Effect of *Faidherbia albida* (Del.) Chev. and *Elaeis guineensis* (Jacq) on upland rice growth and yield.

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Keywords: *Faidherbia albida* (Del.) Chev., *Elaeis guineensis* (Jacq), growth, Rice, yield

Submitted 22/03/2024, Published online on 05/06/2024 in the *Journal of Animal and Plant Sciences (J. Anim. Plant Sci.) ISSN 2071 – 7024*

1 ABSTRACT

This study aims to determine the influence of *F. albida* and *E. guineensis* on rice growth and productivity. In fact, the effect of these two woody species on the physiology and yield of upland rice was assessed. Thus, a total of 40 yield squares with 20 in each sampling distance (under and outside the canopy of trees) was installed to evaluate rice performance. In each square, the height of the stems, the number of tillers, the biomass and the yield were evaluated. These data were analysed using R software version 3.4.2. These analyses showed that the sampling distance and the species had significant influences ($p < 0.05$) on all the parameters measured, except for tillering and yield, on which the species effect has no influence ($p > 0.05$). The rice grown under *F. albida* trees had higher height (105.13 cm) than those in *E. guineensis* (90.75 cm). Sampling distance had affected significantly the height of rice. Rice grown under canopy had higher height (105.13 cm) than those outside canopies (84.36 cm) of *F. albida*. For *E. guineensis,* the height under and outside canopy were 90.75 and 78.42 cm. The rice performed better under than outside canopy of these two species, because the conditions for its development.

2 INTRODUCTION

In Senegal, the decline in yields of staple and industrial crops reflects declining soil fertility and unstable climatic conditions (Diack *et al.,* 2017). According to (Robertson, Gross, and Hamilton 2014), a major cause of reduced agricultural productivity in the tropics is soil depletion, both chemical and physical, leading to a loss of nutrients and organic matter reserves. Inputs such as plant residues, compost or manure can affect yields regardless of the initial organic matter content of the soil (Oldfield *et al.,* 2015), mineral fertilizers and irrigation (Oldfield *et al.,* 2015; Hatfield, Sauer, and Cruse 2017). Therefore, to solve this problem, in the semi-arid regions of West Africa, most farmers consider trees like integral part of the cropping system. Over the centuries, they have maintained the traditional land use system of "agroforestry parks" where trees dot the cultivated or recently ploughed fields (Boffa 2000; Guimbo *et al.,* 2011). Lower Casamance farmers are no exception to this rule. In this area, *F. albida* and *E. guineesis* have always been associated with upland rice production. It is therefore necessary to better understand the interactions between the different components of this tree/soil/annual crop system, by considering each resource likely to be impacted by the presence of the tree (Clermont-Dauphin *et al.,* 2019). The overall objective of this study is to contribute to the understanding of the influence of these types of parks on the growth and yield of upland rice with the research.

3 MATERIAL AND METHODS

3.1 Study area: Located between 12°33'north latitude and 16°16'west longitude, Basse Casamance corresponds to the administrative region of Ziguinchor, covering a total area of 7,339 km2 or 3.73% of the national territory. It lies in the south-western part of the country, in the South Sudanese coastal zone (Sagna 2005). It is bordered by the republics of Gambia to the north and Guinea Bissau to the south. To the east, it shares a border with the Sedhiou region, while to the west; the Atlantic Ocean forms a natural boundary (Figure 1). The Ziguinchor region is made up of three departments: the Bignona department, corresponding to the entire northern part of the region, with a total surface area of 5,295 km2; the Ziguinchor department, with a surface area of 1,153 km2; and the Oussouye department, with a surface area of just 891 km2. These three departments are subdivided into 30 rural communes.

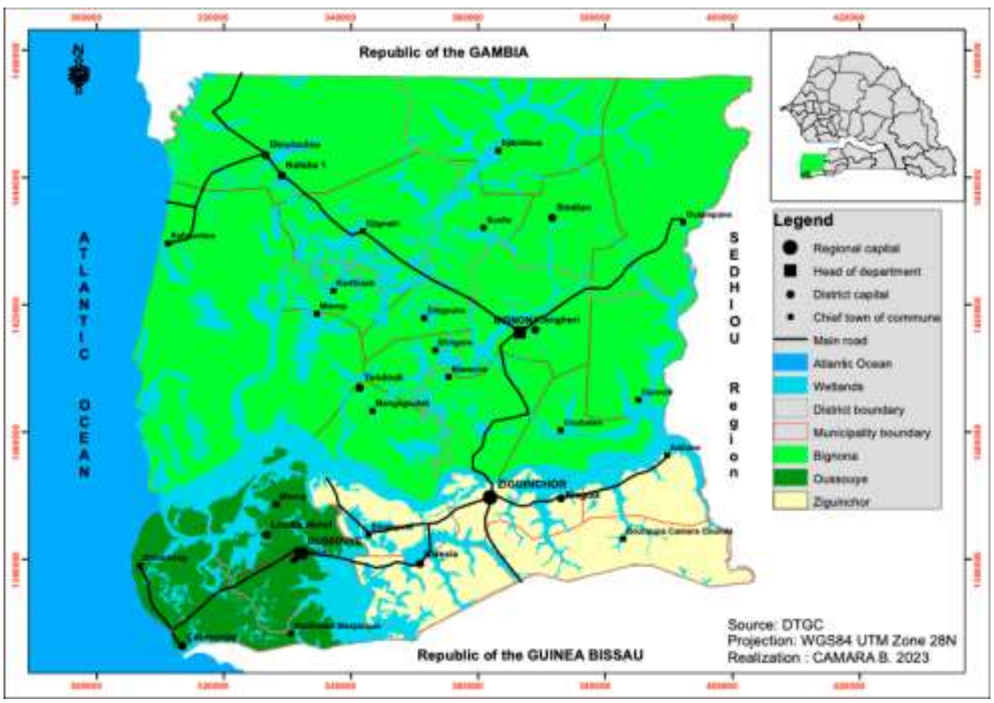

Figure 1: Location of the study area

The climate of Lower Casamance is of the sudano-coastal type, with a strong maritime influence (Sagna 2005). This climate is characterized by two very contrasting seasons: a very long dry season from November to May, and a short rainy season from June to October, during which agricultural activities are carried out. Rainfall is abundant in August and September, but very irregularly distributed: the average annual rainfall recorded between 1980 and 2023 was 1,317 mm. In fact, during this period, 23 deficit years and 22 surplus years were recorded. Most of the deficit years were between 1980 and 1998. The most deficient years in the series were 1980 and 2022, with 746 mm and 811.7 mm respectively. Surplus years, on the other hand, have occurred mainly in recent years. The highest rainfall was recorded in 2020 and 199 with respectively 2042 mm and 1946 mm (Figure 2).

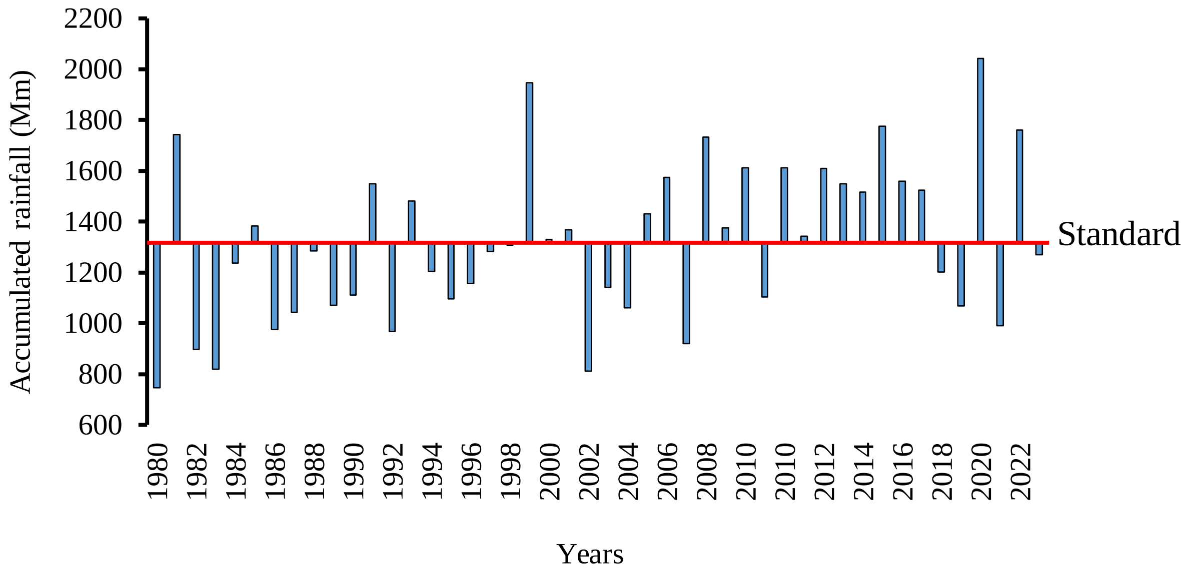

Figure 2: Rainfall variation from 1980 to 2023

3.2 Data collection: To study the influence two species (*F. albida* and *E. guineensis*) on the performance of rice, an experimental design based distance sampling under (R/2) and outside (2R) the canopy of trees was installed. A total 40 yield squares with yield with 20 in each sampling distance (under and outside the canopy of trees) was installed (Figure 3). For this purpose, yield squares of 0.25 m^2were set up under single trees to avoid the influence of the nearest tree's crown. Thus, these squares are installed around five trees of each of the two species according to the orientation (East-West and North-South) and the sampling distance (R/2 and 2R, where R represents the radius of the crown of the tree considered). Thus, slightly larger than the sample size selected as a reference by (Bayala *et al.,* 2016) who selected four trees. In each yield square, the growth (stem height) and yield (tillering biomass, straw weight and yield) parameters were measured (Figure 4). The yield is the production of grain per unit area. It is usually given in quintals per hectare or tons per hectare. It is calculated according to the following expression:

RDT= NP/ha *NT/P * Npa/T * NG/Pa * PG

With:

RDT= Yield/ha

NP/ha = number of plants /ha (NP/m^2 * 10000)

NT/P = number of tillers /stands

NPa/T = number of heat waves /tillers NG/Pa = number of seeds/panicles

PG= weight of a seed (weight of thousand seeds /1000)

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.60(2) : 11047 -11057 *https://doi.org/10.35759/JAnmPlSci.v60-2.4*

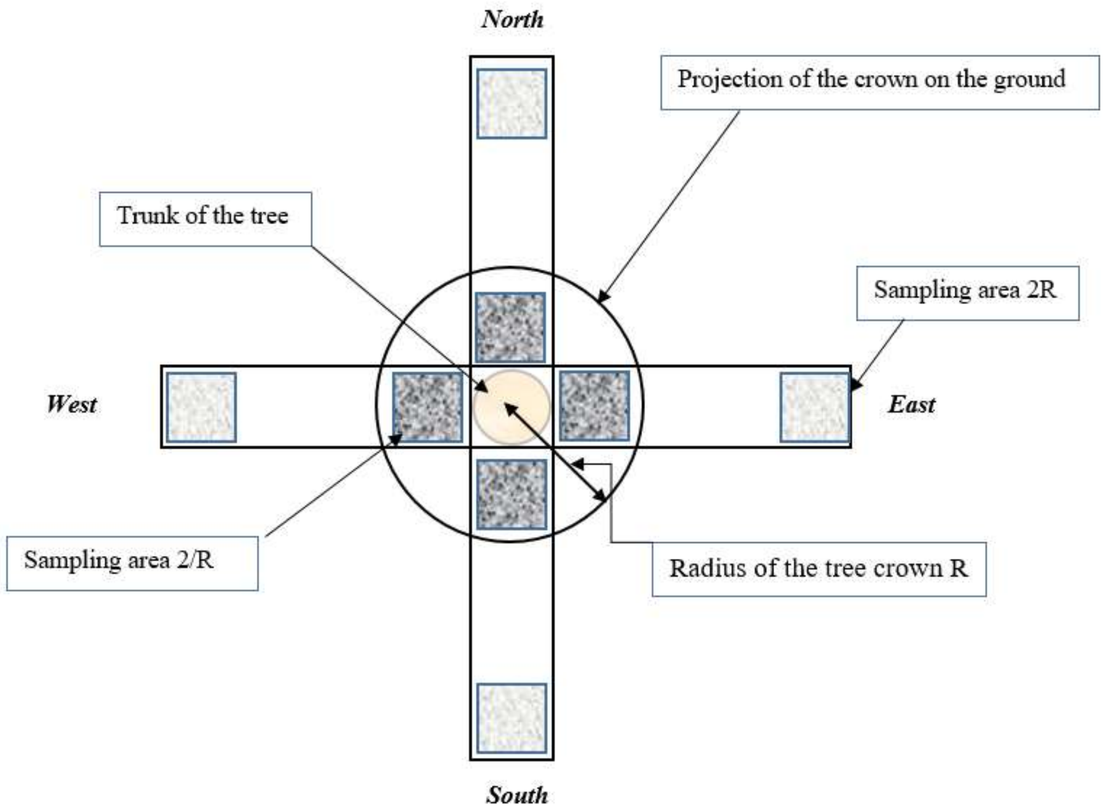

Figure 3: Experimental design for studying the influence of trees on rice

Figure 4: Rice stem height measurements (left) and rice biomass weighing (right)

3.3 Statistical analyses: The collected data were entered into an Excel spreadsheet and then submitted to R software version 3.4.2 for analyses of variance to determine the influence of species and sampling distance on rice performance. When the differences were significant, Tukey's test was used for pairwise comparisons. Statistical significance was fixed at 0.05.

4 RESULTS

4.1 Growth parameter: The analysis of variance on height showed significant difference between species and sampling distance (Table 1, Figure 5). The rice grown under *F. albida* trees had significantly (p= 0.0152164) higher height (105.13 cm) than those in *E. guineensis* (90.75 cm). Sampling distance had affected significantly (p= 0.1244^{e3}) the height of rice. Rice grown under canopy had higher height (105.13 cm) than those outside canopies (84.36 cm) of *F. albida*. For *E. guineensis,* the height under and outside canopy were 90.75 and 78.42 cm respectively (Figure 6).

Tableau 1: Summary of the analysis of variance of physiological parameters and yield

Variables	Sources of Variation	DDL	Sum of Squares	Average squares	F value	Pr (>F)
Overall biomass	Sampling distance	1	77325	77325	42.440	**7.1e-09 *** **
	Species	1	27187	27187	14.921	**0.000234 *** **
	Sampling distance * Species	1	10455	10455	5.738	**0.019064 * **
	Residues	76	138473	1822		
Straw weight	Sampling distance	1	3537.8	3537.8	11.0720	**0.00135 ** **
	Species	1	14526.0	14526.0	45.4610	**2.67e-09 *** **
	Sampling distance * Species	1	312.0	312.0	0.9766	**0.326176**
	Residues	76	24284.1	319.5		
Yield	Sampling distance	1	82.43	82.44	46.874	**1.71e-09 *** **
	Species	1	3.19	3.20	1.815	**0.1819**
	Sampling distance * Species	1	6.30	6.31	3.584	**0.0622**
	Residues	76	133.65	1.76		
Taller	Sampling distance	1	505.01	505.02	42.4874	**6.994e-09 *** **
	Species	1	4.51	4.52	0.3796	**0,5396**
	Sampling distance * Species	1	19.01	19.02	1.5995	**0,2098**
	Residues	76	903.35	11.89		
Height	Sampling distance	1	5478.1	5478.2	16.3646	**0,0001244 *** **
	Species	1	2064.5	2064.6	6.1673	**0,0152164 * **
	Sampling distance * Species	1	356.2	356.3	1.0640	**0,3055795**
	Residues	76	25440.9	334.7		

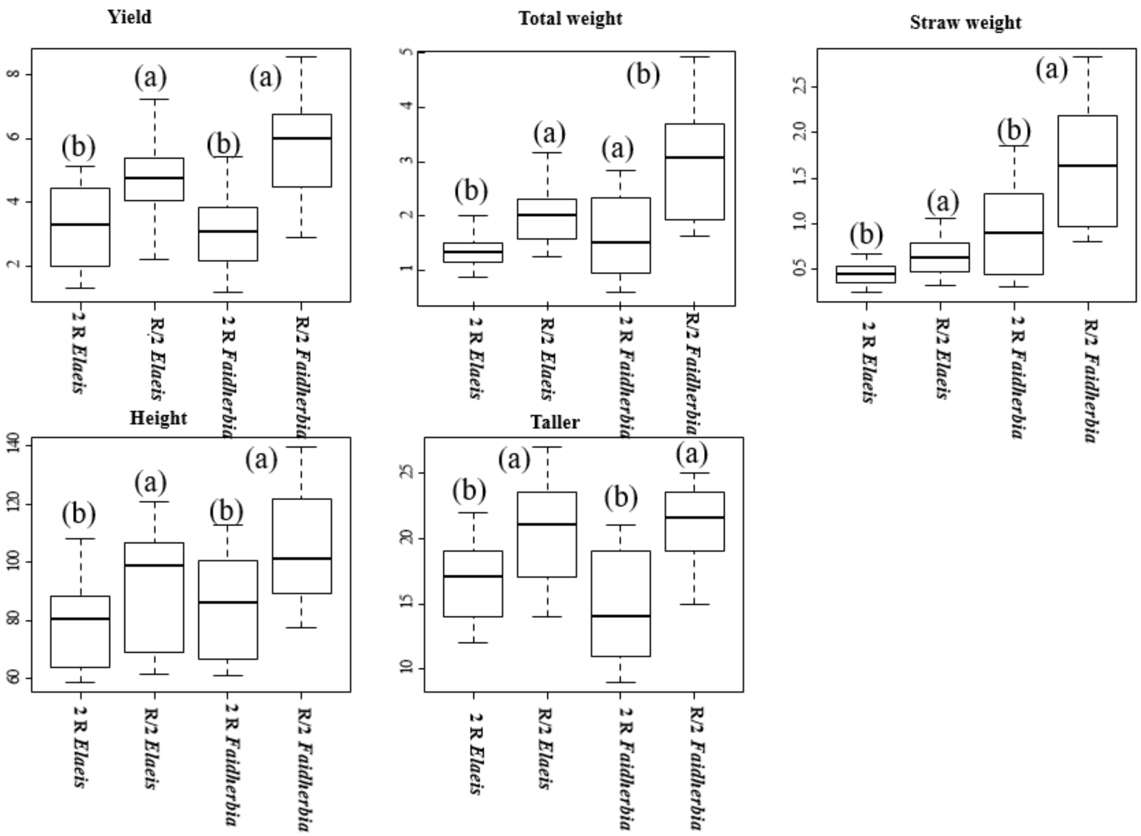

Figure 5: Summary of the Species*Distance interaction

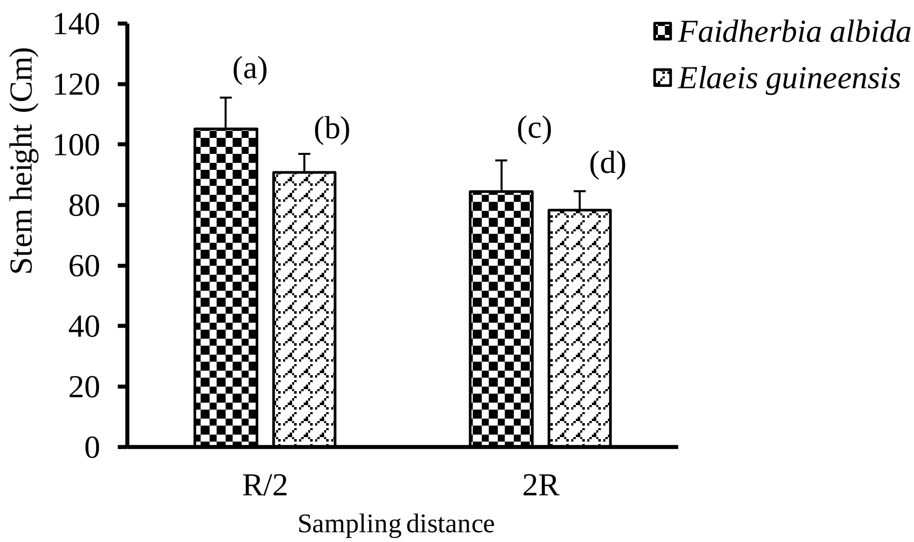

Figure 6: Evolution of stem height as a function of sampling distance and species

The species variable has a significant effect on rice height (p= 0.0152164). There is therefore a difference in height between stems under *F. albida* and *E. guineensis* in favour of *F. albida*. The

Sampling distance also has a very highly significant effect on height (p= 0.0001244) i.e., there is a difference in height between trees below the crowns (R/2) and those outside the crowns (2R). Stems located at R/2 have the greatest heights. In contrast, the Species* Sampling Distance interaction showed no difference (p= 0.3055795).

4.2 Yield parameters

4.2.1 Tillering: The species had no significant effect (p= 0.5396) on rice tillering (Table 1). In contrast, sampling distance had a significant effect (p= 6.994 $^{e-09}$) on rice tillering. The number of tillers varied from 21.1 to 20.6 under *F. albida* and *E. guineensis* respectively (Figure 3). However, the sampling distance influenced significantly (p= 6.994e-09) the number of tillers (Figure 7). Number of Tillers was greater at R/2 (21 tillers) than at 2R (15 tillers) for F. albida. For *E. guineensis*, 21 tillers at R/2 and 16 tillers at 2R were recorded. The interaction species*sampling distance did not affect significantly (p=0.2098) the number of tillers (Table 1, Figure 5). There is a very highly significant difference.

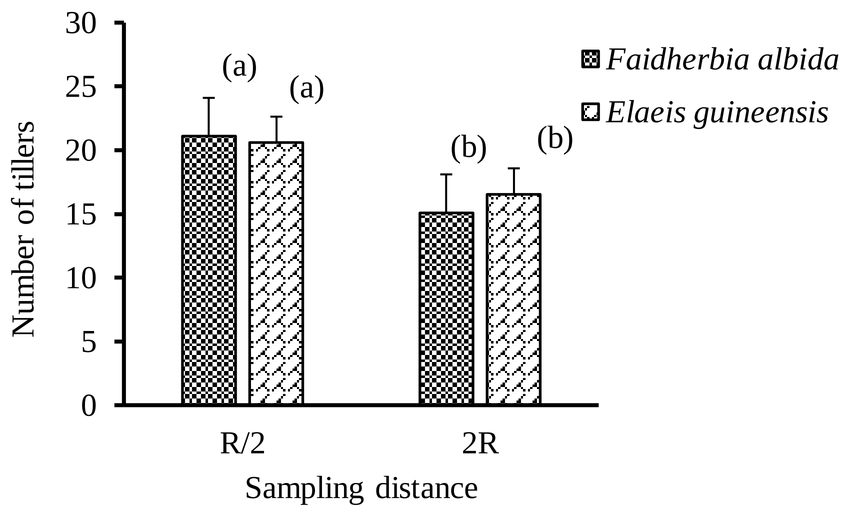

Figure 7: Variation in the number of tillers as a function of species and sampling distance

4.2.2 Straw weight: The Analyse of variance showed that species influenced significantly (p = 2.67^{e-09}) straw weight (Table1). The straw weight was greater in *F. albida (*1.64 kg/m²) compared to *E. guineensis* (0.65 kg/m²). The straw weight varied significantly (p = 0.00135) according to sampling distance. The weight was higher under than outside of canopy. At R/2, straw weight was 1.64 kg/m² compared to 0.94 kg/m² at 2R for *F. albida. For E. guineensis,* weight of 0.65 and 0.45 kg/m² was recorded under and outside canopies respectively (Figure 6). The species* sampling Distance interaction did not influence significantly (p= 0.326176) the straw weight (Table 1, Figure 5).

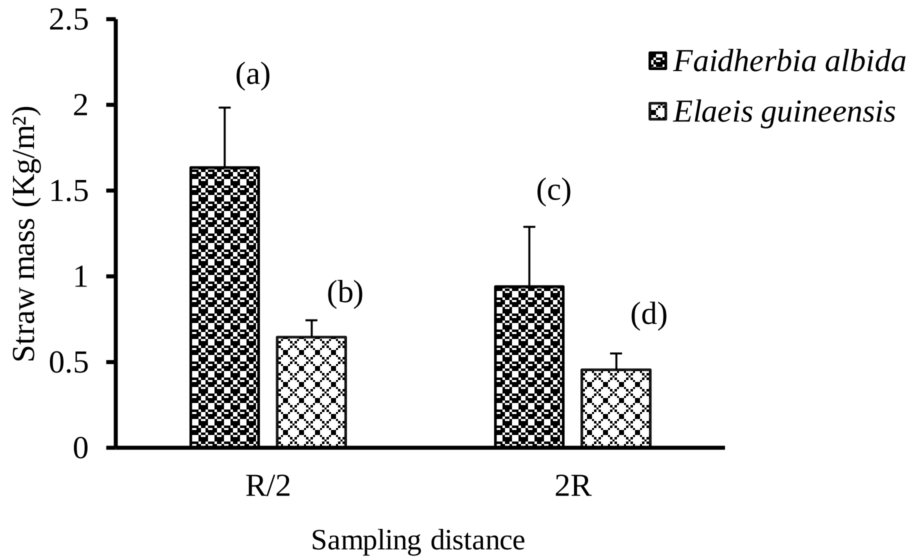

Figure 7: Straw mass variation as a function of species and sampling distance

4.2.3 The biomass: The results showed that species (p= 0.000234) and sampling distance variable (p= 7.1^{e-09}) had significant effects on total biomass (Table 1). Thus, the total biomass under *F. albida (*2.94 Kg/m²) was greater than that under *E. guineensis (*1.99 Kg/m²). Regarding the sampling distance, the total biomass was higher under (2.94 Kg/m²) than outside (1.58 Kg/m²) canopy of *F. albida*. For *E. guineensis* the total biomass was 1.99 and 1.36 Kg/m² at under and outside canopies respectively (Figure 9). The Species*Sampling Distance interaction also had a significant effect (p= 0.019064) on total biomass (Table1, Figure 5).

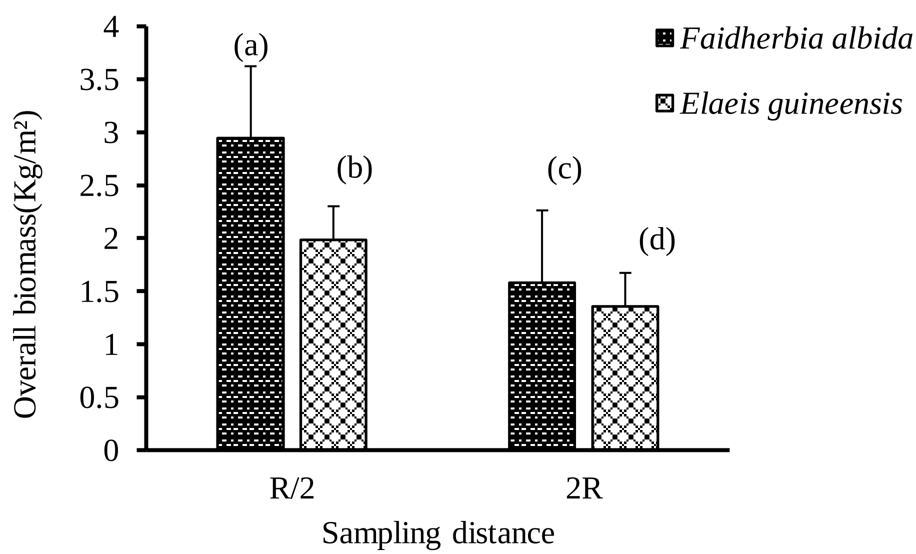

Figure 9: Variation in total biomass by species and sampling distance

4.2.4 Paddy yield: The species variable had no significant effect (p= 0.1819) on paddy yield. The yield varied from 5.66 to 4.70 t/ha under *F. albida* and *E. guineensis respectively*. However, sampling distance had a significant effect (p= 1.71^{e-09}) on paddy yield. The yield was higher under (5.66 t/ha) than outside (3.06 t/ha) canopies of *F. albida*. The paddy yields recorded under and outside canopies of *E. guineensis* were 4.70 and 3.23 t/ha respectively (Figure 10). However, the interaction Species* Distance showed no significant difference (Table1, Figure 5).

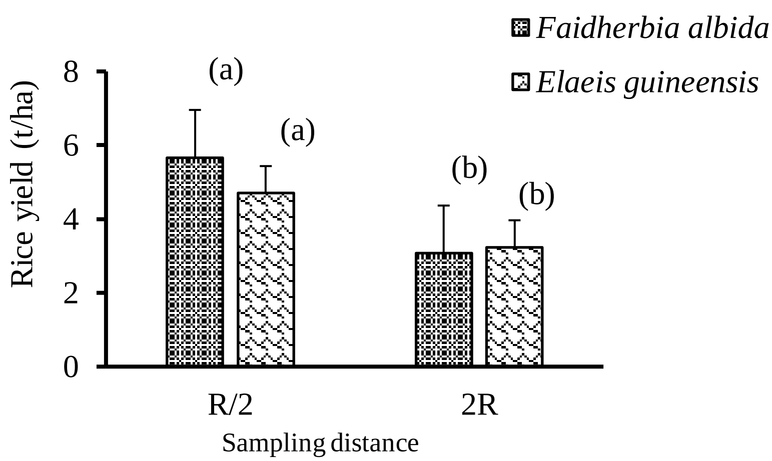

Figure 10: Variation in rice yield with sampling distance and species

5 DISCUSSION

Trees in agroforestry parks would be responsible for noticeable variations in physiological parameters such as stem height, tillering, biomass and yield of crops associated with them. Previous work had shown that crop yields under tree cover varied with toposequence and stand density. Thus, tillering, stem height, biomass, and straw weight and yield were significantly increased when these parameters were compared under the canopy and outside at the *F. albida* and *E. guineensis* sites. These results are in line with those of Siegwart *et al.,* 2023. on millet and groundnut. Some authors have found opposite results to ours with other woody species. This is the case of Bakhoum *et al.,* (2001) according to whom the density of groundnut, millet and sorghum plants increases with the distance to the trunk of *Sterculia setigera* Del. Height growth of millet and sorghum also increases with distance from the trunk. This trend is valid for millet and sorghum cob and stalk biomass, which are higher when the distance to the trunk is greater. Zomboudré *et al.,* (2005) and Saidou *et al.,* (2013) in the same vein, observed lower maize yields and straw under the *Vitellaria paradoxa* Gaertn canopy, despite the importance of moisture and soil fertility under the canopy due to its richness in some elements. Gbemavo *et al.,* (2010) also showed that the average number of cotton bolls is higher at the outgrowth level of *V. paradoxa.* However, many other authors who have also studied the effect of trees on crops have found similar results to ours. According to Charreau and Vidal (1965), the overall increase in soil fertility near *F. albida* has a very important impact on the mineral and water nutrition of millet and on grain yields. Sae-Lee, Vityakon, and Prachaiyo (1992) found that rice height, number of tillers, grain weight, and aboveground biomass decreased from the foot of *Samanea saman* (Jacq) Merr. to the area outside the influence of the crown. Ndiaye *et al.,* (2012) showed that, in sum, all variables measured on millet and groundnut plants i.e. root length, total length, stem and pod biomass were higher on soils sampled in the zone under the influence of the crown (R/2) of *Cordyla pinnata* (Lepr. ex A. Rich.). Approaching in the same sense, Manssour *et al.,* (2014) showed that sorghum productivity, both in panicles and grains, was statistically higher under the crown than outside the crown of *Acacia Senegal* (L.) Willd. (Camara *et al.,* 2016) found that the number of tillers, stem height, total weight, straw weight, and paddy yield were higher under the influence of the *F. albida* canopies compared to outside. Similar results were found by Clermont *et al.,* 2023 on millet in the vicinity of *Faidherbia albida* in northern Senegal. The considerable contribution of these two species to the improvement of physiological parameters and yield in upland rice could be explained by the following facts. As a leguminous species, *F. albida* has an inverted phenology, i.e. when the crop is planted, it loses its leaves, and as it is a flooded rice crop, competition for water, light and nutrients can be negligible. In addition, there is the manure from the ruminants that stay under the trees during the lean season. As for *E. guineensis*, once the tree has been cleared, the problem of shading does not arise. In addition, the decomposition of its flowers is very rich in nitrogen.

6 CONCLUSION

In summary, rice performed better under *F. albida* and *E. guineensis canopies*. It is therefore very beneficial to keep these species in association with rice, as they do not hinder rice productivity but provide additional benefits to the traditional agroforestry parks of the Lower Casamance.

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