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Germination and Growth Potential of a Herbaceous Species: *Cenchrus biflorus* Roxb, on Degraded Dune Soils in Southeast Niger

Maigari Malam Assane[1*], Karimou Jean Marie Ambouta[2], Charles Louis Bielders[3], Adamou Didier Tidjani[2]

[1]Department of Soil and Environment, University of Diffa, Diffa, Niger
[2]Department of Soil Sciences, Abdou Moumouni University, Niamey, Niger
[3]Earth and Life Institute, Catholic University of Louvain, Louvain-la-Neuve, Belgique
Email: *assanemaigari@gmail.com

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Abstract

The restoration of degraded dunes is a major challenge in Niger, and considerable efforts are being made to achieve this. This manuscript investigates the germination and growth of *Cenchrus biflorus* in degraded dune soils of south-eastern Niger, with a focus on how different levels of degradation and topographical variations affect plant development. The study uses a well-structured experimental design to assess factors such as dune type, degradation level, and topographical position, analyzing their effects on root length, biomass, and overall plant growth. The results suggest that degradation level and topographical position significantly influence the growth of *C. biflorus*, providing insights for ecological restoration in desertified areas.

Keywords

Degraded Dunes, Restoration, *Cenchrus biflorus* Roxb, Niger

1. Introduction

The drought cycles experienced by Sahelian countries have manifested in Niger through the reactivation of dunes previously stabilized by vegetation and the formation and advancement of active dunes, an increase in sand accumulation in agricultural and pastoral areas, and constant degradation of the natural environment [1]-[6]. It is particularly the south-eastern part of the country that is most affected by these phenomena, which give rise to degraded dunes without limit. In this part of the country as in the whole Sahel, the climate is characterized by the alternation of two strongly contrasting seasons: a long dry season (9 to 10 months) and a short-wet season (2 to 3 months) [5]. During the dry season, degraded dunes are bare, and their soils are very mobile. The constant movement of these soils buries some of the seeds produced by the sparse and scattered vegetation at depths that make germination or seedling emergence difficult [7]. Moreover, the other parts of the seeds produced on the degraded dunes are either consumed by livestock, insects, rodents, and soil fauna or transported by wind, humans, and/or animals [8]. For example, this author reported an annual cycle loss of 79% to 96% of seed reserves from the beginning of the dry season to the start of the following rainy season. During the rainy season, although the conditions for vegetation establishment are optimal, these degraded dunes, even those that are partially stabilized, are only partially covered by sparse and stunted herbaceous plants and a few plants of *Leptadenia pyrotechnica* that timidly oppose the remobilization of sediments by the wind [7]. It is as if vegetation has difficulty germinating and developing on these degraded dunes, which are easily distinguished from other undisturbed units with verdant surfaces. Of the few species that grow there, *Cenchrus biflorus* dominates [9] [10], and this species is known for its hardiness in developing in arid zones [11] like those of the degraded dunes.

Verifying the ability of these dune soils to support the development of herbaceous plants could facilitate the sustainable stabilization of mobile soils. Indeed, the most effective way to restore degraded dunes is to sustainably restore vegetation to bare, mobile surfaces [12]-[15]. For [16], cited by [17], the importance of vegetation is such that a plant cover of just 4% could reduce soil loss by 15% compared to bare soil.

The Cenchrus species, therefore, offers the opportunity to revegetate the dunes because many Cenchrus species are resistant to harsh environmental conditions [18]. Similarly, [19] and [20] Basharat *et al.*, (2024) demonstrated that Cenchrus is a species capable of developing structural and functional strategies to combat environmental constraints imposed by multiple abiotic stresses, such as aridity. While studying the Effects of environmental factors on the germination of *Cenchrus biflorus* seeds, [21] highlighted the tolerance of the species to extreme temperatures and prolonged drought conditions. It is in this context that this study on the germination and growth of *Cenchrus biflorus* in degraded dune soils was carried out in southeastern Niger.

2. Materials and Methods

To assess the capacity of dune soils to support the development of herbaceous plants, a germination and growth potential test using *Cenchrus biflorus* seeds was conducted. The soil samples used for this test were taken from depths of 0 to 20 cm, based on the type of dune (Dune field and Isolated dune), the level of dune degradation (Partially stabilized dune and active dune), and the topographical position on the dunes (Bottom, Crest and Slope). Thus 32 degraded dunes in southeastern Niger were sampled with 3 samples per dune according to the three topographical positions on the dunes. In total, 96 samples of soils from degraded dunes (32 dunes × 3 positions) were used for this study.

The sowing was carried out in plastic pots (in the shape of a right truncated cone: large base 14.5 cm in diameter, small base 9.5 cm in diameter, and 15 cm high) open, pierced at the bottom, and filled with soil from the considered dune position up to 10 cm. The *Cenchrus biflorus* seeds were carefully placed at a depth of 2 cm (so that they do not touch each other) within the pots on a surface area of 165.13 cm^2 (area of the large base). This depth was chosen because of maximum seedling emergence at 2-cm burial depth [21]. Each pot was seeded with 20 *Cenchrus biflorus* seeds. For the same substrate, 6 repetitions (6 pots) were conducted with each repetition having a control pot filled with soil from the corresponding dune position without being seeded (the number of germinated *Cenchrus biflorus* seeds in a treated pot is obtained by subtracting the number of *Cenchrus biflorus* seedlings counted in this pot from the number of *Cenchrus biflorus* seedlings germinated in the associated control pot). In total, 576 pots (32 dunes × 3 positions × 6 repetitions) were seeded with 11,520 *Cenchrus biflorus* seeds. These seeds were harvested in the study area at the end of the rainy season in 2012 (end of September and beginning of October) and the test was carried out during the winter season of 2013 (starting from June 12, 2013).

The experiment consisted of evaluating the germination rate of *Cenchrus biflorus* and to regularly measure, at weekly intervals, the height of the plants from emergence to maturity. At the end of the test, the mature plants were counted in each pot, the dominant root length was measured, and the dry weight was weighed after the straw was air-dried.

The germination rate (G(%)) of *Cenchrus biflorus* is calculated using Equation 1.

$$G(\%) = \frac{\text{Total number of germinated seeds}}{\text{Total number of sown seeds}} \times 100 \tag{1}$$

where: Total number of germinated seeds = number of seedlings in a pot − number of seedlings in the associated control pot.

The survival rate (S(%)) of *Cenchrus biflorus* is calculated using Equation 2.

$$S(\%) = \frac{\text{Total number of living plants at maturity}}{\text{Total number of sown seeds}} \times 100 \tag{2}$$

The experimental setup is illustrated in **Figure 1**.

The germination rate, survival rate, shoot length, root length, and dry biomass produced by *Cenchrus biflorus* were calculated using Excel software. Statistical treatments were conducted with SPSS version 20. Multivariate ANOVA was used to assess the effect of the type of dune, level of degradation, and topographic position on these different variables. If ANOVA revealed significant effects, a Tukey post hoc test ($p < 0.05$) was performed to compare the means.

3. Results

3.1. Germination Rate of *Cenchrus biflorus*

No source of variation affected the germination rate of *Cenchrus biflorus*

Figure 1. Experimental setup for the germination potential and growth of dune soils.

(**Table 1**) However, some slight trends are sometimes observed between degradation levels. This germination rate means 58.33% ± 14.57%, considering all dunes, all levels of dune degradation, and all topographic positions on the dunes combined.

Table 1. Results of variance analysis of *Cenchrus biflorus* germination rate (TD = type of dune; LD = level of degradation; TP = topographical position).

Source of variation	Degree of freedom	Medium square	F-test	Probability
TD	1	733.507	3.450	0.064 NS
ND	1	25.000	0.118	0.732 NS
PT	2	91.536	0.431	0.650 NS
TD * ND	1	166.840	0.785	0.376 NS
TD * PT	2	176.606	0.831	0.436 NS
ND * PT	2	159.505	0.750	0.473 NS
TD * ND * PT	2	109.679	0.516	0.597 NS
Residual error	564	212.589	-	-
Total	576	-	-	-

NS. not significant.

3.2. Survival Rate of *Cenchrus biflorus*

Topographic position on the dunes significantly ($p < 0.05$) affected the survival rate data of *Cenchrus biflorus*. The type of dune, the level of dune degradation, and the interactions between the different sources of variation do not statistically affect the survival rate of *Cenchrus biflorus* (**Table 2**).

Figure 2 shows the result of the comparison of survival rate of *Cenchrus biflorus* based on topographic position on the dunes. The best seedling survival rate (61.28%) is obtained on the substrate from the "Slope" position, followed respectively by the "Crest" (54.65%) and the "Bottom" (45.2%).

Table 2. Results of *Cenchrus biflorus* survival rate analysis (TD = type of dune; LD = level of degradation; TP = topographical position).

Source of variation	Degree of freedom	Medium square	F-test	Probability
TD	1	2187.294	5.962	0.015 NS
ND	1	86.766	0.237	0.627 NS
PT	2	12531.538	34.159	<0.001***
TD * ND	1	150.517	0.410	0.522 NS
TD * PT	2	125.003	0.341	0.711 NS
ND * PT	2	111.877	0.305	0.737 NS
TD * ND * PT	2	96.017	0.262	0.770 NS
Residual error	564	366.855	-	-
Total	576	-	-	-

NS. not significant; *. significant; **. highly significant; ***. very highly significant.

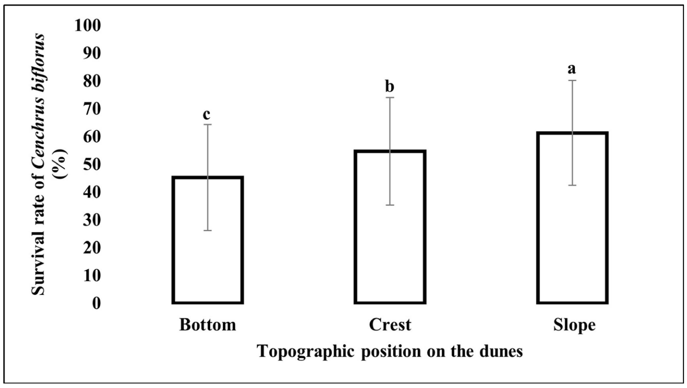


Figure 2. Mean effect on Survival rate of *Cenchrus biflorus* in south-eastern Niger, 2013, based on topographic position on the dune (Means that share different letter are significantly different).

3.3. Growth of *Cenchrus biflorus*

The level of degradation; the topographic position on the dune; the days after sowing; the interaction between the level of degradation and the topographic position; the interaction between the topographic position and the days after sowing as well as the interaction between the level of degradation, topographic position, and days after sowing is affected the height growth of *Cenchrus biflorus.* (Table 3).

Table 3. Results of analysis of variance of the size of *Cenchrus biflorus* (TD = type of dune; LD = level of degradation; TP = topographical position; DAS = Days after sowing).

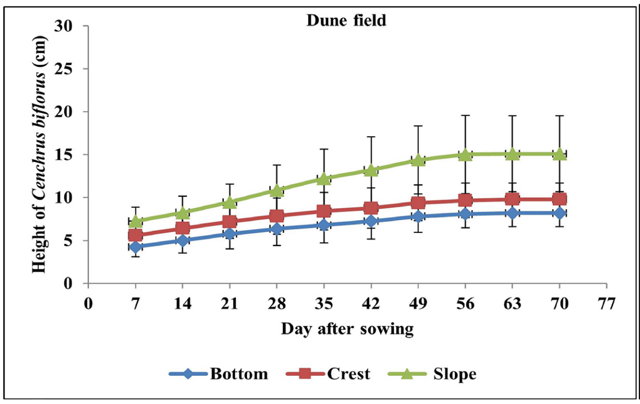
Source of variation	Degree of freedom	Medium square	F-test	Probability
TD	1	2.29	0.68	0.411 NS
ND	1	38.86	11.47	0.001**
PT	2	20572.68	6071.79	<0.001***
DAS	9	2604.12	768.57	<0.001***

Continued

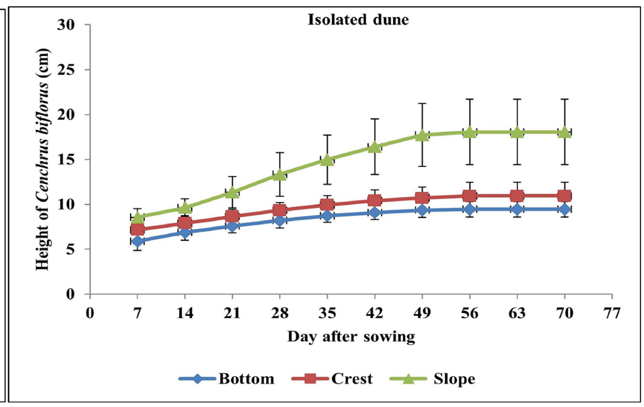
TD * ND	1	0.15	0.04	0.836 NS
TD * PT	2	0.33	0.10	0.908 NS
TD * DAS	9	0.02	0.01	1.000 NS
ND * PT	2	46.03	13.58	<0.001***
ND * DAS	9	5.71	1.69	0.086 NS
PT * DAS	18	355.60	104.95	<0.001***
TD * ND * PT	2	0.14	0.04	0.959 NS
TD * ND * DAS	9	0.01	0.00	1.000 NS
TD * PT * DAS	18	0.00	0.00	1.000 NS
ND * PT * DAS	18	10.64	3.14	<0.001***
TD * ND * PT * DAS	18	0.01	0.00	1.000 NS
Residual error	5640	3.39	-	-
Total	5760	-	-	-

NS. not significant; *. significant; **. highly significant; ***. very highly significant.

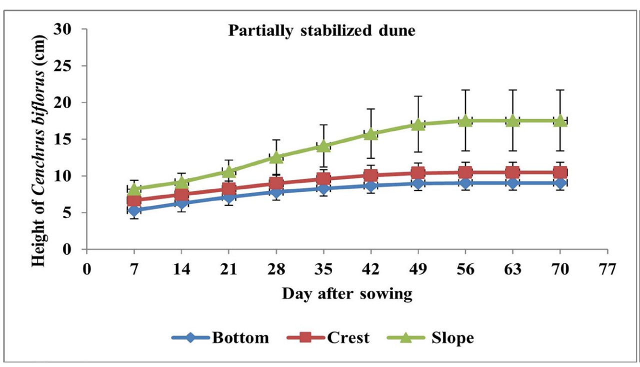
Figure 3 shows the height growth of *Cenchrus biflorus* according to the type of dunes and the level of degradation of the dunes based on the topographic position on the dunes.



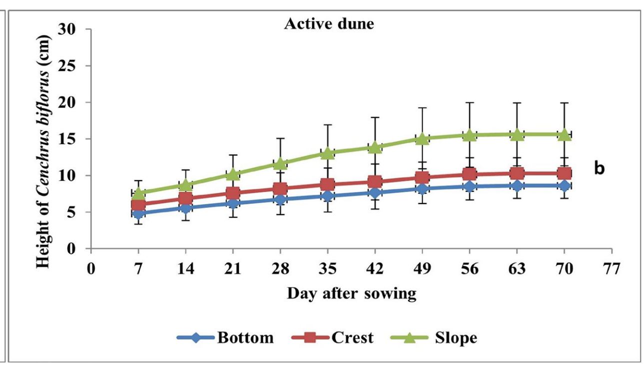
(A)



(A')



(B)



(B')

Figure 3. Mean height growth of *Cenchrus biflorus* plants in southeastern Niger, 2013: (A) and (A') based on type of dune; (B) and (B') based on dune degradation level.

The statistical analysis of the growth of *Cenchrus biflorus* over time (all levels of variation sources combined) reveals that this growth occurred in two phases (**Figure 4**).

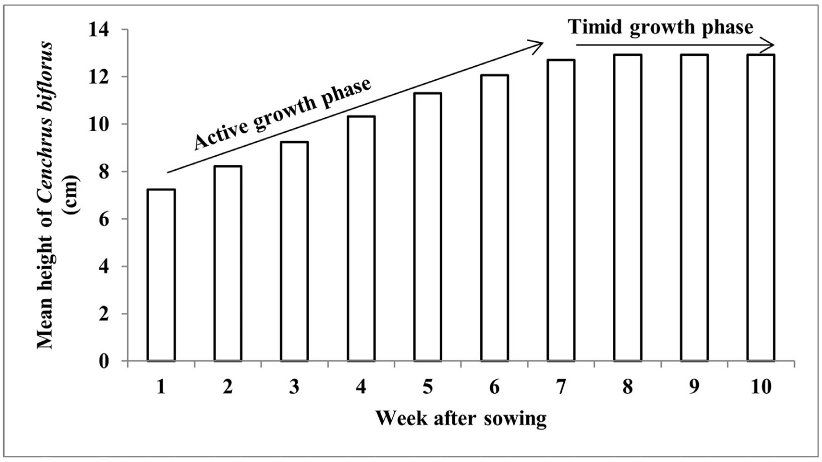


Figure 4. Evolution of the mean height of *Cenchrus biflorus* plants over time in southeastern Niger, 2013, based on all types of dunes, levels of degradation, and topographic positions on the dunes.

The active growth phase, from emergence to the seventh week after sowing (observable in **Figure 5**), where the plant height is statistically different from week to week with a mean height increase of 0.91 ± 0.17 cm per week. After this period, the second phase begins with a modest height increase from the seventh week to the tenth week, at which point the plants are harvested.

(A) (B)

Figure 5. Growth of *Cenchrus biflorus* in southeastern Niger, 2013: (A) two weeks after sowing; (B) eight weeks after sowing

3.4. Development of *Cenchrus biflorus* Roots

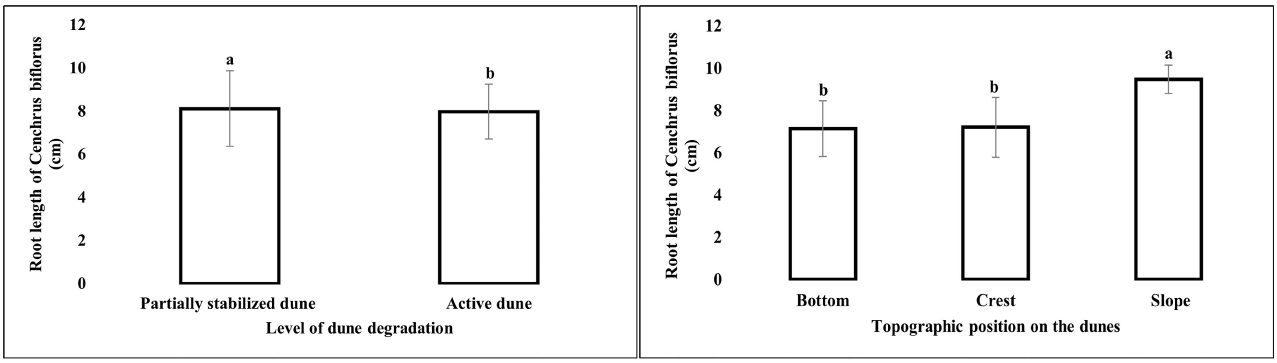
The degradation level of the dunes and the topographic position on the dunes are affected by the root lengths of *Cenchrus biflorus*. (**Table 4**).

Figure 6 presents the results of the comparison of the mean values of the main root lengths of *Cenchrus biflorus* according to the level of dune degradation and the topographic position on the dunes.

Table 4. Results of analysis of variance of the length of dominant roots of *Cenchrus biflorus* (TD = type of dune; LD = level of degradation; TP = topographical position).

Source of variation	Degree of freedom	Medium square	F-test	Probability
TD	1	0.01	0.01	0.925 NS
LD	1	21.20	16.24	<0.001***
TP	2	438.99	336.29	<0.001***
TD * LD	1	0.00	0.00	0.973 NS
TD * TP	2	0.02	0.01	0.988 NS
LD * TP	2	2.13	1.63	0.197 NS
TD * LD * TP	2	0.04	0.03	0.968 NS
Residual error	755	1.31	-	-
Total	767	-	-	-

NS. not significant; *. significant; **. highly significant; ***. very highly significant.



(A) (B)

Figure 6. Mean length reached by the main roots of *Cenchrus biflorus*: (A) according to the level of dune degradation; (B) according to the topographic position on the dune (Means that share different letter are significantly different).

3.5. Dry Biomass Produced by *Cenchrus biflorus*

The level of dune degradation, the topographic position on the dunes, and the interaction between the type of dune and the level of dune degradation are affected by dry matter quantity produced by *Cenchrus biflorus* (Table 5).

Table 5. Results of analysis of variance of dry matter produced by *Cenchrus biflorus*.

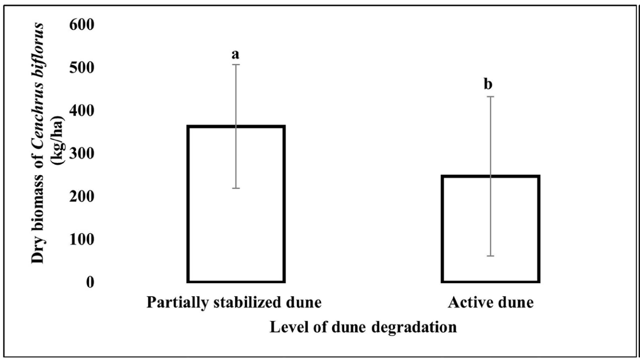
Source of variation	Degree of freedom	Medium square	F-test	Probability
TD	1	3857.42	0.16	0.690 NS
LD	1	2724952.14	112.73	<0.001***
TP	2	1556405.73	64.39	<0.001***
TD * LD	1	189055.31	7.82	0.005 **
TD * TP	2	25785.95	1.07	0.345 NS

Continued

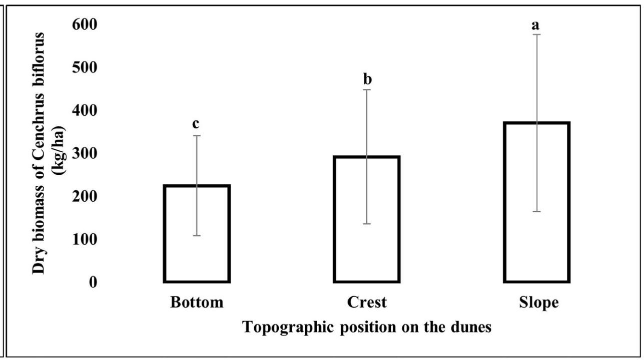
LD * TP	2	46751.88	1.93	0.145 NS
TD * LD * TP	2	6653.49	0.28	0.759 NS
Residual error	819	24172.07	-	-
Total	831	-	-	-

NS. not significant; *. significant; **. highly significant; ***. very highly significant.

Figure 7 presents the results of the comparison of the means of dry matter produced by *Cenchrus biflorus* based on the level of dune degradation, the topographic position on the dunes, and the interaction between the type of dune and the level of dune degradation.



(A)



(B)

Figure 7. Variation in dry biomass produced by *Cenchrus biflorus*: (A) based on dune degradation level; (B) based on topographical position on the dune (Means that share different letter are significantly different).

4. Discussions

The similarity in the germination rate, regardless of variation, occurs because the substrates are placed under identical and optimal germination conditions. The pots are kept under a semi-open roof shed where temperature, humidity, and light, considered the three main factors significantly impacting seed germination [22]-[24], did not vary significantly from one pot to another. Furthermore, according to [25], two physical conditions (the quality of the "soil-seed contact" and the moisture at the seed contact) can affect the germination rate. Similarly, [24] states that the germination of a species can be influenced by the sowing depth and particle size distribution. The concerns of these authors are respected because, on the one hand, *Cenchrus biflorus* seeds are carefully placed at a depth of 2 cm in the pots so that they do not touch each other, and on the other hand, except for some differences in the particle size distribution of the substrate, especially for very fine sand in the dune type, coarse sand in the dune degradation level, and medium and very fine sand in the topographic position on the dunes [26], for his part, points out that the physical characteristics of the soil surface, resulting from differences in texture, compaction, and the presence or absence of a crust, determine the germination rate. The situation described by this author is far from observable in the conditions of degraded dune sandy soils. [24] also noted that the soil and its components are the main physical barriers that the germ must overcome to reach the surface, but sandy soils are generally loose enough to allow the germ to penetrate. They also warm up more rapidly and promote increased and earlier emergence.

Researchers observed differences in the chemical composition of degraded dune soils for all elements analyzed between the levels of dune degradation and organic carbon, assimilable phosphorus, and potassium ions between topographic positions on the dune. However, during germination, the chemical properties of the soil play a very minor role since seeds use their own mineral reserves in the initial phase of germination [27]. Nonetheless, researchers noted that, at high concentrations, some nitrates can stimulate the germination of *Cenchrus biflorus* seeds [28], a situation that is hard to achieve in the generally mineral-poor soils of the Sahel [29]-[32]. The level of dune degradation only partially influences the pH of these soils. Regardless of the level of variation considered, its mean value falls within the pH range (6.5 to 7.0 and/or 5.5 to 7.5), which allows for the development of most plants [33]-[35]. Furthermore, a multidisciplinary study conducted by [36] on "agricultural and pastoral capabilities of soils in CILSS countries" set the optimum between pH 6.5 and 7.5 in non-calcareous environments like that of this study.

This study obtained a mean germination rate of 58.33% for *Cenchrus biflorus*, which is much higher than the 23% (with lateral caryopses) found by [37], 2% (with bearded seeds) mentioned by [26], 16% (with the fruit of *Cenchrus biflorus*), and 26% (with lateral caryopses) reported by [8]. On the other hand, this result is close to 66% (with central caryopses) noted by [37], 65% (with beardless seeds) reported by [26], and 50% (with central caryopses) obtained by [8]. It is below 95% germination obtained by [21]. These authors conducted experiments in laboratories, in Petri dishes for some and/or in greenhouse pots for others. They observed a higher germination rate for *Cenchrus biflorus* seeds extracted from their spiny beards than for whole fruits, and for central caryopses compared to lateral ones. Researchers may relate the differences observed, on the one hand, to the fact that direct sowing in sand improves the germination rate [38] and, on the other hand, to the fact that the seeds are not harvested under the same conditions nor at the same time. Indeed, researchers observed a seasonal variability in the germinative properties of the seeds and an interannual variability related to the state of the seeds for this species, which is itself caused by the ecological factors prevailing during the formation and maturation of the fruits [8].

To explain the difference in the Survival Rate of *Cenchrus biflorus*, we must refer to the germination modalities of the species. Once the seedlings emerge, the seed reserve becomes exhausted. In addition to water (which is available), they need soil nutrients to survive. *Cenchrus biflorus* germinated not in a single wave but during the first two weeks after sowing. Generally (considering all positions), most of the sown grains (78.07%) germinated during the first week. Separately, the Slope had the highest number of germinated grains (82.9%) in the first week, followed by the "Crest" position (78.34%) and the "Bottom" position (67.67%). Moreover, even among the plants that germinated in the first week, we observed more than one wave. This is because *Cenchrus biflorus* has rapid and staggered germination [20]. However, not all seedlings resulting from germination exhibit the same vigor, and less vigorous ones appear to be eliminated over time, allowing the more robust ones to reach maturity selectively. In these wave germination conditions, seedlings from the first wave benefit from better emergence conditions. They take advantage of the total availability of the initial edaphic parameters of the substrate for their establishment. As for the seedlings from subsequent waves, they inherit the competition from the first seedlings already established and find themselves in unfavorable conditions for good emergence. Indeed, seedlings in the environment may modify some initial edaphic parameters of the substrate. Consequently, several strata of seedlings exist, with the first ones installed being more vigorous than those that follow. These results corroborate those of [26], who obtained more germinations in pots by regularly eliminating the first seedlings that have an unfavorable influence on the subsequent ones. This author also concludes that, in the same location, the competitive strength appears closely related to the size of the plants, and the most competitive ones are those with the greatest size. Therefore, we find the number of vigorous seedlings likely to reach maturity higher in the Slope, Crest, and Bottom.

Researchers have widely observed this seedling mortality phenomenon in nature under uncontrolled conditions. Previous studies [8] [26] [39] have shown that among the numerous germinations occurring after the first rains, only a small proportion contribute to the final development of the herbaceous cover. [26] reported that sandy soil supports the survival of only 3% to 10% of plants. According to [39], seedlings reaching the adult stage represent only 8% to 10% of the total number of germinations. However, uncontrolled conditions primarily cause significant mortality due to water deficits. [39] noted that seedling mortality occurs during periods without rain when soil moisture drops to 0.5%.

Looking at the height growth of *Cenchrus biflorus*, it is found that the average height of *Cenchrus biflorus* plants at the end of the experiment (maturity) is 18.11 cm, 11.02 cm, and 9.57 cm, respectively, on the Slope, the Crest, and the Bottom of the dune fields. We observe that it is 18.14 cm, 11.05 cm, and 9.64 cm, respectively, on the Slope, the Crest, and the Bottom of isolated dunes. On the partially fixed dunes, a height of 18.48 cm, 10.59 cm, and 9.53 cm were recorded respectively, on the Slope, the Crest, and the Bottom. This height is respectively 17.78 cm, 11.50 cm and 9.69 cm on the Slope, the Crest, and the Bottom of active dunes. A maximum height of *Cenchrus* at harvest, all dunes and positions combined, of 30.5 cm was recorded. This *Cenchrus biflorus* height is lower than the heights of 0.9 m to 1.0 m reported by [40], but within the height ranges of 17.50 - 46 cm, 30 - 100 cm, and 4 - 90 cm reported, respectively, by [10] in Niger, and [41] in the Kalahari reserve in Botswana. The growth of *Cenchrus* plants depends not only on water but also on the nutrients available to them. According to [42], low organic matter content (and thus nutrients) would limit plant growth. The difference in growth observed between topographical positions may relate, on the one hand, to the fact that the Slope contains more carbon and, therefore, more organic matter, which improves the physical and chemical characteristics of the soil and provides, through mineralization, the nitrogen needed by plants [36] [43]; we consider it as the fuel of the plant that promotes cell multiplication and thus tissue growth. [44] [45] also observed that *Cenchrus biflorus* germinates quickly and dominates other species, especially in soil with a good nitrogen level. We should also note that organic carbon is probably the greatest universal indicator of soil quality [46] [47] because it influences structure, water infiltration and retention, buffering capacity, and soil biological activity. On the other hand, the Slope contains more assimilable phosphorus and potassium ions (K+); in plants, phosphorus controls energy exchanges and acts as a growth factor because it promotes root development. Potassium, for its part, acts as a regulator of plant functions and provides greater rigidity to plant tissues [36]. According to [48], in the Sahel, nitrogen and phosphorus affect the growth of herbaceous plants because they control root development and photosynthesis. According to [49], phosphorus and potassium are nutrients necessary for plant growth. The statistically significant difference in the content of these elements between the Slope and other topographical positions would favor rapid and better growth on the substrate from the Slope. The slight variation in the content of these two elements (P and K+) between the Crest and the Bottom would probably explain the difference in growth between these topographical positions.

The type of dune does not influence the growth of *Cenchrus biflorus* plants. This is because this level of variation does not affect any chemical parameters. However, the growth of Cenchrus plants varies based on the level of dune degradation. Indeed, *Cenchrus* grows slightly better on substrates from partially fixed dunes than from mobile dunes. This difference occurs because all chemical parameters are influenced by the level of dune degradation. [50] observed that in Sahelian soils, even small differences in a single nutrient element like phosphorus or organic matter can, in combination with other factors, significantly impact the growth of millet, and consequently affect the growth of grass like *Cenchrus biflorus*.

The main roots of *Cenchrus biflorus* developed more on partially fixed dunes than on active dunes and more at the Slope than at the Crest and the Bottom. They are approximately 1.01 times longer on partially fixed dunes than on active dunes, and about 1.3 times longer at the Slope than at the Crest and the Bottom. The variation in phosphorus content between these levels likely causes these differences, as this element plays a crucial role in root development [30]. In any case, the main roots reach their most significant length at around 9 cm. This result corroborates [10], who noted that this species, belonging to the Poaceae family, has a root system formed by roots that do not penetrate deep but allow them to anchor firmly to the ground. This also supports the idea of considering the root base of herbs around 20 cm when sampling the soils used for this study.

The partially stabilized dune produces a significantly higher mean dry matter than the active dune. The Slope yields significantly higher production than the Crest, which in turn produces more than the Bottom. The mean production, regardless of variation, is 362.41 ± 143.73 kg/ha on the partially stabilized dune, compared to 246.34 ± 185.70 kg/ha on the active dune. The Slope generates a mean dry biomass production of 370.19 ± 206.20 kg/ha, while the Crest produces 291.44 ± 155.90 kg/ha, and the Bottom yields 224.11 ± 116.41 kg/ha. On average, 4.72 plants per pot mature, equating to about 286 plants/m^2. These results are much lower than those found by [51], who reported a production of 600 kg/ha of dry matter in Senegal and Chad. Conversely, they are more interesting than those reported by [39], who estimated that 11,000 seeds are needed to achieve final densities of around 100 individuals/m^2 for Sahelian species. The differences arise because:

- In the first case, the 600 kg/ha of dry matter is obtained under conditions where Cenchrus grows in an *Acacia Senegal* Park, a species known for improving soil fertility [52]. *Cenchrus* thus benefits from the association with *Acacia senegal*, producing much higher dry biomass than under degraded dune soils poor in nutrients.
- In the second case, the author provided an estimate in a natural environment were severe selection acts on young seedlings due to water constraints [53]. This experiment, however, ensures regular water supply throughout the cycle, allowing seedlings to develop with minimal mortality risk compared to those in a natural environment.

5. Conclusion

Degraded dune soils pose no risk to the germination of herbaceous species, at least not for the species *Cenchrus biflorus*. This species germinates identically in all soil samples, regardless of the level of variation sources. The proportion of germinated plants that survive to maturity decreases depending on whether the soil originates from the Slope, the Crest, and the Bottom part of the soil. Plant growth also follows the same trend, and in addition, it is greater on the soils of partially fixed dunes than on those of active dunes. *Cenchrus biflorus* develops a superficial root system, longer on the soil of the Slope than on that of the other two topographical positions (Crest and Bottom); this trend is also the same on the soil of partially fixed dunes as on that of active dunes. Although the soils of degraded dunes are very poor in mineral elements, they allow the development of *Cenchrus biflorus* until it completes its cycle and obtains a minimum of dry matter. The production of dry matter is higher respectively on the Slope, the Crest and the Bottom. It is much higher on the partially fixed dunes than on the active dunes. In perspective, it would be interesting to test several species, because the species *Cenchrus biflorus* has been recognized for its performance in germinating in the dune environment, but this property can hide certain impacts that these soils could have on the emergence and development of herbaceous plants. However, the inadequacy of this work lies in the fact that it was not conducted in a strictly controlled environment such as a laboratory. Furthermore, the use of a single species limits the opportunity to select a range of species suitable for re-greening degraded dunes.

Conflicts of Interest

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

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