Heliyon 10 (2024) e38400

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Seed production capacity and viability of pasture legumes under the influence of phosphorus management

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ARTICLE INFO

Keywords:
Aeschynomene histrix
Semi-arid ecosystems
Stylosanthes hamata
Rangelands
Reseed

ABSTRACT

Seed production of a forage legume in the natural pastures reflects its ability to reseed and enrich the pasture. This study aimed at improving the productivity and nutritional value of pastures through enhancement the ability of leguminous species to restore pastures under phosphorus management. A field study was conducted at the research station of Farako-Bâ, Burkina Faso. Treatments included two legumes (*Aeschynomene histrix* and *Stylosanthes hamata*) and two levels of phosphorus application (Po = 0 and P1 = 100 kg P ha^1). The experimental design was a split-plot arrangement with legumes as the main treatment and Phospohorus application as the sub-treatment. Results showed that the phosphorus application had a significant effect on the seed production of the two legumes, whereby *A. histrix* seed production of was significantly higher than that of *S. hamata* with or without phosphorus application ($P < 0.05$). Seed production was 566.92 kg/ha and 299.08 kg/ha for *A. histrix*, *S. hamata*, respectively. The fertility of *A. histrix* seeds (92.49 %) is very significantly higher than those of *S. hamata* (62.07 %) ($P < 0.01$). Phosphorus only improved seed weight of *S. hamata* ($P < 0.05$), unlike *A. histrix*, where this improvement was not statistically significant. In view of these results, *A. histrix* and *S. hamata* can be strongly recommended for the enrichment of Sudanian natural pastures.

1. Introduction

In the Sudanian zone of Burkina Faso, the farming system practiced is dominated by the extensive system; with almost all ruminant feeding based on the exploitation of natural pastures (woody and herbaceous fodder species) [1–3].

Unfortunately, the strong seasonal variability of available forage from pastures leads to significant losses in body weight and milk production during the dry season [4]. In addition, this fluctuation is accompanied by the degradation of pasture due to climatic factors (rainfall, temperature and wind), soil factors (soil infertility: low organic matter content, low available phosphorus and nitrogen content …), and the actions of man and animals [4]. This situation is the reason for the presence of characteristics species of degraded pastures such as *Loudetia togoensis* (Pilg.) C.E.Hubb, *Loudetia hordeiformis* (Stapf) C.E.Hubb and the shrub/herbaceous imbalance;

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https://doi.org/10.1016/j.heliyon.2024.e38400
Received 28 June 2024; Received in revised form 18 September 2024; Accepted 23 September 2024
Available online 24 September 2024
2405-8440/

resulting in overgrowth of the rangelands [5].

The herbaceous layer of these pastures is characterised by a low proportion of herbaceous forage legumes in the biomass, whereas that of grasses is extremely high [6]. In the south of Burkina Faso, legumes represent only 4 % of the biovolume; yet in the north of the Ivory Coast, they contribute only 0.5 % to the biomass [7]. However, forage legumes play two essential functions in natural pastures: (i) they balance the feed ration of livestock due to their high content of nitrogenous matter and mineral salts, and (ii) they improve soil fertility by fixing nitrogen [6]. Unfortunately, their low representativeness compromises the development and profitability of animal production. To avoid this, improving their representativeness in natural pastures would greatly contribute to improving the nutritive value and biomass production of these pastures and consequently of livestock.

The fodder crop extension policy and conservation methods in the Sudanian zone were initiated in the 1980s. But these options failed because they were not very suitable, as breeders continued to rely on natural rangelands to feed their livestock. In the short and medium term, intensive livestock farming cannot replace extensive pastoral livestock farming, with substantially the same degree of profitability [5]. This is why studies on the use of herbaceous fodder legumes are initiated in order to improve the productivity and nutritional value of pastures, through better knowledge of the introduced species and the evaluation of their possibility to rehabilitate and improve these pastures.

The deficiency of P causes significant yield reduction in leguminous crops. Yet, it is admitted that the major soils in the tropical area like Burkina Faso are ferruginous with low available P content. There is a need to supply soil with phosphorus for better legume productivity and soil sustainability.

This study aims to determine the effect of phosphorus on the pasture legume seed production under different regime of phosphorus management. We hypothesized that: (1) phosphorus supply improves the seed production of legumes and (2) phosphorus improves the germination characteristics of seeds legumes.

We hope that the findings of this study will make possible to increase the quantity of viable legume seeds in the pasture, which will at the same time enrich the soil seed bank and consequently induce a better representativeness of fodder legumes in the herbaceous biomass.

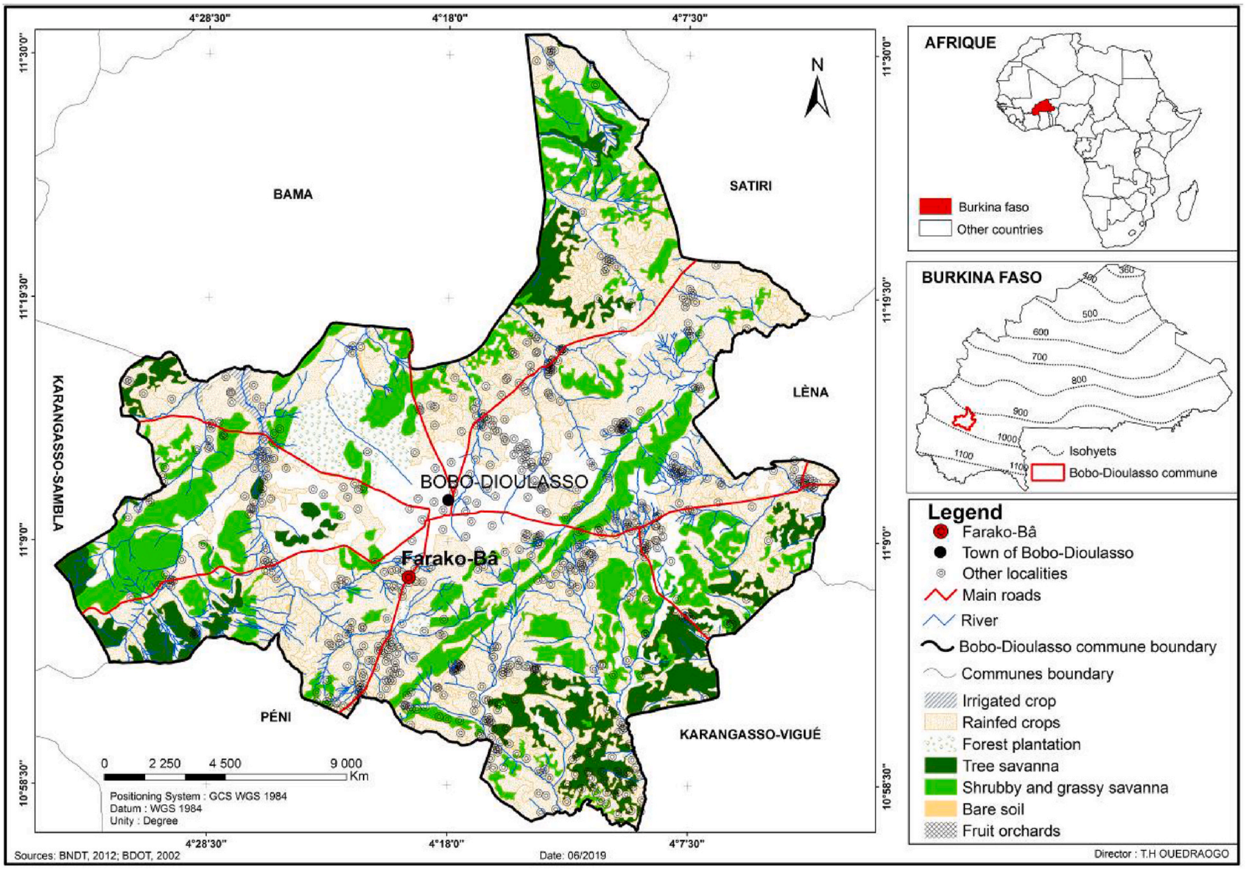

Fig. 1. Location of the study site.

2. Materials and methods

2.1. Study site

The experiment was carried out at the Institute of Environment and Agricultural Research, located at Farako-Bâ in the southern Sudanian zone of Burkina Faso (11°06 N, 04°20 W, 405 m.a.s.l., Fig. 1). The site mean annual precipitation varies between 900 and 1000 mm [8]. The rainfall pattern of this site is unimodal and lasts for about 7 months each year (May to November).

Mean daily minimum and maximum temperatures ranged from 14 to 32 °C in January (the coldest month), from 25 to 41 °C in April (the hottest month). Soil types are mostly the tropical Ferruginous to Ferrallitic [9]. The soils are characterised by a sandy loan texture, with pH 5.2 to 5.4, average organic matter content of 0.95–1.03 %; and low phosphorus content [10].

The natural pastures are dominated by woody species such as *Danielia olivieri*, *Afzelia africana, Isoberlia doka, Pterocarpus erinaceus, Prosopis africana, Parkia biglobosa, Burkea africana and Albizzia chevalieri.* Also present are some characteristic herbaceous species such as *Andropogon ascinodis, Andropogon gayanus, Aristida kerstingii, Ctenium newtonii, Loudetia togoensis, Monocymbium cereciforme, Pennisetum pedicellatum, and Schizachyrium sanguneum* [11]. Legumes species are rarely part of the vegetation of the study site. However, legume, *Indigofera* sp., which is mostly non-palatable, has occasionally invaded some of these natural pastures [3; 11].

2.2. Treatments and experimental design

Treatments included two planted legumes (*Aeschynomene histrix* and *Stylosanthes hamata*) and two levels of phosphorus application (Po = 0 and P1 = 100 kg P ha^{-1}). Experimental design based on split-plot arrangement were laid out. The main plots consisted of planted legumes; while the sub-plots were the phosphorus application. The treatments were replicated four times.

2.3. Experimental management

Aeschynomene histrix and *S. hamata* were grown on a previously ploughed plot. Each sub-block was composed by four main plots and each of the legumes was sown on two sub-plots. Each main plot was 4 m × 6 m and was separated from the next plot by 1 m inside the block. Sowing density was 400 plants m^{-2} for each of the two legumes.

Sowing was done on the fly so as to have a good distribution of seeds on the plot [12]. *Stylosanthes hamata* seeds were soaked in hot water at 80 °C, and completely cooled, to break dormancy before sowing [13,14]. Seeds of *A. histrix* were not been treated because they were characterized to have a good germination percentage [13,14].

2.4. Data collection

2.4.1. Assessment of seed production

At physiological maturity stage, seed production was evaluated by harvesting all plants on two-unit plots, each of 1 m^{-2}. Physiological maturity was marked by total senescence of leaves on the plant. Pods were threshed and screened from chaff using a sieve of 2 mm mesh, and then 1 mm. This was supplemented by manual sorting in order to obtain pure seeds.

2.4.2. Physical characterisation of seeds

For each species, 10 batches of 1000 pods were randomly sampled from the stock of seeds collected from per plot. Each batch was weighed using a precision balance (±1 mg, with a maximum of 320 g). They were shelled using mounted needles, then the number of seeds obtained and their weight were recorded. A deduction of the weight of the shells corresponding to 1000 pods was done. The seeds of the batches were completed to 1000 by shelling other pods, and then weighed. The Ratio of weight obtained with 1000 pods/weight of 1000 pods, and the fertility rate = 100*(number of pods with seeds/total number of pods), were calculated.

2.4.3. Seed germinative behaviour

The germination test was done at two times of the year; namely, February (cold dry season); and May (beginning of the winter season), in accordance with the principle of ISTA [15]. During each test, six batches of 50 seeds per treatment, were randomly taken from the seed stock. The tests were carried out in petri dishes placed in a germination cabinet, at a constant temperature of 32 °C from 06:00 to 18:00 in the laboratory.

Lighting was carried out in the same time interval using a 40-W bulb. The system was linked to a timer socket, which controlled the start-up from 06:00 and the automatic shutdown at 18:00 in order to consider the duration of the sunshine and to control the environmental conditions.

A thermometer was used to check the temperature inside the laboratory. An additional supply of distilled water was made each day, when determining the germinated seeds. Germination was monitored daily and at fixed times, 24 h from planting, for 21 days. After each count, the germinated seeds were removed from the batch. A seed was considered to have germinated if the radicle was visible [15]. Overall, eight seed lots were considered for each test, *viz.*

(i) entire pods of *A. histix* with phosphorus (P1) or without phosphorus (P0);
(ii) entire pods of *S. hamata* with phosphorous (P1) or without phosphorous (P0);

(iii) entire pods of *S. hamata* with phosphorus (P1) or without phosphorus (P0) treated with hot water by soaking in boiling water off the heat for 1 h and;
(iv) seeds of *S. hamata* not treated with phosphorus or without phosphorus.

The seeds of *A. histrix* were not subject to pretreatments, because the results of [13,14] showed that there was no particular problem with its pods that have a percentage of germination greater than 90 %. At the end of each germination test, the number of germinated seeds, the number of seeds soaked in water but not germinated; and the number of hard seeds (not soaked in water), were counted for each treatment.

At the end of each germination test, a test with 2,3,5-triphenyltetrazolium chloride 1 % according to the prescriptions of Handbook on Tetrazolium Testing [15] and International Rurales for Seed Testing [15], was performed on ungerminated seeds of the test pasture species. The ungerminated seeds were cut at 1/3 of the upper end, to access the radicle, which is located just after this part [15]. The cut seeds were collected in petri dishes, 1 % tetrazolium chloride salt solution was poured to submerge them using a pipette. Then, they were placed in an oven at 32 °C, for 18 h. The seeds were then removed, and rinsed with distilled water, before the colour of the tissues was read under amplification with a magnifying glass. Living seeds stain a stable, non-diffusible red; dead ones are entirely unstained [15]. The following parameters were computed (Equations (1)–(3)):

Germination rate (%) = [number of germinated seeds)/number of sown seeds] x 100 Equation 1

$$\text{Coefficient of velocity of germination} : \text{CVG} = \frac{\sum ni}{\sum nij} \times 100 \qquad \text{Equation 2}$$

Where: ni = number of seeds germinated on day i; and ij = the number of days from seeding corresponding to ni;.

$$\text{Mean Germination Time} : \text{TMG} = \left(\frac{\mathbf{1}}{\text{CV}}\right) \times 100. \qquad \text{Equation 3}$$

2.5. Data analysis

The collected data allow to calculate the germination rate, the mean germination time and the coefficient of velocity. The calculated parameters (legumes seed production, seed weight, fertility rate, seed germination characteristics) were first analyzed with a nested ANOVA considering legume as a random factor and phosphorus application as a fixed factor nested within legumes. 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 seed production of fodder legumes (*A. histrix* and *S. hamata*) and characteristics of their seeds were analyzed using the generalized linear model (GLM) to detect the effect of treatments [legumes: *A. histrix* and *S. hamata*] and [Phosphorus application: control 0 kg/ha and 100 kg/ha] on the seed production and characteristics of both legumes. Legume and phosphorus 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 Ref. [16].

3. Results

3.1. Seed production

Seed production of a forage legume in the natural pasture reflects its ability to reseed and enrich the pasture. The species has a very highly significant effect ($p < 0.0001$) on seed production. The same is true for the phosphorus factor (Table 1a). The seed production per hectare of *A. histrix* is significantly higher than that of *S. hamata* with or without phosphorus input. However, the difference is less between the two species with the addition of phosphorus. A yield of 566.92 kg/ha was obtained with *A. histrix*, against 299.08 kg/ha for *S. hamata* without phosphorus input. With the addition of phosphorus, this yield was 679.79 kg/ha against 493.75 respectively for the same species. Phosphorus resulted in a significant improvement ($p < 0.05$) of 39.16 % in seed production of *S. hamata*. Conversely, there was no significant effect of phosphorus fertilization with *A. histrix* despite 17 % of improvement (Table 1b).

Table 1a
Seed production of *A. histrix* and *S. hamata* according to phosphorus supply (kg/ha).

Legume	Phosphorus application	Seed yield (kg/ha)
A. histrix	P1	$679.75^{a} \pm 108.42$
	P0	$566.92^{ab} \pm 201.24$
S. hamata	P1	$493.75^{b} \pm 214.87$
	P0	$299.08^{c} \pm 125.38$

Values with the same letters in the same column are identical ($P > 0.05$); P0 = Without phosphorus supply; P1 = input of 100 kg/ha of phosphorus.

Table 1b
Summary of GLM results on the effects of legumes seed production according to phosphorus supply (kg/ha).

Sources of variation	F	P
Species (DF = 1)	33.7	<0.0001
Phosphorous (DF = 1)	15.47	0.0003
Species × Phosphorous (DF = 1)	1.1	0.3017

DF = degree of freedom; F = variation between samples Means; P = Value of probability.

3.2. Physical characteristics of seeds of A. histrix and S. hamata

The weights of 1000 pods and 1000 seeds observed varied from 1.96 to 2.01 g and 1.49–1.54 g for *A. histrix* respectively with or without phosphorus application (Table 2a). For *S. hamata*, they varied from 2.45 to 2.59 and 1.65–1.89 g with and without phosphorus application. Legume had high significant effect on the 1000 pods weight (*S. hamata* > *A. histrix*). Therefore, phosphorus application doesn't affect significantly the 1000 pods weight. For the 1000 seeds weight, either legume and phosphorus application had significant effect ($P < 0.05$). In the case of *S. hamata*, the 1000 seed weight was significantly higher in phosphorus application than without phosphorus application.

Seed occupies significant part of the weight of the entire pod through the ratio of 1000 seeds weight/1000 pods weight of *A. histrix* where, this proportion varied from 77 % to 76 % respectively with and without phosphorus application. The situation is lightly different with *S. hamata*, where this ratio varied from 73 % to 67 % respectively with and without phosphorus application (Table 2b).

3.3. Fertility rate

The fertility of *A. histrix* seeds (92.49 %) is very significantly ($p < 0.01$) higher than that of *S. hamata* (62.07 %). Phosphorus only improved seed weight of *S. hamata* ($P < 0.05$), unlike *A. histrix* where this improvement was not statistically significant (Table 3a).

With or without phosphorus supply, the physical characteristics of *S. hamata* are better than those of *A. histrix* except for the fertility rate. The analysis of variance of the factors (species and phosphorus) on these characteristics shows that the species variable has a significant effect not only on the weight of pods, seeds, the seed/pod ratio but also on the fertility rate (Table 3b).

3.4. Seed germinability/viability

The species is the factor that had the most significant effect on the germination parameters of the seeds of the two legumes (Table 4). Phosphorus had an effect mainly on the rate of hard seeds at the end of the germination test. The treatment also had a significant effect on the rate of hard seeds and on the rate of viability. The comparison of the averages of the germinative characteristics between the two species independently of the contribution of phosphorus. *Aeschynomene histrix* seeds have a high germination rate (87 %) about one month after harvest than *S. hamata* seeds. The hard seed content is very low with this species (3.5 %). The correction of the viability rate of the seeds with the fertility rate makes it possible to conclude that the viability is 100 %, significantly higher ($p < 0.05$) than that observed with *S. hamata*.

3.5. Mean germination time (MGT) and coefficient of velocity of germination (CVG)

The MGTs are relatively low in the case of *S. hamata* (between 4.8 and 5.9 days) compared to those observed with the seeds of *A. histrix* (between 7.1 and 7.3 days). More than 90 % of seeds germinated in *A. histrix* germinated in 7 days, while only 10 % of *S. hamata* seeds germinated in 6 days (Table 5). The average germination time is influenced by the importance of the germination rate and the spread of germination over time. Coefficients of velocity of germination (CVG) were 17.1–21.1 and 13.7–14.1, for *S. hamata* and *A. histrix*, respectively.

4. Discussion

4.1. Seed production of the two legumes

The availability of fodder seeds is one of the major technical constraints to their development [17–19]. The seed yields of the two

Table 2a
Characteristics of legume seeds according to treatments (N = 6).

Species	Treatments	Weight of 1000 pods (g)	Weight of 1000 seeds (g)	percentage of fertility
A. histrix	P1	$2.01^b \pm 0.09$	$1.54^c \pm 0.09$	$91.90^a \pm 8.20$
	P0	$1.96^b \pm 0.05$	$1.49^c \pm 0.04$	$93.08^a \pm 3\ 0.92$
S. hamata	P1	$2.59^a \pm 0.22$	$1.89^a \pm 0.05$	$61.42^a \pm 11.\ 00$
	P0	$2.45^a \pm 0.15$	$1.65^b \pm 0.11$	$62.73^a \pm 10.41$

Table 2b
Summary if GLM results on the effects of legumes seed characteristics according to treatment (N = 6).

Sources of variation	DF	F: variation between samples Means		
		Weight of 1000 pods (g)	Weight of 1000 seeds (g)	percentage of fertility
Species	1	75.99**	49.34**	177.70**
Phosphorus	1	2.61	16.42*	0.14
Species × Phosphorus	1	0.55	0.20*	1.80

P0 = Without phosphorus supply; P1 = input of 100 kg/ha of phosphorus; For the same species, the values with the same letters in the same column are identical (p > 0.05); P0 = Without phosphorus supply; P1 = input of 100 kg/ha of phosphorus; Values marked with * indicate a significant effect (* at 5 % and ** at 0.01 %); DF = degree of freedom.

Table 3a
Germination characteristics of *S. hamata* seeds (mean ± standard deviation) according to treatment (N = 6).

Parameters		Germination rate	Viability rate	hard seeds rate	Corrected viability rate	Corrected germination rate
P0	Treated pods	7.7 ± 5.4	58.7 ± 10. 8	2.3 ± 2.3	93.3 ± 12	10.6 ± 7.5)
	Natural pods	8.3 ± 7.1	63.3 ± 10.3	38.3 ± 11.1	96.9 ± 3.5	11.5 ± 9.8
	Seeds	13.7 ± 9.8	84.0 ± 3.8	48.3 ± 14.4	84.0 ± 3.8	13.7 ± 9.8
P1	Treated pods	6.7 ± 5.3	52.0 ± 17.3	43.0 ± 12.7	93.8 ± 5.1	9.6 ± 7.7
	Natural pods	7.7 ± 6.9	53.0 ± 13.3	43.0 ± 12.7	94.5 ± 3.9	11.1 ± 9.9
	Seeds	11.7 ± 5.4	92.0 ± 8.9	60.3 ± 15.4	92.0 ± 8.9	11.7 ± 5.4

Table 3b
Summary of GLM on the effects of legumes seeds germination characteristics according to treatments.

Sources of variation	DF	F: variation between samples Means		
		Germination rate	Viability rate	hard seeds rate
Species	1	79.90**	14.55*	79.05**
Phosphorous	1	0.02	0.76	8.08*
Treatments	2	0.44	4.82*	6.72*
Species × phosphorous	1	0.1	0.27	9.22*
Phosphorous × treatments	2	0.03	2.38	29.10**

DF = degree of freedom; *p < 0, 05, **p < 0,01.

Table 4
Comparison of germination characteristics of seeds of *A. histrix* and *S. hamata*.

Species	*Corrected percentage of germination rate*	*Corrected percentage of hard seed*	*corrected percentage of viability*
A. histrix	89.88[a] ± 4.17	3.47[b] ± 2.17	100.00[a] ± 0.00
S. hamata	11.26[b] ± 9.37	68.19[a] ± 17.78	95.65[b] ± 3.72

Values with the same letters in the same column are identical (p > 0.05).

Table 5
Mean germination time (MGT) and germination rate (CV) of *A. histrix* and S. hamata seeds according to phosphorus supply.

Parameters	A. histrix		S. hamata					
	Pods		Go. N	Go water.	Gr.	Go. nat.	Go water.	Gr
	P0	P1	P0			P1		
TMG	7,3	7,1	5,9	5,5	5,7	5,0	4,8	5,8
CV	13,7	14,1	17,1	18,0	17,5	20,2	21,1	17,2

Go. N = Natural pods; Go. water = Pods treated with hot water; Gr. = Seeds.
P0 = no phosphorus input and P1 = 100 kg/ha phosphorus input.

legumes observed (299–494 kg/ha for *S. hamata* and 567–680 kg/ha for *A. histrix* respectively without and with phosphorus application) are similar to those of [20] with 250–600 kg/ha for *S. hamata* [21]. also showed that it is possible to obtain up to 600 kg/ha of seeds by improving the harvesting technique. For *A. histrix*, our results are superior to those of [22] who evaluated it at 92–200 kg/ha. This difference can be attributed to harvesting techniques, climatic and soil factors. In this sense [19], found in Benin that by improving soil fertility with the addition of 12 t/ha of cow dung plus 40 kg/ha of P_2O_5, the seed yield of *A. histrix* reached 443.73 kg/ha. Phosphorus allowed better growth and branching of *S. hamata*; this allowed an increase in the floral parts of this species. This would be explained by the fact that phosphorus would play an important role in the formation of reproductive organs.

4.2. Physical characteristics of the seeds

Seed weight is a variable that estimates the number of seeds or pods corresponding to a given amount of seed. This variable is essential in the determination of the sowing density for the crop, and therefore, for the improvement of the pasture. The weights of 1000 pods and 1000 seeds observed were (1.96–2.1 g) and (1.46–1.54 g) respectively for *S. hamata* [14]. also showed that the seed of *S. hamata* occupies a significant part of the weight of the entire pod through the weight ratio of 1000 seeds/weight of 1000 pods. These results corroborate those of [19] in southern Benin.

In addition, the effect of phosphorus has only affected the weight of 1000 seeds of *S. hamata*. The values of the ratio seeds/pods showed that the seed occupies a more important part in the seed of *A. histrix* compared to that of *S. hamata*. The non-improvement in the weight of seeds of *A. histrix* by supplying phosphorus would be linked to the genetic characteristics of this species. Indeed, *A. histrix* grows well on marginal, acidic and infertile soils [23]. The soil of the site of study is indeed very acidic, poor in organic matter with a low level of assimilable phosphorus [10].

4.3. Fertility rate

Fertility gives an idea about the quality of the seeds that influences the germination rate. The results obtained on the percentage of seed fertility (number of seeds obtained in 100 entire pods) are similar to those obtained by Ref. [14] who are 97.5 % for *A. histrix* and 64 % for *S. hamata*. The relatively low of percentage of seed fertility of *S. hamata* could be explained by its flowering that is spread over time, so, pockets of drought could affect the fruiting and ripening phase. The viability percentage of seeds obtained with *A. histrix* are similar to those of [14] who found 98 %. with *S. hamata*. They are significantly higher than those obtained by Ref. [14], who assessed the seed viability rate of the species at 54 %, 10–40 % and 36 % respectively. This difference could be explained not only by the harvesting method, but also by the viability test method used. Indeed, *S. hamata* does not have a homogeneous maturation on feet like *A. histrix*. The complete harvest after total leaf falls therefore made it possible to obtain a higher proportion of mature pods. Also, the fact of cutting the seeds of *S. hamata* at the end of the Tetrazolium test, allowed a high permeability of the seeds and their clear coloration. *A. histrix* recorded a lower hard seed value (3.47 %) than *S. hamata* (68.19 %). The values obtained are comparable to those of [14], that are 3 % and 64 % for *A. histrix* and *S. hamata*, respectively.

4.4. Seed germinability/viability

The germination of a seed is linked to its viability. The determination of viability makes it possible to better understand its germinative behaviour. The germination test at controlled temperature and light in a germination cabinet made it possible to follow the evolution of the germination parameters for three weeks. With seeds of *S. hamata*, the observed germination rate is less than 10 %. Dormancy is then not only linked to the envelopes of the pod, but also to those of the seed. Treatment by soaking in boiling water off the heat for 1 h was not enough to break this dormancy.

4.5. Seed germination rate

The percentage of germination of seeds of *A. histrix* (89.88 %) is significantly better ($p < 0.01$) than that of *S. hamata* (11.26 %). These results are comparable to those of [24,25] who found 10 % and 10–40 % for *S. hamata*, respectively. They are also comparable to those of [14] who obtained 94 % with *A. histrix*. The low germination rate of *S. hamata* seeds is linked on the low of percentage of fertility, and the dormancy of its seeds with a high percentage of hard seeds. This allows the pod and seed coats to be tough and waterproof. However, in the process of germination of a seed, the imbibition of water is essential to the triggering of the chemical processes which initiate the development of the embryo. The presence of parasites and molds (*Curvularia eragrostides* P. HENN) observed on these seeds could partly explain the poor seed emergence. The addition of phosphorus does not change this trend. It also had no influence on the characteristics of these seeds. Contrary to Refs. [13,14], an improvement in the germination of *S. hamata* seeds treated with hot water was not observed. This may be linked to the integumentary dormancy effect of the seed; the germination test having taken place less than 2 months after harvest.

4.6. Seed viability and kinetics of seed germination

Seed viability was lower than that of pods ($p < 0.05$) (Table 5). This low viability must be partly linked to the fact that these seeds were exposed to attack by molds. Since the hot water treatment did not affect the viability of the seeds, the lack of improvement in their percentage of germination can be linked to the short period between the harvest and the test, insofar as the breaking of the dormancy of the seeds of *S. hamata* is positively correlated with time [14]. The addition or not of phosphorus has no significant effect on the viability rate or the germination rate of seeds of *A. histrix* and *S. hamata*. The treatment had no significant effect on the germination and viability of the seeds of *A. histrix* and *S. hamata*, whereas the phosphorus*treatment interaction had an effect on the hardness of these seeds. It can be seen that phosphorus had no significant effect on the percentage of hard seeds. The hardness of the seeds would be partly linked to the interaction between treatment and phosphorus combination. Despite the hot water treatment, the rate of hard seeds is high with *S. hamata*. For germination kinetics, our results are comparable to those of [13,14] who found 4.6–10.75 days and 9.30 to 21.9 for GMT and CVG, respectively.

The germination kinetic parameters such as the mean germination time (MGT) and the velocity coefficient (CVG) which represent the germination rate also characterize germination. These two parameters vary according to the species.

5. Conclusion

This study aimed to improve the productivity and nutritional value of pastures through the evaluation of the ability of two leguminous species (*Aeschynomene histrix* and *Stylosanthes hamata*) to restore pastures. The addition of phosphorus improved significantly seed yield and the weight of the 1000 seeds of *S. hamata* ($p < 0.05$). The seeds of *A. histrix* are more fertile (93 %), more viable (100 %) with a better percentage of germination (90 %) than those of *S. hamata* which are respectively 62 %, 96 % and 11.26 %. Based on the main findings, *A. histrix* and *S. hamata* can be strongly recommended for the enrichment of natural Sudanian pastures.

CRediT authorship contribution statement

Souleymane Ouedraogo: Writing – original draft, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lassina Sanou:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Patrice Savadogo:** Writing – original draft, Validation, Supervision, Conceptualization. **Chantal Yvette Kabore-Zoungrana:** Writing – original draft, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was funded by the Institute of Environment and Agricultural Research. Thanks are also due to Dr. John A. Meadows for proofreading and editing the paper.

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