

THE AGRICULTURAL SUITABILITY OF CASHEW NUT SUBSTRATE ON THE GROWTH AND YIELD OF SORGHUM BICOLOR L. (SORGHUM) AND ARACHIS HYPOGAEA L. (PEANUT) ACCORDING TO THE SAMPLING DISTANCE (CASAMANCE / SENEGAL)

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ABSTRACT

The issue of cashew tree allelopathy and in particular the association with annual crops often comes up in the agronomy debate. The aim of this study is to test the agricultural suitability of cashew nut substrate on sorghum and groundnut crops. For this purpose, three types of substrates were sampled at a distance from the crown of the cashew tree (R/2), at the edge of the crown (R) and at a distance equivalent to twice the crown radius (2R). These substrates are then placed in trays for the cultivation of these two species under semi-controlled conditions. The experiment was carried out in a site completely exposed to the sun and isolated from the trees in order to avoid shading and competition with soil nutrients. A total randomized experimental design consisting of three treatments (three types of substrate) in 5 replicates was used. Results showed that the total biomass production of sorghum on the R/2 substrate was twice as high as that obtained on R and 2R. It is estimated at 252g under R/2, 135g for R and 138g under 2R. As for sorghum, total groundnut biomass (leaves, roots, pods and stems) total biomass is higher on R (331g) and R/2 (294g) substrates compared to 2R (257g) with a significant difference ($p = 0.0129$). Most of the variables of the crops studied were more important on under cover than off cover. These results would indicate that if allelopathy is present, it would not be related to the substrate under the tree. A field experiment allowing the introduction of other parameters, such as the shading effect, would allow a better understanding of the conditions under which crops are associated with cashew nuts. This would be an alternative in improving crop yields and would also contribute to a better security for producers.

Keywords: Cashew nut, Annual crops, Soil sampling distance, Casamance.

1. INTRODUCTION

In Senegal, *Anacardium occidentale* L. parks are more common in Casamance, where they occupy 70% of the plateau land in the Sédhiou region [1]. Some annual crops such as (*Arachis hypogaea* L., *Vigna unguiculata* (L.) Walp., *Ipomoea batatas* (L.) Lam, *Zea mays* L. etc.) are associated in these parks [2]. In these classical traditional production systems, the associated crops, located under the tree canopy, benefit from the nutrients resulting from the decomposition

and mineralization of the tree's organic matter [3]. This association allows agricultural production to be intensified and diversifies the producers' sources of income. However, the almost bare herbaceous cover under the cashew tree crown leads some producers to believe that the cashew tree is an allelopathic species with a negative influence on crops. However, allelopathy is defined by some authors as direct or indirect biochemical interactions, positive or negative, based on allelochemical substances involved in interspecific communication, as distinct from pheromones involved in intraspecific communication. These are most often interactions between a plant species and another species (including microorganisms), usually by means of secondary metabolites such as phenolic acids, flavonoids, terpenoids and alkaloids [4,5]. According to Waller [6] and Siqueira [7], these secondary compounds were first characterized by their protective role against pests (insects, bacteria, fungi, algae, etc.), but they can also affect the growth of other plants.

In order to test this hypothesis, an experiment was conducted for the first time in a real environment during the rainy season, where market garden crops (Tomato, okra and chilli) were grown under and out of the cashew tree cover. This was not successful because of the large amounts of rain that fell on the latter but also the crops suffered numerous attacks. Based on this finding, the study was repeated in a semi-controlled environment to see if the soils under the cashew tree are favourable for the growth and development of annual crops such as groundnut and sorghum.

In Senegal, cashew tree cultivation is developing at a very high rate. Between 1986 and 2017, the area under cashew tree cultivation increased from 910.55 km² to 1908.5 km² [8]. This expansion is at the expense of agricultural land and forest areas.

Given its socioeconomic importance in Senegal and more particularly in Casamance, it is necessary to study the interaction of this species with annual crops for a better valorisation of the cashew cashew nut parks. It is in this context that the present study aims to test the agricultural suitability of cashew nut substrate on crop growth and yield.

2. MATERIALS AND METHODS

2.1. Experimental site

The trial was conducted on the farm of the agroforestry department of the Assane Seck University of Ziguinchor located at 12°33 North latitude and 16°16 West longitude (Figure 1). This farm is located south of the town of Ziguinchor. The region of Ziguinchor covers an area of 7,339 km² or 3.73% of the national territory and is bordered to the north by the Republic of The Gambia, to the south by the Republic of Guinea Bissau, to the east by the regions of Kolda and Sédhiou, and to the west by the Atlantic Ocean [9].

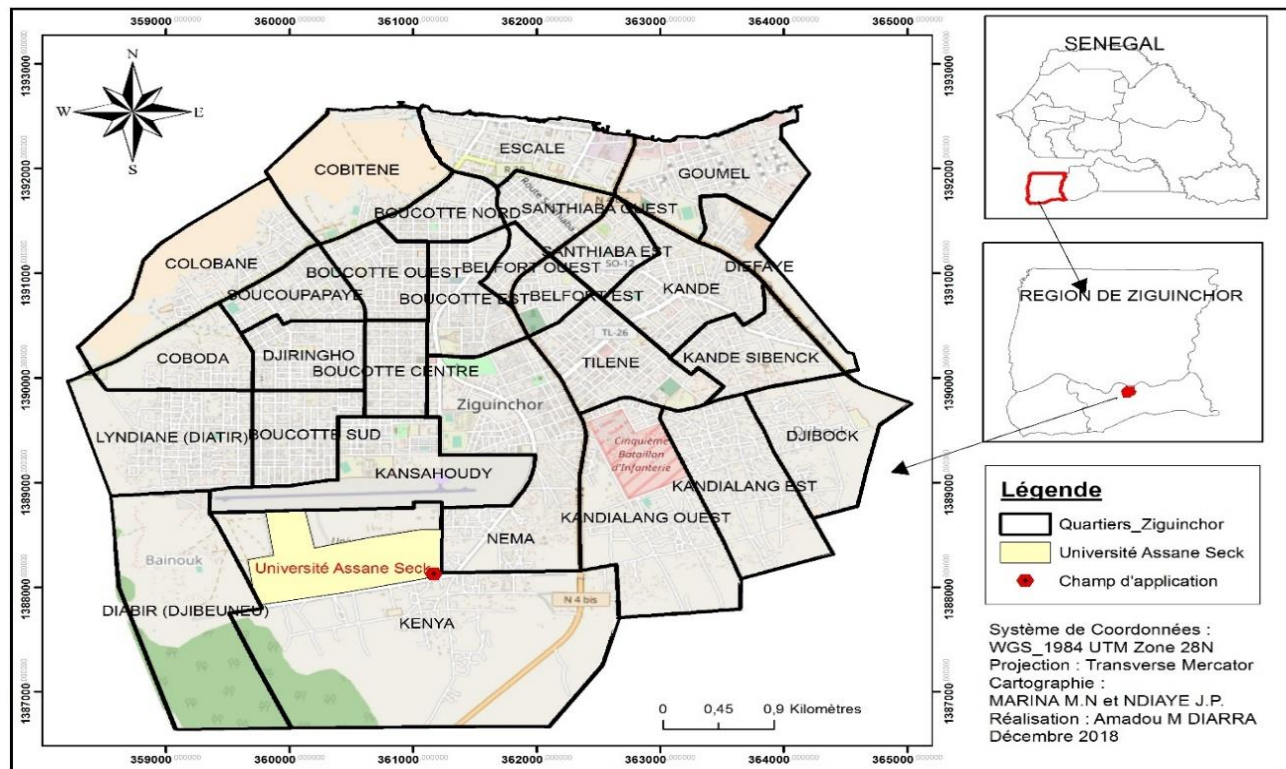


Figure 1: Location map of the experimental site

2.2. Plant material used

Two cultures were tested on the different substrates. These were *Arachis hypogaea* L. (peanut) (Figure 2a) and *Sorghum bicolor* L. (sorghum) (Figure 2b). The characteristics of these two crops are recorded in Table 1.

Table 1: Characteristics of the cultures tested on the different substrates

Scientific Names	Varieties	Origin	Cycle (Days)
<i>Arachis hypogaea</i> L.	GH119-20	Georgie (USA)	120
<i>Sorghum bicolor</i> L.	CE180-33	Senegal	90

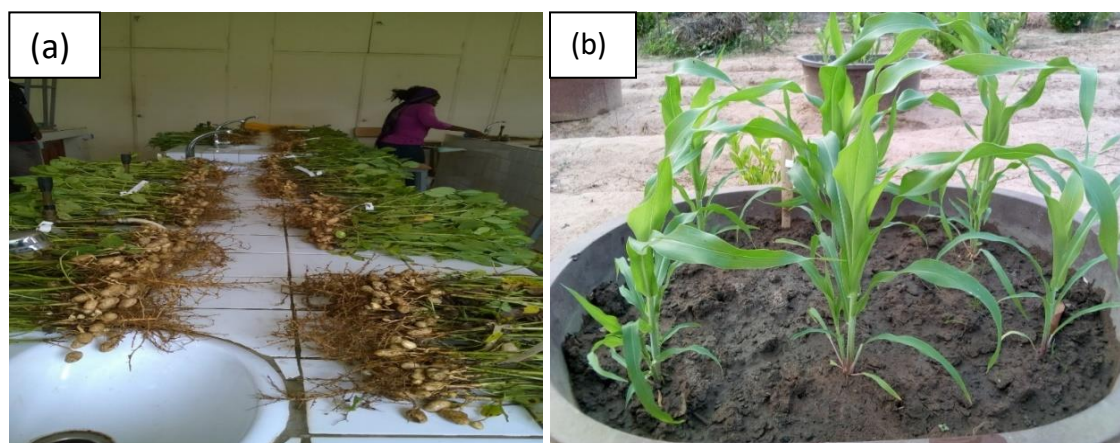


Figure 2: Annual crops tested: Peanuts (a) and Sorghum (b)

2.3. Methods

2.3.1. Substrate characterization

Soil sampling and analysis methods were used to characterize the different types of substrates used. Substrate types were collected at three levels in relation to the cashew nut crown (R/2, R and 2R where R is the radius of the cashew nut crown) in all four directions (East-West-North-South). A total of 12 samples were taken, four of which were taken from each level at a depth of 30 cm. Three composite samples were formed. The analysis of soil samples was carried out at the "Soil-Plant-Water" laboratory of the National Centre for Agronomic Research in Bambe (CNRA/Bambe). The physico-chemical parameters analysed are total nitrogen (N_{total}), organic carbon (CO), assimilable phosphorus (Passimilable), organic matter (OM), pH, exchangeable bases (Ca²⁺, Mg²⁺ and K⁺) and granulometry (clay-sand-limon fraction).

The pH of the water is determined by the dose of 1/2.5. Assimilable phosphorus is determined by the modified Bray method [10], organic carbon by the modified Walkley-Black method, total nitrogen by the modified Kjeldhal method [11] and the organic matter has been oxidised by a mixture of potassium dichromate and concentrated sulphuric acid. The excess dichromate was titrated with Mohr salt. Particle size was carried out on the basis of 20g of ground soil in 25ml of water. Fractionation of the different particles was performed using the particle size fractionation method used by Saharta [12]-[13].

2.3.2. Experimental design

In order to evaluate the growth and yield parameters of two annual crops (sorghum and groundnut) on the different substrates, a completely randomized experimental design was used with four replicates and only one factor studied: the sampling distance (SD) with three levels (R/2, 1*R and 2*R, where R was the crown radius of the tree under consideration). The

experimental units are rings 80 cm long and 50 cm wide. For Trial 1 (groundnut), 135 bunches were made up of 09 bunches/ring, equidistant by 15 cm. Trial 2 (sorghum) required 90 bunches due to 06 bunches/ring. In total, individuals were followed through to the production stage (Figure 3).

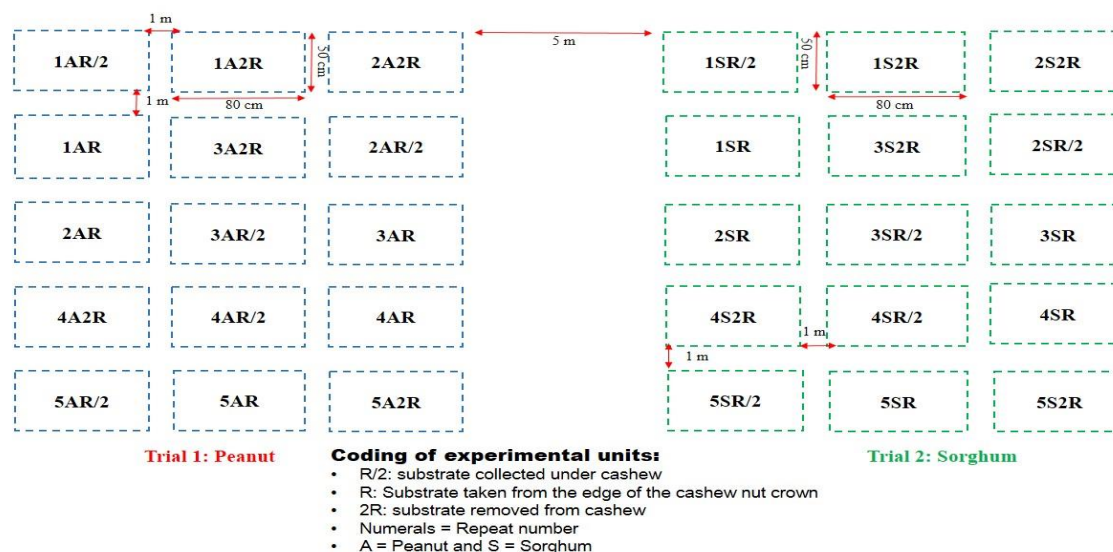


Figure 3: Experimental design

2.3.3. Conduct of the trial

The experiment was carried out in a site completely exposed to the sun and isolated from the trees to avoid shading and competition with soil nutrients.

Planting was carried out on 24 May 2018 for sorghum and 30 May 2018 for groundnut. The sowing density is two seeds per poquet. Measurements of growth parameters were made every 15 days after sowing (JAS). Marriage was done one week after germination (SAG) due to one plant / pots.

2.3.4. Parameters evaluated on sorghum and peanut

The parameters evaluated are:

For peanuts the number of stem branching, pod production, above-ground biomass (pods + tops) and below-ground biomass (roots) the ratio of total biomass and pod production but also the ratio of total biomass and mature seeds.

For sorghum, the height, diameter at collar, above-ground biomass (panicle + stems), underground biomass (roots) were evaluated.

After harvest, all crops (groundnut and sorghum) were sun-dried for 72 hours before measurement with a precision scale.

2.3.5. Data processing

The data were processed using software R.3.4.2. The Shapiro test was applied to all the variables studied in order to verify the conditions of normality of the data. Thus, for the comparison of means, parametric (for variables with p -value < 0.05) and non-parametric (p -value > 0.05) tests were used. Analysis of variance (ANOVA) was used to show the effect of a factor. The Newman Keuls test at the threshold $\alpha = 0.05$ was used to compare the means and show the differences between the factors studied. The coefficient of variation ($CV = \frac{\sigma}{\mu}$, where μ is the mean) was presented to indicate the degree of dispersion of the values around the mean. A Principal Component Analysis (PCA) was carried out to see the correlation between the types of substrates used and the yield of sorghum and groundnut.

3. Results

3.1. Physico-chemical characteristics of the different substrates used

Chi2 tests of N, total C, organic matter and C/N ratio, organic matter, exchangeable bases and soil texture show that the difference is not significant at any sampling distance (Table 2).

Table 2: Chi-square test of the physico-chemical properties of different substrates according to sampling distance

Variables	Substrate removal distance from cashew nut trunk			p-value
	R/2	R	2R	
pHeau (1/2,5)	5,16	4,94	4,88	0,995
P assimilable (ppm)	11,590	13,307	18,029	0,459
C total (%)	0,495	0,353	0,358	0,984
N total (%)	0,056	0,049	0,031	0,996
MO (%)	0,85	0,61	0,62	0,973
C/N	8,91	7,16	11,44	0,603
Ca ²⁺ (méq/100g)	1,911	2,119	1,578	0,960
Mg ²⁺ (méq/100g)	0,238	0,201	0,119	0,980
K ⁺ (méq/100g)	0,093	0,097	0,071	0,997
Clay (%)	6,78	7,97	8,61	0,895
Limon (%)	4,21	4,31	4,27	0,999
Sand (%)	89,02	87,73	87,12	0,989

3.2. Influence of cashew nut substrate on sorghum growth

The yield of sorghum on different substrates was studied according to biomass growth and production.

3.2.1. Sorghum height growth according to different substrates

Analysis of variance on sorghum height growth shows a significant difference ($p = 0.0202$). Thus the height in R/2 increases from 9.88 mm at T1 to 116.6 mm at T6. On the R substrate, it increases from 9.66 mm in T1 to 80.36 mm in T6. Finally, for 2R, it increases from 10 mm in T1 to 86.19 mm (Figure 4).

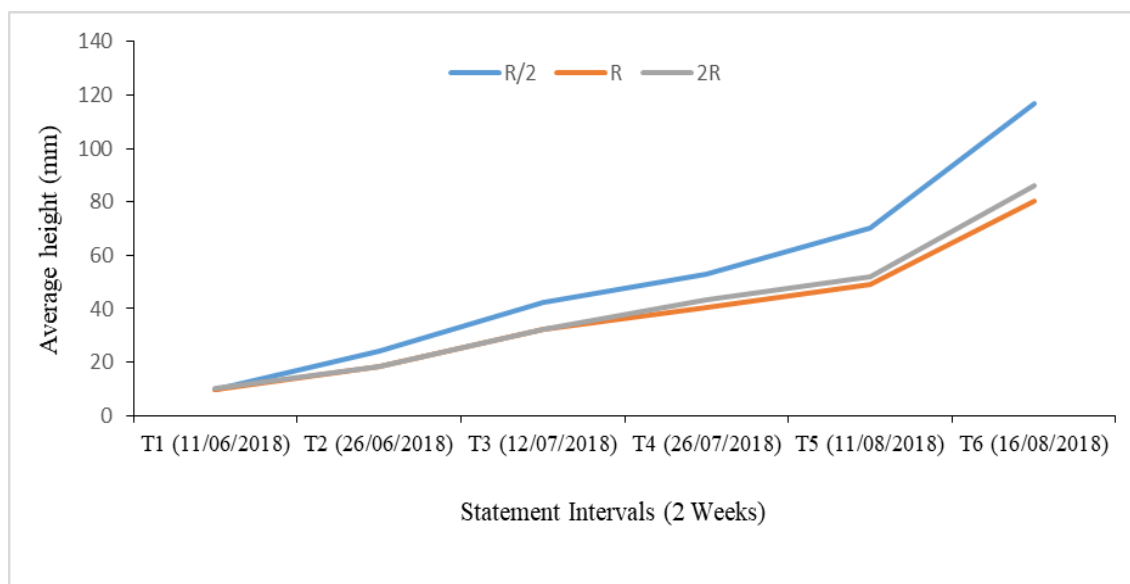


Figure 4: Sorghum height growth on different substrates as a function of time

3.2.2. Diameter growth at the sorghum collar

Comparison of the averages of diameter at the collar does not show a significant difference ($p = 0.55$). On the other hand, on the R/2 substrate a mean diameter equal to 12.17 mm is noted as opposed to 10.1 mm in R and 9.69 mm in 2R (Figure 5).

However, the analysis of variance shows a significant difference ($P < 0.05$) in mean diameter between dates T2, T3, T4 and T5 except T1 and T6 (Table 3).

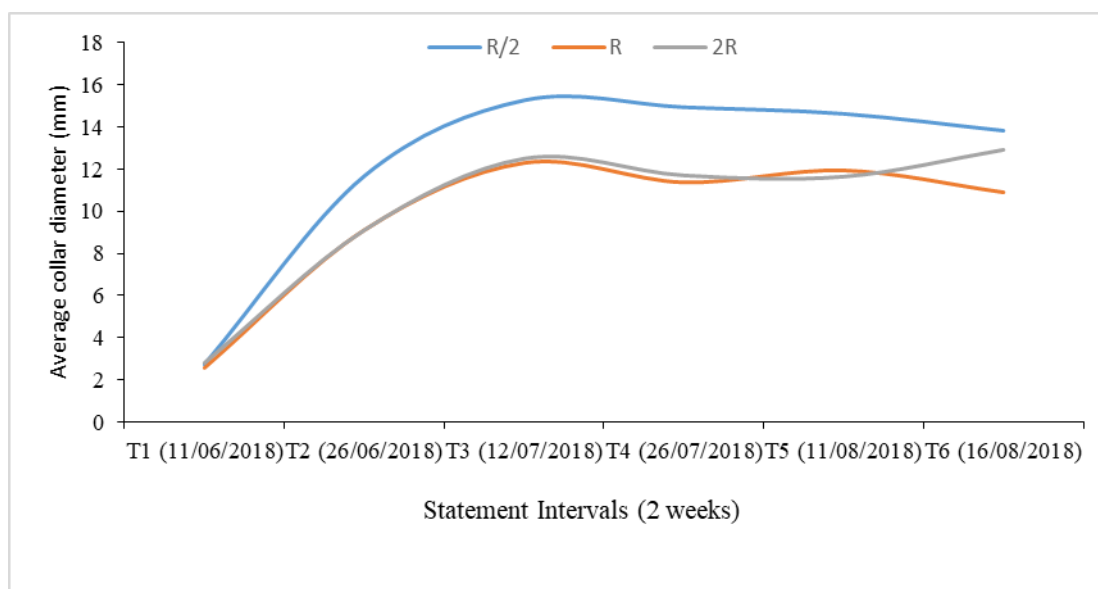


Figure 5: Average collar diameter on different substrates

Table 3: Analysis of variance of sorghum collar diameter by sampling distance

Variables	Df	Sum of Squares	Average of Squares	F-value	Pr (>F)
Dmc en T1	2	0,36	0,358	0,019	0,893 ^{ns}
Dmc en T2	2	84,26	84,26	6,609	0,0213 *
Dmc en T3	2	96,25	96,25	8,139	0,0136 *
Dmc en T4	2	112,1	112,07	10,56	0,00633 **
Dmc en T5	2	133	133	14,78	0,00203 **
Dmc en T6	2	4,36	4,356	0,231	0,639 ^{ns}

Legend : Dmc = Average diameter at collar

Meaning codes: 0 '**' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 ' ' 1**

3.2.3. Effect of cashew nut substrate on sorghum biomass production

Analysis of variance shows significant differences in above-ground biomass ($p = 0.00129$), root biomass ($p = 0.014$) and total biomass ($p = 0.00129$). Thus, for the above-ground biomass, the median values of R/2, R and 2R vary respectively 215; 112 and 117 (Figure 6a). For root

biomass, they vary from 37 for R/2, 21 for R and 21 for 2R (Figure 6b). Finally, for total biomass, they vary from 252 for R/2, 135 for R and 138 for 2R (Figure 6c).

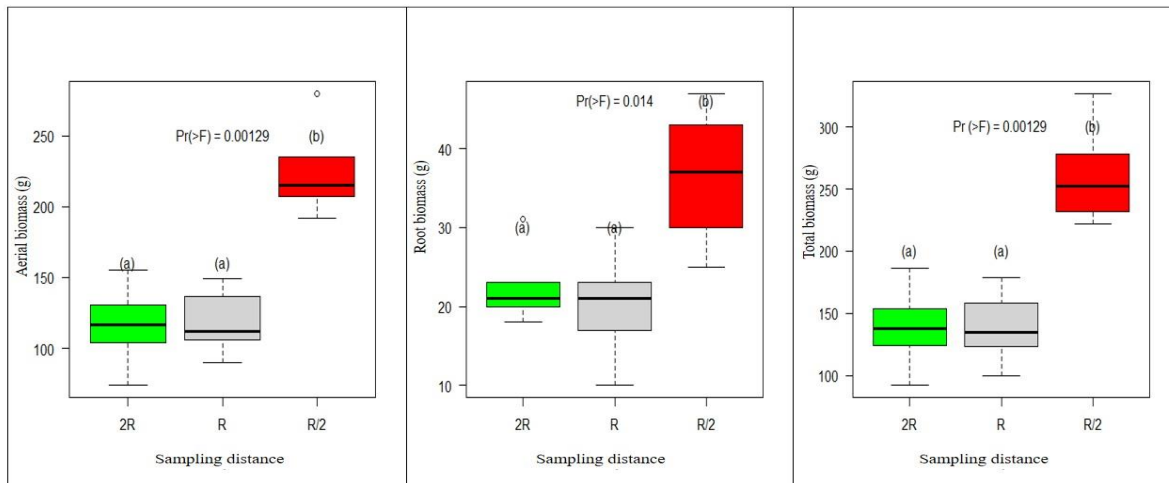


Figure 6: Evaluation of the above-ground (A), root (B) and total (C) biomass of sorghum according to sampling distance

3.3. Influence of cashew nut substrate on peanut growth

3.3.1. Dynamics of peanut leaf growth by substrate type

Figure 8 shows the dynamics of growth, including the number of branches of the peanut as a function of time following the sampling distance (R/2, R and 2R). The R/2 substrate favoured more branching with an average of 33.13 ± 7.49 branches followed by R with 31.18 ± 6.74 branches and 2R with 26.27 ± 7.83 branches. However, the mean comparison test showed no significant difference between the different types of substrates ($p = 0.898$).

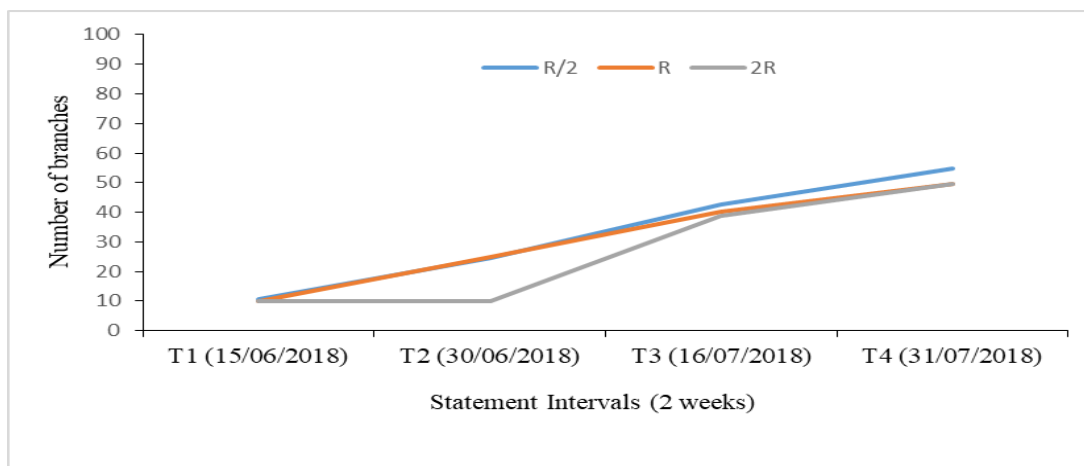


Figure 8: Dynamics of peanut leaf branching as a function of time following sampling distance

3.3.2. Influence of Soil Sampling Distance on Peanut Yield

The test comparing the averages of pod production over sampling distances (Figure 9a) shows a significant difference ($p = 0.0388$). Pod production is significantly higher at R/2 and R substrates with 230.2 ± 15.2 g and 230 ± 8.6 g respectively compared to 2R with 189.4 ± 25.9 g. On the other hand, the comparison of averages in mature pods (Figure 9b) shows no significant difference ($p = 0.425$) even though the highest average is recorded on R/2 (209 ± 15 g) compared to 203 ± 5.8 g in R and 163.8 ± 23.9 g in 2R. No significant differences were noted in the total biomass/pod production ratio ($p = 0.169$) and the total biomass/ mature seed ratio ($p = 0.503$). However, on R/2 and R, the ratios are 3.270 and 3.022 respectively, compared to 2.794 on R (Figure 9c). The ratio of biomass to mature seed gives almost the same values regardless of the sampling distance (Figure 9d).

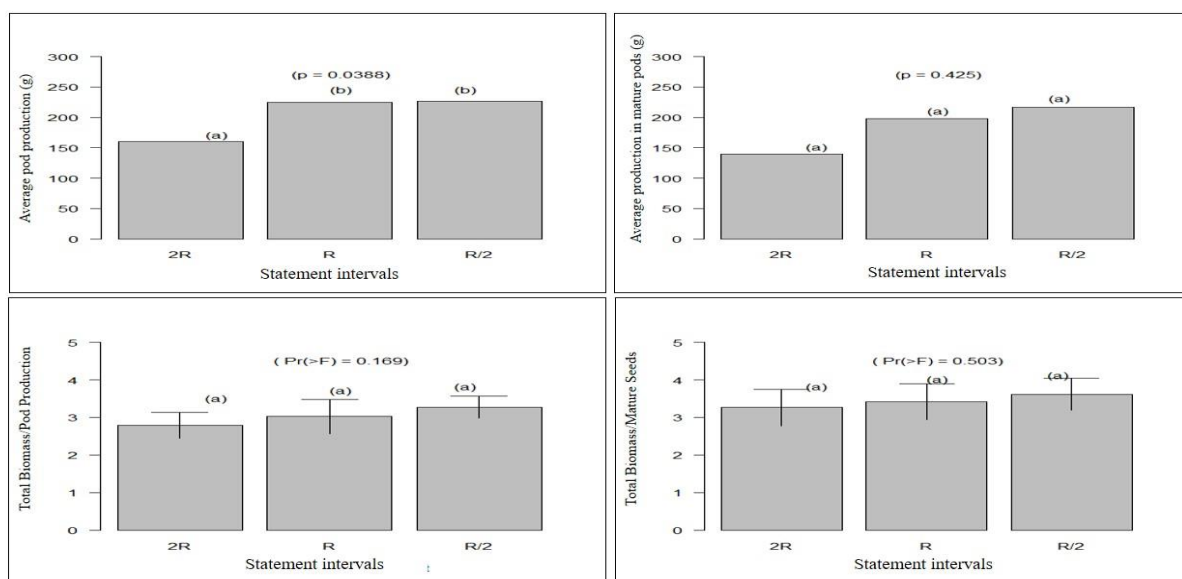


Figure 9: Effect of crop soil sampling distance on pod production (a), mature pod production (b), total biomass/pod production ratio (c) and total biomass/mature pod production ratio (d)

3.3.3. Effect of sampling distance on peanut biomass production

An analysis of variance shows that the above-ground biomass is higher on the R/2 substrate with a significant difference between the different substrates ($p = 8.58e-05$), the root biomass is high on the R substrate without significant difference ($p = 0.355$) and the total biomass is higher on the R (331g) and R/2 (294 g) substrates compared to 2R (257 g). However, the difference is significant ($p = 0.0129$). (Figure 10).

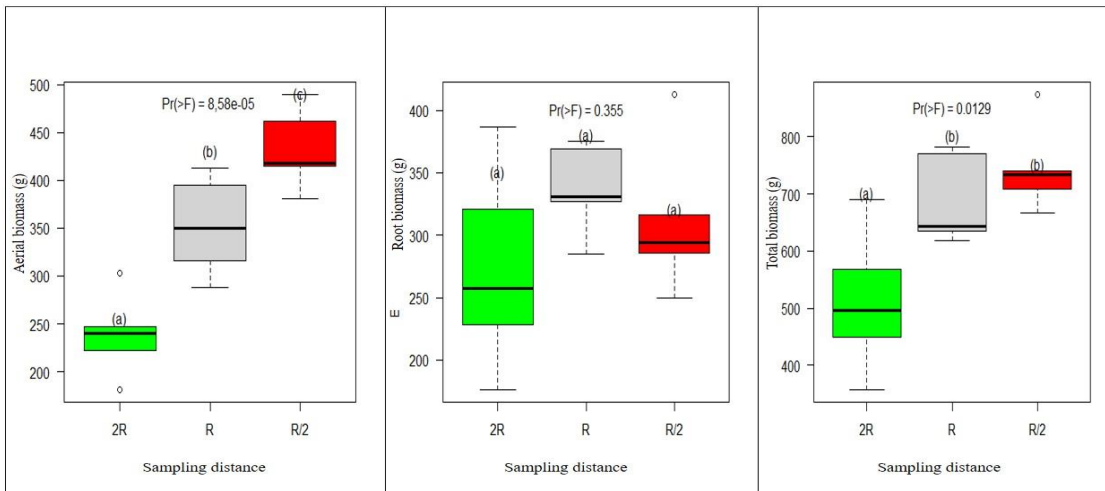


Figure 10: Assessment of aerial (a), root (b) and total (c) biomass of peanuts by sampling distance

4. DISCUSSION

Sorghum growth and yield parameters such as height, crown diameter and total biomass were more important on soil collected at R/2 crown. This difference in yield could be explained by the fact that the physico-chemical properties of the substrate used in the experiment showed higher levels of carbon, nitrogen and phosphorus at R/2 than at R and 2R. This phenomenon was demonstrated in a bioassay, that the above-ground biomass and height growth of *Sorghum vulgare* was greater on the substrate collected under the canopy than outside the canopy of *A. albida* and *Ziziphus spina christi* [3]. According to these authors, both species improved soil fertility over a distance equivalent to twice the tree crown radius. In addition, Sama-Lang [14] noted in a corridor cropping system that 10 years after planting, tree hedges of *Senna spectabilis*, *Leucaena leucocephala*, *Calliandra calthyrsus* and *Gliricidia sepium* enriched the corridor soils compared to controls. This association of crops with cashew may have mutual benefits. Previous studies have shown that legumes associated with cashew seedlings also promote cashew growth [2]. Abeyasinghe [15] makes the same point in explaining the benefits of combining annual crops with cashew nuts. Studies conducted by Opoku-Ameyaw [16] on the effect of annual crop combination on cashew tree growth and production in Ghana showed that the use of maize and sorghum or groundnut significantly improved tree height and trunk circumference of cashew trees.

The results obtained on groundnut growth and yield showed that the substrate sampled under the cashew nut compared to that sampled outside the cashew nut. Pod production, mature pod production and total biomass were higher on the "R/2" substrate (under cashew nut). This reflects the difference in fertility of these types of substrates used. This result confirms the nature of the physico-chemical properties of the substrates which clearly shows a slight difference in fertility in carbon, nitrogen, organic matter and exchangeable bases essential for crop growth and productivity. Indeed, carbon is important as the main food element for soil organisms. It is an

essential element for the growth of hulls and seeds [17]. A deficiency in this element is therefore manifested by a high rate of empty pods and a brittle shell for groundnut. The results of the experiment showed that empty pods were more noticeable on the 2R substrate. However, a nitrogen deficiency would result in an early cessation of growth with discoloured leaves. This difference in fertility level could be due to the poor nature of Senegalese agricultural soils. According to Aubert and Duchaufour [18], Senegal's peanut lands belong to the tropical ferruginous soils marked by a deficiency in organic matter, slightly acidic and very low in phosphorus. The cultivation of recently cleared ferralitic soil leads very quickly to a decrease in total nitrogen stock at an annual rate of about 4%. These findings confirm the characteristics of the different types of substrate.

5. CONCLUSION

The results of this experiment would indicate that while cashew nuts are an allelopathic species, the substrate under the tree is favourable for the development of annual crops. A field experiment allowing the introduction of other parameters, such as the shade effect, would provide a better understanding of the conditions under which crops are associated with cashew nuts. This would be an alternative in the improvement of crop yields and would also contribute to a better security for producers.

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