Seeding density, persistence and contribution to biomass of two forage legumes *Aeschynomene histrix* Poir. and *Stylosanthes hamata* (L.) Taub. in a natural pasture

Short title: *Enrichment of natural pasture with leguminous plants*

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Abstract

The study aimed to investigate the possibilities to enrich natural pastures in the Sudanian zone of Burkina Faso by introducing *Aeschynomene histrix* and *Stylosanthes hamata*, two forage legumes. Thus, the experimental design installed was two blocks within which the treatments were randomly distributed with 6 repetitions. The ten treatments were as follow : natural pasture without legume introduction; natural pasture sown with one of the two legumes or without; two seeding densities of the two legumes (400 feet and 800 feet of legumes/m²); two levels of phosphate fertilization (100 kg P_2O_5/ha/yr and 0 kg P_2O_5/ha/yr). Results showed that legumes were established with high seedling densities (329-595 plants/m²). The legumes introduced into the pasture had a variable specific contribution between 15 and 30%. *A. histrix* contributed about 1.1 t DM/ha and 2.9 t DM/ha for the treatments without and with phosphorus application, respectively. P_2O_5 application particularly increased biomass production in the recipient plots by about 25%, and *A. histrix* biomass production by about 50%. Phosphorus fertilization improved the biomass contribution of the two legumes where *S. hamata* gave the best results with 49% and 48% of the biomass without phosphorus input respectively for the two seeding rates. *A. histrix* and *S. hamata* improve the fodder available for livestock and at the same time ecologically restore natural rangelands..

Keywords: Dry matter, Ecological restoration, Fodder legumes, Phosphorus, Rangelands, Semi-arid ecosystems.

Résumé

Densité de semis, persistance et contribution à la biomasse dans un pâturage naturel de deux légumineuses fourragères *Aeschynomene histrix* Poir.et *Stylosanthes hamata* (L.) Taub

L'objectif de l'étude était d'évaluer les possibilités d'enrichissement des pâturages naturels de la zone soudanienne du Burkina Faso par l'introduction de *Aeschynomene histrix* et *Stylosanthes hamata*, deux légumineuses fourragères. Ainsi, le dispositif expérimental mis en place a été deux blocs à l'intérieur desquels les traitements ont été distribués de manière aléatoire avec 6 répétitions. Les traitements au nombre de dix étaient les suivants : pâturage naturel sans introduction de légumineuse ; pâturage naturel ensemencé avec l'une des deux légumineuses ou sans ; deux densités de semis des deux légumineuses (400 pieds et 800 pieds de légumineuses/m²) ; deux niveaux de fertilisation phosphatée (100 kg P_2O_5/ha/an et 0 kg de P_2O_5/ha/an). Les résultats ont montré que les légumineuses s'installaient avec des densités de jeunes plants élevées (329-595 plants/m²). Les légumineuses introduites dans le pâturage ont enregistré une contribution spécifique variable entre 15 et 30%. *A. histrix* a contribué à environ 1,1 t MS/ha et 2.9 t MS/ha respectivement pour les traitements sans apport et avec apport de phosphore. L'apport de P_2O_5 a particulièrement augmenté la production de biomasse des parcelles bénéficiaires de l'ordre de 25%, et la production de biomasse de *A. histrix* de l'ordre de 50%. La fertilisation en phosphore a amélioré la contribution à la biomasse des deux légumineuses où *S. hamata* a donné les meilleurs résultats avec 49% et 48% de la biomasse sans apport de phosphore respectivement pour les deux densités de semis. *A. histrix* et *S. hamata* améliorent le disponible fourrager pour le bétail et même temps restaurent écologiquement les parcours naturels.

Mots-clés : Matière sèche, Restauration écologique, légumineuses fourragères, Phosphore, Parcours, Ecosystèmes semi-arides.

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Introduction

Grasslands are the main source of fodder for ruminants, including in intensive sheep and cattle systems for milk and meat production (Ouédraogo *et al*., 2022; Ouédraogo *et al*., 2019; Corbett and Freer, 1995). In pastoral systems of tropical environments, grasses are mainly provided by natural pastures. The nutritive value of these grasses varies over the course of the year. From bolting point, the digestibility of the grasses decreases due to the lignification of the cell walls. The nutritive value of annual grasses decreases rapidly as the leaves get older, so that the period of maximum phytomass occurs when the grasses have become almost inconsumable (Fournier *et al*., 1999). In particular, the low nitrogen content restricts the valorization of these forages. For this reason, leguminous plants of natural pastures are the main sources of nitrogen (herbaceous and woody). In contrast to Sahelian pastures, Sudanian pastures contain few legumes in the herbaceous flora. Herbaceous legumes are very poorly represented and only a few of them are palatable (Yaméogo *et al*., 2013). Cesar (1994) argues that the herbaceous stratum of Sudanian pastures in northern Côte d'Ivoire is composed by 98% (biomass weight) of caespitose hemicryptophyte grasses. However, studies have shown that legumes can improve the dry matter intake of ruminants by at least 30% (Poppi and McLennan, 1995). The fact that ruminants experience production losses during the lean periods of the year (Muhr *et al*., 1999) is partly explained by this fact. Animals adjust by increasing selection on pasture. Unfortunately, the low pasture productivity, the high variability in the quality of available forage, and the degradation of natural resources caused by high animal stocking rates, limit the ability of ruminants to select and feed on pasture. These major constraints limit the productivity and development of livestock production on farms in the Sudanian zones during the dry season.

Several alternatives have been mentioned to help increase the feeding value of natural pastures, including production of fodder crops, supplementation with Agro-Industrial By-Products (AIBP), etc. (Ouédraogo *et al*., 2019). However, AIBP have a very high cost and are not always available. However, a well-managed legume fodder crop provides forage that can complement crop residues and natural pastures that are poor in digestible nitrogen. They also help to improve the productivity of native pasture by providing naturally fixed nitrogen (Lazenby and Tow, 2001). Pure forage crops also pose a management problem in open pastoral systems in West Africa in general, and in Burkina Faso in particular. Collective management of pastures limits their adoption and development in production systems. In order to combine the advantages of grasses and legumes in grazing, it would appear very interesting to have them coexist in proportions where each has a significant contribution to the biomass produced (Lazenby and Tow, 2001). The objective of the study was to evaluate the potential for the enrichment of natural pastures through the introduction of two forage legumes, namely *Aeschynomene histrix* Poir. and *Stylosanthes hamata* (L.) Taub. The performance of the two introduced legumes in competition with other herbaceous plants in natural pastures was characterized. The productivity of these two legumes and their establishment in the pasture as well as their specific contribution were evaluated under light grazing conditions. Expected results from the study will help in a better enrichment of rangelands based on the introduction of efficient legumes and the improvement of soil fertility in pastures.

Material and methods

Study site

The study was carried out at the Farako-Ba research station located in the Sudanian zone of Burkina Faso (4°20'W; 11°06'N; Alt. 405 m Figure 1). Fontès and Guinko (1995), have indicated that the climate of Farako-Ba is dominated by a tropical Sudanian climate. Rainfall is often greater than 1,000 mm, and the rainy season averages between April and November. The Farako-Ba station has a natural and anthropic vegetation of shrub and tree type. Open forests are found on the periphery of the lowlands and along the rivers. Species such as *Parkia biglobosa* R. Br. ex G. Don, *Detarium microcarpa* Guill. and Perr, *Vittelaria paradoxa* C.F. Gaertn, *Gmelina arborea* Roxb, *Mangifera indica* L., *Khaya senegalensis* A. Juss and *Tamarindus indica* L. constitute mainly the woody stratum. The herbaceous layer is composed mainly of *Andropogon gayanus* Kunth, *Andropogon pseudapricus* Stapf, *Andropogon fastigiatus* Sw., *Indigofera* sp, *Loudetia togoensis*, *Eragrostis tremula, Digitaria horizontalis, Brachiaria* sp and *Cyperus* species. Ferruginous soils with little or no leaching are frequently found on sandy, sandy-clay and sandy-clay materials. These soils are poor in clay, organic matter, calcium, potassium and phosphorus, which explains their low cation exchange capacity. They have a poor structure and are susceptible to erosion. Their average depth remains an important asset in a country where soils are mostly superficial, ranging from 40 to 100 cm deep.

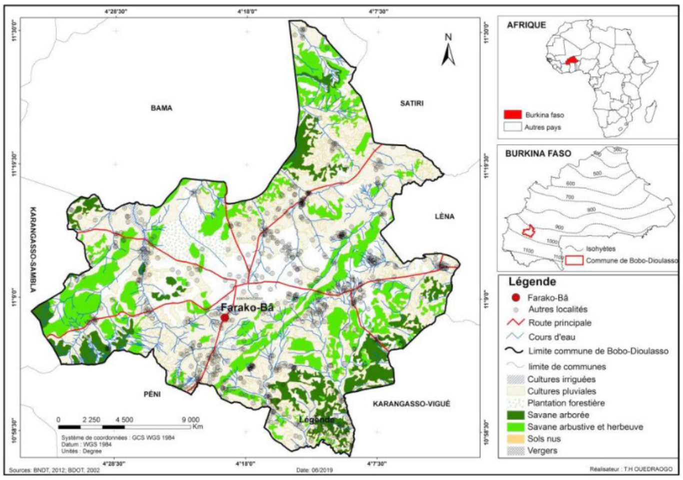


Figure 1: Location of study site

Studied species

Aechynomene histrix Poir. is a perennial herbaceous taproot legume with an average height of 25-80 cm for the main stem reaching 64 cm in 8 weeks; 83 cm in 12 weeks; 173 cm in 17 months (Ehouinsou *et al*., 2004). The leaves are compound and the inflorescences axillary (Merkel *et al*., 2000). Seed production is ranged from 92 to 200 kg/ha (Merkel *et al*., 2000;;). *A. histrix* is one of the most promising herbaceous leguminous species with a biomass production of about 6 t dry matter (DM)/ha in the second cropping season (Tarawali, 1994) with Crud Protein content (CP) values of 12.5 to 14% (Ehouinsou *et al*., 2004).

Stylosanthes hamata Verano is a perennial or semi-perennial grass legume depending on climatic conditions. It is an erect plant, sometimes prostrate, with trifoliolate, alternate leaves with petioles 2-6 mm wide and leaves up to 16-26 mm long. It has an average height of 1.4 m (Tarawali and Ogunbile, 1995); extensive root growth and an efficient seed dispersal mechanism. Its seed production ranges from 250 to 600 kg/ha when harvested manually (Boudet, 1984). *S. hamata* has a potential biomass production under optimal conditions of 17 t DM/ha in pure culture, 1 to 7 tons DM/ha in natural pasture. Tarawali *et al*. (1998), found 2.5 to 2.9 t DM/ha in natural pastures in Nigeria. *S. hamata* have 17 to 24% CP in green leaves, 6 to 12% CP in stems with in vivo DM digestibility of 60 to 65%.

Experimental design description

At the research station of the Institut de l'Environnement et de Recherches Agricoles de l'Ouest (Figure 2), an experimental design in two blocks (with and without phosphorous application) within which the ten treatments were randomly distributed with 6 repetitions was set up. The experimental plot areas were 12 m^2 (4 m× 3 m). The main plot level was phosphorous application or not. The subplots were the legumes×seeding densities.

The trial was set up after a total destruction of the epigeous biomass by burning the natural pasture. Seeds were uniformly spread in the plots, followed by a slight scarification with a rake to ensure their optimal incorporation into the soil. The sowing occurred after sufficient rainfall to account for the fact that *S. hamata* seeds were treated by soaking in hot water before sowing in order to remove dormancy. The treatments (Ti) were the following:

- T0 or control: natural pasture without legume introduction;

- T1 to T5: natural pasture sown with one of the two legumes or without;
- T6 and T7: two seeding densities of the two legumes (400 plants and 800 plants of legumes/m²);
- T8 and T9: two levels of phosphate fertilization of 100 kg P_2O_5/ha/year and 0 kg P_2O_5/ha/year.

The treatments were repeated in 6 blocks. The set-up included a total of 60 plots of 12 m². The target seeding rates were corrected after the results of a pre-germination test to 400 and 800 potentially viable seeds per m² in the field. The germination rate that resulted from the pre-germination test was 92% and 43% for *A. histrix* and *S. hamata*, respectively. The corresponding corrected seeding rates in g/plot and kg/ha were presented in Table 1.

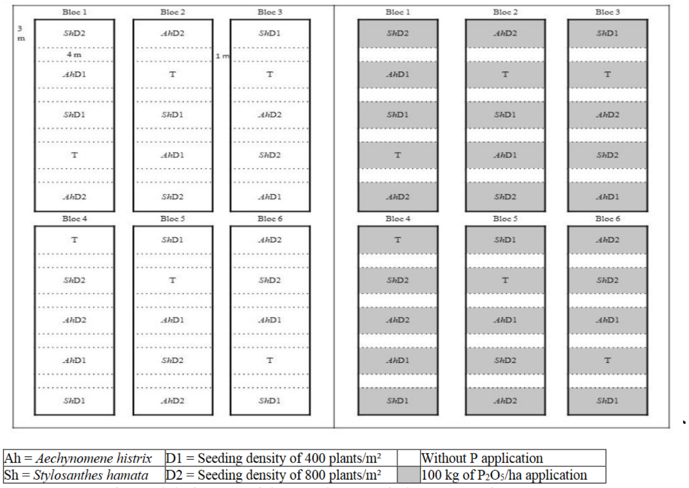


Figure 2: Experimental design to enrich natural pasture in legume species

Table 1: Seeding densities of the fodder legumes in the pasture

Species	Units	Initial seeding density		Adjusted seeding density	
		D1	D2	D1	D2
Aeschynomene histrix	Number of targeted plants/m²	**400**	**800**	400	800
	g seeds/plot	4,21	8,41	9,14	9,14
	kg seeds/ha	3,006	7,012	7,62	7,62
Stylosanthes hamata	Number of targeted plants/m²	**400**	**800**	400	800
	g seeds/plot	5,66	11,31	13,15	26,30
	kg seeds/ha	4,71	9, 42	10,96	21,92

and a sample of approximately 500 g was taken for dry matter (DM) content determination. Each 500 g sample was subdivided into 2 subsamples of approximately comparable weight, placed in labelled cloth bags. Determination of DM content was performed after oven drying at 65°C for 48 hours. For each cut, the DM content considered was the average of the DM contents of the two samples. The biomass cut on the rest of the plot was collected and transported outside the system. Observations and measurements were made on two 1 m² squares permanently located on a northwest/southeast diagonal in each plot at the time of sowing by stakes. In the 1st year, the measurements were made on:

- A first count of the number of introduced legume seedlings 30 days after sowing;
- A second count made 60 days after sowing the legumes. At this time, other legumes, annual grasses and perennial grasses present in the native pasture were counted at the same time;
- A third count was made 90 days after seeding the legumes;
- A final count was made in mid-October, and was related to the introduced legumes.

In the second year, the observations focused on:

- A first count of the number of seedlings of leguminous plants on the plots 15 days after the first significant rainfall (> 20 mm), with a distinction between perennial plants and young shoots, other leguminous plants, annual grasses and the number of tufts of perennial grasses;
- A count in October of the number of seedlings of introduced legumes, flowering tillers of perennial grasses;
- A cut of the biomass at 15 cm from the ground followed by a decomposition of the introduced leguminous plants and that of the other herbaceous plants considered globally on the biomass of two square plots of 1 m of the side, randomly selected in the plots in October.

In the 1st and 2nd year, an inventory of herbaceous species using the quadrat point method (Daget and Poisson, 1971) was carried out just before the last legume count. It consisted of stretching a metric tape over the herbaceous mat along a diagonal of each plot. A wire was lowered into the herbaceous mat every 10 cm and all herbaceous species with an organ in contact with the wire were counted for presence/absence. On each elementary plot, 50 reading points were thus carried out. If at a given point, the wire is not in contact with a plant, the soil is bare. The following parameters were measured:

- The number of plants of introduced legumes, other legumes and dicotyledons, annual grasses, clumps of perennial grasses one month after sowing in the first year and at the end of the rainy season in the three years following the establishment;
- The total biomass production at each annual cut in the three years following the establishment using the method of full cutting at 10 cm from the ground of the grasses contained within the boundaries of a 1 m square metal frame. This biomass is broken down into introduced legumes, other dicotyledons and grasses;
- The evolution of the proportion of introduced legumes in the biomass produced in the different treatments in the second rainy season;
- The specific frequencies as well as the specific contributions of each herbaceous species.

The productivity of rainfall into biomass PRFB (Ouattara *et al.*, 2018) was calculated using the formula:

$$PRFB\ (kg\,ha^{-1}mm^{-1}) = \frac{biomass\ yield\ (kg\ DM/ha)}{Rainfall\ (mm)}.$$

The amount of rainfall used is that corresponding to the rainfall from the beginning of the rainy season to the date of biomass assessment. Rainfall data were provided by the Farako-Bâ Weather Station.

Statistics analysis:

A four-factor analysis of variance [species, dose, phosphorus, management] followed by a comparison of means was performed using XLSTAT version 2016. This was done for the frequencies and specific contributions of the introduced legumes, the density of the introduced legumes seedlings per m², the biomass production of the pasture, the contribution of the legumes and the biomass productivity of the rainwater as a function of the seeding rate parameters.

Results

Establishment of the introduced legumes

Strong increase in plant density from seeding to the end of the third year was observed. The evolution of the number of introduced legumes plants in the natural pasture according to the seeding rate as well as the contribution or not of phosphorus was presented in table 2. The legumes established well from the beginning, with high seedling densities. *A. histrix* seemed to establish better compared to *S. hamata*, despite the pre-treatment of its seeds before sowing. Very high plant densities per m² were observed in the first two to three months after planting, i.e. 346 and 955 plants/m² without phosphorus application, 329 and 595 plants/m² for *A. histrix* in July for the two planting densities respectively. With *S. hamata*, the highest densities of plants/m² were observed three months after installation, in August. Thus, 197 and 375 plants/m² were observed in the plots without phosphorus application and 167 and 265 plants/m² in the plots with application of 100 kg/ha of P2O5 respectively for the sowing densities of 400 (D1) and 800 (D2) plants/m². Thus strong seedling melts were observed from the sowing period to the end of the first year of the experiment. This relatively high density of legumes at installation broke down rapidly in the second year after the establishment. Therefore, in the second year, *A. histrix* had only 53 to 67 plants/m², whatever the seeding rate and the application of phosphorus or not. With *S. hamata*, observed densities ranged from 45 to 108 plants/m². In the third year, these values were only 45 to 80 and 20 to 77 plants/m² respectively for *A. histrix* and *S. hamata* with and without phosphorus application. This represented between 10 - 20% and 10 - 19% of the potential viable seeds initially sown in the natural pasture.

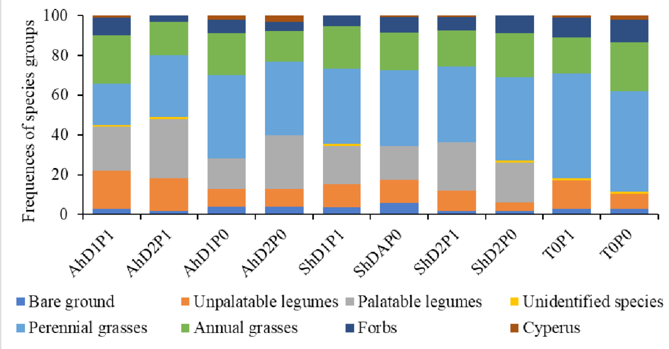
Table 2: Evolution of the number of introduced leguminous plants/m² (average ± sd).

Treatment/Phosphorus/Seeding rate			1rst year				2nd year			3rd year
			June	July	August	September	July	August	September	September
Natural pasture	0 kg P_2O_5/ha									
	100 kg P_2O_5/ha									
Natural pasture + *A. histrix*	0 kg P_2O_5/ha	400 plants/m²	149±72de	346±142^{c}	183±108^{c}	146±103^{d}	74±77^{b}	52±35^{bc}	55±52^{b}	62±79^{ab}
		800 plants /m²	152±63de	955±421^{a}	585±528^{a}	491±376^{a}	83±152^{ab}	65±57^{b}	57±39^{b}	52±53^{ab}
	100 kg P_2O_5/ha	400 plants /m²	394±197^{a}	329±199^{c}	175±150^{c}	134±104^{d}	65±91^{bc}	58±51^{bc}	53±42^{b}	45±45^{bc}
		800 plants /m²	296±145^{b}	595±230^{b}	393±351^{b}	313±272^{bc}	98±77^{ab}	70±42^{ab}	67±43^{b}	80±54^{a}
Natural pasture + *S. hamata*	0 kg P_2O_5/ha	400 plants /m²	97±75^{ef}	112±44de	197±138^{c}	184±158^{cd}	90±47^{ab}	69±37^{b}	63±29^{b}	66±39^{ab}
		800 plants /m²	55±28^{e}	218±107^{cd}	375±239^{b}	335±202^{b}	126±94^{a}	84±46^{a}	108±53^{a}	77±33^{a}
	100 kg P_2O_5/ha	400 plants /m²	154±84de	86±34^{e}	167±114^{c}	152±103^{d}	88±106^{ab}	58±47^{bc}	45±22^{b}	20±10^{c}
		800 plants /m²	102±58^{ef}	162±84^{be}	265±180^{bc}	230±154^{bcd}	78±53^{b}	68±41^{ab}	61±33^{b}	36±25^{bc}

Note: in the same column, averages marked with different letters do not differ significantly at the 5% level.

Pasture structure

The pasture structure at the end of the rainy season in the first year of the experiment setup showed a predominance of perennial grasses whose sum of specific contributions varied from 21 to 53% (Figure 3). In the control plots, they represent 50 to 53% of the specific contributions respectively for the treatments without and with phosphorus addition. The second important group in terms of contribution was the group of annual grasses (17 to 24%). The legumes introduced into the pasture recorded a specific contribution varying between 15 and 30%. These were followed by the unpalatable legumes, with a variable specific contribution between 4 and 19%. Forbs were also present in all plots, with a specific contribution varying between 3 and 11%. Overall, the pasture had a very high soil cover over 95%.



NB. Ah = *A. histrix*; Sh = *S. hamata*; D1 = sowing density of 400 plants/m²; D2 = sowing density of 800 plants/m²; P0 = no phosphorus input; P2 = application of 100 kg P_2O_5/ha; T0 = control.

Figure 3: Structure of the pasture at the end of the first year of establishment

Biomass production

In the second year after the introduction of the legumes, their contribution to the biomass of the treatments was low for *A. histrix* (about 300 kg DM/ha) and average for *S. hamata* (500 to 600 kg DM/ha) (Table 3). From the third year onwards, the contribution to the biomass of *A. histrix* became more important while that of *S. hamata* decreased strongly. Thus, *A. histrix* contributed about 1.1 t DM/ha and 2.9 t DM/ha for the treatments without and with phosphorus input, respectively. The P2O5 input particularly increased the biomass production of the recipient plots by about 25%, and the biomass production of *A. histrix* by about 50%. It was able to conclude that *S. hamata* regressed strongly in the sown plots, while *A. histrix* persisted relatively well in the plots where it was introduced. This was related to the regression of the number of plants per m² of pasture, reported earlier.

Treatment/Sowing density		Year	0 kg P_2O_5/ha				100 kg P_2O_5/ha			
			Other dicotyledonous	Gramineous	Introduced leguminous	Total	Other dicotyledonous	Gramineous	Introduced leguminous	Total
Natural pasture		Year 2		1 228	0	1 228		1 266	0	1 266
		Year 3	641	5 474	66	6 182	573	5 527	16	6 116
		Year 4	476	3 931	42	4 449	561	3 989	53	4 603
Natural pasture + *A. histrix*	D1 (400 plants/m²)	Year 2		756	291	1 047		1 277	288	1 564
		Year 3	570	6 437	1 133	8 141	643	7 943	2 914	11 500
		Year 4	404	4 583	1 011	5 998	633	5 644	2 798	9 076
	D2 (800 plants/m²)	Year 2		825	238	1 063		1 030	473	1 503
		Year 3	781	8 356	1 113	10 250	864	8 677	2 011	11 552
		Year 4	456	6 001	1 075	7 532	526	6 197	1 792	8 516
Natural pasture + *S. hamata*	D1 (400 plants/m²)	Year 2		664	523	1 188		944	399	1 343
		Year 3	418	8 510	131	9 059	502	9 607	310	10 419
		Year 4	387	6 063	146	6 596	467	6 803	218	7 489
	D2 (800 plants/m²)	Year 2		736	613	1 349		1 086	532	1 618
		Year 3	861	8 151	193	9 205	754	9 196	123	10 072
		Year 4	565	5 787	197	6 549	657	6 491	144	7 293

Rainfall productivity in biomass

There was a large variation in rainfall productivity into biomass across treatments and years (Table 4). In the 2nd year, this productivity was on average 1 kg DM/mm of rainfall/ha whatever the treatment. Between the third and fourth years, it ranged from 4 to 7 kg DM/mm rainfall/ha for the control plots with or without phosphorus application. It varied from 5 to 11 kg DM/mm rainfall for the plots sown with legumes and without phosphorus application, compared to 6 to 13 kg DM/mm rainfall/ha for the plots that received phosphorus. In plots seeded to *A. histrix* and without phosphorus, rainwater productivity of the legume biomass was 1.2 and 0.8 kg DM/mm rainwater/ha, regardless of legume seeding rate. With the addition of phosphorus, this rainwater productivity reached 3.2 and 2.2 and then 1.4 and 2.2 kg DM/mm rainfall/ha respectively for seeding densities D1 and D2 of the legume.

Contribution to biomass

The contribution of the introduced legumes to the pasture biomass was highly variable depending on the species, seeding rate and phosphorus supply (Table 5). At the beginning of the experiment, *S. hamata* gave the best results with 49 and 48% of the biomass without phosphorus supply respectively for seeding densities D1 and D2, and 17 to 29% for the same seeding densities without and with phosphorus supply respectively. At the same time, the contribution of *A. histrix* to pasture biomass was 23 and 17% with seeding rate D1 and 25 and 29% with and without phosphorus supply for seeding rate D2. This contribution dropped sharply to between 2 and 3% in the fourth year, regardless of seeding rate and whether or not phosphorus was applied for *S. hamata.* On the other hand, *A. histrix* performed better with a contribution to the biomass of the seeded pasture of 13 and 12% for seeding rates D1 and D2 without phosphorus application. With phosphorus fertilization, this contribution was 30 and 21% respectively for the same seeding densities D1 and D2. Phosphorus application improved the biomass contribution of *A. histrix*, although the observed values are far below the 30-40% order of magnitude desired for natural pasture improvement. The species *S. hamata* has difficulty maintaining itself in Sudanese pastures and its contribution to biomass declines very rapidly. Its ability to compete remains weak in terms of its vegetative behaviour compared to *A. histrix*. Both legumes started to appear in the control plots with a contribution to biomass in the range of 0.3 to 1.5%.

Table 3: Evolution of the composition of the biomass harvested on the pasture according to the treatments (kg DM/ha)

Treatment/Sowing density		Year	0 kg P205/ha				100 kg P205/ha			
			Other dicotyledonous	Gramineous	Introduced leguminous	Total	Other dicotyledonous	Gramineous	Introduced leguminous	Total
Natural pasture		Year 2	0,0	1,1	0,0	1,1	0,0	1,1	0,0	1,1
		Year 3	0,7	6,0	0,1	6,8	0,6	6,1	0,0	6,7
		Year 4	0,4	3,0	0,0	3,5	0,4	3,1	0,0	3,6
Natural pasture + *A. histrix*	D1 (400 plants/m²)	Year 2	0,0	0,7	0,3	0,9	0,0	1,1	0,3	1,4
		Year 3	0,6	7,1	1,2	9,0	0,7	8,7	3,2	12,7
		Year 4	0,3	3,6	0,8	4,7	0,5	4,4	2,2	7,0
	D2 (800 plants/m²)	Year 2	0,0	0,7	0,2	0,9	0,0	0,9	0,4	1,3
		Year 3	0,9	9,2	1,2	11,3	1,0	9,5	2,2	12,7
		Year 4	0,4	4,7	0,8	5,8	0,4	4,8	1,4	6,6
Natural pasture + *S. hamata*	D1 (400 plants/m²)	Year 2	0,0	0,6	0,5	1,0	0,0	0,8	0,4	1,2
		Year 3	0,5	9,4	0,1	10,0	0,6	10,6	0,3	11,5
		Year 4	0,3	4,7	0,1	5,1	0,4	5,3	0,2	5,8
	D2 (800 plants/m²)	Year 2	0,0	0,6	0,5	1,2	0,0	1,0	0,5	1,4
		Year 3	0,9	9,0	0,2	10,1	0,8	10,1	0,1	11,1
		Year 4	0,4	4,5	0,2	5,1	0,5	5,0	0,1	5,7

Table 5: Evolution of the contribution of the introduced legume to the total biomass of the pasture (in %)

Treatment/Sowing density		Year	0 kg P_2O_5/ha	100 kg P_2O_5/ha
Natural pasture		Year 2	0,0	0,0
		Year 3	0,9	0,3
		Year 4	0,8	1,5
Natural pasture + *A. histrix*	D1 (400 plants/m²)	Year 2	23,3	17,2
		Year 3	12,0	26,0
		Year 4	13,3	30,3
	D2 (800 plants/m²)	Year 2	25,0	29,3
		Year 3	9,0	17,7
		Year 4	11,6	20,5
Natural pasture + *S. hamata*	D1 (400 plants/m²)	Year 2	49,3	28,6
		Year 3	1,2	2,7
		Year 4	1,9	3,2
	D2 (800 plants/m²)	Year 2	48,2	32,3
		Year 3	2,0	1,7
		Year 4	2,8	2,6

Discussion

Method of introducing legumes

Unlike forage crops that require soil preparation, in the case of the present study, a simple scarification of the soil is carried out to ensure a minimum of adhesion of the introduced seeds to the soil and to promote their germination. Eriksson and Ehrlén (1992), are emphasized that the availability of seeds and favourable microsites for their germination and development are potential factors that can limit plant turnover in plant stands. The results show some effectiveness of this method for *in situ* germination of seeds of introduced legumes. Similar results are obtained by Stockwell (1993) with *S. scabra* cv Fitzroy and *S. hamata* cv Verano at 2.5 kg of seed per ha after only one very early winter fire. This represents a labour and time saving, compared to forage crops that require weeding (Muhr *et al.,* 1999). Thus, enrichment of the pasture with this seeding technique can allow for large areas to be covered with little effort.

Representativeness of legumes and contribution to the biomass

It is evidence that forage legumes are better for humans, animals and environment (Adjolohoun *et al*., 2008; Sowiński and Adamczewska-Sowińska, 2022). Introducing the legume species along the natural pastures present more benefit and require to take into account some conditions. When a new species is introduced in an environment because of human activities (voluntarily or involuntarily), this species enters in competition with the already present (native) species. The impact of these species will depend on their ability to adapt to their new environment, their reproduction strategy. In the present case, there is indeed competition in the sense of Marion (2010) who argued that there is competition when an interaction between several individuals or populations leads to a reduction in the performance (biomass, growth, survival, fecundity) of at least one of the individuals or populations. It is certainly this weak capacity to compete with Sudanese grasses that can partially explain the low representativeness of legumes in natural pastures of tropical savannahs as observed by Yaméogo *et al*. (2013). The two studied legumes have not the same ability to compete in the Sudanian savannah environment. *A. hsitrix* is revealed to be more competitive compared to *S. hamata*, in terms of the evolution of the number of plants of this species in the pasture and also its higher contribution to the total biomass. Despite the decrease observed during 3 years after its introduction, the number of plants/m² remains far higher than the values of 1.4 to 12 plants/m² as reported by Stockwell (1993) for *S. hamata* cv Verano and *S. scabra* cv Fritzory respectively. Olanite *et al.* (2004) add that if the cutting is practised as frequently as for grasses, the main problem with herbaceous legumes lies in the reduction of regrowths and of seed production, decreasing finally the capacity of the pasture to persist, even under a vegetative form.

Herbaceous legumes can also contribute to soil protection because they provide good ground cover, thereby minimizing soil erosion through a reduction of raindrop impact and runoff (Lal et al., 1991). Legumes increase plant nutrient supply in the soil (especially N) and improve soil physical characteristics, thereby improving crop yields (Tarwali and Peter, 1996).

Grazing by ruminants earlier after the introduction of the legumes can help the legumes to establish better, as the animals would select the young grasses over the legumes (Muhr *et al*., 1999). Bushfires are another important factor to study, as they can influence the representativeness of legumes introduced into the pasture in the medium and long terms. Indeed, in view of the large quantities of biomass observed, bushfires at the end of the wet season destroy the plants in situ, but also the seeds on the soil surface (Savadogo et al., 2017; Zida et al., 2020). The results obtained with *S. hamata* cv Verano are in agreement with the low development and consequently low biomass production (0.1 t DM/ha) of this species, after three years of introduction in a pasture with tall perennial grasses (Stockwell, 1993). The author justifies this by greater competition from perennial grasses at this study site.

Conclusion

The study shows that overseeding of legumes in tropical savannah rangeland is an alternative to improve the representativeness of legumes in these rangelands. The introduced species persist during the 4 years of observation, although their numbers decline sharply over time. Their contribution to the total pasture biomass is significantly higher for *Aeschynomene histrix* than for *Stylosanthes hamata*. Also, the seeding density of the legume and the application of phosphorus have no significant effect on the persistence of the two legumes in the pastures. Species *Aeschynomene histrix* is better adapted to compete with grasses in Sudanian zones than *Stylosanthes hamata*, and can be recommended for extension in this way. The initial seeding percentage has no significant influence on the persistence of the legumes under grazing, so the 400 plants/m² seeding rate save seed costs. However, research must continue with other legume species with interesting characteristics for competition in savannah environments with tall grasses (*Chamaecrista rotundifolia*). Insofar as the present experiments are conducted without grazing, it will also be interesting to take into account the presence of animals during vegetation in order to better assess the evolution of legumes in the improved pasture.

Acknowledgements

The authors are grateful to the Institut de l'Environnement et de Recherches Agricoles for its invaluable support during this study.

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