



Optimizing maize productivity in the Sahel region through the incorporation of exotic shrub species and reduced mineral fertilization

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Abstract Smallholder farming systems in the Sahel face severe vegetation loss and declining soil fertility, which threatens food security and livelihoods. While native shrubs and trees have traditionally been used as mulch, some exotic species have recently gained attention due to their faster decomposition rates and potential to increase crop productivity. Therefore, identifying optimal combinations of mulch species and fertilizer inputs is essential for developing low-cost, sustainable soil fertility strategies suited to Sahelian conditions. A two-year field study (2023–2025) at the Farako Agricultural Research Station in Mali compared the decomposition rates and effects

on maize productivity of two exotic species (*Gliricidia sepium*, *Leucaena leucocephala*) and three local species (*Parkia biglobosa*, *Vitellaria paradoxa*, *Guiera senegalensis*). Decomposition was modeled using an exponential regression to estimate 50% and 100% decomposition. Maize grain yield and dry matter responses were assessed under pruning applications with or without mineral fertilizer. The results showed that *Leucaena leucocephala* and *Gliricidia sepium* significantly improved maize productivity, achieving yields comparable to or greater than those with full mineral fertilization applied alone or with half the recommended fertilizer rate. In contrast, *Parkia biglobosa* and *Vitellaria paradoxa* reduced maize yields compared to the control. These findings demonstrate the strong potential of *Leucaena leucocephala* and *Gliricidia sepium* to enhance productivity while reducing fertilizer dependence. Future research should investigate the long-term impacts of these species on soil restoration and evaluate the potential of slower-decomposing local species such as *Guiera senegalensis* and *Piliostigma reticulatum* across diverse agroecological zones in partnership with smallholder farmers.

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Introduction

Declining soil fertility in sub-Saharan Africa is one of the main explaining reasons for low agricultural production, reinforcing food insecurity (Gupta 2019; Kirui et al. 2021). Over one-third of region's soils are rapidly degrading due to poor soil management and unsustainable agricultural practices, such as nutrient mining and limited soil and water conservation (Niemeijer and Mazzucato 2002; Gianoli et al. 2025). The problem is particularly acute in the Sahel region, where land degradation – driven by soil erosion and declining soil quality, directly threatens agricultural production. Erratic and insufficient rainfall further exacerbates these challenges (Doso 2014). Since the 1980s, Mali's rapidly growing population has intensified pressure on land. Coupled with the breakdown of traditional agroforestry parkland systems and the spread of unsustainable farming techniques, this has led to a marked decline in soil health and crop yields (Sanogo et al. 2023).

To address the problem of low soil fertility and declining yields, farmers apply mineral fertilizers, particularly for maize, which accounts for 34% of total cereal production in Mali (DNA 2024). However, fertilizers are costly for smallholders (Diacono and Montemurro 2011) and do not always guarantee sufficient yield even for self-subsistence (Massai et al. 2020). An alternative to mineral fertilizers is the use of locally available natural resources such as improved fallows, shrub and tree residues, green manure, and plant residues for composting. These organic amendments are a key source of nutrients for the soil (Diouf et al. 2008; Ba et al. 2014; Fairhurst et al. 2015; Massai et al. 2020). A recent meta-analysis provided strong evidence application of tree and shrub residues significantly improved soil chemical, biological, and physical properties, ultimately leading to higher yields (Roessler et al. 2025).

The Sahel region is home to a variety of native shrub and tree species that are traditionally used as mulch in smallholder farming systems (Yélérou et al. 2014). These species vary widely in their residue quality and decomposition – or mineralization – rates. These rates can significantly influence nutrient release patterns and crop productivity. In the Sudanian zone of Mali, shea (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) trees dominate parkland systems, providing organic matter through the

decomposition of above-ground biomass (Kelly et al. 2022). Shrub species, such as *Guiera senegalensis* are also commonly found in the area (Diouf et al. 2021). Although agroforestry studies have examined the advantages of integrating trees in cropping systems and established the importance of species selection, limited research exists on the biomass decomposition rates of locally available species and their impacts on crop productivity, especially from perennial species (Nord et al. 2022; Sileshi et al. 2025).

Unlike in other tropical regions where fast-decomposing species such as *Leucaena leucocephala* and *Gliricidia sepium* are commonly used, native shrub and tree species with similarly rapid mineralization rates are lacking in the Sahel (Diouf et al. 2008; Likoko et al. 2018; Ouedraogo et al. 2023). Most readily available local species are recalcitrant, releasing nutrients slowly and often requiring supplementation with mineral fertilizers to meet crop nutrient demands. This has led to the widespread assumption that mulching alone is insufficient to sustain yields (Bayala et al. 2012). However, introducing fast-decomposing exotic species such as *L. leucocephala* and *G. sepium* could shift this paradigm. Their residues decompose quickly and release nutrients more readily, potentially reducing or even eliminating the need for additional fertilizer inputs (Srinivasa Rao et al. 2011). This opens new possibilities for low-input fertility management strategies in Sahelian farming systems.

Although still scarcely found, *Leucaena leucocephala* and *Gliricidia sepium* have been gaining increasing interest in the Sahel in the recent decades (Bayala et al. 2011). Fast-decomposing species release nutrients quickly, while species high in lignin and polyphenols break down slowly and contribute to longer-term improvements in soil structure and organic matter (Halde and Entz 2016). Research from other regions suggests that combining these slow-decomposing mulches with small amounts of mineral fertilizers can improve nutrient synchronization and overall crop performance (Mweta et al. 2007). However, there is still limited knowledge about which plant species are most effective as mulch under Sahelian conditions, especially when used alongside mineral fertilizers (Nord et al. 2022).

Identifying the best combinations of mulch species and fertilizer rates is crucial for developing affordable, sustainable soil fertility management practices

suited to the region. To address this knowledge gap, a study was conducted at the Farako Agricultural Research Station in Mali to assess how prunings from five woody species affect maize growth and yield. The objectives were: (i) to determine how quickly each tree and shrub species decomposes over time, and (ii) to evaluate the effects of applying prunings alone or combined with half of the nationally recommended fertilizer rate on maize performance. The findings aim to provide practical guidance for small-holder farmers in the Sahel to enhance soil fertility, boost crop yields, and improve livelihoods.

Material and methods

Study area

This research was carried out at the Institut d'Economie Rurale, Farako Agricultural Research

Station (11.21°N, -5.48°W) in southern Mali in 2023 and 2024 (Fig. 1). The bioclimatic zone is South Sudanian (Mali/USAID 1983). Average annual rainfall at this site between 2000 and 2024 was 1224 mm, during which the rainy season extends from May to September with average monthly precipitations between 100 and 300 mm (data not shown). The average annual temperature is between 24 and 32 °C. The area's natural vegetation consists of wooded savannah and gallery forests along watercourses. The main species encountered are *Isoberlini adoka*, *Parkia biglobosa*, *Vitellaria paradoxa*, *Daniella oliveri*, *Guiera senegalensis*, *Pterocarpus erinaceus*, *Combretum glutinosum* and *Andropogon gayanus* (Sacande et al. 2016).

A preliminary soil analysis (Supplementary material) of the test site determined the soil texture as sandy-loamy with 86% sand in the first 20 cm of soil and 84% sand for 10% silt from 20 to 40 cm depth. Clay content ranged from 2% at the surface to 6%

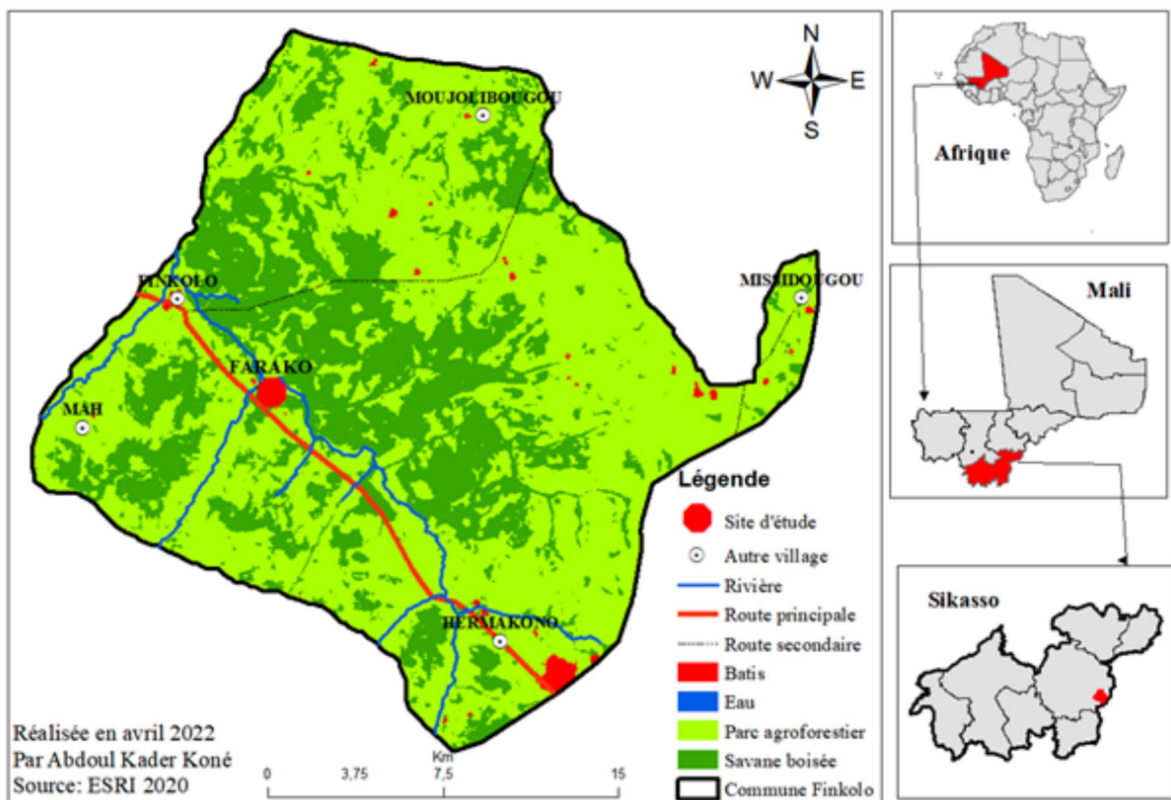


Fig. 1 Location of the Farako agricultural research station in Mali

in depth. The average soil pH was evaluated at 5.9; with an average soil organic carbon content of 0.65% and a total nitrogen content of 0.03%, which is representative of soils in the region (Jimenez et al. 2025). The average assimilable phosphorus content was 11.22 ppm at the start of the study, with an average effective CEC of 5.56 cmol per kg of soil.

Experimental design and management

The experiment was conducted over two consecutive seasons in 2023 and 2024. Treatments were kept on the same plots and were not reassigned from one year to the next. The experimental set-up consisted in 33 plots of 6 m×4.8 m each, divided into Fisher blocks on which 11 treatments were repeated three times.

The established treatments (Table 1) included one control, five treatments with the incorporation of the selected species prunings and five other treatments with the incorporation of prunings combined with half dose of the recommended mineral fertilisation. The nationally recommended rate of mineral fertiliser for maize consists of 100 kg ha⁻¹ of Complexe cereale ® (Toguna agro-industrie, NPK 17–17-17) and 150 kg ha⁻¹ of urea ® (Toguna agro-industrie, 46% N) (IFDC 2018). The species prunings were applied at a 3 t ha⁻¹ rate once each year three days before the sowing of maize and incorporated in the first 15 cm of the soil. Mineral fertilization was applied respectively 15 and 45 days after germination. The application of

mineral fertilizer was conducted along the plants line on a 7 cm shallow row where the fertilizer was homogeneously spread before closing the row.

Maize (*Zea mays* variety *Obatanpa* or *Dembanyuman*, Coulibaly 1998) was sown mid- and early July in 2023 and 2024 respectively on all the study plots with a spacing of 80 cm between rows and 40 cm between each plant.

The following parameters were monitored annually over the two years of the study:

- Maize vegetative growth: two variables were monitored, namely the height and collar diameter of maize plants in centimetres. These observations were made on 5 consecutive plants on the two central rows of each plot at 30 (germination stage), 45, 60 (vegetative stage) and 75 days (maturing stage) after the sowing date.
- Yield: dry matter weight, i.e. above-ground biomass, and grain weight were measured for each plot on the two central lines.

Species decomposition trial

A Fisher block design was used to study the decomposition of the five woody species in three replicates over two years. For each species and repetition, four holes corresponding to the four sampling periods were dug. Shrub materials were sourced from either

Table 1 Description of treatments studied in the crop productivity trial

Abbreviated names used in the article	Treatments components	
	Tree and shrub prunings	Mineral fertilisation
Control	None	100 kg ha ⁻¹ of NPK 17–17-17 150 kg ha ⁻¹ of urea (46% N)
<i>L. leucocephala</i>	<i>Leucaena leucocephala</i> (Fabaceae)	None
<i>G. sepium</i>	<i>Gliricidia sepium</i> (Fabaceae)	
<i>P. biglobosa</i>	<i>Parkia biglobosa</i> (Fabaceae)	
<i>V. paradoxa</i>	<i>Vitellaria paradoxa</i> (Sapotaceae)	
<i>G. senegalensis</i>	<i>Guiera senegalensis</i> (Combretaceae)	
<i>L. leucocephala</i> + 50%MF	<i>Leucaena leucocephala</i>	50 kg ha ⁻¹ of NPK 17–17-17
<i>G. sepium</i> + 50%MF	<i>Gliricidia sepium</i>	75 kg ha ⁻¹ of urea (46% N)
<i>P. biglobosa</i> + 50%MF	<i>Parkia biglobosa</i>	
<i>V. paradoxa</i> + 50%MF	<i>Vitellaria paradoxa</i>	
<i>G. senegalensis</i> + 50%MF	<i>Guiera senegalensis</i>	

the surrounding areas where *P. biglobosa*, *V. paradoxa* and *G. senegalensis* grow naturally, or from the research station where *G. sepium* and *L. leucocephala* had been planted. Collected prunings consisted mainly of leaves and stems with a diameter inferior to 4 mm. Litter bags were filled with 20 g of shade-dried prunings and buried at a 15 cm depth from the soil surface.

Leaf decomposition was monitored by collecting one litter bag from each plot every 4 weeks from incorporation till week 16. Collected litter bags were cleaned of debris and oven-dried at 70 °C until a constant dry weight was reached.

Mass loss during decomposition was assessed using the following formula:

$$\text{ing dry weight} = Pt/Pi \times 1$$

Pt: average dry weight at time *t*.

Pi: initial dry weight.

Data analysis

Statistical analyses were carried out using R Core team software (2024, version 12.1), while descriptive analyses were performed in Excel (Microsoft Corporation 2018, version 16.0).

Decomposition analysis

Decomposition analysis was conducted first by fitting an exponential regression model to the observed data using the following formula for decay:

$$N(t) = N_0 e^{(-kt)}, \text{ where}$$

N(t) is the amount of litter remaining after time *t*,
*N*₀ is the initial amount (20 g in this experiment),
k is the decay constant.

Predictions were then estimated using the modelled curves to calculate the time needed to reach 50% (*t*₅₀) and 100% (*t*₁₀₀) decomposition. ANOVA tests were performed to test for differences between the predicted *t*₅₀ and *t*₁₀₀ values of each species using years as repetitions. A correlation analysis was also performed between the modelled *k* rates of each species and grain yield and dry matter of the corresponding treatments.

Productivity and growth

Statistical analyses were carried out to compare each treatment independently. When necessary, biomass yield data were transformed using the *boxcox* function in the “MASS” package. Treatments were then categorized by fertilization type (control with 100% MF, prunings alone, and prunings combined with 50% MF) and by species type (control with no-pruning, *L. leucocephala*, *G. Sepium*, *P. Biglobosa*, *V. Paradoxa*, and *G. Senegalensis*).

For each yield variable, a multiple linear regression test was performed using the *lmer* function in the “lm4” package to identify the main parameters affecting grain and dry matter yields. Treatment variances were compared for each year. The models included grain or biomass yield as a variable parameter, treatment/fertilization type/species type as a fixed parameter and repetition as a random parameter.

For maize plant height and diameter analyses, a Kruskal Wallis test *kruskal.test* function of the (“stats” package) was used to compare treatments for each observation date in each year. The *kruskal* function in the “agricolae” package was used to determine the statistical groups.

Results

Decomposition rate of species prunings

Over the two years of the experiment, prunings from *G. sepium* and *L. leucocephala* decomposed at a significantly faster rate than prunings from *P. biglobosa*, *V. paradoxa* and *G. senegalensis*. Indeed, the half-life decay threshold – i.e. time by which the litterbags’ weight had decreased by half – was reached significantly earlier for these 2 species than for the other ones (Fig. 2). This threshold was reached within 23 and 32 days respectively for *G. sepium* and *L. leucocephala*, whereas it required 67.5 days or more for the 3 other species to reach it. *G. senegalensis* prunings were the slowest to decompose, although not statistically slower than *P. biglobosa* and *V. paradoxa*. For a full decomposition, the modelled exponential decay predicted that it would require 36 weeks for *G. sepium* prunings, 50 for *L. leucocephala* prunings, and over 105 weeks for the 3 other species. Lastly, grain yield was significantly positively correlated

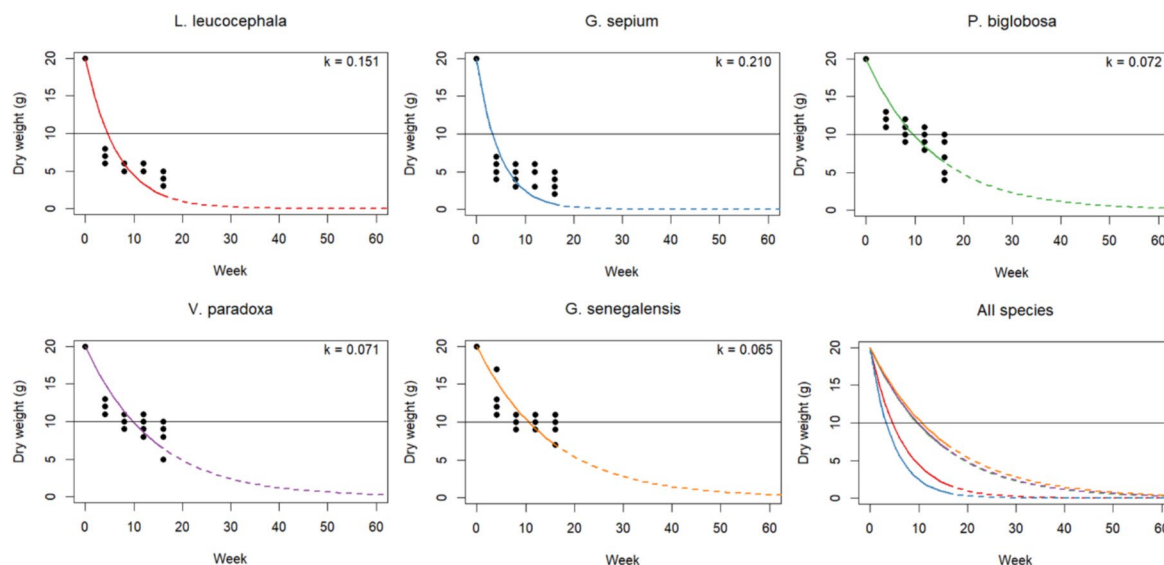


Fig. 2 Decomposition curve of tree and shrub prunings with an exponential regression. Horizontal line represents the half-decay threshold set at 10 g. Dotted line represents statistical predictions of decomposition rate over time

with the predicted decomposition rates of the species (k values) ($R=0.58$, $p<0.05$), and so was biomass yield, to a stronger extent ($R=0.65$, $p<0.05$).

Effects of species prunings on maize growth

The average height of maize plants 75 days after sowing was 160 cm and 163 cm in 2023 and 2024 respectively. The average diameter of maize plants was 1.52 cm in 2023 and 1.73 cm in 2024. Analysis of variance revealed a significant difference both between observation dates and for the two trial years. In 2023, treatments *G. sepium* and *L. leucocephala*+50%MF showed a height similar to the control, while treatment *V. paradoxa* had a significantly lower growth than the control. In 2024, *G. sepium* treatments with or without fertilization and *L. leucocephala*+50%MF had a statistically higher height than the control. Conversely, treatments *P. biglobosa*, *V. paradoxa* and *G. senegalensis* showed a lower height than all other treatments including the control. For all observation dates except the maturation stage (75 days after sowing), maize plants were taller in 2023 than in 2024.

Plant diameter differed significantly between each observation and each year. In 2023, treatments *G. sepium*, *L. leucocephala*+50%MF and *G. sepium*+50%MF performed similarly to the control,

while the other treatments showed weaker growth – with treatment *V. paradoxa* showing the lowest growth compared to every other treatment. At the end of the vegetative period (60 to 75 days after sowing), treatments *L. leucocephala* and *V. paradoxa*+50%MF also showed similar results to treatments *G. senegalensis*, *L. leucocephala*+50%MF, *G. sepium*+50%MF and control. In 2024, across all observations, results for plant diameter were identical to those for plant height.

Comparison analysis of the averages by type of species used showed differences at each observation (Fig. 3), with *P. biglobosa*, *G. senegalensis* and *V. paradoxa* in 2023 and 2024 statistically lower in height than the control, *L. leucocephala* and *G. sepium*. In 2024, *L. leucocephala* and *G. sepium* showed the strongest growth, statistically superior to all other species and to the control. The same results were obtained for maize plant diameter.

Plant height according to categorization by type of fertilization (control with 100% mineral fertilization rate, prunings+50% fertilizer rate, and prunings alone) differed statistically between groups at each observation, with a clear distinction in 2023 as control > prunings+50%MF > prunings alone. In 2024, a similar trend was observed, but with only lower growth in the prunings-alone treatments. Maize plant diameter also varied according to fertilization type.

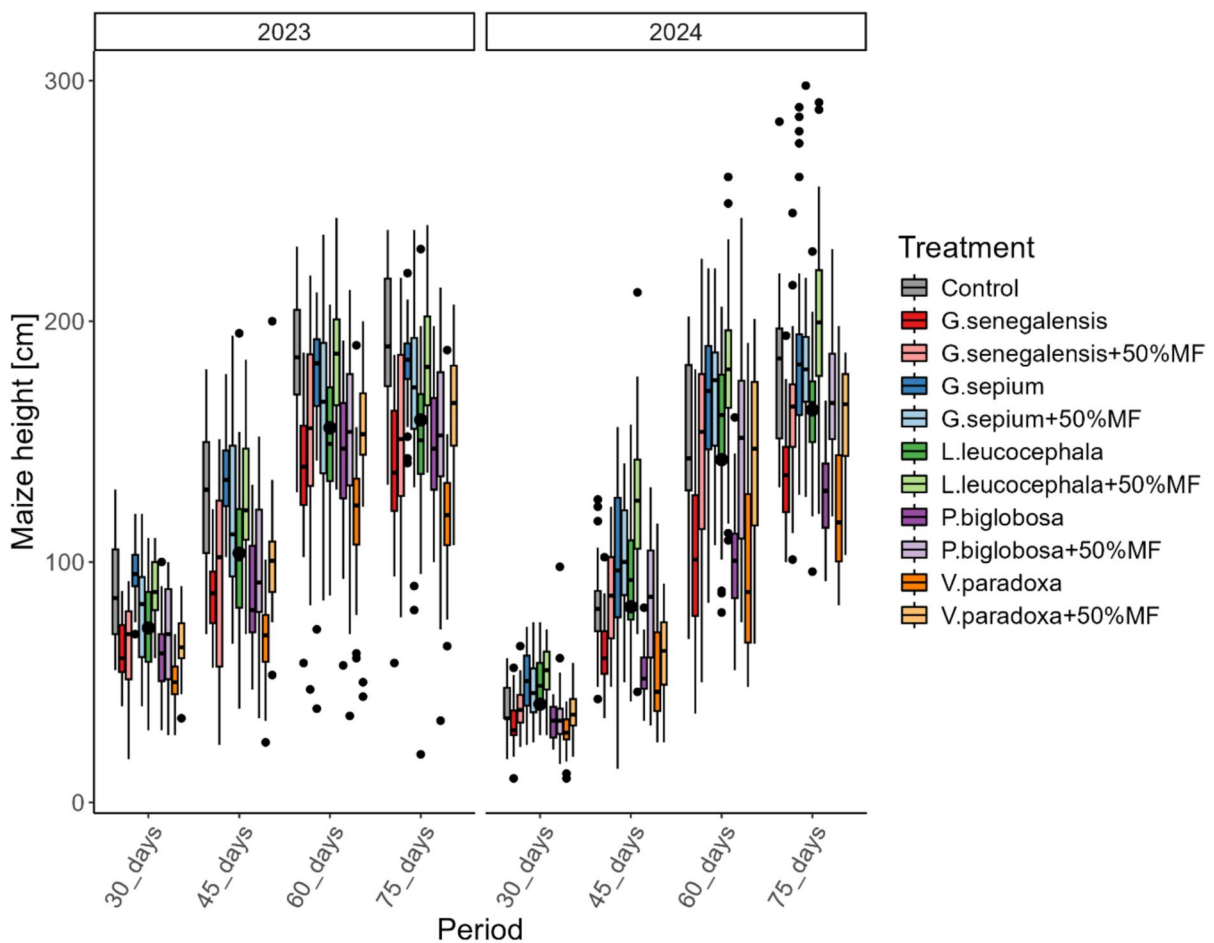


Fig. 3 Maize height in cm per type of prunings incorporated in 2023 and 2024

In 2023, the control treatment obtained the largest diameter for each observation, followed by prunings + 50%MF, then prunings alone. In 2024, observations at 30 days after sowing showed no significant differences between treatments. For observations at 45 and 60 days after sowing, the control and prunings + 50%MF treatments showed identical diameter widths, while observations at 75 days after sowing showed larger diameters for the prunings + 50%MF treatments compared with the control and prunings alone ($\chi^2 = 10.71$, $p < 0.05$).

Effect of species prunings on maize dry matter yield at harvest

The average dry matter yield in the trial was 997 kg/ha in 2023, compared with 1132 kg/ha in 2024. In

2023, dry matter yields did not differ statistically between treatments ($p = 0.231$), however the highest average biomass yields were obtained in plots with treatments *G. sepium* (average yield 2026 kg/ha), control (1448 kg/ha) and *L. leucocephala* + 50%MF (1390 kg/ha, Fig. 4). The lowest yields were observed for treatment *V. paradoxa* (511 kg/ha). In 2024, only treatments *V. paradoxa* and *G. senegalensis* had significantly lower dry matter yields than the control ($F = 3.929$, $p < 0.05$). The best yields were obtained in the *L. leucocephala* + 50%MF (2408 kg/ha). Most yields increased between 2023 and 2024, except for treatments control, treatments *G. sepium*, *P. biglobosa*, *G. senegalensis* applied alone, and treatment *V. Paradoxa* + 50%MF. Treatments of *L. leucocephala* with or without mineral fertilization had the highest rate of increase; 104% and 73% respectively.

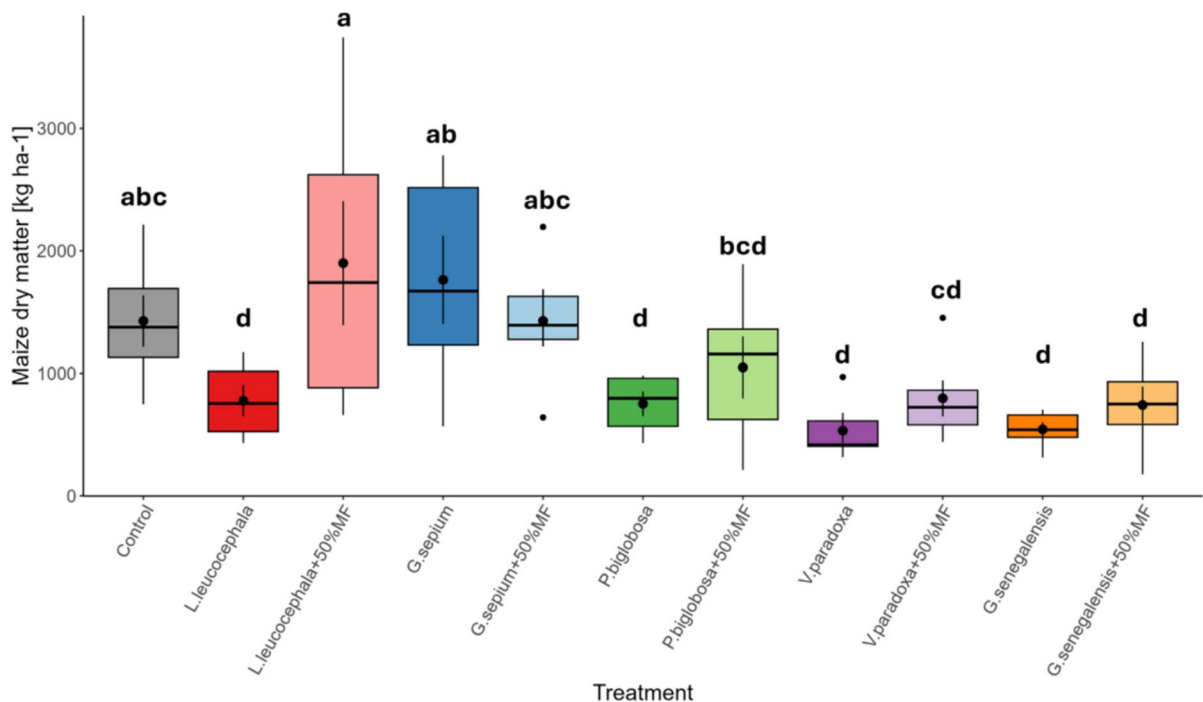


Fig. 4 Average maize dry matter yield (kg/ha) per treatment between 2023 and 2024. Letters represent statistical grouping from LSD post-hoc test

Comparison of yield averages according to the type of fertilization categories showed no statistical difference in 2023 and 2024 ($p=0.272$ and $p=0.092$ respectively). Conversely, comparison of dry matter yield value means according to species type indicated lower yields for *P. biglobosa*, *V. paradoxa*, and *G. senegalensis* (each with or without mineral fertilization) compared to the control over the two years ($F=4.37$, $df=5$, $p<0.001$). While in 2023 the effect of species type on yield was not significant ($p=0.0829$), in 2024 *V. paradoxa* and *G. senegalensis* had statistically significantly lower yields than all other treatments, except than *P. biglobosa*.

Effects of species prunings on maize grain yields

In 2023, yields obtained from treatments *G. sepium* alone; *L. leucocephala*+50%MF; *G. sepium*+50%MF; and *P. biglobosa*+50%MF were statistically equal to the yields obtained in the control treatment. This 100% MF treatment resulted in the highest maize grain yield, with an average of 2995 kg/ha. In 2024, yield obtained from treatment

L. leucocephala+50%MF was the highest, while still being statistically equivalent to the control treatment and treatment *G. sepium*+50%MF. Incorporation of *L. leucocephala* prunings with and without mineral fertilizer resulted in yield increases of 8% and 39% between 2023 and 2024 respectively. On the other hand, yield reductions ranging from 5 to 36% were observed for the control treatment, as well as for treatments *P. biglobosa*, *V. paradoxa* and *G. senegalensis*, each with and without mineral fertilization. Treatment *V. paradoxa* alone obtained the lowest yield both in 2023 and 2024 with an average of 578 and 367 kg/ha respectively (Fig. 5).

When comparing treatments per species (applied with and without mineral fertilization), in 2023, only *G. sepium* treatments obtained yields statistically equal to the control. In 2024, yields did not differ statistically either according to the type of species used as prunings or compared with the control ($F=2.268$, $df=5$, $p=0.07$). When comparing treatments based on their mineral fertilization inputs (100%MF, 50%MF or no MF), yields were statistically higher with 100%MF (control) followed by

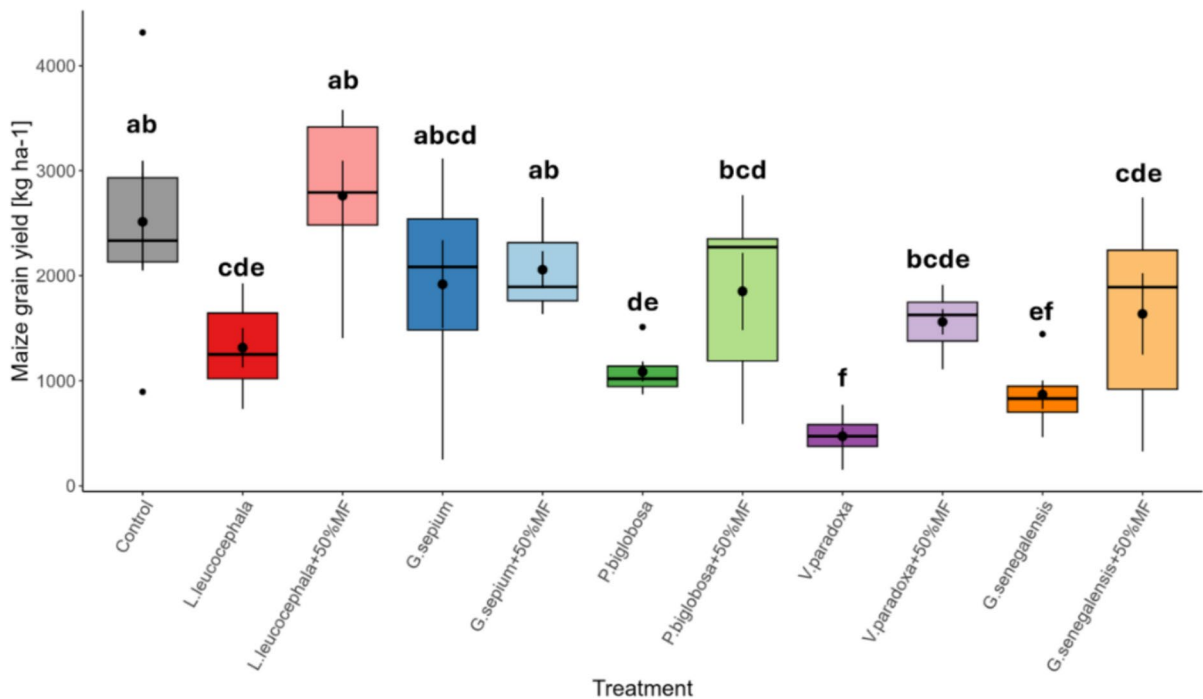


Fig. 5 Average maize grain yields (kg/ha) per treatment between 2023 and 2024. Letters represent statistical grouping from LSD post-hoc test

treatments including 50%MF (Anova, $F=7.575$, $df=2$, $p<0.005$). However, no such distinction could be made in 2024, as average yields did not differ between 100%MF, 50%MF or no MF.

Discussion

Effect of pruning species on maize growth and yield parameters

The results provide compelling evidence that using prunings of some of the shrub species (*L. leucocephala* and *G. sepium*) can achieve yields equivalent to a full rate of mineral fertilizer. They resulted in both better grain and dry matter yields, as well as a growth rates similar or even superior to the control treatment with a 100%MF rate. From one year onto the next, *L. leucocephala* with or without mineral fertilizer obtained the highest rate of increase in grain and dry matter yields. These results are similar to Likoko et al. (2018), who obtained a significant increase in maize yields with the addition of *L. leucocephala*

prunings, compared with the control without prunings. These results are also in line with Diouf et al. (2008) and Ouédraogo et al. (2023), who obtained a greater than 100% increase in maize yields with mineral fertilization combined with different doses of *G. sepium* prunings, compared to a control without prunings. Conversely, treatments based on the addition of *P. biglobosa* and *V. paradoxa* prunings alone did not result in higher yields or better maize growth than the control treatment, and on the contrary showed average yields respectively 50% and 80% lower than the control for each of the two trial years for *P. biglobosa* and *V. paradoxa* treatments without fertilization.

The lower yields obtained with the addition of these species in comparison with *L. leucocephala* and *G. sepium* can be first explained by different decomposition parameters. Several chemical parameters of shrub and tree residues – here fresh leaves – are indeed known to play an important role in decomposition, including C:N ratio as well as lignin content (Tian et al. 2007). The observed and predicted times of decomposition for the five different species of this study can clearly be differentiated into 2 groups.

Exotic species *L. leucocephala* and *G. sepium* decomposed significantly faster than local species *P. biglobosa*, *V. paradoxa*, and *G. senegalensis*. A comparison between values found in literature for these five species suggests that although *L. leucocephala* and *G. sepium* do not present the most optimal values to allow for a fast decomposition, they however combine a balance of C:N ratio and lignin:N ratio which enables both increased soil biological activity and fast degradation, and thus, as observed in this study, supporting higher yields (Bayala et al. 2003; Ba et al. 2014; Adekiya et al. 2018).

On the other hand, the observed yield reductions with *P. biglobosa* and *V. paradoxa* could also be explained by an allelopathic effect inhibiting seed germination. These negative interactions have been observed on grain millet yield as well as on cowpea seed germination and growth (Bayala et al. 2003; Aleem et al. 2014). Indeed, Bayala et al. (2003) noted a 33% drop in grain millet yield for *P. biglobosa* and a 19% to 37% drop in sorghum germination for *V. paradoxa* and *P. biglobosa* respectively when seeds were brought into contact with leachates of each of these species. Aleem et al. (2014) also found a clear inhibition effect of *P. biglobosa* and *V. paradoxa* on cowpea seed germinability, which was stronger than other tested tree species.

Other decisive parameters must still be considered when reflecting on prunings decomposition and their effects on yields. The positive correlation between maize grain and biomass yield and predicted k values found in this study highlights the critical role of aligning the application time of the fresh leaves to the nutrient needs of the crops at critical growth stages including flowering and grain filling (Ssemugenze et al. 2025). If keeping the same application time, the presented findings suggest that *L. leucocephala* and *G. sepium* decomposition dynamics would be the best aligned to maize nutrient needs compared to other tested species. However, combining exotic and local species such as *G. senegalensis* into treatments could also enable the release of nutrients into the soil both early and later during the growing season, potentially improving grain and dry matter yield better than when applied individually. This approach would therefore contribute to restoring soil fertility in the long term. Lastly, residue decomposition is strongly influenced by climatic factors such as rainfall, solar radiation, potential evaporation, and humidity. As

underlined by Tian et al. (2007), the same species may decompose at different rates across different agroecological zones. This is particularly relevant for a country such as Mali and the larger Sahel region, which covers multiple agroecological zones. Different climate conditions would also impact the productivity of the trees themselves and the availability of residues for farmers, as observed by Doumbia et al. (2020) for *G. sepium* in Mali.

Interannual variation

The inter-annual variation in maize yields and growth can be explained first and foremost by the amount of precipitation, and therefore water available for the crops. Indeed, total rainfall during the maize -growing period was 19% higher in 2024 than in 2023, with a total of 1296 mm in 2023 for 1592 mm in 2024. In addition, the early sowing of maize in 2024, fifteen days before the sowing in 2023, enabled crops to benefit from more rainfall during key development stages. For example, total rainfall in July was 136 mm in 2023 compared to 204 mm in 2024, while in September 2023 the rainfall reached 208 mm against 326 mm in September 2024.

Effect of pruning species combined or not with nitrogen fertilization on maize yield parameters

During the second year of the study, statistically equal yields were obtained between the 100%MF control, the combination of treatments with 50%MF and the combination of treatments without mineral fertilization. This can be explained by the decomposition and mineralization of the prunings, which compensated for the reduction or absence of mineral fertilization. A similar pattern was observed for the maize growth, although the compensation of the 50%MF treatments was mainly observed during the maize maturing stage, whereas the prunings alone did not compensate for height and diameter, as opposed to the grain yields. Lastly, the fertilization type had no effect on maize dry matter yields, for which the variation was mainly attributed to the plant species used for mulching.

These results contradict those of Kuntashula et al (2004), who obtained better yields with mineral fertilization combined with the use of manure compared to the addition of *G. sepium* leaf biomass. However,

this study also demonstrated a positive effect of *G. sepium* prunings compared to mineral fertilization alone, suggesting that this species may be a strong potential alternative to the use of mineral inputs.

Conclusion, recommendations and outlook

This comparative study highlighted the strong potential of the exotic species *Leucaena leucocephala* and *Gliricidia sepium* to maintain or enhance maize productivity in the Sahel region while reducing the reliance on mineral fertilizers. Applying prunings from these species alone produced maize yields comparable to those achieved with full mineral fertilization. Moreover, combining prunings with a reduced amount of mineral fertilizer tended to result in even higher yields than those obtained with the nationally recommended fertilization rate. In contrast, the local species *Parkia biglobosa* and *Vitellaria paradoxa* negatively impacted maize productivity, resulting in lower yields than the control treatment without pruning application. Future research should first focus on the impact of *Leucaena leucocephala* and *Gliricidia sepium* on soil characteristics to investigate their potential for soil restoration. Additionally, comparative experiments should include other local species with slower decomposition rates such as *Guiera senegalensis* and *Piliostigma reticulatum* should also be included in such comparative experiments to explore how their potential could be leveraged more effectively. This approach could also be repeated with other important cereal crops and in different agroecological zones across the Sahel to gain further understanding of crop responses to combined fertilization under different conditions. Such investigations should be conducted in partnership with smallholder farmers and organizations to facilitate the adoption of the best identified practices and knowledge exchange.

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Data availability Data is available upon request.

Declarations

Competing interests The authors declare no competing interests.

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