*Journal of Experimental Agriculture International*

***Volume 46, Issue 1, Page 17-26, 2024; Article no.JEAI.111620***
***ISSN: 2457-0591***
*(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)*

# Influence of Soil Parameters and Sowing Technics on Different Genotypes of Pearl Millet (*Pennisetum glaucum* (L.). R. Br

**Nouhou Salifou Jangorzo [a,b*], Nana Salima Mouhtari Sabiou [a,b], Abou-Soufianou Sadda [b,c] and Issoufou Ango Kassari [d]**

*[a] Département des Sciences du Sol et de Télédétection, Université Dan Dicko Dankoulodo de Maradi, BP 465 ADS, Maradi, Niger.*
*[b] Unité Mixte de Recherche « Diversité et Adaptation des Plantes » (UMR DAP), Université Dan Dicko Dankoulodo de Maradi, BP 465 ADS, Maradi, Niger.*
*[c] Institut de Recherche pour le Développement, 276 Avenue de Maradi, Niamey, Niger.*
*[d] Institut National de la Recherche Agronomique du Niger, centre régional de Maradi, Niger.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. Author NSJ prepared the first draft of the manuscript. Authors NSMS, A-SS and NSJ did Soil sampling. Authors NSMS and NSJ did soil analysis. Authors A-SS and NSMS did Soil mapping. Authors NSJ, IAK and NSMS did Data analysis. Author IAK helped as project coordinator, Authors NSJ, NSMS, A-SS and IAK edited the manuscript. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JEAI/2024/v46i12287

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111620

***Original Research Article***

***Received: 06/11/2023***
***Accepted: 11/01/2024***
***Published: 12/01/2024***

---

**Corresponding author: E-mail: nouhou.jangorzo@gmail.com;*

## ABSTRACT

Productivity improvement by adapting varieties to their environment was a major concern in the Sahel countries. Climatic constraints and low soil fertility are the main factors conditioning millet yield. The objective of this study is to evaluate the influence of edaphic parameters, sowing technics, and fertilization on the improvement of eight genotypes of millet. For this, a trial including eight varieties of millet in split plot was installed on the experimental station of CERRA in Maradi in 2020 during the rainy season. Soil samples at a depth of 20 cm were collected at the beginning and the end of experiment. Soil pH, organic carbon, and assimilable phosphorus were determined. Two sowing technics, seed balls, and direct sowing were applied. In seed balls, two types of fertilizer were used: the NPK (15-15-15) and ash. Phenology parameters and grain yield of each variety was measured. A statistical analysis of these data showed that edaphic parameters do not significantly influence yield. However, a significant variation in grain yield was observed among genotypes. Specifically, the variety ICMV IS 89305 exhibited a significantly higher grain yield (789 +/- 590 kg ha$^{-1}$) compared to ICVH 18 (348+/-289 kg ha$^{-1}$). Moreover, the different types of treatments applied to the seedlings showed a significant difference in terms of grain yield. The SSB treatments yielded more (1101+/-541 kg ha$^{-1}$) than the BSC (480+/-463 kg ha$^{-1}$) and BSE (317+/-322 kg ha$^{-1}$) ball treatments. These results highlight substantial variability both within and between treatments. The positive effect of seed balls and fertilizer included vary according to the context. Specifically, when rainfall is scarce, seed balls prove to be non-efficient in improving the yield of millet.

*Keywords: Soil fertility; seed balls; pearl millet; Niger; sowing techniques; fertilization.*

## 1. INTRODUCTION

Sahelian agriculture faces several challenges linked to population growth, agricultural pressure, and soil fertility degradation. Additionally, crucial environmental factors, such as rainfall characterized by spatial and temporal variability [1], significantly impact it. The ongoing depletion of soils due to mining agriculture [2], and associated with subsistence-driven farming lead farmers to expand cultivation into marginal lands [3]. Integrated soil fertility management practices like fallowing have almost disappeared in certain areas due to the expansion of agricultural land that has reached its limits [4-5]. These soils face intense anthropogenic pressure, coupled with increasingly unfavorable climatic conditions. Consequently, they become highly susceptible to degradation and are unable to sustainably support current agricultural production systems and methods [4].

Moreover, creating varieties with genotypes that perform well in improving production and resisting the challenges of the Sahel has become a priority in agricultural policies in West Africa [6]. Millet (*Pennisetum glaucum* (L). R.Br.) stands out as one of the most studied cereals, given its importance and unique characteristics. Indeed, millet serves as a crucial subsistence food crop in the Sahel region of West Africa, forming the staple diet for several million people [7-8]. Millet cultivation stands as one of the predominant cropping systems in Niger, the second largest producer in Africa after Nigeria [9]. It occupies over 65% of harvested areas, yielding less than 500 kg ha$^{-1}$ [10], and contributes to 75% of the country's total cereal production [11]. In 2016, millet production reached 3.8 million tons, ranking it the first among cereals produced and consumed in the country [12]. However, its production faces decline due to soil impoverishment and low rates of organic and mineral fertilization [10].

Efforts have been made to enhance millet productivity, with innovations such as the seed ball technology developed for Sahelian agrosystems to address water scarcity and optimize seed usage [13]. This technology, refined [14], and tested on certified millet varieties under farmers' conditions, has demonstrated a significant increase in pearl millet performance, encompassing aspects such as emergence, growth, grain yield, and phenology [15]. While many unregistered pearl millet varieties, mostly held by farmers and some under development by researchers, have shown promising performance in diverse conditions, their behavior in seed balls remains uncertain. Moreover, most trials conducted overlook soil characteristics and fertility status.

The present study aims to evaluate the influence of soil characteristics and sowing techniques on the grain yield of eight genotypes of pearl millet in a Sahelian agrosystem in Niger.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

This study was conducted at the experimental station of the National Institute of Agriculture in Maradi. The climate is of the Sahelian type and is characterized by three seasons: a cold dry season from September to January, a hot dry season from January to May (extending to July) marked by a hot and dry wind, and finally, a rainy season from May to September, characterized by significant precipitation. Over the past ten years, the annual average rainfall at this station has been 509.17 mm. However, rainfall quantity is highly variable, ranging from 380 to 625mm/year, and often poorly distributed over time. The soils at this location are tropical ferruginous soils with a sandy texture, exhibiting low chemical fertility but good permeability. They include leached or depleted tropical ferruginous soils, characterized by pounding and low permeability that favors runoff, though they are difficult to work. Additionally, there are hydromorphic soils or lowland soils, featuring a sandy-clay texture and generally rich in organic matter.

### 2.2 Genetic Materials

The genetic material comprises eight pearl millet varieties developed by the National Institute of Agricultural Research and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). These varieties are: HKP, PPB-SH, INMI-PM, ICMV IS 89305, MIL DE SIAKA; ICVH 15; ICVH 17, and ICVH 18.

### 2.3 Experimental Design

The experimental setup consists of a split-plot design with 3 replications, each containing 3 large plots and 8 small plots. Two factors are under study: the variety factor with 8 modalities (HKP, PPB-SH, ICMV IS 89305, INMI PM, MIL DE SIAKA, ICVH15, ICVH17, and ICVH18), and the fertilization or sowing technique factor with three modalities (Seed balls with NPK, Seed balls with Ash, direct sowing). The replications are spaced 1.6m. Each elementary plot measures 17.8m² and represents a genotype, while each large plot represents a treatment. Within each replication, three types of treatments are implemented.Sowing was conducted in 4 lines of 10 seed holes, with row spacings and line spacings set at 0.8m*0.8m (Fig. 1).

### 2.4 Technical Itinerary

The trial took place between June and November 2020. Sowing occurred on June 30, with and without seed balls. Two types of fertilizers, NPK (15-15-15) and ash, were used to prepare seed balls according to the following formula:

> Seed ball = sand + clay + ash or NPK + seed + water,

with the quantities as follows:

> Sand = 1.60 kg; Clay = 1.20 kg; Seed = 0.06 kg;
>
> Ash or NPK = 0.08 kg.

During sowing, only one seed ball was placed per seed hole. Plants were thinned to 2 plants per seed hole 13 days after sowing. Harvesting was carried out plot by plot in November 2020.

### 2.5 Soil Sampling and Analysis

Soil samples were collected from a depth of 20cm within all the plots using a manual auger. For this a diagonal was drawn inside the elementary plots along which three sub-samples were collected. These sub-samples were then mixed to create one composite sample. pH, organic carbon, and phosphorus analyses were conducted on each composite sample.

### 2.6 Grain Yield Measurements

Harvesting was conducted separately for each plot, and the grain weight was measured. The results were extrapolated to calculate the yield in $kg.ha^{-1}$.

### 2.7 Data Analysis

Soil data were used to map the distribution of various elements in the field using Q-GIS 2.18.16. The variation according to the treatment was determined with XLSTAT. Correlation between soil parameters and grain yield was calculated. The effects of soil parameters, millet genotype, and fertilization (sowing techniques) were studied using Analysis of Variance (Anova).

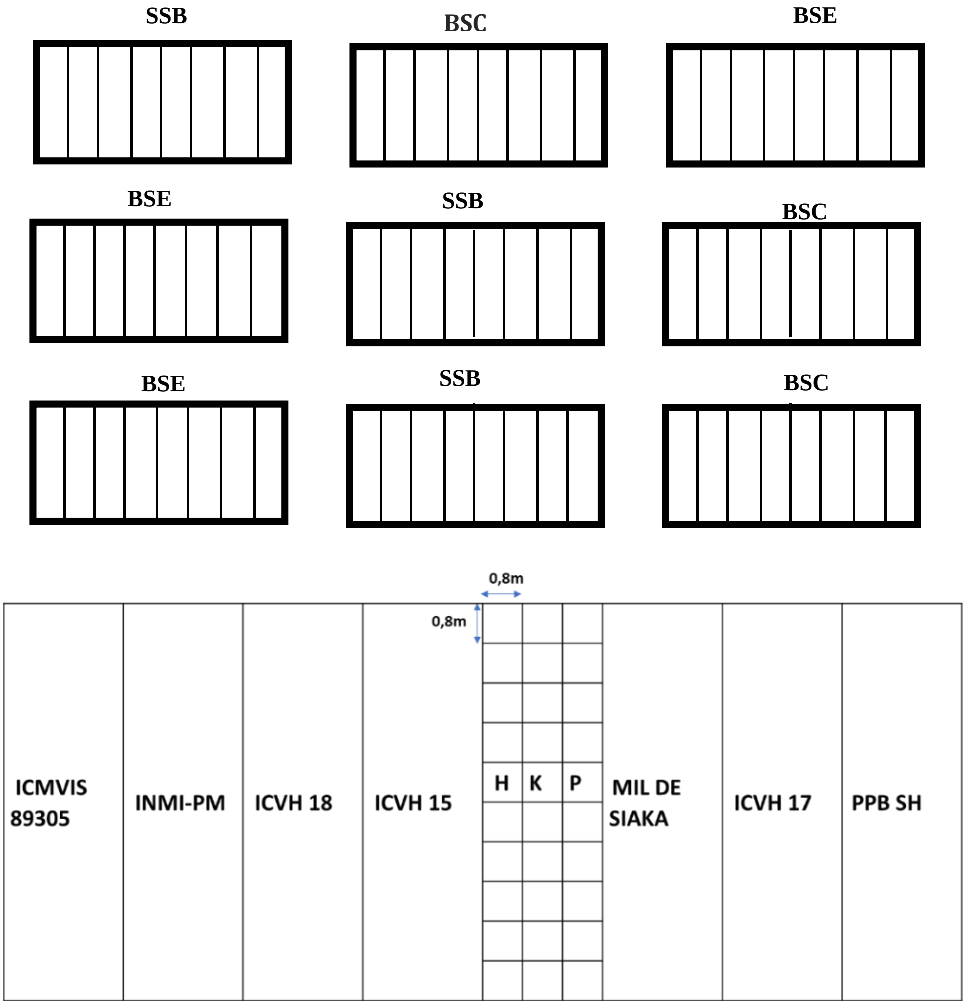


**Fig. 1. Experimental design showing the complete dispositive and detail of sowing spacing in an elementary plot**

*SSB: direct sowing; BSC: sowing with ash ball; BSE: sowing with NPK ball*

## 3. RESULTS AND DISCUSSION

### 3.1 Variation of Soil Phosphorus According to the Treatment

Before installing the trial, the average phosphorus value at the site was 1.50 mg $kg^{-1}$. Following the tests, the average phosphorus decreased to 0.77 mg $kg^{-1}$, indicating a difference of 0.73 mg $kg^{-1}$. The results reveal that, in the BSE treatments, the phosphorus content is the lowest (Fig. 2). While the contents in the BSC and SSB treatments are approximately identical, statistical analysis indicates that the difference is not significant (ANOVA, *P*= .781).

West African soils are known for their low phosphorous content [16-17], and this content further diminishes due to the export of agricultural residues [18]. Consequently, the available phosphorous for plants becomes insufficient, leading to reduced yields and long-term soil impoverishment. Phosphorus fertilization, being the most limiting factor in West African soils, may enhance crop yield according to Liebig's law, but the quantity included in the seed ball is not sufficient. While nutrients in seed balls are close to the seed, their availability for plant roots may be limited.

### 3.2 Variation of Soil Organic Carbon According to the Treatment

The carbon content available on the site before setting up the trial was 110 mg·$kg^{-1}$. By the end of the cropping, the value increased to 166.43

mg $kg^{-1}$, representing an approximate increase of 56 mg $kg^{-1}$. The results of the organic matter content at the end of cropping indicate that in the SSB treatment, the carbon content is higher than in the other two treatments (Fig. 3a). However, statistical analysis shows that this difference is not significant (ANOVA, *P* = .358) among the treatments.

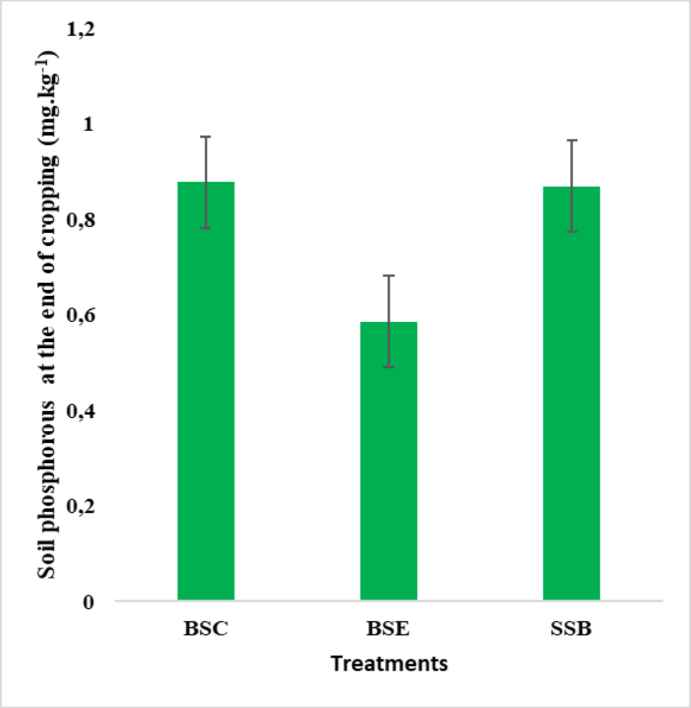
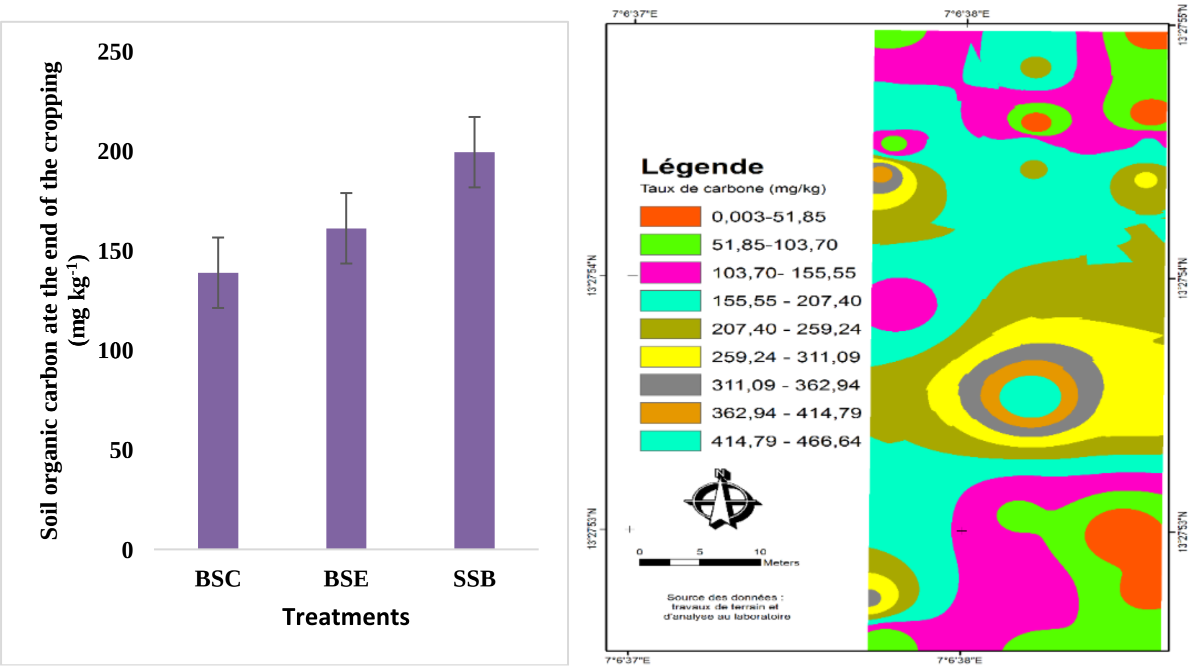


**Fig. 2. Variation of soil phosphorous according to the treatment at the end of cropping**



a

b

**Fig. 3. Variation of soil organic carbon according to the treatment (a) and spatial distribution (b) at the end of cropping.**

The spatial distribution map of organic carbon in the field exhibits variability in the soil, although the randomization of the trial ensures an even distribution of treatments across the entire plot. This uniform distribution explains the homogeneity observed throughout the plot based on treatments. Nevertheless, a wide range of organic carbon is noted, ranging from 0.003 mg $kg^{-1}$ to 466 mg $kg^{-1}$.

This variation in organic carbon may be attributed to a lack of humus mineralization at the end of the cropping period. This situation can arise due to either excess humidity [19], or the absence of microorganisms responsible for the decomposition of organic matter [20].

## 3.3 Variation of Soil pH According to the Treatment

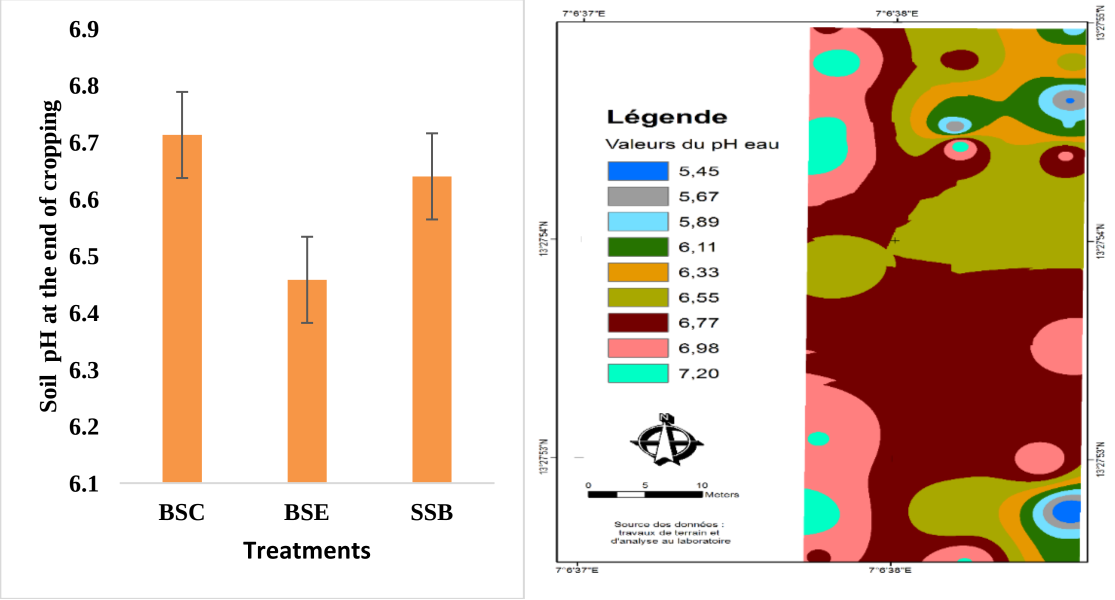
The initial pH of the site before establishing the cultures was highly acidic with an average value of 5. After the cultivation period, it increased to an average value of 6.60, approaching neutrality. Analysis of the pH results at the end of the study indicates a slightly lower pH in the BSE treatment (Fig. 4a). However, statistical analyses reveal no significant difference among treatments (ANOVA, *P*=.704). The slight difference could be explained by the presence of ash as the samples were collected in the vicinity of seed hole. However, ash is known to have the property of highly increasing soil pH [21,22].

The pH map analysis shows that while the values are not entirely homogeneous throughout the plot, the difference is not statistically significant (Fig. 4b). In general, the majority of the plot has pH values close to neutral, within the range favorable for biological activities and the availability of fertilizing elements for plants. Only a small portion of the plot has acidic pH levels, ranging between 5 and 6.

## 3.4 Effect of Soil Phosphorus, Organic Carbon and pH on the Yield of Millet

The test results reveal weak relationships between phosphorus and grain, with correlation coefficients of r=0.317. While phosphorus shows a proportional relationship with grain weight but it is not statistically significant (*P*= .407). Consequently, there is no significant relationship between phosphorus and millet grain yield.

Similarly, the correlation test results indicate weak relationships between carbon and grain yield, with correlation coefficient of r=0.090. Although carbon demonstrates a proportional relationship with grain weight but not statistically significant (*P*=.817). Therefore, there is no significant relationship between carbon and millet grain and ear yields.



a b

**Fig. 4. Variation of soil pH according to the treatment (a) and spatial distribution (b) at the end of cropping**

Lastly, the test results show weak relationships between pH and grain, with correlation coefficients of r=0.065. While pH is proportional to the weight of the grains this relationship is not statistically significant (*P*=.865). Hence, there is no significant relationship between pH and millet grain yield.

### 3.5 Effect of Genotype on the Yield of Millet

The results of the statistical analysis revealed a significant difference in grain weight among millet varieties (ANOVA, *P*=0.03). Post-hoc comparison tests further demonstrated that this difference was particularly notable between the varieties ICVH 18 and PPB-SH (*P*=.043), as well as ICVH 18 and ICMV IS 89305 (*P*=0.046) (Fig. 5).

The observed differences in yield among the varieties ICVH18, PPB-SH, and ICMV IS 89305 underscore the significant impact of genotype on millet yield. This emphasizes the importance of genotype-specific adaptation to environmental conditions, productivity, and resilience against various constraints, as noted in prior studies [23].

Research has demonstrated that certain varieties exhibit greater efficiency in fertilizer uptake [17], and this efficiency can substantially influence yield outcomes, irrespective of the soil's fertilizer content. The inherent genetic characteristics of millet varieties play a crucial role in their performance, highlighting the need for tailored agricultural approaches based on specific genotypes for optimal productivity and resource utilization.

### 3.6 Variation in Grain Yield of Millet According to the Treatment

The statistical analyses, employing ANOVA, indicate a significant variation in grain yield among the treatments (*P*=.006). This variation is reflected in the means, with the highest yield observed in the SSB treatment at 1101 kg ha⁻¹, followed by BSC at 480 kg ha⁻¹, and the lowest yield in BSE at 317 kg ha⁻¹ (Fig. 6).

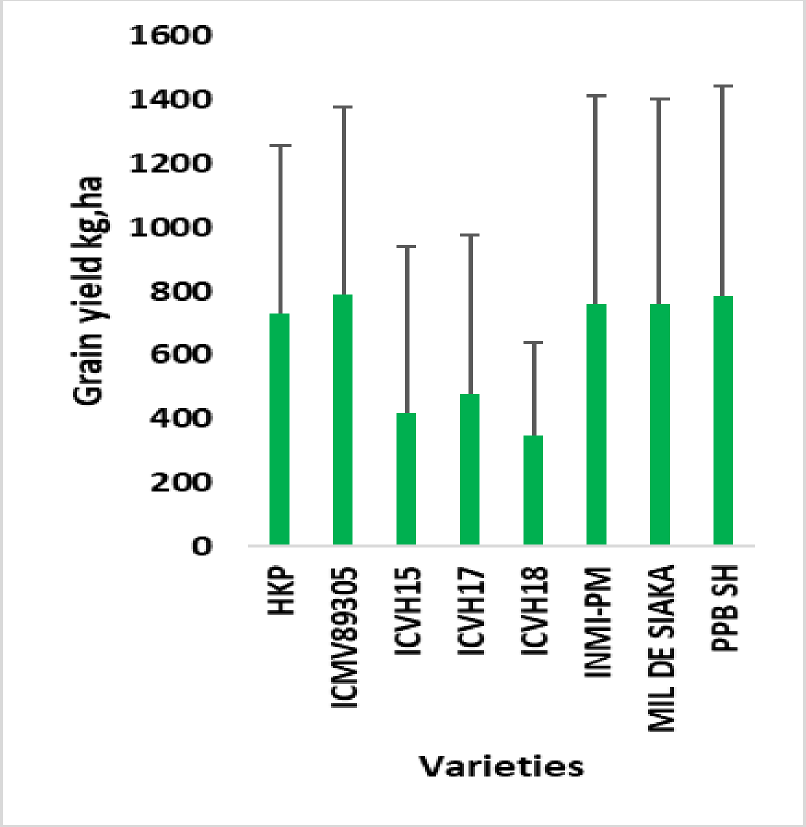


**Fig. 5. Variation of millet yield according to the treatment**

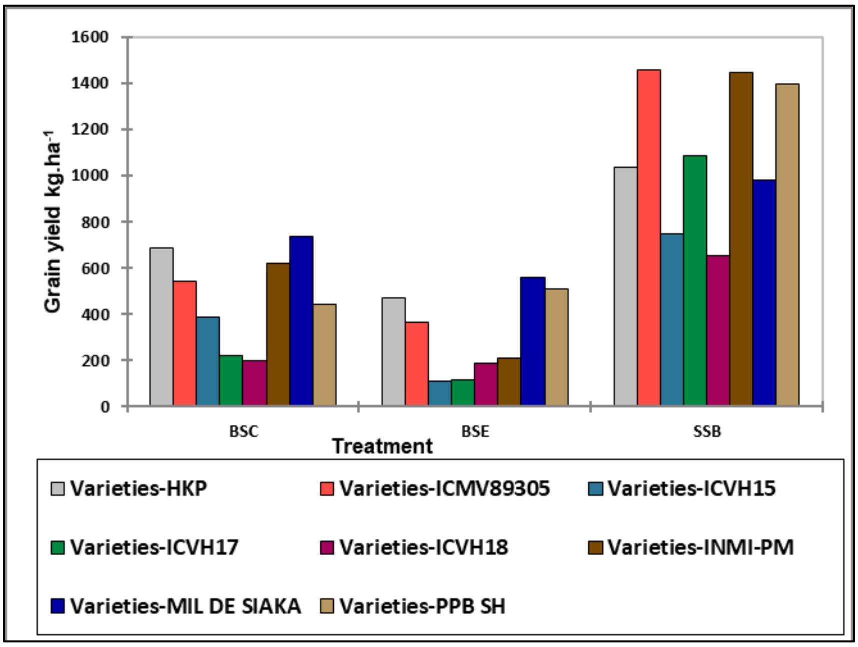


**Fig. 6. Effect of the interaction between treatment and varieties on the yield of millet**

The analysis of results based on different treatments indicated that the SSB treatment exhibited greater efficiency compared to the other two treatments. Irrespective of the millet varieties, the yield under SSB was consistently two to three times higher than that observed under BSC and BSE (Fig. 6).

The various treatments applied to seedlings exhibited a significant difference in grain yield, with SSB treatments yielding more than the BSC and BSE ball treatments. This disparity in yield may be attributed to potential drawbacks in seed ball technology, particularly concerning the quality of the sand, which might contain eggs or larvae of microorganisms that could adversely affect seedlings once placed in the seed holes. Additionally, the type of clay used may be compact, rendering it impermeable to water and hindering ball germination [24].

Furthermore, a higher number of seed holes were lifted and harvested in the SSB treatment compared to the other two treatments. The percentage loss in SSB (48%) was lower than the percentage losses (55% and 78%) for the BSC and BSE treatments, respectively. These losses can be explained by the compositions of the BSC and BSE treatments. In the BSC treatment, the presence of ash has a negative impact on the chemical and biological balance of the soil, leading to increased soil pH and limiting nutrient absorption for plants [25]. Regarding BSE, the presence of fertilizers might contribute to modifications in soil properties [26] and increase in crop yield, but the quantity present in the ball is likely insufficient to have a significant effect, especially in the case of our study where the soils are highly impoverished.

## 4. CONCLUSION

The present study confirms the deficiency of micronutrients in Sahelian soils and underscores their contributory role in diminishing crop yields. Addressing this challenge necessitates a combination of soil fertilization and plant breeding strategies. While enhancing soil fertility through conventional fertilization is a widely acknowledged approach, the development and promotion of crop varieties with lower dependence on fertilizers present an alternative avenue for sustainable agriculture.

This study sheds light on the nuanced effectiveness of seed balls as a sowing technology. While previous research has indicated positive effects in favorable conditions, our findings emphasize the context-dependent nature of this technology. Specifically, in situations of limited rainfall, conventional millet sowing methods outperform the use of seed balls. This discovery underscores the importance of considering environmental conditions when evaluating the efficacy of novel agricultural technologies.

In light of these findings, future breeding programs should incorporate an understanding of the diverse soil fertility states prevalent in the Sahel region before extending the developed varieties to real farming conditions. By accounting for these variations, breeders can ensure the successful adaptation and performance of crop varieties in the dynamic and challenging agroecological context of the Sahel.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. CILSS. Agricultural and pastoral suitability of soils in CILSS countries. AGRHYMET Regional Center (CRA). 2001;173.
2. Bationo A, Saïdou, K, Aykuk E. Soil fertility and environment for cereal production in the Sahelo-Sudanian zone and valorization of natural phosphates in Dossier: Soil fertility and environment: some tools, indicators and recent approaches. Cahiers Agriculture.1998:7.
3. Traore K, Toe AM. Capitalization of initiatives on good agricultural practices in Burkina Faso. Study report, MAHRH, Ouagadougou, Burkina Faso. 2008; 83.
4. Adamou KA. Characterization of the biophysical and sociotechnical contexts of decentralized cowpea trials in village lands in the Dosso and Maradi regions. Master's thesis II. Abdou Moumouni Niamey University, Faculty of Letters and Human Sciences, Department of Geography; 2020.
5. Loireau M, D'herbes J-M, Delabore E. Evolution and place of fallow land through a spatial analysis of resource-use interactions in the Nigerien agro-pastoral Sahel. Fallow in Tropical Africa. 1997;32-42.
6. CORAF/WECARD. Operational plan 2008-2012. Deploy innovative agricultural systems in West and Central Africa. Dakar, Senegal, Coraf/wecard. 2008:10.
7. Abasse T, Yaye A, Abdoul HZ, Adamou AI, ADAM T. Influence of Piliostigma reticulatum agro-forestry parks on the infestation of millet plants by floricultural insects and Coniesta ignefusalis (Hmps) (Lepidoptera pyralidae) in the Aguié zone in Niger. Journal of Applied Biosciences. 2013;66:5140-5146.
   Available:https://doi.org/10.4314/jab.v66i0.95011
8. Goudiaby MF, Sarr I, Sembeme M. Source of resistance in pearl millet varieties against stem borers and the car head miner. Journal of Entomology and Zoology Studies. 2018;6(1):1702-1708.
9. Hamadou M, Idrissa S, Mahamadou C, Oumarou S, Valentin K. Fodder potential of millet (*Pennisetum glaucum* (L.) R.Br.): literature review. Journal of Animal & Plant Sciences. 2017; 34(2):5424-5447.
10. JAICAF (Association for International Collaboration in Agriculture and Forestry of Japan). Cereals in Niger focus on millet and sorghum. 2009;117.
11. Soler CMT, Maman N, Zhang X, Masson SC, Hoogenboom G. Determining optimum planting dates for pearl millet for two contrasting environments using a modeling approach. The Journal of Agricultural Science.2008;146(4):445-459.
   Available:https://doi:10.1017/S0021859607007617
12. Modor Intelligence. Millet Market – Size, Demand and Consumption by Countries. Modor intelligence, India; 2022.
   Available:https://www.mordorintelligence.com/fr/industry-reports/millets-market.
   (Accessed on: 12/31/2023)
13. Nwankwo CI. Seed ball technology development for subsistence-oriented pearl millet production systems in Sahelian West Africa. PhD thesis University of Hohenheim, Germany; 2019.
   Available:http://opus.uni-hohenheim.de/volltexte/ 2019/1597/
14. Nwankwo CI, Herrmann L, Neumann G. Physical and chemical optimization of the seed ball technology addressing pearl millet under Sahelian conditions. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 2018;119(2): 67–79.
   Available:https://doi.org/10.17170/kobra-2019011596
15. Ndah H, Knierim A, Moussa H, Nwankwo CI, Herrmann. Farmers' perception on the effects of interactive training and on-farm testing of Seedball technology for enhancing adoption -Maradi region, Niger; 2020.
16. Moussa MB, Diouf A, Abdourahamane IS, Jangorzo NS, Mahamane A, Axelsen J, Ambouta J-MK. Soil Physicochemical Characteristics Under Different Ecosystems in Western Niger.

International Journal of Current Microbiology and Applied Sciences. 2015;8 (4):375–383.
Available:https://doi.org/10.5539/jas.v8n4p126

17. Gemenet DC, Leiser WL, Beggi F, Herrmann LH, Vadez V, Rattunde HF, Weltzien E, Hash CT, Buerkert A, Haussmann BI. Overcoming Phosphorus Deficiency in West African Pearl Millet and Sorghum Production Systems: Promising Options for Crop Improvement. Frontiers in Plant Science. 2016; 7:1389.
Available:https://doi.org/10.3389/fpls.2016.01389
18. Charreau C. Soils of tropical dry and dry-wet climatic areas of West Africa and their use and management: a series of lectures at the Department of Agronomy, Cornell University, Spring, Dept. of Agronomy, Cornell University, Ithaca, N.Y; 1974.
19. Tulina AS, Semenov VM, Rozanova LN, Kuznetsova TV, Semenova NA. Influence of moisture on the stability of soil organic matter and plant residues. Eurasian Soil Science. 2009;42:1241–1248.
Available:https://doi.org/10.1134/S1064229309110064
20. Wu H, Cui H, Fu C, Li R, Qi F, Liu Z, Yang G, Xiao K, Qiao M. Unveiling the crucial role of soil microorganisms in carbon cycling: A review. Science of The Total Environment. 2024;909:168627,
Available:https://doi.org/10.1016/j.scitotenv.2023.168627
21. Campbell, A. Recycling and disposal of wood ash. Tappi Journal; 1990.
Available:https://www.semanticscholar.org/paper/Recycling-and-disposing-of-wood-ash-Campbell/82a967eacf5faa26c21e326f21db1 c58eabe35b9
(Accessed on: 12/31/2023).
22. Demeyer A, Voundi Nkana JC, Verloo MG. Characteristics of wood ash and influence on soil properties and nutrient uptake: an overview. Bioresource Technology, 2001; 77:287–295,
Available:https://www.sciencedirect.com/science/article/pii/S0960852400000432
(Accessed on: 12/31/2023).
23. Soumana I. Diagnostic assessment of millet and sorghum production in Niger. Initiative for the development of millet and sorghum in West and Central Africa: downstream management. Journal of Plant Breeding. 2001;1(4):347-440.
24. FUMA Gaskiya (Federation of Producers' Unions of Maradi). Seed ball manufacturing technique within the Federation of Producers' Unions of Maradi under the SMIL.Maradi project. 2020;8.
25. Delvaux C. Wood ash in the garden, multi-use. Garden relaxation n°141. 2020; 66.
26. Pernes-Debuyser A, Tessier D. Influence of fertilizing materials on soil properties. Case of the 42 INRA plots in Versailles. Soil Study and Management. 2022;9(3): 177-186.

---

*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*https://www.sdiarticle5.com/review-history/111620*