

Seed Potential of Ruminants Organic Manures in Sahelian Agro-Pastoral Systems

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Abstract

In degraded Sahelian agro-systems, livestock manures increase agricultural production and ensure natural regeneration through their selective seed potential. Yet, this seed potential that contributes to species dissemination is still poorly known. This study aimed to determine the seed potential of different livestock ruminant manures. To this end, cattle (*Bos indicus*), goat (*Capra hircus*) and sheep (*Ovis aries*) manures were collected in 45 distinct enclosures in the Sahelian zone of Burkina Faso following the three seasonal periods of the year. A total of 36 species in 13 families and 26 genera was identified in the coarse fraction of the three type of manure. The most abundant seeds in the manure are those of Fabaceae-mimosoideae, Fabaceae-caesalpin-oideae, Rhamnaceae and Balanitaceae. The results showed that the contribution of goats to the total seed potential was 61% against 36% for sheep and 3% for cattle. The average number of seeds was 205 seeds/Kg of manure for goats, 125 seeds/Kg for sheep and 11 seeds/Kg for cattle. Depending on the collection period, the cold-dry season contributed 70% to the total annual seed potential against 22% of the hot-dry season and 8% for the rainy season. Following the species functional traits, goat spread more seeds of woody indehiscent pods (barochores species) containing one, 4 to 10 seeds with hard cores and integuments. Sheep spread more seeds of annual legumes having dehiscent pods (autochores) and more than 10 seeds. The most abundant seeds in the manure are those of agroforestry (*Vachellia nilotica*, *Faidherbia albida*, *Piliostigma reticulatum*), ruderal (*Ipomoea eriocarpa*) or invasive (*Senna obtusifolia*) species. The most frequently (RI < 50) herbaceous species in manures were: *Dactyloctenium aegyptium*, *Eleusine indica*, *Corchorus tri-*

dens, *Sporobolus festivus* and *Ipomoea eriocarpa*. Taxonomic and functional characteristics of the seed potential of ruminants manures shape the regeneration traits of agro-ecosystems through selective seed dissemination.

Keywords

Cattle, Goat, Sheep, Manure, Seed Potential, Species

1. Introduction

Regeneration is an important step in the ecosystems dynamic that is subject to many disturbances. Among these disturbances, livestock farming, especially overgrazing, has an impact on the dynamics of plant biodiversity [1]. The intensity of plant species removal by herbivores may question the potential renewal of plant cover by modifying the composition, structure and productivity of plant populations [2]. Animals by trampling cause compaction of rangeland making them sensitive to erosion and by reducing soil seed banks through seeds crushing [2]. Also, grazing of some species limits growth [3] by preventing the production of fruit essential for sexual reproduction [4]. Selective grazing plant species by animals can lead to colonization of the environment by species that tolerate their impact and endanger others by juvenile mortality, hence the low regeneration of woody species in grazing areas [5] [6]. However, grazing has positive effects and is often used as a grazing ecosystem management tool to change the balance and competition between plant species [5] [7]. It also helps avoiding environmental closures to maintain landscape diversity, reduce the risk of fires in ecosystems where herbaceous biomass is important, and prevents excessive growth of shrubs [1] [2]. Animals allow the dissemination of plant seeds by epizoochory and endozoochory far away from the mother's feet [8] [9]. This allows the colonization of new habitats and increases the species survival rate regarding the natural environment conditions variability. Animals can help to increase the regeneration of certain plant species such as legumes through the action of digestive juices during intestinal transit which, can scarify their seed coats which are hard and promote their germination [10] [11]. The dispersal of zoochore seeds is done directly with the animals during the grazing or indirectly by human who transfers manures of domestic herbivores in agro-ecosystems as amendment. While the impact of grazing on the floristic composition of grazed ecosystems is widely studied [1] [12], the positive impact of the animal's manure use, particularly domestic ruminants, in the dynamics of agroecosystem remains little studied. It is interesting to know the seed potential contained in these manures which used in agro-ecosystems could influence their regeneration trait. In the Sahel area of Burkina Faso, the recovery and rapid restoration of bare land are explained by the contribution of organic amendments associated with soil and water restoration and conservation agricultural techniques such as zaï, half-moons,

stone barriers. The seed potential contained in animal feces should therefore be evaluated since incorporating into the soil, it offers a high potential for natural regeneration of plant communities well adapting to local conditions and reducing the risk of plant population's extinction [13] [14] [15] [16]. Knowledge of these manures seed potentials is important to determine their floristic diversity and use them according to the importance and ecological role of the plant species they contain in the conservation and enhancement strategies of biodiversity. However, the quantity and diversity of seeds contained in feces would be related to each type of animal, the phenology of plant species, and the traits of disseminated seed from which the following questions arise: 1) does the seed potential vary depending on the manure type? 2) do types of manure determine the taxonomic and functional diversity of seed potential? 3) what is the fluctuation of seed potential over the seasons? This study aimed to determine the seed potential of organic manure from domestic ruminants in Sahelian agropastoral systems. The specific objectives were: 1) to determine the taxonomic and functional diversity of the seed potential of the cattle, goats and sheep manures; 2) to determine the seasonal fluctuations of this seed potential; and 3) to determine the influence of species functional traits on seed potential.

2. Materials and Methods

2.1. Description of the Study Areas

The study was carried out at three sites located in the northern region of Burkina Faso between the northern latitudes of 12°38' and 14°18' and the western longitudes of 1°33' and 2°55' in the Sahelian climatic zone belonging to the agroecological band of the Sahel. The three sites were: Sillia, Ramdolla and Tibtenga (**Figure 1**). Sillia is located in the province of Loroum, (Department of Titao), Ramdolla in the province of Yatenga (Department of Barga) and Tibtenga also located in the province of Yatenga (Department of Koumbri). The selection of these sites followed previous studies that showed the predominant role of livestock, organic manures in the plant species conservation and regeneration within these sites agroecosystems.

The climate is Sahelian, characterized by a dry season of 9 months from October to June and a rainy season of 3 months from July to September. Average annual precipitation over the past 20 years (2005 to 2019) was 702 mm. The lowest temperatures are observed in December and January with an average of 26°C while the highest are observed between March and May with an average of 43°C. The main sectors of activity are agriculture and livestock. Livestock farming is extensive and dependent on natural resources (pastures, water points) and concerns cattle, small ruminants such as sheep and goats and poultry (chickens, guinea fowl). Fodder lack due to grazing areas degradation under the climate influence, land pressure and overgrazing has led people to adopt integrated agriculture-livestock practices. The feed is provided by the crop residues stored at the end of the harvest. The main fodder woody species are legumes: *Vachellia sp*,

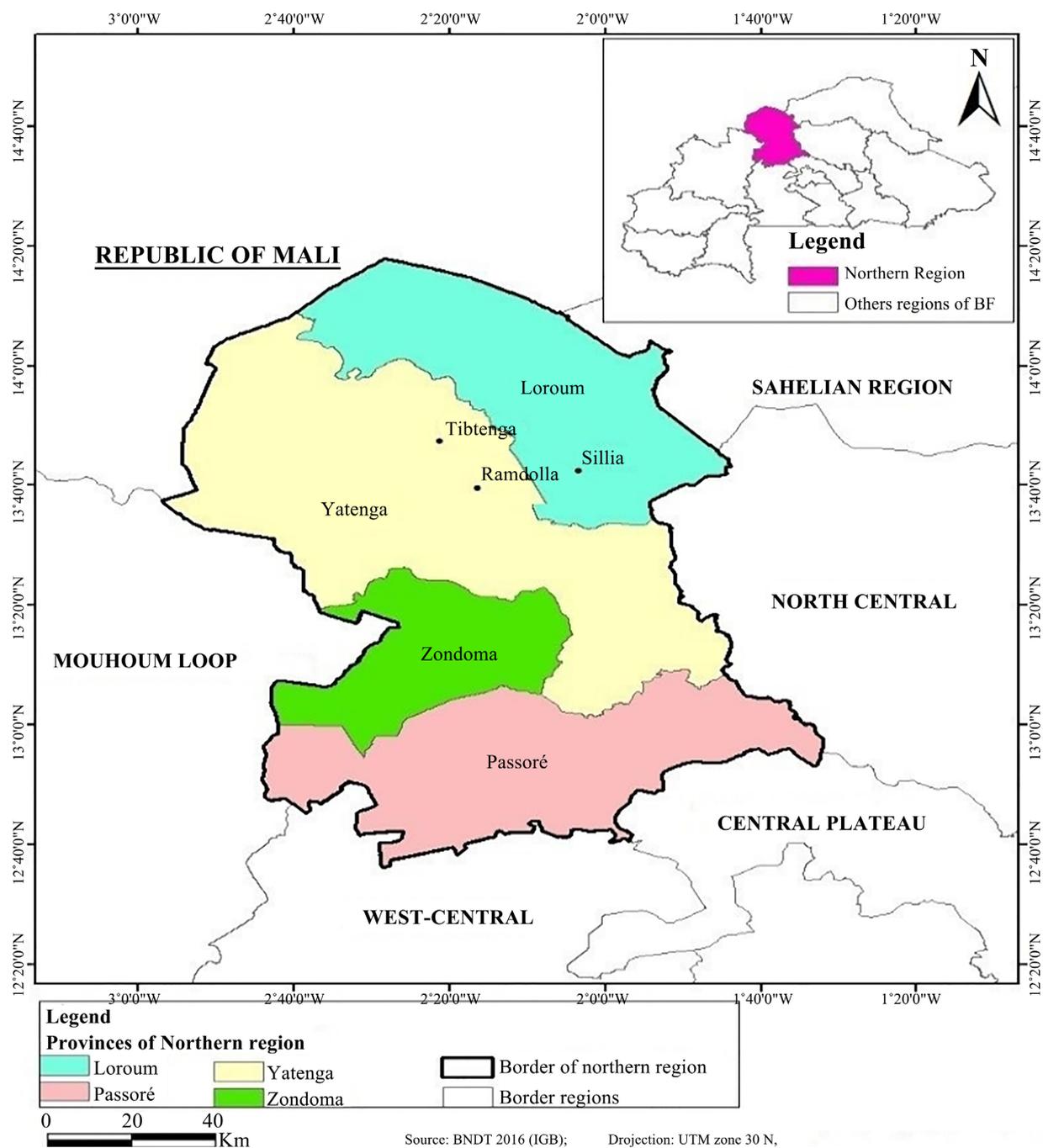


Figure 1. Map of the three study areas in Northern Burkina Faso.

Senegalia sp, *Faidherbia albida* and *Piliostigma reticulatum*. In addition to these, there are *Balanites aegyptiaca*, *Mitragyna inermis*, *Pterocarpus lucens*, *Sclerocarya birrea* and *Ziziphus mauritiana* [17]. Herbaceous pastures are heavily degraded even in the rainy season (August).

2.2. Manure Sampling Procedures

Three types of organic manure from domestic ruminants were sampled. These

were the manures of goats (*Capra hircus*), sheep (*Ovis aries*) and cattle (*Bos indicus*). Each type of manure was sampled in 15 enclosures with five separate enclosures in each study site. Manures were collected in three periods to account for storage practices and species phenology. In fact, farmers start storing organic manure in the rainy season in July of the current year until June of the following year. The three sampling periods are October (end of the rainy season that contained manure from July to October), January (mid-dry season or cold-dry season that contained manure from November to January) and June (an early rainy season or hot-dry season that contained manure from February to June). The collected manure samples were sent to the laboratory for the determination of the seed potential.

2.3. Determination of Seed Potential

For each type of manure, 5 Kg (dry mass) of each sample was taken for the determination of seed potential following the scheme procedure (Figure 2).

Each sample is first sieved to sort the large seeds (*Balanites aegyptiaca*, *Sclerocarya birrea*, *Ziziphus mauritiana*). Then, the coarse fraction from the first sieve is subjected to successive sieves. Sieving was carried out using a sieve of 2 mm mesh. The seeds from this fraction are then sorted, identified with the local population expertise by the identification of the seed plant, followed by the collection of seeds of these seed plants and confirmed by herbaria and photographs. The seeds were finally counted by species, according to the types of manure for each given period. After sieving, the fine fraction (powder) obtained from the organic manure was put to germinate in order to identify species with seed size <

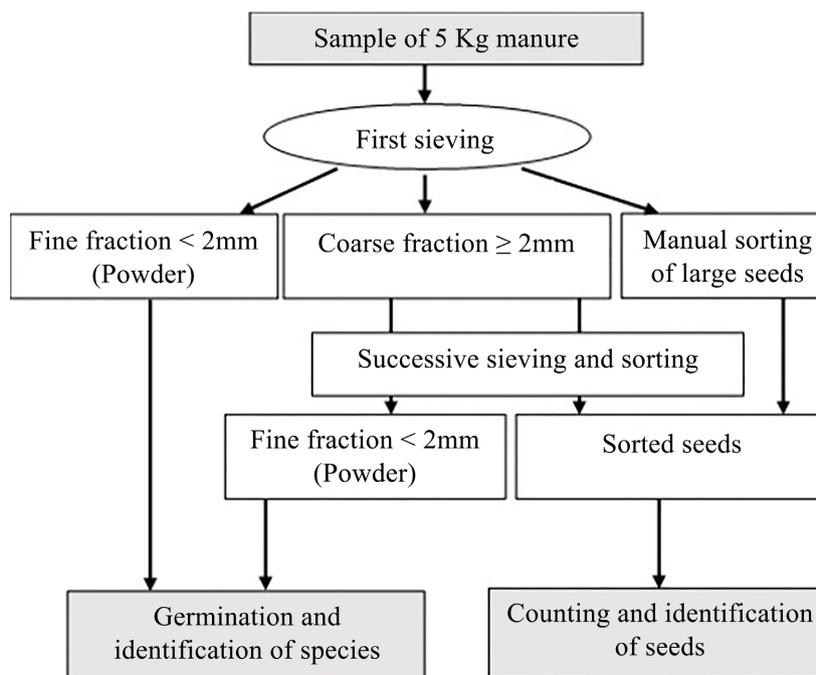


Figure 2. Schematic for determining seed potential in organic manure.

2 mm. Since these seeds are largely derived from herbaceous plants with seasonal phenological cycles, the germination of the fine fraction concerned only the samples collected at the end of October. In view of their phenology, herbaceous species after the rainy season dry out and are very little consumed by animals because of their very low nitrogen content [18] [19]. After germination the seedlings were identified using flora and the herbarium of Joseph Ki-Zerbo University.

2.4. Statistical Analyses

The contribution (percentage) of each plant species (i) to the seed potential has been calculated in order to identify the plant species that more enrich the manure seeds according to the variables j (type of manure and period). Also, the contribution of each manure and period to the seed potential was calculated. Data on quantitative variables have been subject to descriptive statistical analyses (means, standard deviations, quantiles). The effect of the types of manure as well as the effect of the collection periods and plant species functional traits on the seed potential have been tested with generalized linear models (GLM) to account for nonnormal errors and high variances with high averages associated with count data. Thus the counting data (seed potential) were adjusted to the Poisson or quasi-Poisson distribution (high dispersion). The best fit of the data (goodness of fit) is retained following the examination of the diagnostic graphics. In the case of a significant difference, a pairwise comparison was made using the Tukey multiple comparison test. The analyses were done using R software. The diagnostic species of each variable or group (type of manure and period) were determined by their indicator value index using the Monte Carlo Maximum Indicator Value Significance Test [20]. The indicator value (IV) of a species i was expressed as the product of the mean abundance of species i in group j compared to all groups (A_{ij}) and the relative frequency of this species in group j (B_{ij}) [21].

$$IV_{ij} = A_{ij} \times B_{ij} \times 100 \quad (1)$$

PCORD software was used for this analysis with 1000 random permutations. Diagnostic species analysis is a non-parametric analysis technique that identifies species with high fidelity for a given group [22] [23]. All species with a probability (p) of less than 0.05 ($p < 0.05$) were selected as diagnostic species of the manure type or period. Specific richness: total number of species identified within a type of manure or period has been determined. The number of species/kg of manure in each sample manure (goat, sheep and cattle) and period (rainy season, hot and cold dry season) were determined using the PCORD software. The results obtained were used to determine the mean specific richness (number of species) and maximum species/kg of manure, according to the studied variables (type of manure and period) in the R software. For species identified in the fine fraction, rarity indices were calculated according to the types of manure.

$$RI_{ij} = \left[1 - \left(\frac{n_i}{N} \right) \right] \times 100 \quad (2)$$

with RI_{ij} = rarity index of a species i in a manure j . n_i = number of samples of the manure j in which species i is present and N = total number of samples of the manure j . So for a given species if $RI < 60\%$, the species is said to be very frequent, if $60 RI < 80\%$, it is moderately frequent and if $RI 80\%$ it is rare [24].

3. Results

3.1. Seed Potential in the Coarse Fraction

A total of 36 species in 13 families (Figure 3) and 26 genera were identified in the coarse fraction of the three types of manure.

The dominant families were: Fabaceae-mimosoideae, Fabaceae-faboideae and Fabaceae-caesalpinoideae. Seed potential varied with biological families (Figure 4). Goat manures contained respectively more than 72 and 47 times the seeds of Fabaceae-mimosoideae, Balanitaceae and Rhamnaceae than the cattle manures and respectively more than 4, 3 and 2 times those of sheep. Goat and sheep manures contained more than 14 times the seeds of Fabaceae-caesalpinoideae than those of cattle (Figure 4).

3.1.1. Seed Potential in the Coarse Fraction According to Manure Types

The contribution of goat manure to the general seed potential (seed potential of the three manures collected during the three sampling periods) was 61% against 36% for sheep manure and 3% for cattle manure. The average number of seeds in goat manure was 18 times higher than in cattle manure and more than once in sheep manure (Table 1).

The diagnostic species of goat manures according to Monte Carlo test ($p < 0.05$) were: *Vachellia nilotica*, *Balanites aegyptiaca*, *Sclerocarya birrea*, *Vachellia*

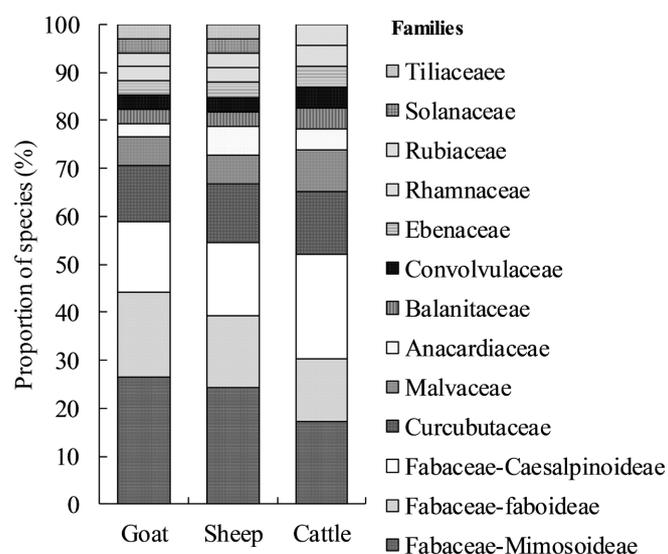


Figure 3. Proportion of species by family in the coarse fraction of organic manure.

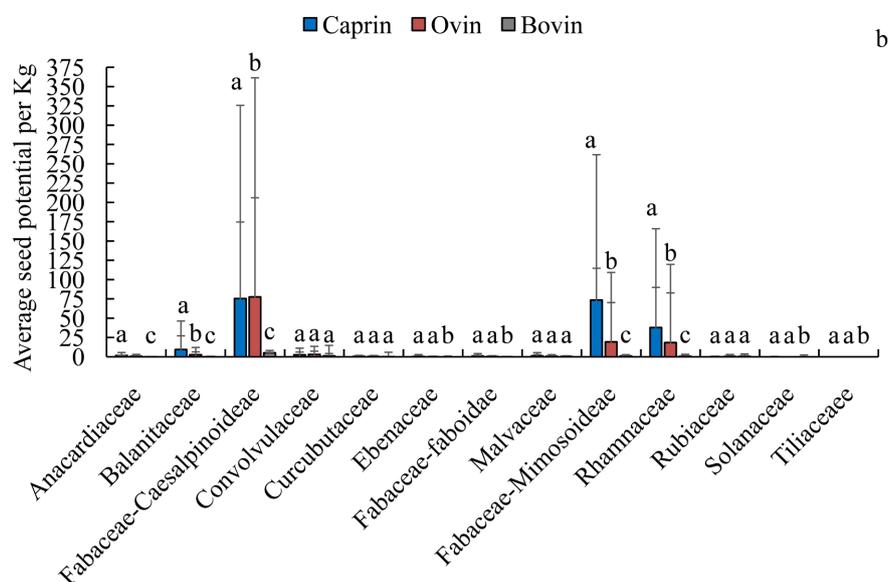


Figure 4. Average seed potential \pm standard deviation/kg of manure according to biological families in the coarse fraction of manure.

Table 1. Average seed potential in manure during the year.

Manure	Mean	Minimum	Q1	Q2	Q3	Maximum	Sample number
Goat	205 a	3	29	60	292	1596	43
Sheep	125b	5	15	41	96	1750	41
Cattle	11 c	0	0	5	17	49	45

sieberiana, *Vachellia seyal*, *Faidherbia albida* and *Ziziphus mauritiana* (Table 2). During the year (the three periods of manure sampling), 8818 seeds were counted in 43 samples (43 kg) of goat manure. The most abundant seeds were those of *Piliostigma reticulatum* (34%) followed by *Vachellia nilotica* (22%), *Ziziphus mauritiana* (19%), *Faidherbia albida* (8%) and *Balanites aegyptiaca* (5%). The diagnostic species of sheep manure was *Senna obtusifolia* (Table 2). During the year, 5134 seeds were counted in 41 samples (41 kg) of sheep manure. The most abundant seeds were those of *Piliostigma reticulatum* (31%), *Senna obtusifolia* (28%), *Ziziphus mauritiana* (15%) and *Prosopis juliflora* (10%). The diagnostic species of cattle manures were: *Spermacoce chaetocephala*, *Citrullus colocynthis* and *Abelmoschus esculentus* (Table 2). A total of 492 seeds were counted in 45 samples (45 kg) of cattle manures. The most abundant seeds were those of *Piliostigma reticulatum* (23%), *Senna obtusifolia* (21%), *Ipomea eriocarpa* (12%), *Ziziphus mauritiana* (7%) and *Spermacoce chaetocephala* (6%).

3.1.2. Seed Potential in the Coarse Fraction According to Sampling Periods

Depending on the sampling period, the rainy season contributed 8% to the general seed potential against 22% for the dry-hot season and 70% of the dry-cold

season. Herbaceous species represented 57% of the total seed potential species and enriched it at a rate of 71%, 28% and 9% respectively at the rain, dry-hot and dry-cold seasons. The diagnostic species of the rainy season according to Monte Carlo test were: *Citrullus colocynthis*, *Solanum incanum*, *Cassia occidentale* and *Grewia bicolor* (Table 3). During this period, 1124 seeds were counted in 45 manure samples (45 kg). The most abundant seeds were those of *Senna obtusifolia* (44%), *Balanites aegyptiaca* (14%), *Ipomoea eriocarpa* (11%), *Prosopis juliflora* (9%), *Cassia occidentale* (7%) and *Sclerocarya birrea* (3%). The diagnostic species of the dry-cold season were: *Ziziphus mauritiana*, *Diospyros mespiliformis*,

Table 2. Diagnostic species by type of manure (indicator values observed, Monte Carlo test).

Species	Manure type	Observed indicator value (IV)	p*
<i>Vachellia nilotica</i>	Goat	65.2	0.001
<i>Balanites aegyptiaca</i>	Goat	59.6	0.001
<i>Sclerocarya birrea</i>	Goat	50.3	0.001
<i>Faidherbia albida</i>	Goat	49.1	0.006
<i>Vachellia sieberiana</i>	Goat	35.8	0.005
<i>Vachellia seyal</i>	Goat	14.6	0.006
<i>Senna obtusifolia</i>	Sheep	61.3	0.034
<i>Spermacoce chaetocephala</i>	Cattle	28.9	0.011
<i>Citrullus colocynthis</i>	Cattle	24	0.013
<i>Abelmoschus esculentus</i>	Cattle	13.5	0.035

Table 3. Diagnostic species by period (observed indicator values, Monte Carlo test).

Species	Manure sampling period	Indicator Value (IV)	p*
<i>Ziziphus mauritiana</i>	Dry-cold season	74.2	0.001
<i>Diospyros mespiliformis</i>	Dry-cold season	32	0.001
<i>Vachellia sieberiana</i>	Dry-cold season	38.4	0.003
<i>Vachellia nilotica</i>	Dry-cold season	62.3	0.004
<i>Piliostigma reticulatum</i>	Dry-cold season	53.8	0.008
<i>Tamarindus indica</i>	Dry-cold season	26	0.015
<i>Vachellia seyal</i>	Dry-hot season	20.5	0.001
<i>Sclerocarya birrea</i>	Dry-hot season	32.5	0.02
<i>Citrullus colocynthis</i>	Rainy season	24.8	0.006
<i>Solanum incanum</i>	Rainy season	13.3	0.008
<i>Cassia occidentale</i>	Rainy season	22.7	0.009
<i>Grewia bicolor</i>	Rainy season	10	0.013
<i>Ipomoea eriocarpa</i>	Rainy season	32	0.055

Vachellia sieberiana, *Vachellia nilotica*, *Piliostigma reticulatum* and *Tamarindus indica* (Table 3). During this period, 10,178 seeds were counted in 45 manure samples (45 Kg). The most abundant seeds at this time were those of *Piliostigma reticulatum* (33%), *Ziziphus mauritiana* (21%), *Vachellia nilotica* (18%), *Senna obtusifolia* (8%), *Prosopis juliflora* (6%) and *Faidherbia albida* (4%). The diagnostic species of the dry-hot season were: *Vachellia seyal* and *Sclerocarya birrea* (Table 3). During this period, 3141 seeds were counted in 39 samples (39 Kg of manure). The most abundant seeds at this period were those of *Piliostigma reticulatum* (41%), *Senna obtusifolia* (13%), *Faidherbia albida* (10%), *Ziziphus mauritiana* (9%), *Vachellia nilotica* (9%) and *Ipomoea eriocarpa* (5%).

3.1.3. Seed Potential in the Coarse Fraction According to Manure Type and Sampling Periods

Specific richness in manure varied with sampling periods and was higher in goat manures (Table 4).

The mean seed potential differed from one type of manure to another, depending on the sampling period (Figure 5). In the rainy season, the mean seed potential in sheep manures was more than double of goat manures. No seed was found in the coarse fraction of cattle manure during the rainy season. In this period, goat manures contained respectively an average number of 6, 4 and 2 seeds of *Balanites aegyptiaca*, *Prosopis juliflora* and *Sclerocarya birrea* per kg of manure, more than one and three times those of sheep. On the dry-cold season, the mean seed potential in the goat manures was 22 and 2 times higher than in cattle and sheep manures (Figure 5).

Goat manures contained respectively an average number of 156, 113, 93 and 27 seeds of *Piliostigma reticulatum*, *Vachellia nilotica*, *Ziziphus mauritiana* and *Faidherbia albida* per kg of manure, more than 28, 153, 45 and 65 times cattle manures and more than 2, 11, 2 and 8 times those of sheep at this period. Sheep

Table 4. Specific richness in manure following collection periods.

Season	Rainy season			Dry-cold season			Dry-hot season			
	Manure type	Goat	Sheep	Cattle	Goat	Sheep	Cattle	Goat	Sheep	Cattle
Number of sample		15	15	15	15	15	15	13	11	15
Species richness		26	24	0	31	23	23	28	25	22
Average species/Kg		8	7	0	10	8	7	11	8	6
Minimum species/Kg		3	4	0	6	4	3	3	2	1
Q1		7	5	0	8	6	6	11	5	4
Q2		8	6	0	9	7	7	11	8	5
Q3		10	8	0	12	9	9	13	10	9
Maximum species/Kg		14	14	0	15	12	11	16	15	13

One sample = 1 kg of manure, Specific richness = total number of species in all samples of the given manure at the given period.

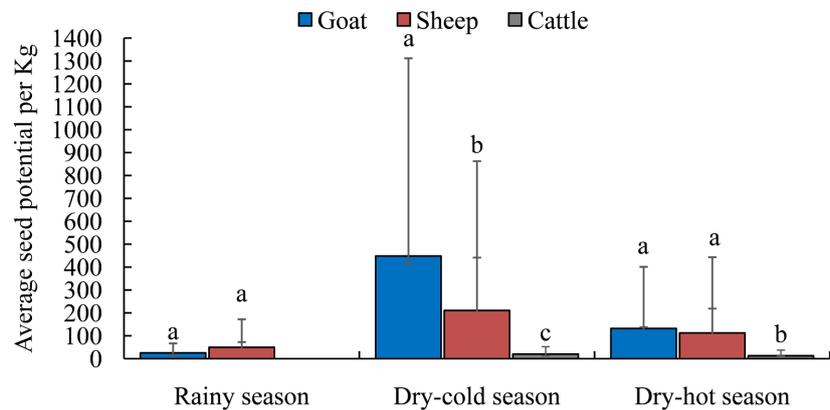


Figure 5. Average seed \pm standard deviation/kg of manure according to sampling periods and manure types.

manures contained respectively an average number of 45 and 30 seeds of *Senna obtusifolia* and *Prosopis juliflora* per kg of manure, more than 8 and 46 times those of cattle and more than 12 and 2 times those of goats. On the dry-hot season, the mean seed potential in goat manures was respectively 10 and more than once times in cattle and sheep manures (Figure 5). Goat manures during the dry-hot season contained respectively an average number of 21, 19, 18 and 4 seeds of *Faidherbia albida*, *Vachellia nilotica*, *Ziziphus mauritiana* and *Ipomea eriocarpa* per kg of manure, more than 57, 47, 51 and once times those of cattle and more than 9, 12, 3 and once times those of sheep. Sheep manures contained respectively an average number of 55 and 32 seeds of *Piliostigma reticulatum* and *Senna obtusifolia* per kg of manure, more than 25 and 20 times those of cattle and more than one and 15 times those of goats. Also, the mean seed potential differed from one period to another, depending on the type of manure and was higher in the dry-cold season (Figure 5). The goat and sheep manures in the dry-cold season contained respectively more than 17 and 4 times seeds than at the rainy season and more than 3 and once on the dry-hot season. Cattle manures contained more than one seed in the dry-cold season than in the dry-hot season.

3.2. Seed Potential in the Coarse Fraction according to Functional Traits of Plant Species

The results showed that the diversity and abundance of the seed potential in the manures depend on the morphological (Figure 6(a)) and biological (Figure 6(b)) traits of the palatable plant species, but also on the traits of their fruits (Figures 6(c)-(e)) and their seeds (Figure 6(f)). Goats disseminated more seeds of shrubs and trees (Figure 7(a)), phanerophytes (Figure 7(b)), indehiscent drupes and pods (Figure 7(c)), barochore seeds (Figure 7(d)), fruits with one seed and 4 - 10 seeds (Figure 7(e)), and seed with a hard coat (Figure 7(f)) respectively more than 32, 48, 14, 38, 37, 35, 40 and 35 times cattle manures and more than one, 3, 2, 2, 2, 1, 3 and 2 times sheep manures. The sheep disseminated

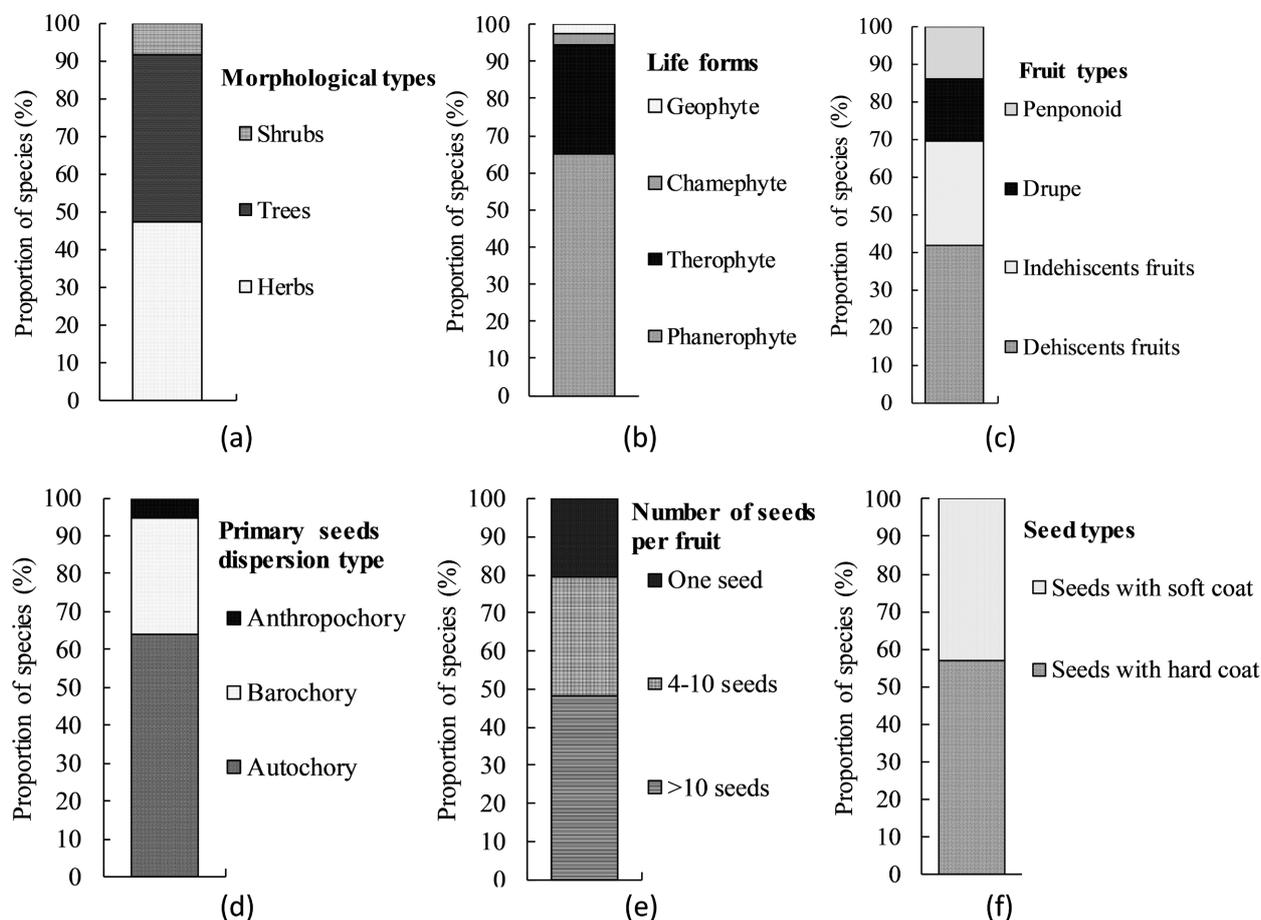


Figure 6. Proportion of species in coarse fraction of manure following species functional traits.

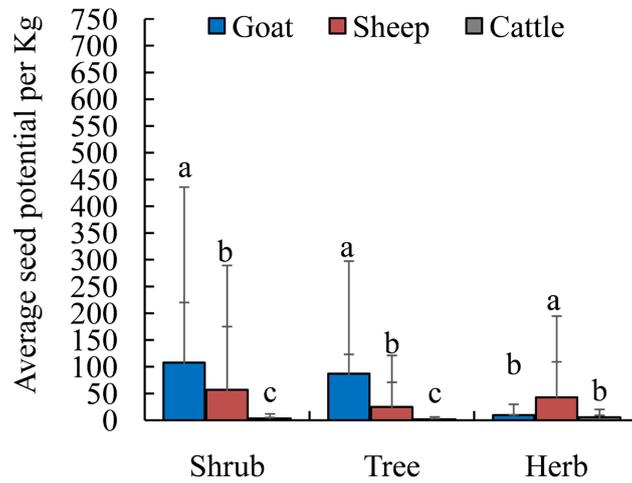
more the seeds of herbaceous plants, therophytes, dehiscent fruits, autochore fruits and those of fruits containing more than 10 seeds, respectively, more than 7, 8, 7, 10 and 9 times the cattle manures and more than 4, 4, 4, 8 and once the goat manures.

3.3. Seed Potential in the Fine Fraction of Manure

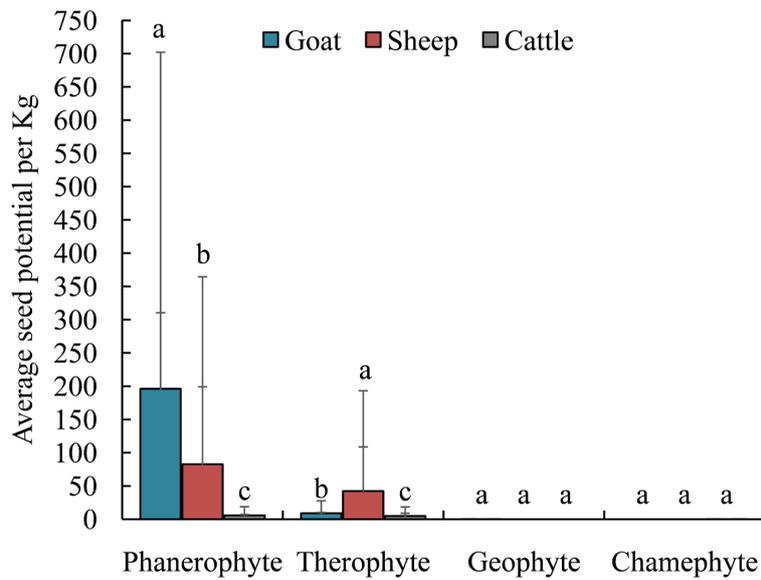
In the fine fraction, 18 herbaceous species divided into 08 families and 15 genera were identified (**Figure 8**) with a dominance of Poaceae (45%). No woody species were identified in the fine fraction.

The plant species frequently encountered ($RI < 50$) in the fine fraction of cattle manures were: *Dactyloctenium aegyptium*, *Eleusine indica*, *Corchorus tridens* and *Sporobolus festivus* (**Table 5**).

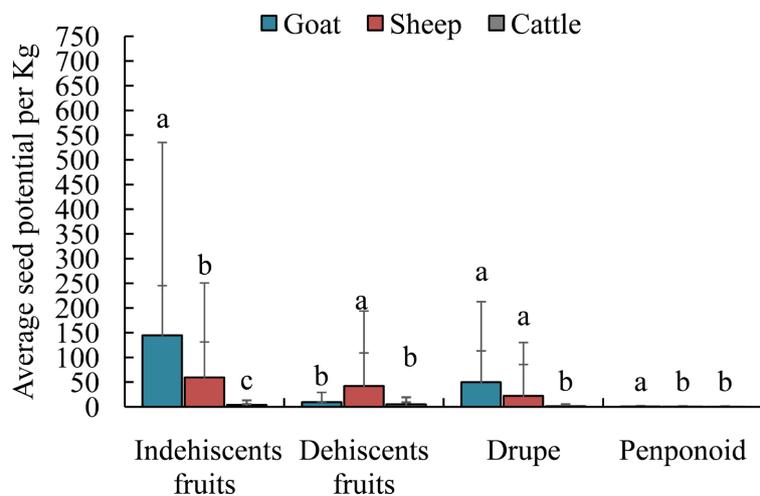
The first three species in addition to *Amaranthus spinosus* were common in sheep manures. In addition to these five species, there was *Ipomoea eriocarpa*. Rare species ($RI > 80$) such as *Panicum pansum* and *Spermacoce chaetocephala* were present only in cattle manures, *Tephrosia pedicellata* only in sheep manures, *Corchorus olitorius*, *Pennisetum pedicellatum*, *Sesamum indicum* and *Setaria pumila* only in goat manures.



(a)



(b)



(c)

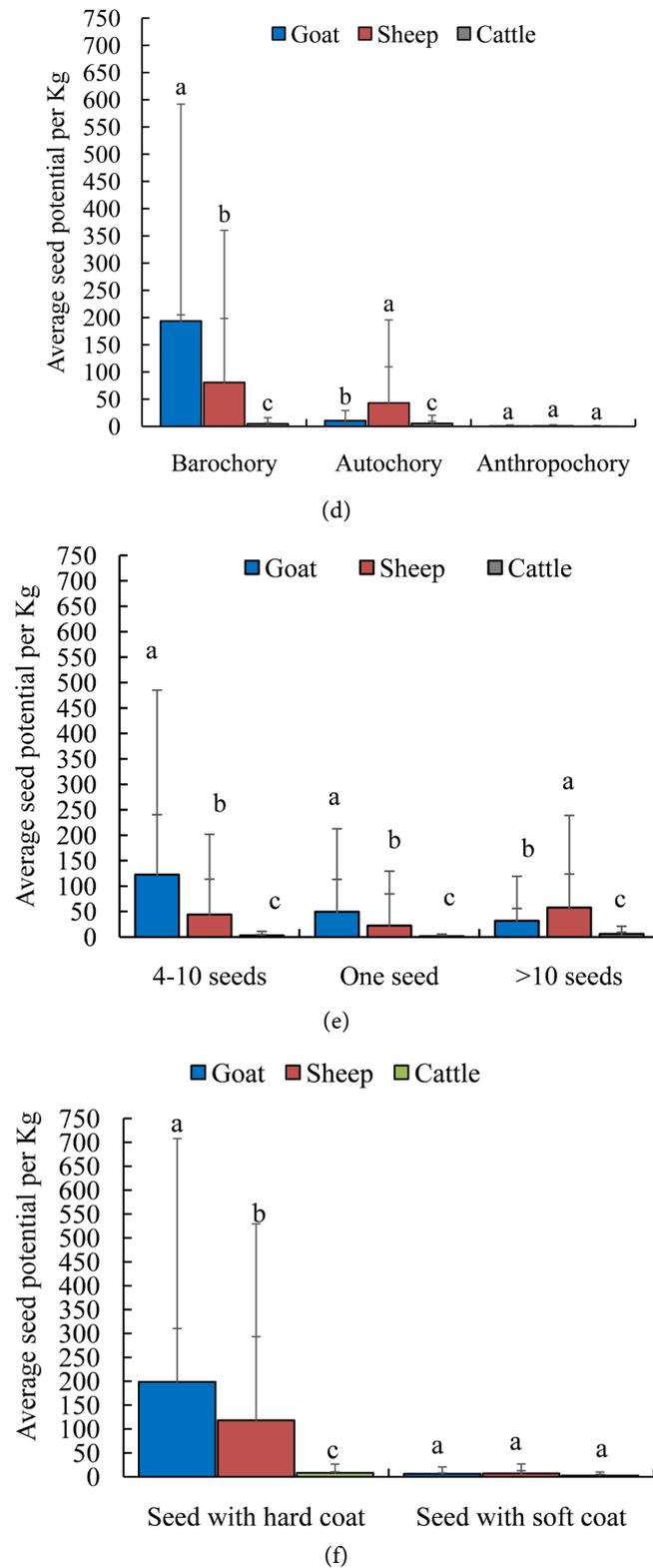


Figure 7. Average seed potential \pm standard deviation/kg of manure during the year according to species functional traits and manure types. (a) morphological types, (b) biological types, (c) fruit types, (d) primary seed dispersal mode, (e) number of seeds/fruit, (f) seed type.

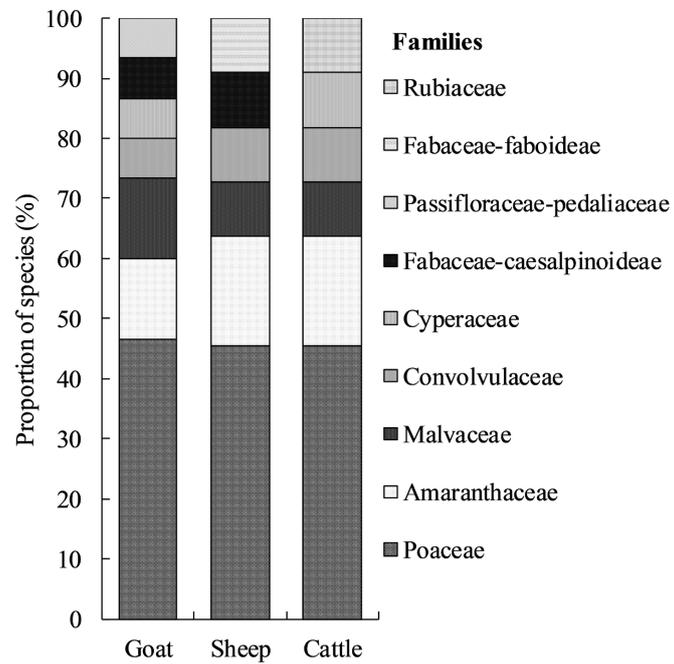


Figure 8. Proportion of species identified in the fine fraction of different manures following biological families.

Table 5. Plant species in the fine fraction with their rarity index (RI) depending on the type of manure.

Species	Goat	Sheep	Cattle
<i>Amaranthus graecizans</i>	67	60	93
<i>Amaranthus spinosus</i>	20	40	60
<i>Sennna obtusifolia</i>	93	67	100
<i>Corchorus olitorius</i>	93	100	100
<i>Corchorus tridens</i>	47	27	40
<i>Cyperus rotundus</i>	87	100	87
<i>Dactyloctenium aegyptium</i>	13	20	13
<i>Eleusine indica</i>	27	20	27
<i>Eragrostis cilianensis</i>	87	87	93
<i>Ipomoea eriocarpa</i>	33	67	60
<i>Panicum pansum</i>	100	100	87
<i>Pennisetum americanum</i>	93	100	100
<i>Pennisetum pedicellatum</i>	93	93	100
<i>Sesamum indicum</i>	93	100	100
<i>Setaria pumila</i>	93	100	100
<i>Spermacoce chaetocephala</i>	100	100	93
<i>Sporobolus festivus</i>	33	67	47
<i>Tephrosia pedicellata</i>	100	93	100

The species with IR < 60% is very frequent, if 60 ≤ RI < 80, it is moderately frequent and if RI ≥ 80%, it is rare.

4. Discussion

4.1. Seed Potential According to Manure Types

The amount of seed found in cattle manure was very low. The manure of goats contained more seeds than sheep. Thus, the food preferences of each animal determine its contribution to the dissemination of plant seeds. [25] reported that goats feed mainly on woody and subligneous (80%); sheep have the most balanced diet (60% of grass, 20% of other grass and 20% of woody and subligneous) and cattle eat mainly grasses (90%). According to [26] classification, cattle and sheep are “grazers” capable of effectively digesting grass cell walls thanks to their developed reticulo-rumen. On the other hand, he considers goats as mixed consumers who avoid foods that are too high in fiber. The low contribution of cattle to seed potential confirms that they consume woody crops only in the grassy fodder deficit period [27] as a protein supplement. The choice of food also depends on the digestive capacities (masticatory activity and digestive enzymes) of each animal [28] [29]. Cattle are better able to digest very fibrous fodder because of their higher ruminal fermentation volume and longer feed residence time in the rumen [30] [31]. As a result, *Piliostigma reticulatum* is the only woody species whose seeds are best represented in cattle manures because its pods are rich in lignin [32]. Small ruminants are unable to meet their energy needs by consuming cellulose-rich foods [33] and obtain their energy from the most digestible foods [34]. Lignin and cellulose contained in the cell membranes of fibrous fodder are not degraded by mammalian enzymes [35] and require the intervention of symbiotic microbes present in the rumen. Big ruminants have a larger gastrointestinal tract than small ruminants [36] [37], which favors a longer duration of food life and therefore a nutrient extraction through microbial fermentation [33] [34]. In fact, the effectiveness of plant seed dispersal by herbivores depends on the percentage of losses due to crushing and mechanical abrasion during the mastication process and chemical abrasion during the digestion process [38]. The nutritional value of the feed consumed influences the feed choice by livestock. For example, legume seeds are most abundant in manures, especially those of goats. Throughout their lives, herbivores develop preferences, especially for foods that provide them the most nutrients by recognizing those that provide them better digestive or nutritional satisfaction, due to post-nutritional effects [39]. The high tannin content characteristic of legume species decreases their appetite [40] [41] [42] and their ingestion by astringency in the mouth [43] [44]. However, goats would be less sensitive to high tannin levels than sheep or cattle due to the presence of a proline-rich salivary protein that has a high affinity for tannins [42] [45] [46] [47]. This would explain the predominance of the seeds of *Vachellia nilotica*, *Faidherbia albida*, *Piliostigma reticulatum* and *Vachellia sieberiana* in the manure of goats as in the manure of cattle and sheep.

4.2. Seed Potential According to Sampling Periods

The seed potential was important in the dry and cold season followed by the dry

and hot season and low in the rainy season. Therefore, species phenology is an important factor in seed dissemination by herbivores. In fact, the rainy season is marked by the maturity of herbaceous species. Thus, more than 70% of the seeds at this time are those of herbaceous plants. With the exception of *Balanites aegyptiaca*, *Scleocarya birrea* and *Prosopis juliflora*, few woody species bear fruit during this period. The woody mature fruits are only observed at the end of the first quarter of the dry season (January). During the dry season, herbaceous plants contribute little to seed potential. The herbaceous layer [18] is a quality and attractive fodder available at less than 4 months (July to October). Fruit fruiting and maturity of herbaceous fodder (vegetables and grasses) occurs between August and October. Thus, all the species found in the fine fraction are herbaceous. In the dry season, herbaceous plants are low in nitrogen, although they are sought by animals. The herbaceous stratum has approximately 15% - 20% total nitrogen content in August, less than 10% in October and less than 3% in January while the woody, they have a total nitrogen content of up to 35% of the dry matter with average values close to 15% throughout the year [18] [19]. As a result, the total mineral matter from herbaceous fodder is very important in the growing stage and then gradually decreases in the fruiting phase [48]. Thus, the diet is determined primarily by the seasonality factor, which affects appetite and availability [25]. From the onset stage, the stems and inflorescences of grasses become hard (rich in cellulose) [49] [50] leading animals to consume the fruits of the woody species especially the legumes which are abundant at this time and digestible [51]. In the dry and hot season, the contribution of woody trees to seed potential decreases (72%) compared to 90% in the dry and cold season. Animals vary their diet throughout the year, depending on the phenology of the species.

4.3. Influence of Functional Traits on the Dissemination Capacity

We found that the seed potential varied from one type of manure to another according to the functional traits of plant species. The most numerous seeds in the manure come from the indehiscent fruit species spread by barochory (*Vachellia nilotica*, *Vachellia sieberiana*, *Piliostigma reticulatum*, *Faidherbia albida*, *Cassia sieberiana*, *Balanites aegyptiaca*, *Ziziphus mauritiana*). For example, seeds of certain plant species (*Senegalia senegal*, *Vachellia seyal*) with high fodder value present in the study area have not been found in the manure or have been weakly present because their dehiscent fruits are distributed by autochory. The effectiveness of endozoochore seed dispersal depends on the state of the seed, leaving the digestive tract of the animals [52]. This explains the predominance of hard-coat seeds of leguminous [11]: *Faidherbia albida*, *Piliostigma reticulatum*, *Senna obtusifolia* and *Vachellia nilotica* and seed with lignified-walled seeds that are difficult to ferment [10]: *Balanites aegyptiaca*, *Sclerocarya birrea* and *Ziziphus mauritiana*.

5. Conclusion

The study showed that livestock manure plays a major role in preserving biodi-

versity. By selecting the most palatable species, animals participate in the dissemination of plant seeds. The ability of seed to be disseminated by animals depends on several factors, including animal species (food preferences, palatability, oral and digestive systems), plant species (biological type, phenology, availability and accessibility), characteristics of the palatable fruits (nutritional values, type of fruit), the seeds (with or without seed coat), the primary dispersion mode of the fruit (autochory, barochory, anemochory). Small ruminants, especially goats, have a high potential for seed dispersal, especially in the first quarter of the dry season (November to January). The seeds most represented in domestic herbivores manures (goat, sheep and cattle) are those of *Vachellia nilotica*, *Balanites aegyptiaca*, *Faidhebia albida*, *Ipomoea eriocarpa*, *Piliostigma reticulatum*, *Prosopis juliflora*, *Sclerocarya birrea*, *Senna obtusifolia* and *Ziziphus mauritiana*. The dissemination of the seeds of *Senna obtusifolia* is more assured by the sheep. Other species are more disseminate by goats. The herbaceous seeds are dominated by crop weeds, hence the need to compost raw manures before their use in agroecosystems. Since most seeds are hard seeds, composting could keep the seeds intact and promote their germination during the rainy season. Thus, for the ecological restoration of degraded agroecosystems, agropastoral practices offer opportunities at a lower cost. Viewing the degradation of the areas reserved for grazing in this study area, the use of organic manure combined with soil and water conservation techniques, soil defense and restoration could help rehabilitate pastures with poor fodder.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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