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Evaluation of Intercropped *Aloe vera* with Plantain on Growth and Yield Status in a Real Culture Situation in Daloa, Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rains decrease and irregularity represent a threat to farmers and call for crops of interest's promotion like *Aloe vera*, requiring little water. Therefore, lands rarity compels the valorization inter-row crops' spacing occupying wide spaces. Thus, the research has been led in the Central - West of Côte d'Ivoire in order to evaluate the effect of plantain banana tree (*Musa* sp) and *Aloe vera* association on these crops growth and yield. For this, an implement with a complete randomization design including two treatments with eight repetitions was achieved. The processings were consisted in planting either one *Aloe vera* plant (treatment 1) or two *Aloe vera* plants (treatment 2)

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between four plantain tree plants. The interval used for the planting of banana shoots in the 40-cm deep seed holes was 3 m x 2 m. The results showed that treatment 2 has speeded up the appearance of *Aloe vera's* leave and encouraged the generation of a high number of leaves (39 leaves) longer (20.06 cm) and wider (2.78 cm) bringing about large fresh and dry biomasses, compared to treatment 1 and the control, with 125.42 g and 64.27 g, respectively. As for plantain banana tree, the intercropping favored a higher leaf emergence rate with a high number of leaves (23 leaves) longer and wider, 113.53 cm and 58.70 cm long, respectively. The intercropping also favored in plantain banana a large number of hands (7) and fingers (32) with a finger length of 35.25 cm weighing on average 0.46 kg and causing a mass of 9.23 kg / bunch. Bananas bunch yield higher in the associated plantain banana trees (15.39 t. ha^{-1}) compared to controls (7.83 t. ha^{-1}).

Keywords: Rain irregularity; plantain banana tree; inter-row spacing.

1. INTRODUCTION

Forest exploitation (logging operation and business, timber harvesting, etc.) and farming have always been the primary activities which widely set up the country (Côte d'Ivoire) economy's ground. These practices vantage an imprecise land code, which was worsen later by greater uncontrolled immigration flow. Undeniably, the deeds harm and change the natural environment, particularly the rain forest (primeval forest). So, many zones of the forest have been destroyed and transformed either into farms (food, commercial or agro-industrial plantations), or into fallow land [1]. Currently, the Ivorian forest coverage approximatively 2.7 million hectares with an estimated annual deforestation rate of 4.32% between 1990 and 2005 [2]. This destruction of the forest is one of the main causes of the climate change observed.

Worries about the climate change effects are bright, especially regarding the rising of temperatures, the risk of floods and other extreme weather events, as well as reduced water availability. The agricultural production of Côte d'Ivoire is essentially food- and rain-fed; only 0.2% of the country's cultivated land is currently equipped for irrigation [3]. Small farmers therefore suffer particularly from the impacts of climate variability which limits their sources of food and increases the risk of hunger and poverty. The little adaptive capacity of the agricultural sector underscores the country's vulnerability to climate change.

Besides, environmental stresses, especially water stress, seriously limit plant growth as well as plant productivity [4]. Indeed, water stress affects several plants functioning variables, such as leaf temperature [5], stomatal conductance and leaf area [6], as well as photosynthesis [7]. A decrease in the water content of the plant results immediately in a reduction in the growth of the different organs even before photosynthesis is affected [8]. In front of this observation, the optimization of crops diversification policy, through the seek for new speculations of interest in which little water requirement is essential.

It is in this line of approach that *Aloe vera* is introduce as an attracting attention crop. Indeed, *Aloe vera* is a succulent plant resist to drought and some diseases responsible for the destruction of many crops [9]. It can also be developed with water irregularity and weak availability. *Aloe vera* is cultivated mainly for its leaves from which juice and gel are extracted, which give rise to the manufacture of products with diversified uses to such an extent that the plant has today become a marketing strategy [9]. It is involved in the fabrication of several food, cosmetic and pharmaceutical products. The main producing countries are Mexico, Venezuela and the Dominican Republic [10]. In this regard, the American continent alone produces 60% of the *Aloe vera* gel marketed in the world while the remaining 40% comes from Asia and Australia. In these countries, *Aloe vera* is cultivated to meet constantly increasing international demand. According to IMF estimates, the *Aloe vera* market could bring in more than 3.3 trillion dollars by 2026 [11]. For Africa and other developing countries, this could therefore become a significant financial windfall.

In Africa, research programs on *Aloe vera* have mainly focused on its properties ([12,13,14,15]). Very few scientific studies have been carried out at agronomic trait. In Côte d'Ivoire, the only known study is that of N'goran et al. [9], on the search for an amendment for optimum growth of *Aloe vera* in nurseries. This study will therefore provide useful additional information with a view

to promoting and popularizing the cultivation of *Aloe vera* in Côte d'Ivoire. However, facing with the scarcity of arable land, this boost requires the valorization of inter-row spacing of crops occupying large spaces like plantain banana tree, ideally cultivated with a spacing of 3 m x 2 m, that is, a density of 1666 plants per hectare [16].

Thus, the hypothesis that we put forward is that *Aloe vera* intercropping in plantain banana plantations would positively influence the growth and yield parameters of both speculations. This work is effectuated in Daloa at the West Central of Côte d'Ivoire and the purpose aims is to evaluate the effect of intercropped *Aloe vera* with plantain banana (*Musa* sp) on the both crops' growth and yield.

2. MATERIALS AND METHODS

2.1 Study Site

This study was conducted on the experimental plot of the University Jean Lorougnon Guédé in the West Central of Côte d'Ivoire in the county of Daloa (6.48° and 6.41° and 6.91° and 6.84°). The climate of this area is of the Attiéan subequatorial type [17] with two seasons, namely a dry season and a rainy season. The dry season extends over four months from November to February. As for the rainy season, it lasts eight months and extends from March to October. The wettest months are April, August and September when an average of 103.58 mm of rain is recorded each year. The soils in this area are generally ferralitic, moderately leached on firm land and sandy hydromorphic [18].

2.2 Method

The plant material used was composed of corne 1 variety plantain tree shoots, mainly cultivated in Côte d'Ivoire, and *Aloe vera* shoots. The plantain shoots were taken from a rural field in the department of Daloa and transported to the University Jean Lorougnon Guédé (UJLoG). The most vigorous shoots were then selected for the experiment. As for *Aloe vera* shoots, they were collected from a nursery within the UJLoG. These shoots had an average leaf length ranging from 15 to 20 cm [19] with 5 to 7 leaves.

Preparation of the experimental site began with the cutting of a 288 m^2 plot, followed by the staking stage, which consisted of marking out the locations of the planting beds for the banana shoots with stakes. The spacing used for planting banana shoots is 3 m x 2 m [16]. Pockets 40 cm deep were dug at each stake location using a pickaxe. Then, 500 g of cow dung was poured into each pile before planting the banana shoots.

The *Aloe vera* shoots were planted one month after the banana plants were put in place. This time was necessary for the banana plants to recover properly. To do this, the diagonals formed by four banana plants were traced using a tape measure. The point where the diagonals meet was then marked with a stake. A mound 25 cm high was made at this point to accommodate one *Aloe vera* plant between four banana plants.

Secondly, two mounds 25 cm high, separated by one meter and located on either side at an equal distance (50 cm) from the point of concordance of the diagonals were made for the placement of two *Aloe vera* plants between four banana plants. The spacing used for planting *Aloe vera* shoots is therefore 1 m x 1 m [19]. The *Aloe vera* shoots were planted after adding 500 g of cow dung to the pockets made in each mound. The *Aloe vera* shoots were planted on mounds to allow better root fixation of the plants [20].

The experimental design (Fig. 1) used to set up the trial was a complete randomization design with two treatments and eight replicates. The treatments consisted of planting one *Aloe vera* plant between four banana plants (treatment 1) and two *Aloe vera* plants one meter distant between four banana plants (treatment 2).

2.3 Parameters Measured

Observations started 20 days after establishing *Aloe vera* and focused on the growth and yield parameters of *Aloe vera* and plantain tree. The measurement of growth parameters was conducted over 05 months. Indeed, from 05 months, it becomes almost impossible to measure *Aloe vera* leaves without breaking them because of the clump of leaves formed and their fragility. The measurement concerned leaf emergence rate, the number of emerged leaves, the length and width of *Aloe vera* leaves. At the end of the experiment, the biomass of *Aloe vera* leaves was determined. A leaf was considered new when its length reached 4 cm [21]. The length of new generated leaves as well as their width were taken using a graduated ruler every 20 days. Regarding plantain banana tree, the leaf growth was also appreciated every 20 days by counting the number of generated leaves and

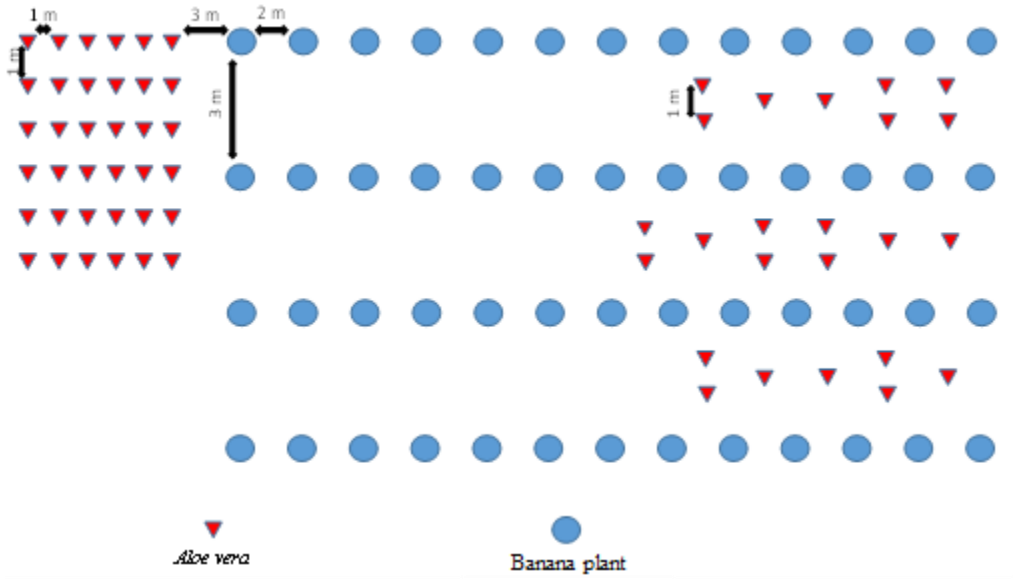

Fig. 1. Experimental design

measuring their length and width using a tape measure. The yield parameters evaluated were the number of hands and fingers, finger mass (kg), finger length (cm), and bunch mass (kg). Yield in terms of bunch (t.ha^{-1}) was calculated using the formula below [22]:

$$\text{Bunch yield (t.ha}^{-1}\text{)} = \text{bunch mass x planting density} \quad (1)$$

2.4 Statistical Analysis of Data

The collected data were subjected to statistical tests using Statistica 10.0 software. An analysis of variance made it possible to appraise the effect of combinations on *Aloe vera* and plantain banana tree growth and yield. Equality of means hypothesis was estimated at α = 5% risk. In case of rejection of this hypothesis, the Newman-Keuls multiple comparison test (at α = 5% threshold) made it possible to classify the means into homogeneous groups.

3. RESULTS

3.1 Effect of the Intercropping *Aloe vera* with Plantain on *Aloe vera* Growth

3.1.1 *Aloe vera* leaf emergence rate

Fig. 2 shows that the number of leaves increased depending on time regardless of the treatment. From the 20th day to the 60th day after intercropping *Aloe vera* with plantain, the evolution curves of the number of leaves almost overlapped. From the 60th day after the planting, the evolution curve of the number of *Aloe vera* leaves resulting from the arrangement of two *Aloe vera* shoots between four plantain plants was clearly above the other two ones with an average of 4 leaves every 20 days. However, the evolution curve of the number of *Aloe vera* leaves from treatment 1 overlapped the one of control suckers until the 160th day after combination.

3.1.2 Number of *Aloe vera* leaves generated

Table 1 shows the number of new *Aloe vera* leaves generated during the experiment. We observed that this number was higher from the 60th day after planting regarding treatment 2. However, the statistical analysis showed a significant difference between the number of leaves generated depending on the treatments only from the 100th day after planting. Thirty-nine leaves on average were generated 160 days after combination regarding treatment 2 against 33 for treatment 1. The lowest value regarding the number of leaves was observed in the control (32 leaves on average). However, the number of leaves generated in the control was statistically identical to that of treatment 1 as of 160 days after combination.

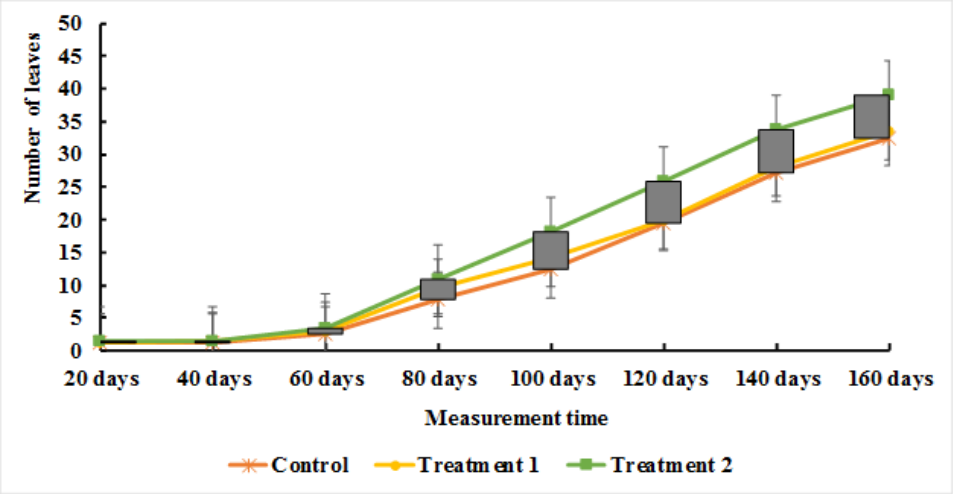

Fig. 2. Evolution of the number of *Aloe vera* leaves generated depending on time
Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants

Table 1. Number of new *Aloe vera* leaves generated

Time after combination	Control	Treatment 1	Treatment 2	P
20 days	1.25 ± 0.46^{a}	1.25 ± 0.46^{a}	1.38 ± 0.52^{a}	0.84
40 days	1.25 ± 0.46^{a}	1.38 ± 0.52^{a}	1.38 ± 0.52^{a}	0.85
60 days	2.50 ± 1.20^{a}	3.00 ± 1.20^{a}	3.50 ± 1.31^{a}	0.3
80 days	7.75 ± 4.20^{a}	9.63 ± 4.24^{a}	10.88 ± 2.10^{a}	0.29
100 days	12.38 ± 4.78^{b}	14.13 ± 3.18^{ab}	18.13 ± 4.32^{a}	0.03
120 days	19.50 ± 3.85^{b}	19.88 ± 6.03^{b}	25.88 ± 5.49^{a}	0.03
140 days	27.13 ± 4.67^{b}	28.00 ± 6.82^{b}	33.75 ± 5.01^{a}	0.04
160 days	32.50 ± 4.14^{b}	33.50 ± 5.83^{b}	39.00 ± 5.50^{a}	0.03

The means of the same line followed by different letters are significantly different at 5% threshold
P: Probability. Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants

3.1.3 *Aloe vera* leaf length

The evolvement of the generated leaves length depending on time it is shown in Fig. 3. The lengths of generated leaves with treatment 2 were found to be the highest from the 20th day to the 160th day after planting. Leaf length varied from 6.88 ± 2.09 cm to 20.06 ± 7.66 cm (Table 2). The highest leaf lengths after those of treatment 2 were those of treatment 1. The lengths of generated leaves with treatment 1 varied on average from 6.44 ± 1.50 cm (20 days after planting) to 17.55 ± 7.89 cm (160 days after planting). Statistically, a significant difference ($p < 0.05$) between the leaf lengths of the control and treatments 1 and 2 appeared from the 100th day after planting. From the 140th day to the 160th day after planting, the lengths of the leaves generated by treatment 1 were statistically identical to those of the control.

3.1.4 *Aloe vera* leaf width

The development of the width of the leaves generated depending on time is represented by Fig. 4. The widths of the leaves generated with treatment 2 (two *Aloe vera* plants combined with four plantain plants) from the 20th day to the 160th day after planting were the highest. Leaf width varied on average from 0.70 ± 0.21 cm to 2.78 ± 0.61 cm. The highest leaf widths after those of treatment 2 were those of treatment 1. The widths of the leaves generated with treatment 1 fluctuated from 0.65 ± 0.23 cm (20 days after planting) to 2.43 ± 0. 81 cm (160 days after planting). The narrowest leaves were those generated by the control. Table 3 shows the results after analysis of variance. Statistically, a significant difference ($p < 0.05$) between the widths of the leaves of the control and treatments 1 and 2 appeared from the 100th day after planting.

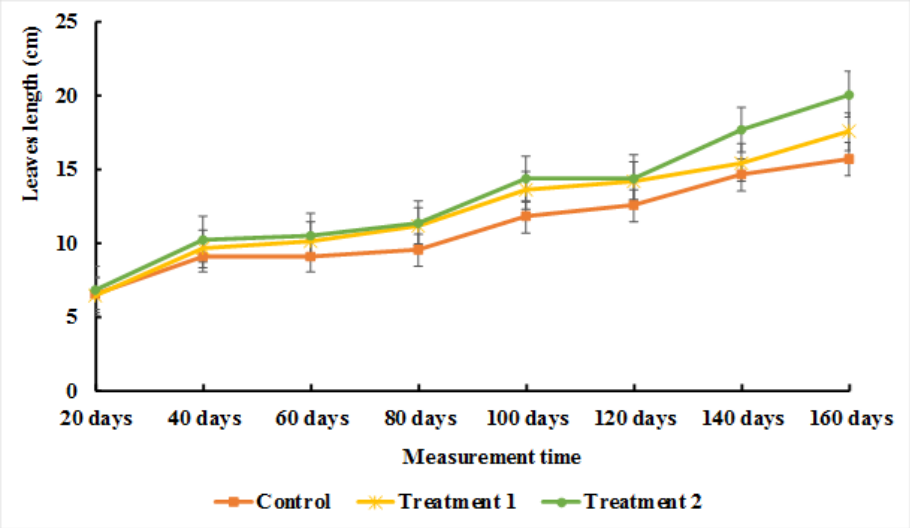

Fig. 3. Evolution of the length of *Aloe vera* leaves generated depending on the treatments
Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants.

Table 2. Length of *Aloe vera* leaves generated depending on the treatments

Time after combination	Control	Treatment 1	Treatment 2	P
20 days	6.58 ± 2.10[a]	6.44 ± 1.50[a]	6.88 ± 2.09[a]	0.89
40 days	9.13 ± 3.66[a]	9.65 ± 3.33[a]	10.27 ± 3.73[a]	0.77
60 days	9.11 ± 4.72[a]	10.15 ± 4.44[a]	10.50 ± 4.66[a]	0.61
80 days	9.55 ± 5.80[a]	11.17 ± 5.46[a]	11.35 ± 6.27[a]	0.17
100 days	11.79 ± 6.24[b]	13.57 ± 6.67[a]	14.33 ± 5.15[a]	0.01
120 days	12.54 ± 6.51[b]	14.22 ± 6.64[a]	14.41 ± 6.29[a]	0.02
140 days	14.61 ± 6.48[b]	15.42 ± 6.87[b]	17.65 ± 6.81[a]	0.00
160 days	15.69 ± 7.25[c]	17.55 ± 7.89[b]	20.06 ± 7.66[a]	0.00

Means on the same line followed by different letters are significantly different at 5% threshold. P: Probability. Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants

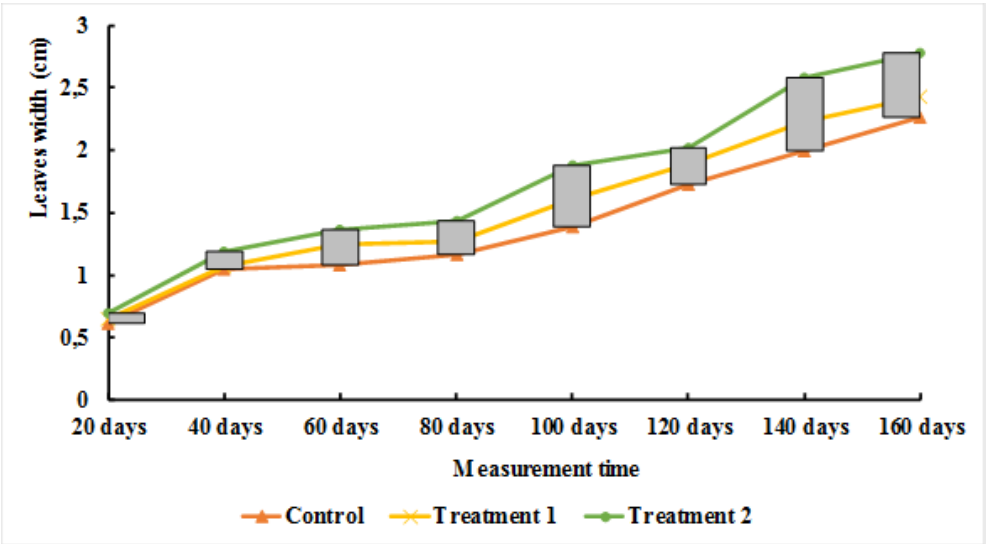

Fig. 4. Evolution of the width of *Aloe vera* leaves generated depending on the treatments
Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants

Table 3l. Width of leaves generated depending on the treatments

Time after combination	Control	Treatment 1	Treatment 2	P
20 days	0.61 ± 0.18[a]	0.65 ± 0.23[a]	0.70 ± 0.21[a]	0.70
40 days	1.05 ± 0.46[a]	1.07 ± 0.34[a]	1.19 ± 0.35[a]	0.68
60 days	1.08 ± 0.54[a]	1.25 ± 0.59[a]	1.36 ± 0.64[a]	0.33
80 days	1.16 ± 0.70[a]	1.27 ± 0.64[a]	1.43 ± 0.72[a]	0.09
100 days	1.39 ± 0.72[c]	1.61 ± 0.62[b]	1.88 ± 0.83[a]	0.00
120 days	1.73 ± 0.79[b]	1.89 ± 0.79[ab]	2.02 ± 0.76[a]	0.01
140 days	2.00 ± 0.76[c]	2.23 ± 0.74[b]	2.58 ± 0.59[a]	0.00
160 days	2.26 ± 0.76[c]	2.43 ± 0.81[b]	2.78 ± 0.61[a]	0.00

The means of the same line followed by different letters are significantly different at 5% threshold
P: Probability. Treatment 1: One Aloe vera plant between four plantain plants; Treatment 2: Two Aloe vera plants between four plantain plants

Table 4. Fresh and dry masses of *Aloe vera* leaves

Leaf masses	Control	Treatment 1	Treatment 2	P
Fresh mass	88.59 ± 7.02[b]	103.48 ± 12.11[b]	125.42 ± 3.12[a]	0.00
Dry mass	27.80 ± 7.31[b]	42.70 ± 13.62[b]	64.27± 5.93[a]	0.00

The means of the same line followed by different letters are significantly different at 5% threshold P: Probability

3.1.5 *Aloe vera* yield

Aloe vera yield (Table 4) was expressed in quantity of fresh and dry leaf matter. The mass of fresh leaf matter generated by treatment 2 (125.42 ± 3.12 g) was greater than those of the leaves generated by treatment 1 (103.48 ± 12.11 g) and the control (88.59 ± 7.02g). The dry biomass of the leaves generated by treatment 2 (64.27 ± 5.93 g) was also higher than those of the leaves generated by treatment 1 (42.70 ± 13.62 g) and the control (27.80 ± 7.31g). The statistical analysis showed a significant difference between leaf biomasses depending on the treatments. However, there was no significant difference between the fresh and dry biomass of the leaves from treatment 1 and the control.

3.2 Effect of the Intercropping *Aloe vera* with Plantain on Plantain Tree Growth

3.2.1 Plantain tree leaf emergence rate

Fig. 5 shows us the emergence rate curves of plantain tree leaves. These overlapped from the 20th to the 40th day after combination. However, we noted that from the 40th day after combination, the emergence rate curve of the leaves from combined plantain trees was above that of control plantain trees with an average of 3 leaves every 20 days.

3.2.2 Number of plantain tree leaves

Table 5 shows us the number of leaves generated by plantain trees during the experiment. We remark that this number was higher from the 40th day after planting in the combined plantain trees. However, the statistical analysis showed a significant difference between the numbers of leaves generated only from the 120th day after planting. Twenty-three leaves on average were produced 160 days after combination in the combined plantain trees compared to 21 for the controls.

3.2.3 Plantain banana tree leaf length

The evolution of the length of plantain tree leaves generated depending on time is represented by Fig. 6. The results showed that the leaf length curve of combined plantain trees was above that of control plantain trees. The length of leaves generated by combined plantain trees was greater than that of control plantain trees from the 20th day to the 160th day after planting. This vacillated between 48.60 cm and 113.53 cm for combined plantain trees and between 38.73 cm and 85.61 cm for control plantain trees 20 and 160 days after combination, respectively.

3.2.4 Plantain tree leaf width

Fig. 7 shows the evolution of the width of plantain tree leaves depending on time. The leaf width evolution curve of plantain trees resulting from the combination was above that of control plantain trees. It thus appeared that combination favored better plantain tree leaf growth. The leaf width of plantain trees combined with *Aloe vera* varied from 26.84 ± 5.38 cm (20 days after

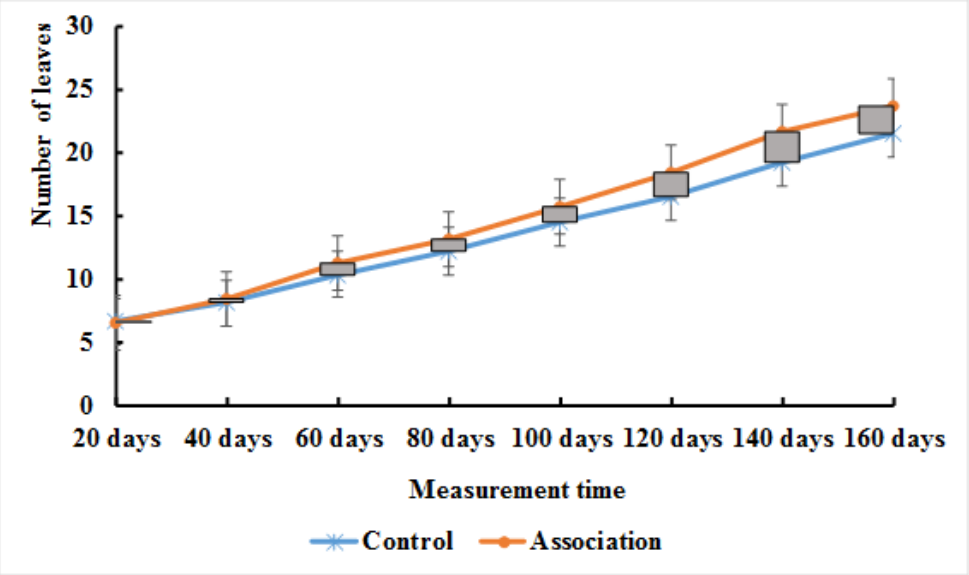

Fig. 5. Evolution of the number of plantain tree leaves generated over time

Table 5. Number of leaves generated by plantain trees

Time after combination	Control	Combination	P
20 days	6.63 ± 1.06[a]	6.50 ± 0.53[a]	0.77
40 days	8.13 ± 1.13[a]	8.50 ± 0.93[a]	0.47
60 days	10.38 ± 1.06[a]	11.25 ± 0.89[a]	0.09
80 days	12.25 ± 1.16[a]	13.13 ± 1.13[a]	0.14
100 days	14.50 ± 1.41[a]	15.75 ± 0.89[a]	0.05
120 days	16.50 ± 1.41[b]	18.38 ± 0.92[a]	0.00
140 days	19.25 ± 1.83[b]	21.63 ± 0.74[a]	0.00
160 days	21.50 ± 1.41[b]	23.63 ± 0.74[a]	0.00

The means of the same line followed by different letters are significantly different at 5% threshold
P: Probability

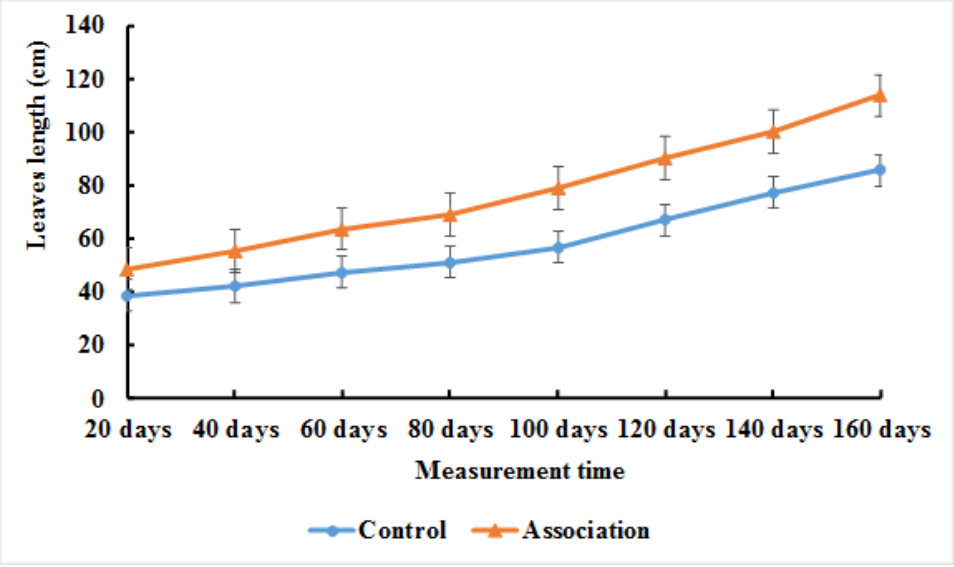

Fig. 6. Evolution of the length of plantain tree leaves

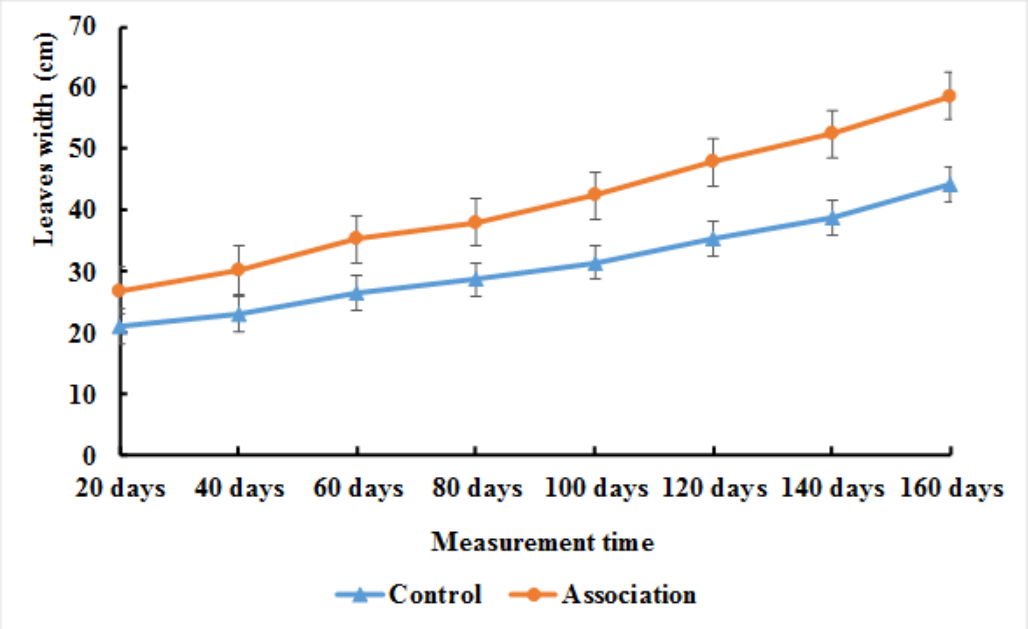

Fig. 7 . Evolution of the width of plantain trees leaves

Table 6. Yield and yield parameters of plantain trees

	Control bunches	Combined bunches	P
Number of hands	6.80 ± 0.22[a]	7.00 ± 0.41[a]	0.86
Number of fingers	31.33 ± 0.87[a]	32.00 ± 0.25[a]	0.75
Finger length (cm)	34.6 ± 1.72[a]	35.25 ± 1.87[a]	0.78
Finger mass (kg)	0.24 ± 0.01[b]	0.46 ± 0.01[a]	0.00
regime mass (kg)	4.70 ± 0.53[b]	9.23 ± 0.18[a]	0.00
Regime yield (t.ha^{-1})	7.83 ± 0.25[b]	15.39 ± 1.21[a]	0.00

The means of the same line followed by different letters are significantly different at 5% threshold
P: Probability

combination) to 58.70 ± 13.38 cm (160 days after combination). As for that of control plantain trees, it ranged from 21.14 ± 3.62 cm (20 days after combination) to 44.18 ± 13.80 cm (160 days after combination). The leaf widths of combined plantain trees were statistically different from those of control plantain trees from the 20th day after combination.

3.2.5 Plantain tree yield

The results of yield parameters and bunch yield plantains trees are shown in Table 6. Yield parameters included the numbers of hands and fingers, finger length, finger mass per regime, and regime mass. The results showed that the number of hands, fingers as well as the length of fingers were not significantly different depending on whether the plantains trees were combined with *Aloe vera* or not. However, a statistical difference (at 5 % threshold) was observed in finger mass (0.24 ± 0.01 kg for control bunches and 0.46 ± 0.01 kg for combined bunches), bunches (4.70 ± 0.53 kg for control bunches and 9.23 ± 0.18 kg for combined bunches) and bunch yield (7.83 ± 0.25 t.ha^{-1} for control bunches and 15.39 ± 1.21 t.ha^{-1} for combined bunches).

4. DISCUSSION

This study was conducted to evaluate the effect of plantain banana tree (*Musa* sp) – aloe (*Aloe vera*) combination on the growth and yield of both crops. The results showed that the plantain banana tree -*Aloe vera* combination was beneficial for both crops. Indeed, the *Aloe vera* shoots planted between the plantain banana plants had a higher leaf emergence rate, number of leaves, leaf length and leaf width than those of the controls. This result can be explained by the fact that the *Aloe vera* shoots arranged between plantain plants benefited from

the shade and, in turn, the humidity created by plantain tree leaves, hence their harmonious growth. The importance of shade for the good growth and development of plants, especially shade plants such as *Aloe vera*, is mentioned by several authors ([23,14]). Indeed, shade improves soil humidity, helps moderate ambient temperature and increase air humidity. Thus, plants under shade considerably reduce their transpiration even in periods of extreme heat [24]. *Aloe vera* shoots combined with plantain trees thus escape the limitation of water availability in the soil while reducing their transpiration unlike the control suckers which were exposed to the sun and faced with water stress. As a result, the high temperatures observed during the first quarter after planting and combination (February to April 2023) would therefore have slowed down the growth of control *Aloe vera* shoots. Our results confirm the conclusions of Gharib & Ben [14] in their assertion that shade is important for the good development of *Aloe vera* plants. Besides, the beneficial demonstration of the combination of plantain trees with other crops has been widely documented ([25,26,27]).

Aloe vera under shade also benefited from the availability of mineral elements stemming from the large plantain tree leaves which fall and decompose quickly because of the humid microclimate generated by the combination. In this context, the mineral elements released by the falling of plantain tree leaves followed by their decomposition favored optimal mineral nutrition of the combined *Aloe vera* suckers unlike the controls. Plantain tree leaves are used in the manufacture of certain compost [28]. Plantain tree leaves are obviously green materials that decompose to provide a nutrient-rich additive for aloe growth. According to one study, banana-based compost has greater nutrient efficiency in the soil compared to other fertilizers, good aeration associated with relatively low water application, and decreased nutrient loss through leaching [29]. The high values of fresh and dry matter of *Aloe vera* leaves observed in *Aloe vera* plants combined with plantain trees would be one of the consequences [30].

Regarding plantain trees combined with *Aloe vera* shoots; they were able to grow and develop more healthily unlike the controls. Indeed, control plantain trees were severely attacked by pests of the genus *Mycosphaerella sp*. This genus is responsible for Sigatoka disease in plantain tree. These attacks would have had an impact on the growth and development of control plantain trees. Tuo *et al*. [31] reported the presence of these diseases in the area of Daloa and argue that they reduce the photosynthetic capacity of leaves and affect the growth and development of plantain trees. As for the combined plantain trees, the low attack rate observed in this study would probably be due to the proximity of the plantain trees to *Aloe vera* shoots which would create a natural protection provided by the latter. According to Gharib & Ben [14], the presence of bitter anthraquinones and other polyphenolic components in *Aloe vera* leaves makes it unattractive to pests and pathogens [32,33].

5. CONCLUSION

In a nutshell, one can say that this study has demonstrated that plantain tree - *Aloe vera* combination is beneficial for both crops. Indeed, *Aloe vera*, which is a shade plant, could benefit from the shade and humid microclimate caused by the large plantain tree leaves, especially during periods of high temperature. In addition, the fall of large plantain tree leaves would favor optimal mineral nutrition of *Aloe vera*. As for plantain trees, the presence of *Aloe vera* could reduce the rate of attack on plantain trees by pests. Thereby plantain tree-aloe combination can be recommended and could be done at the density of two *Aloe vera* plants between four plantain plants. In outlook (perspective) we are planning to combine *Aloe vera* with other crops such as rubber tree and palm oil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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