legend:

Cc: carrying capacity; C: feed intake capacity (in the tropics this corresponds to 6.25 kg); D: rearing time, 365 days; Ki: consumable fraction without complete denudation of the pasture (this corresponds to 1/3); DM: dry matter.

Statistical analysis of data

Phytomass and carrying capacity data were processed by R software, version i386 4.1.0. Normality and T-Test or Student's t-test were performed at the 5% significance level to differentiate the herbaceous above-ground phytomass and carrying capacity of forage crops, in pure culture and in associated culture between 1, 2 and 3 months. Means and standard errors were calculated using Microsoft Excel version 2013. The means are presented in the text with their standard error or standard error to express the standard deviation of the sampling distribution of the different parameters studied (Dagnelie, 2013). The standard error expresses the precision of the measurement made on the sample (Altman and Bland, 2005). The upper limit chosen for the probability related to the first kind risk α is 5%. Probability values p calculated for statistical inference tests will be said to be significant, highly significant, or very highly significant at probability values p between 5% and 1%, 1% and 0,1% and less than 0,1% respectively.

Results

Herbaceous above-ground phytomass of forage plants in pure culture and in association and carrying capacity of these improved pastures

In pure or monospecific cultivation

Data on the herbaceous above-ground phytomass of *Vigna unguiculata* (L.) Walp., *Pennistum purpureum Schum.* and *Hyparrhenia diplandra* (Hack.) Stapf. in pure cultivation and the carrying capacity of the experimental plots (improved pastures) during three months of testing are presented in Table 1. They vary from one forage species to another and as a function of time.

In pure cultivation, the average herbaceous above-ground phytomass of *Vigna unguiculata* (L.) Walp. varies from 0.64 ± 0.02 t DM/ha to 2.49 ± 0.27 t DM/ha. It is highest at two months (2.49 ± 0.27 t DM/ha), with an average carrying capacity of 0.36 ± 0.04 LU/ha/year, and drops considerably at three months (1.06 ± 0.41 t DM/ha with 0.15 ± 0.06 LU/ha/year) because during this period the plant has reached senescence. The first month is the least productive (0.64 ± 0.02 t DM/ha). The herbaceous above-ground phytomass of *Vigna unguiculata* (L.) Walp. varies during its life cycle.

Table 1. Herbaceous above-ground phytomass data of three forage plants in pure cultivation and carrying capacity during the 3-month trial.

Period	Pure culture	Average herbaceous above-ground phytomass (t DM/ha)	Average carrying capacity. (LU/ha/year)	Statistical test (P-Value, threshold of 0.05)	
				Normality	T. test
1 month	*V. unguiculata* (L.) Walp.	0.64 ± 0.02	0.09 ± 0	0.74	0.16
	P. purpureum Schum.	0.2 ± 0.14	0.02 ± 0.14		
	H. diplandra (Hack.) Stapf.	1.35 ± 0.54	0.19 ± 0.08		
2 months	*V. unguiculata* (L.) Walp.	2.49 ± 0.27	0.36 ± 0.04	0.06	0.12
	P. purpureum Schum.	7.01 ± 0.69	1.02 ± 0.1		
	H. diplandra (Hack.) Stapf.	2.32 ± 0.005	0.33 ± 0.005		
3 months	*V. unguiculata* (L.) Walp.	1.06 ± 0.41	0.15 ± 0.06	0.81	0.17
	P. purpureum Schum.	10.07 ± 1.04	1.46 ± 0.15		
	H. diplandra (Hack.) Stapf.	4.81 ± 2.84	0.19 ± 0.08		

Legend:
V: *Vigna*; P: *Pennisetum;* H: *Hyparrhenia*; t DM/ha: tonne of dry matter per hectare; LU: Livestock Unit.

The average herbaceous above-ground phytomass of *Pennisetum purpureum* Schum. and *Hyparrhenia diplandra* (Hack.) Stapf. in pure cultivation varies from 0.20 ± 0.14 to 10.07 ± 1.04 t DM/ha and from 1.35 ± 0.54 to 4.81 ± 2.84 t DM/ha respectively. The third month is more productive for these two species, with phytomasses of 10.07 ± 1.04 t DM/ha and 4.81 ± 2.84 t DM/ha respectively, followed by the second month, which provides phytomasses of 7.1 ± 0.69 t DM/ha (*Pennisetum purpureum* Schum.) and 2.32 ± 0.005 t DM/ha (*Hyparrhenia diplandra* (Hack.) Stapf.). In this plot, at one month, the phytomass is very low (0.20 ± 0.14 t DM/ha). The carrying capacity evolves in the same direction as the herbaceous above-ground phytomass (0.02 ± 0.14 to 1.46 ± 0.15 LU/ha/year).

These results show that *Pennisetum purpureum* Schum. is more productive at 3 months after establishment and could support a higher pastoral load than the other two.

The analysis of these results shows that the herbaceous above-ground phytomass varies from one forage species to another and with time. The age of the plant influences the herbaceous above-ground phytomass. The most productive forage species is *Pennisetum purpureum* Schum, with mean phytomass of 7.01 ± 0.69 t DM/ha at two months and 10.07 ± 1.04 t DM/ha at three months, followed by *Hyparrhenia diplandra* (Hack.) Stapf, with mean phytomass of 2.32 ± 0.005 t DM/ha at two months and 4.81 ± 2.84 t DM/ha at three months. *Vigna unguiculata* (L.) Walp. is the least productive forage species in this rotation with an average phytomass of 2.49 ± 0.27 t DM/ha obtained at two months after sowing. However, the average herbaceous above-ground phytomass and carrying capacity results for each forage species in pure cultivation are not significantly different between 1 (p = 0.16), 2 (p = 0.12) and 3 (p = 0.17) months at the 5% probability threshold.

In associated or multi-species cultivation

Table 2 shows the herbaceous above-ground phytomass and carrying capacity data of three forage crops in association during a 3-month trial. They vary from one association to another, depending on time and the forage species present.

Binary association

The binary association (Pennisetum purpureum Schum. - Vigna unguiculata (Hack.) Stapf.) provides an average phytomass that varies from 0.66 ± 0.08 to 15.73 ± 3.58 t DM/ha. Overall this phytomass is high. The average carrying capacity of this plot varies from 0.09 ± 0.01 to 2.29 ± 0.52 LU/ha/year. At two (2) months, it provides an average phytomass of 8.12 ± 0.82 t DM/ha and an average carrying capacity of 1.18 ± 0.12 LU/ha/yr.

This phytomass doubles at 3 months after planting as does the carrying capacity. The binary association Hyparrhenia diplandra - Vigna unguiculata also provides a satisfactory average phytomass compared to pure crops. At two months this average phytomass is 5.61 ± 0.27 t DM/ha and it reaches 7.05 ± 0.64 t DM/ha at three months.

Table 2. Herbaceous above-ground phytomass and carrying capacity data of three forage crops in association during a trial.

Period	Associated culture	Average herbaceous above-ground phytomass (t DM/ha)	Average carrying capacity. (LU/ha/year)	Statistical test (P-Value, threshold of 0.05)	
				Normality	T. test
1 month	V-P	0.66 ± 0.08	0.09 ± 0.01	0.63	0.007
	V-H	1.44 ± 0.18	0.21 ± 0.02		
	H-P	1.04 ± 0.18	0.15 ± 0.02		
	V-P-H	1.33 ± 0.32	0.19 ± 0.04		
2 months	V-P	8.12 ± 0.82	1.18 ± 0.12	0.38	0.006
	V-H	5.61 ± 0.27	0.82 ± 0.04		
	H-P	5.82 ± 0.48	0.85 ± 0.07		
	V-P-H	10.15 ± 1.36	1.33 ± 0.29		
3 months	V-P	15.73 ± 3.58	2.29 ± 0.52	0.4	0.007
	V-H	7.05 ± 0.64	1.03 ± 0.09		
	H-P	12.75 ± 1.57	1.86 ± 0.23		
	V-P-H	14.20 ± 1.19	2.07 ± 0.17		

Legend:
V-P: *Vigna unguiculata* (L.) Walp. - *Pennisetum purpureum* Schum; V-H: *Vigna unguiculata* (L.) Walp - *Hyparrhenia diplandra* (Hack.) Stapf; H-P: *Hyparrhenia diplandra* (Hack.) - *Pennisetum purpureum* Schum.
V-P-H: *Vigna unguiculata* (L.) Walp. - *Pennisetum purpureum* Schum. - *Hyparrhenia diplandra* (Hack.) Stapf.; t DM/ha: tonne of dry matter per hectare; LU: Livestock Unit.

The average herbaceous above-ground phytomass and average carrying capacities per association were highly significantly different at the 5% probability threshold between 1 (p = 0.007), 2 (p = 0.006) and 3 (p = 0.007) months of testing in this area. The inclusion of a legume, increases the productivity of a pasture in general and the grass in particular and could improve the forage autonomy of the farm. The binary grass-grass association (Hyparrhenia diplandra - Pennisetum purpureum) is interesting for feeding domestic herbivores, for the production of grass biomass. It provides an average herbaceous above-ground phytomass that varies from 1.04 ± 0.18 to 12.75 ± 1.57 t DM/ha with an average carrying capacity varying from 0.15 ± 0.02 to 1.86 ± 0.23 LU/ha/year.*Association de trois espèces fourragères*

: *Hyparrhenia diplandra (Hack.) Stapf. - Vigna unguiculata (L.) Walp. - Pennisetum purpureum Schum.*

The combination of the three forage crops concerned produces an average herbaceous above-ground phytomass ranging from 1.33 ± 0.32 to 14.2 ± 1.19 t DM/ha, and an average carrying capacity ranging from 0.19 ± 0.04 to 2.07 ± 0.17 LU/ha/year. This is a quantitatively high phytomass. This association at two months provides an average herbaceous above-ground phytomass of 10.15 ± 1.36 t DM/ha and an average carrying capacity of 1.33 ± 0.29 LU/ha/yr. At three months this average phytomass reaches 14.2 ± 1.19 t DM/ha and the average carrying capacity reaches 2.07 ± 0.17 LU/ha/yr.

Analysis of these results shows that forage associations as a whole provide very high phytomasses compared to pure crops. The inclusion of a legume in an association increases the production of the association in general and of the grass in particular. All these associations provide very satisfactory results compared to monocultures. But in terms of comparison, the binary association with grass and a legume such as *Pennisetum purpureum* - *Vigna unguiculata* is more productive at three months. Considering that the second month is the best month for grazing due to the age of the plant and the quantity of fodder, the association *Hyparrhenia diplandra* - *Vigna unguiculata* - *Pennisetum purpureum* is the best, followed by *Pennisetum purpureum* - *Vigna unguiculata*, and statistically, the differences are highly significant at the 5% threshold between 1 ($p = 0.007$), 2 ($p = 0.006$) and 3 ($p = 0.007$) months of the trial. The forage association with the inclusion of the legume provides a very satisfactory phytomass quantitatively and could ensure feed autonomy.

Discussion

In general, crop combinations provide high average herbaceous above-ground phytomass compared to pure crops. The most productive pure crop is *Pennisetum purpureum*. This can be explained by the growth rate, which seems to be related to the high phosphorus content. The Student's t. test shows that the differences between the average herbaceous above-ground phytomass and the average carrying capacity provided by these three forage crops in pure cultivation, whatever the duration, are not significant at the 5% threshold, unlike those of the associated crops, where the differences are highly significant. With 15.73 ± 3.58 t DM/ha at 3 months of establishment, the *Pennisetum purpureum* - *Vigna unguiculata* association is the most productive with a highly significant difference, and the distribution of the data is normal at the 5% significance level. This level of production can be explained by the presence of the legume, which accelerates the production of the grass by fixing atmospheric nitrogen in the soil. This analysis is related to the work of Emile *et al.* (2016).

The grass-legume association is very important quantitatively and qualitatively for a pasture. Legumes can play a considerable role in the autonomy, efficiency and sustainability of farming and livestock systems (Delaby *et al.*, 2016). Mixtures of species, especially legumes and grasses, are, a priori, more interesting than pure crops.

The presence of *Vigna unguiculata* (L.) Walp. in the association is necessary because it generally increases the production of the farm, especially that of the grasses (*Pennisetum purpureum* Schum. and *Hyparrhenia diplandra* (Hack.) Stapf). This analysis confirms the work of Ouédraogo (2004), Defly *et al.* (2006), Baijukya *et al.* (2006), who report that legume cultivation can also increase gross farm income. Baijukya *et al.* (2006) suggest that legume residues can reduce mineral fertilization. The management of forage associations is particularly advantageous from an agronomic, environmental and zootechnical point of view. In these trials, as in most farms, no chemical fertilisers or pesticides are used (neither weedkillers nor fungicides). Emile *et al.* (2016) point out that the legume makes it possible to greatly limit, or even eliminate, the use of mineral nitrogen, which is not the case with a pure cereal. In addition, it can contribute to the supply of nitrogen for subsequent crops in the rotation.

Research data on herbaceous above-ground phytomass in savannahs in the intertropics show that phytomass production varies from one ecological zone to another.

In tropical Africa, farmers can harvest up to 400 kg/ha of Vigna unguiculata leaves. Studies on the Vigna unguiculata crop development project in Niger gave a yield of 1.35 t DM/ha with the variety IN92E-26 (Moutari *et al.*, 2002). In the Congolese Cuvette, Yoka *et al.* (2014) found a leaf phytomass of Vigna unguiculata at two months after sowing of 888 kg/ha. This phytomass is lower than that found in the present study.

This difference could be explained by the different sowing spacing of 75 cm × 50 cm used by Yoka *et al.* (2014.

Conclusion

The introduced fodder crops (*Vigna unguiculata* (L.) Walp., *Pennisetum purpureum* Schum. and *Hyparrhenia diplandra* (Hack.) Stapf.) are well adapted to the soil and climatic conditions of Boundji. They provide a high phytomass. The most productive introduced forage species is *Pennisetum purpureum* Schum. at 3 months after cutting, in pure culture. The forage association is more productive than the pure crop. The forage association composed of one grass and one legume (*Vigna unguiculata-Pennisetum purpureum*) is more satisfactory for plant biomass production at 3 months after planting, followed by a multi-species association composed of two (2) grasses and one (1) legume (*Pennisetum purpureum-Vigna unguiculata-Hyparrhenia diplandra*) with highly significant differences at the 5% threshold. For grazing two months after the establishment of fodder crops, the association of *Hyparrhenia diplandra - Vigna unguiculata - Pennisetum purpureum* seems to be the best, followed by *Pennisetum purpureum - Vigna unguiculata*. Grass-legume fodder associations would be a reasoned and sustainable option to improve degraded pastures and thus ensure the fodder autonomy of farmers in the context of climate change.

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