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Assessment of Agro-morphological Parameters of Two Accessions of Undergrowth Yam (*Dioscorea* sp.) Cultivated in the Inter-rows of Mature Rubber Trees (*Hevea brasiliensis*) in Daloa, Côte d'Ivoire

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Abstract

The valorization of mature rubber tree inter-rows by food crops could solve the problem of food insecurity in rubber tree-growing areas. This study aims to assess the agro-morphological parameters of understory yams sown under mature rubber trees. To this end, a trial was carried out in Daloa on a mature rubber tree plantation and a control plot of sole yam. Two accessions of undergrowth yams, "Bacoué" and "Soupkataloa", were grown in the rubber tree inter-rows and monoculture. The experimental design was a completely randomized block with 15 repetitions. The parameters measured on the yams were emergence rate, specific leaf area (SLA), number of days to emergence, number of days to first leaf, stem height (Ht), crown diameter (CD) and production. The results showed that the accessions tested under rubber trees emerged relatively well, with 66.67% and 70.83% rates for Bacoué and Soupkataloa, respectively. These combined accessions also showed the largest SLAs of 343 cm^2/g for Bacoué and 328.5 cm^2/g for Soupkataloa during the dry season. However, emergence was late under the rubber trees compared with the yam monoculture. Bacoué emerged 179.19 d after sowing and had its first leaves 42.88 d later, whereas these values were 58.18 d and 11.71 d respectively for Soupkataloa. However, although Bacoué performed better, with an Ht of 825 cm in 70 days and a large CD (11.18 mm), its production was identical to that of Soupkataloa. These results show that undergrowth yams can be combined with mature rubber trees to guarantee food security.

Keywords: agro-morphological parameters, food security, undergrowth yam combined with rubber tree

1. Introduction

Yam, a staple food for populations, occupies an important place in agricultural food production in Côte d'Ivoire, as it alone accounts for 63.72% of the area under food crops (Assiri, 2017). It is the leading food crop in Côte d'Ivoire (Dibi et al., 2014; Kouakou, 2012) with a production of 7.4 million tons in 2018-2019 (FIRCA, 2020). Moreover, yam is the most important source of calories in this country, also making a substantial contribution in terms of protein to the diet (Dibi et al., 2014). It is increasingly becoming a source of income for producers (N'Goran et al., 2007).

Unfortunately, despite this top ranking, national yam production faces several constraints, including declining soil fertility, a scarcity of arable land, increasing pressure from diseases and pests, and a scarcity of seeds, resulting in a decline in national yam production (Kouakou et al., 2019). Indeed, the average yield of 7 to 12 t/ha (N'Goran et al., 2007), is well below the potential of 65 t/ha (Koswal & Kassam, 1978). This drop in yields is prompting farmers to abandon the plots they have just cultivated, in favor of shifting cultivation. This extensive agriculture is performed to the detriment of the forest and damages the ecological balance and, consequently, any possibility of sustainable development (Kouakou et al., 2019). Furthermore, according to Gnagne et al. (2016), Côte d'Ivoire is facing land saturation in rubber tree-growing areas. Indeed, with the expansion of rubber tree cultivation, rubber tree-growing areas have increased from 74 217 ha in 2002 to 600 000 ha in 2019 (APROMAC, 2020).

Thus, in order to remedy the scarcity of arable land, and the practice of shifting cultivation, this study proposes to valorize the unexploited inter-rows of mature rubber trees. Indeed, these inter-rows make up media that are rich in organic matter. However, given the shade created by mature rubber trees, it is no longer possible to combine them with food crops, for a period over 40 years (Obouayeba et al., 2015). Consequently, given the height of the rubber plants and the extensive canopy they develop at maturity, it is essential to use a certain type of plant that can grow and wrap itself around the trees in search of light for its development. Thus, among the diversity of yams encountered, there are undergrowth yams. These yams are generally combined with cocoa and coffee trees in Côte d'Ivoire and Cameroon (Ocren, 2022). They benefit from the mineral fertilization provided to coffee trees (Dumont et al., 1994).

Our hypothesis is that undergrowth yams are able to grow and develop under mature rubber trees, as they find there an environment favorable to their development. This study, carried out in Daloa, in west central Côte d'Ivoire, aims at assessing the agro-morphological parameters of undergrowth yams cultivated in the inter-rows of mature rubber trees, compared with yams grown in sole cropping.

2. Materials Studied

2.1 Study Area

The study was conducted in west-central Côte d'Ivoire (longitude 6°27′ West, latitude 6°53′ North), in a plantation located on the Daloa-Issia road, 3 km from the town of Daloa. The department of Daloa has a hot, humid tropical climate (Bamba, 2019). Its average temperature ranges from 24.65 °C to 27.75 °C. The average annual rainfall of 1302 mm over the last 10 years favors sustained plant growth throughout the year. In general, average hygrometry in this locality is around 86%, with a minimum of 56% in December and January (INS, 2014). Daloa's vegetation is characterized by dense, humid forest in the south and savanna woodland in the north. The soil is ferralitic (Adjiri et al., 2018).

2.2 Plant Material

Two types of plant material were used in this study. The first consisted of two accessions of undergrowth yam (*Discoreae* sp.). Undergrowth yams are called "cocoassié" in the local language. The second consisted of rubber tree (*Hevea brasiliensis*) clone GT1.

2.2.1 Accessions of Undergrowth Yams

The undergrowth yam accessions used in this study were collected from two regions of Côte d'Ivoire. These included yams with vernacular names Bacoué and Soupkataloa. Bacoué is characterized by violet-green leaves (Figure 1A), a high number of spines (Figure 1B), no flowering and purple flesh (Figure 1C). As for Soupkataloa, it showed dark-green leaves (Figure 2A), medium spines (Figure 2B), flowering and yellow flesh color (Figure 2C). The Bacoué accession was collected in Tanda in eastern Côte d'Ivoire, and the Soupkataloa accession in Soubré in the country's southeast. These included indeterminate-growth varieties, chosen for their high yield (Mlan, 2021; Ocren, 2022), and their ability to adapt to shade (N'Goran, 2023). Yam seeds were stored in a cool, well-ventilated place, away from sun, rain and rodents, until planting (N'Gue et al., 2007).

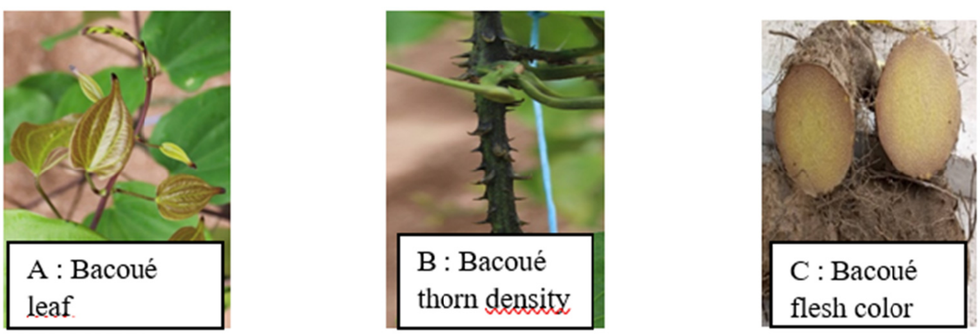

Figure 1. Characteristics of Bacoué accession

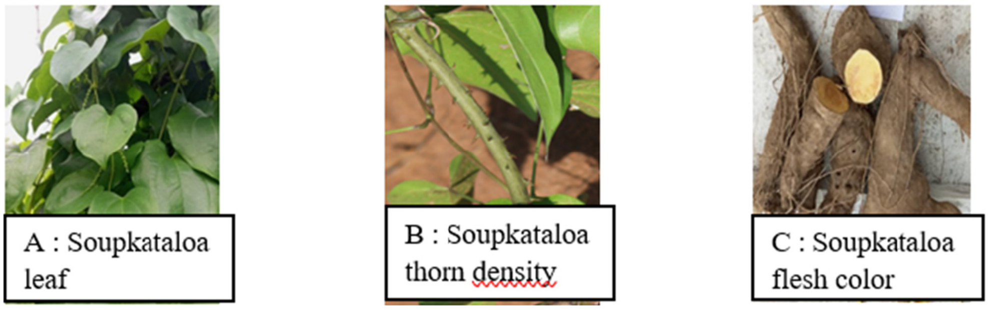

Figure 2. Characteristics of Soupkataloa accession

2.2.2 Rubber Tree Clone

The rubber tree plantation in which this study was carried out was a village plantation consisting of several IRCA 41, PB 217, GT1 and PB 230 monoclonal plots. Within the plantation, the GT1 monoclonal plot was chosen. GT1 is considered the reference clone in Côte d'Ivoire (Essehi, 2019). According to Obouayeba et al. (2000), clone GT1 has moderate radial vegetative growth and is the only clone currently grown in Côte d'Ivoire's 18 rubber tree-growing sectors. Clone GT1 trees selected were those not affected by tapping panel dryness, and having a girth greater than 40 cm at 1.70 m above ground. These trees were planted in 2007 at a density of 555 per hectare (6 m x 3 m) and started being tapped in 2013. At the start of the experiment in 2022, the trees were in the 9th year of downward half-spiral tapping (S/2), while in crop year 2023, the trees were tapped in upward quarter-spiral (S/4U).

3. Methods

3.1 Setting up the Experiment

The experiment was carried out on a total surface area of 1.55 ha. The rubber tree plot, consisting of clone GT1, covered a surface area of 1.5 ha, while the control plot, consisting of sole yam cropping, covered an area of 0.05 ha. The yam accessions were grown in the rubber tree inter-rows at the intersection of four rubber trees. The distance between two yam locations on the same row was 9 m, and the yam planting lines were 18 m apart. Planting density was 62 seeds/ha. In sole yam cropping, the distance between two yam locations on the same row and from one row to another was 2 m. The seeds of both accessions were planted at a depth of 20 cm. The yam seeds underwent no chemical treatment before sowing. The experiment was set up during the rainy season on July 7, 2022. The experimental design was a completely randomized block with four treatments and 15 repetitions. The treatments were as follows:

(1) Bacoué sown in sole cropping (control 1);

(2) Soupkataloa sown in sole cropping (control 2);

(3) Bacoué sown under rubber trees;

(4) Soupkataloa sown under rubber trees.

3.2 Data Collection

3.2.1 Undergrowth Yam Emergence: Number of Days to Emergence (NDE) and Yam Emergence Rate

The time elapsed for each yam cutting from sowing to stem emergence on the soil surface is the number of days before emergence. Thus, one month after sowing the yams, a weekly survey of emerged cuttings was carried out. The date of stem appearance on the surface of the mound or seed hole was noted for each yam location. The average number of days to emergence was then determined by summing the number of days to emergence of each emerged yam over the total number of emerged yams.

$$\text{ANDE (d)} = \sum(\text{Nde})/\text{Tnec} \quad (1)$$

where, ∑Nde: Sum of the number of days to each cutting emergence; Tnec: Total number of emerged cuttings.

Counting the number of emerged cuttings helped estimate emergence rate by the following relationship:

$$\text{ER (\%)} = (\text{Nec}/\text{Tnc}) \times 100 \quad (2)$$

where, ER: Emergence rate; Nec: Number of emerged cuttings; Tnc: Total number of cuttings sown.

3.2.2 Growth Parameters of Undergrowth Yams

3.2.2.1 Stem Height (Ht)

Seven days after emergence of the yams, the height of the stems was measured using a tape measure. Measurements were taken from the ground to the stem apex over a period of 70 days, at regular weekly intervals. The weekly height values were used to generate a curve of yam stem height depending on time.

3.2.2.2 Morphological Growth Parameters

(1) Number of Days to First Leaf (NDFL)

After the yam cuttings had emerged, a daily survey was carried out. The date of first leaf emergence was noted for each yam location. Then, the average number of days to yam first leaf was determined by summing the number of days to first leaf for each emerged yam over the number of yam plants bearing leaves.

$$ANDFL\ (d) = \sum(Ndfl)/Npbl \tag{3}$$

where, ∑Ndfl: Sum of the number of days to first leaf; Npbl: number of plants bearing leaves.

(2) Crown Diameter (CD)

Seven days after emergence of the yams, the crown diameter of the seedlings was measured. At this stage, the seedling is less fragile and measurements can be taken easily. This measurement was carried out weekly for 84 days using a caliper at the base of the stem, precisely at the separation zone between the root system and the aerial part (Mamadou et al., 2014). Average values were determined by summing the crown diameters of the different yam plants over the total number of yam plants measured. The values were expressed in millimeters (mm).

$$CD\ (mm) = \sum(CD)/Npm \tag{4}$$

where, ∑DC: Sum of crown diameters; Npm: number of plants measured.

(3) Specific Leaf Area (SLA)

Specific leaf area (SLA) measurements were carried out at two different stages, during the rainy season and during the dry season when the plant was in full vegetative growth. Mature, green and healthy leaves were collected for measurement. Measurements were taken on 3 plants per treatment. On each plant, 3 leaves were cut at three levels in the foliage of the plant (bottom, middle and top), then wrapped in newspaper. A total of 9 leaves per treatment were used. Each leaf was then scanned using a scanner. The scanned images were saved in jpg format (Ghoudbane, 2021). The leaf samples were then oven-dried at 60°C for 48 hours. After drying, the leaves were weighed on an electronic precision scale in the laboratory. This weighing operation was carried out to get dry matter (DM) weight. Finally, photofiltre 7 software was used to convert the standard pixel unit of the scanned images into centimeters (cm) in order to get the size references for calculating their surface areas.The surface area of each leaf (LA) was determined using Image J software (Dossounon, 2023) and the specific leaf area (SLA) was calculated from the following relationship:

$$SLA\ (cm^2/g) = LA\ (cm^2)/DW\ (g) \tag{5}$$

where, LA: Leaf area; DW: Leaf dry weight (Cornelissen et al., 2003).

3.2.3 Yam Production (Prod)

Yam production was determined for each treatment, one year after planting. Harvested tubers were weighed using a scale. Yam production was expressed in kilograms per location (kg/loc). The average value of yam production was then determined by the following relationship:

$$Prod = \sum(Wtl)/Tnl \tag{6}$$

where, Prod: Production; Wtl: weight of tubers weighed per location; Tnl: total number of locations.

3.3 Statistical Analysis

The data collected were first entered into Excel 2016 spreadsheet. They were then subjected to an analysis of variance using SAS 9.4 software. Treatment means were compared at 5% probability threshold using the Newman-Keul test.

4. Results

4.1 Undergrowth Yam Emergence

Table 1 shows the results for emergence rate and average number of days to emergence for the different accessions per treatment. Analysis of variance revealed that the emergence rates of the Bacoué and Soupkataloa accessions were statistically different when grown in different environments (under rubber trees and in sole yam cropping (control)) ($P = 0.0489$). The Bacoué accession combined with rubber trees had a lower emergence rate (66.67%) than Bacoué in sole cropping (94.44%). The same applied to the Soupkataloa accession, where Soupkataloa in sole cropping (control) recorded an emergence rate of 88.89%, compared with 70.83% under the rubber trees. However, the emergence rate of Bacoué was similar to that of Soupkataloa, whatever the cropping environment.

As for the number of days to emergence, the analysis showed a significant difference between Bacoué accessions sown under rubber trees and those in sole cropping (control), and between Bacoué and Soupkataloa sown under rubber trees ($P < 0.0001$). The Bacoué accession under rubber trees recorded a high number of days (179 days) compared with the other accessions. The Soupkataloa accession under rubber trees and the Soupkataloa accession in sole cropping showed statistically identical NDE.

Table 1. Emergence rate and average number of days to emergence of accessions per treatment

Treatments	ER (%)	NDE (d)
(1) Bacoué sown in sole cropping (control 1)	94.44±12.43 [a]	62.26±51.24 [b]
(2) Soupkataloa sown in sole cropping (control 2)	88.89±15.72 [a]	48.44±13.8 [b]
(3) Bacoué sown under rubber trees	66.67±23.57 [b]	179.19±87.52 [a]
(4) Soupkataloa sown under rubber trees	70.83±17.18 [b]	58.18±23.27 [b]
F	2.9243	22.3511
P	0.0489	< 0.0001

Note. In each column, the values assigned the same letters for each designated parameter are not statistically different at 5% threshold according to the Newman-Keul test.

ER: Emergence rate; NDE: Number of days to emergence.

4.2 Growth Parameters of Undergrowth Yams

4.2.1 Yam Stem Height Depending on Time

The evolution of stem height of the two yam accessions depending on time is illustrated in Figure 3. All curves show the same pattern. However, the curve for the Bacoué accession sown under rubber trees is higher than the other three curves, with a maximum height of 825 cm at day 70. From day 7 to day 35, the curves for the Bacoué accessions in sole cropping (control 1), Soupkataloa under rubber trees and Soupkataloa in sole cropping (control 2) are merged. From day 35 onwards, the curve for Soupkataloa under rubber trees moves slightly above those for Bacoué and Soupkataloa in sole cropping (control 2), which remain merged until day 70, with a maximum height of 391 cm.

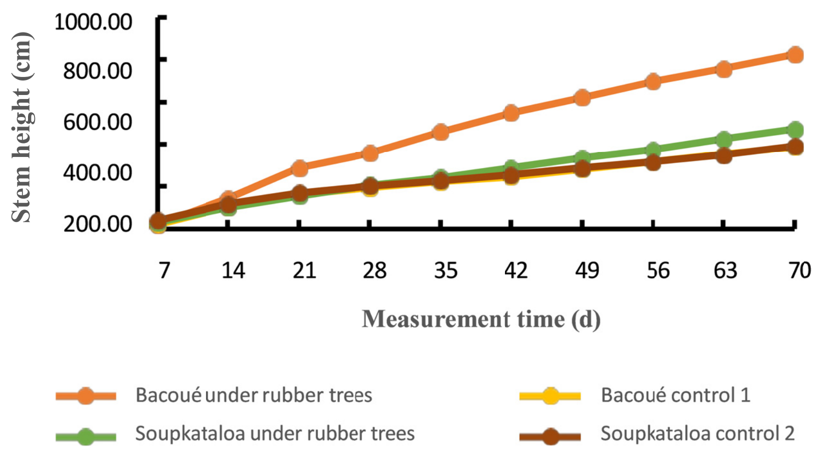

Figure 3. Evolution of stem height depending on time per treatment

4.2.2 Morphological Growth Parameters

The results relating to morphological growth parameters of undergrowth yams are given in Table 2.

With regard to the number of days to first leaf emergence, statistical analysis showed a significant difference between the Bacoué accession sown under rubber trees and that in sole cropping (control 1), and between Bacoué and Soupkataloa sown under rubber trees (P < 0.0001). The number of days to leaf emergence was longer in the Bacoué accession sown under rubber trees (42.88 d) than in the Soupkataloa accession sown under rubber trees (11.71 d). Moreover, the control accessions (Bacoué and Soupkataloa) showed the lowest duration to leaf emergence. This recorded duration was statistically identical to that of the Soupkataloa accession under the rubber trees.

In terms of crown diameter, analysis of variance revealed a significant difference between the accessions (P < 0.0001). Under rubber trees, the Bacoué accession showed a larger crown diameter (11.18 mm) than Soupkataloa (6.7 mm). Similarly, in sole cropping (control), Bacoué showed a larger crown diameter (10.49 mm) than Soupkataloa (8.57 mm). Bacoué in sole cropping (control 1) reached a crown diameter statistically identical to the one under the rubber trees, while in the Soupkataloa accession the control showed the greatest crown diameter value.

As for yam specific leaf area, analysis of variance revealed that the dry-season specific leaf area of the Bacoué and Soupkataloa accessions were statistically different when grown in different environments (P < 0.0001). The highest specific leaf area values were recorded with both accessions under rubber trees. The controls showed the lowest values. For the same cropping environment, Bacoué and Soupkataloa recorded identical specific leaf areas. During the rainy season, Bacoué recorded the highest specific leaf area (518 cm^2/g). Moreover, Soupkataloa grown under rubber trees and Soupkataloa in sole cropping gave the same specific leaf areas (341.50 and 303.00 cm^2/g, respectively).

Table 2. Morphological growth parameters of two understory yam accessions by treatment

Traitements	NDFLE (d)	CD (mm)	SLAd (cm^2/g)	SLAr (cm^2/g)
(1) Bacoué sown in sole cropping (control 1)	17.53±12.93 ^{b}	10.49±2.37 ^{a}	183.00±24.34 ^{b}	128.00±8.47 ^{c}
(2) Soupkataloa sown in sole cropping (control 2)	8.67±2.69 ^{b}	8.57±2.08 ^{b}	168.50±40.12 ^{b}	303.00±55.34 ^{b}
(3) Bacoué sown under rubber trees	42.88±20.49 ^{a}	11.18±1.66 ^{a}	343.00±53.86 ^{a}	518.50±140.64 ^{a}
(4) Soupkataloa sown under rubber trees	11.71±4.99 ^{b}	6.70±1.88 ^{c}	328.50±61.52 ^{a}	341.50±32.54 ^{b}
F	22.3511	22.3511	19.3578	21.4108
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note. In each column, the values assigned the same letters for each designated parameter are not statistically different at 5% threshold according to the Newman-Keul test.

NDFLE: Number of days to first leaf emergence; CD: Crown diameter; SLAd: Specific leaf area in dry season; SLAr: Specific leaf area in rainy season.

4.3 Yam Production

Table 3 shows yam production results for the different accessions per treatment. Analysis of variance revealed a significant difference (P = 0.0000). The production of the Bacoué and Soupkataloa accessions was low under the rubber trees (0.16 kg/loc and 0.23 kg/loc, respectively), whereas it was higher with the controls (5.42 kg/loc and 5.42 kg/loc, respectively). The results also showed that there was no difference in yam production between Bacoué and Soupkataloa, either in the controls or under the rubber trees.

Table 3. Yam production per treatment

Treatments	Prod (kg/loc)
(1) Bacoué sown as in sole cropping (control 1)	4.42±1.64 [a]
(2) Soupkataloa sown in sole cropping (control 2)	5.42±2.66 [a]
(3) Bacoué sown under rubber trees	0.16±0.07 [b]
(4) Soupkataloa sown under rubber trees	0.23±0.20 [b]
F	22.2729
P	0.0000

Note. Values assigned by the same letters are not statistically different at 5% threshold according to the Newman-Keul test.

Prod: Production.

5. Discussion

Several studies have shown that it is possible to insert certain food crops or perennial species as intercrops with rubber trees during the first 3 to 4 years of planting, without any danger to the rubber plants (Kéli et al., 2005). In contrast, combinations including mature rubber trees with cultivated species are poorly documented and mostly lead to failure due to the heavy canopy developed by the rubber trees, which prevents the combined crops from growing and developing properly (Wibawa & Gunanwa, 1997; Thierry, 2005). This study, carried out in west-central Côte d'Ivoire, aims at combining two *Dioscorea sp* accessions that grow under trees and shrubs as well as in monocropping, and assessing their agro-morphological performance. Overall, the two Bacoué and Soupkataloa accessions studied performed better in monocropping than under rubber trees.

In monocropping, Bacoué and Soupkataloa recorded emergence rates of 94% and 88%, respectively. These rates are close to those of Sankara (2017), who measured germination rates of over 90% on *Dioscorea alata*. These values are also close to those of Bazié (2018), who measured an average germination rate of 93%. Already in 2003, Soro et al. were able to demonstrate that an emergence rate above 80% reflects the good physiological health of seeds. From these results, I can affirm the undergrowth yam seeds used are of good physiological quality. However, variability was observed between the Bacoué and Soupkataloa accessions for the agro-morphological traits studied. Firstly, emergence time between the two accessions varied by 14 days. Secondly, the crown diameter of Bacoué was greater than that of Soupkataloa. Finally, the divergence between both accessions was remarkable at the date of first leaf emergence. This variability in the parameters measured suggests that both accessions collected from two different regions of Côte d'Ivoire are different. These findings are similar to those of N'Goran (2023) who, in studying the agro-morphological diversity of a collection of 40 accessions of undergrowth yams including Soupkataloa and Bacoué, affirmed that they belong to different classes. Thus, Soupkataloa is placed in class 1, characterized by dark-green leaves and a stem covered with medium-sized upward-curving thorns, while Bacoué is in class 3, with violet-green foliage and a high density of thorns. The presence of significant diversity mainly for growth and development parameters within the *Dioscorea* genus has already been mentioned by several authors (Obidiegwu et al., 2009; Azéoun & Dansi, 2010; Siqueira et al., 2012; Adoukonou-Sagbadja et al., 2014). Furthermore, based on these observations, both accessions showed no difference in tuber production.

Under rubber trees, both accessions not only showed divergence in the traits measured, as in monoculture, but also had more delayed growth and development. Thus, emergence duration of the Bacoué and Soupkataloa accessions under mature rubber trees were 179 and 58 days longer, respectively, than in monocropping. The same applies to growth parameters such as average number of days to first leaf emergence, stem height and specific leaf area of yams, which were greater under rubber trees. The emergence rate of the yams also fell compared with the control in sole cropping. While emergence rates were 94% and 88% in monocropping, under rubber trees the rates were 66% and 70%, for Bacoué and Soupkataloa, respectively. These results show that, contrary to preconceived ideas, the inter-rows of mature rubber trees can be used to grow staple crops such as undergrowth yams. These results confirm those of Kouadio et al (2021), who demonstrated that coffee trees grown in combination with double rows of mature rubber trees spaced 33 meters apart produced as much per hectare as those grown in sole cropping. The seed emergence rate of yams under rubber trees, although lower than those obtained in monocropping, is higher than that of certain plants grown under shade. These include *Cyperus esculentus*, which has a germination rate of 28.9% under shade (Dodet, 2006), and cassava, which has a very low germination rate under shade (Adjata et al., 2015). The height of yam stems under rubber trees was also lower than under sole cropping. The slower growth and development of accessions under rubber trees would be due to the presence of large rubber trees, which through the density of their foliage create a shady microclimate preventing the proper diffusion of light and slowing down the process of yam growth and development. Wibawa and Gunanwa (1997) have shown that the reduction in light intensity due to rubber trees' crown development prevents the proper development of the intercrop. Thiery (2005) has also shown that even in weeds, the shading provided by rubber trees' canopy at a certain level is sufficient to naturally limit weed development. In addition, stem height under the rubber trees was a factor of great divergence between both accessions. The Bacoué accession was taller, with a maximum height of 825 cm at day 70 after emergence, while Soupkataloa recorded a maximum height of 391 cm at the same development stage. According to Zoundjihekpon (1995), growth speed is a factor of divergence between yam varieties, and height is among the morphological parameters that best predict a plant's performance (Boukhari, 2013). From these assertions, I can attest that Bacoué is more vigorous and efficient. One of the performances also showed by Bacoué was a considerable delay in the emergence of its leaves. This delay is explained by the fact that the nutrient reserves mobilized by the plant's roots are used to elongate the stem in search of the light found at the top of the rubber tree (Tousignant & Delorme, 2006). The late emergence of leaves in Bacoué is an advantage that enables it to reach the rubber tree canopy, and thus emerge from the shady undergrowth before generating the first leaves (Cornet, 2015). This trait is a very important adaptation mechanism for growing yams in rubber trees. Another shade adaptation strategy deployed by the accessions studied was the development of wider leaves than under sole cropping conditions. The large leaves allow them to capture more light rays under shade to carry out photosynthesis. This increase in leaf size under shade has also been observed in *D. alata* (Rodriguez, 1997). According to Reddy et al. (1989), specific leaf area is known to vary depending on stage and cultivation conditions. Despite all the mechanisms put in place under the rubber trees, the production recorded with the Bacoué and Soupkataloa accessions is lower compared with yam monocropping. This result could be attributed to the fact that the yams are shaded by the rubber trees, creating competition for light and slowing down photosynthesis. Vaillant et al. (2005) affirm that photoperiod has an effect on yam development. Indeed, it is one of the most important physical factors influencing yam tuberization (Dibi et al., 2016) and, in turn, yield. Although yam production under rubber trees is low, the results of this study show that the inter-rows of mature rubber trees can be valorized by the cultivation of undergrowth yam.

6. Conclusion

This study showed that undergrowth yams Bacoué and Soupkataloa can grow and develop under the shade of mature rubber trees. This remarkable performance is illustrated by an emergence rate of over 66%. In addition, these yams develop various adaptive mechanisms that favor their optimal development, including delayed leaf emergence and the deployment of larger leaves. Compared with the Soupkataloa accession, the Bacoué accession was distinguished by a longer emergence time and a delayed leaf emergence. However, it had the highest stem height. Nevertheless, Bacoué's production was identical to that of Soupkataloa. Thus, the combination of mature rubber trees with undergrowth yam could be recommended to rubber tree farmers in order to increase yam production and, in turn, solve the problem of food insecurity.

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