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Comparative study of spatial occupancy and agronomic performance four morphotypes (M1, M2, M3 and M7) of taro *Xanthosoma* spp. in Côte d'Ivoire

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Abstract

Ensuring sustainable food and nutritional security is paramount for Côte d'Ivoire. To contribute to this, work has begun on taro, a local plant that is underutilized. The aim is to promote taro cultivation and facilitate its integration into Côte d'Ivoire's cropping systems. Thus, a trial was set up to compare the agronomic performance and spatial occupancy of four morphotypes taro *Xanthosoma* spp. M1, M2, M3 and M7. A three-block experimental device was used. Data collected during the trial covered plant height, wingspan of plant, leaves, main tuber and secondary tubers. Among the four morphotypes compared, morphotype M7 recorded the highest average yield of edible tubers (8.79 ± 4.02 tonnes per hectare vs. 8.23 ± 4.00 tonnes per hectare, 6.11 ± 2.96 tonnes per hectare and 5.52 ± 3.62 tonnes per hectare for M2, M3 and M1 respectively). M7 is also the morphotype that occupies the least space in cultivation. These two characteristics make M7 the most productive taro morphotype in terms of edible tubers. It is also the best suited to easily integrate cultural associations into the farming systems in Ivory Coast. These results could contribute to the valorization and integration of taro and strengthen local food and nutritional security.

Keywords: *Xanthosoma* spp; Taro; Morphotypes; Agronomic performance; Spatial occupation

1. Introduction

Food security is a major challenge for developing countries. The proportion of the world's population suffering from chronic hunger in 2022 was 9.2%. This proportion is much higher in Africa (20%) than in other regions of the world (8.5% in Asia, 6.5% in Latin America and the West Indies and 7% in Oceania) [1].

In this context, ensuring and guaranteeing food security in Africa in general and particularly in Côte d'Ivoire is both necessary and urgent. Added to this challenge is the worrying change in the climate. In recent years, around 36% of the African population has been exposed to at least one form of climate risk, such as drought, heat, water stress or flooding. In recent years, Côte d'Ivoire has experienced vulnerability in the agricultural sector due to climate change. This is marked by early or late agricultural starts, short rainy seasons and much more [2].

To meet these challenges and contribute to the food and nutritional security of households, the valorization of under-exploited local crops is an alternative to consider. These local plants are very interesting phytogenetic resources in terms of their nutritional quality, hardiness and adaptability [3]. Among these crops, we find taro, a plant cultivated for its tubers and leaves. Taro tubers are rich in high-grade starch and dietary fiber [4]. Dietary fibre in taro can help prevent

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cancer by absorbing carcinogens [5]. In addition to tubers, taro leaves are an excellent source of carotene, potassium, calcium, phosphorus, iron, vitamin A, vitamin C and dietary fiber [6].

Its rich nutrient content, hardiness and economic potential make taro an important ally in the fight against food insecurity. More attention needs to be paid to taro cultivation in Côte d'Ivoire. In a recent study, Koffi *et al*. [7] reported that the taro *Xanthosoma* spp. consists of four morphotypes (M1, M2, M3 and M7). As characterized by Koffi *et al*. [8]. This characterization study showed a high morphological variability of the taro *Xanthosoma* spp. in Côte d'Ivoire.

In our study, agronomic performance and spatial occupancy of the four taro morphotypes of the *Xanthosoma* genus were compared. The aim of this study is to contribute to the valorization of taro and facilitate its integration into cropping systems in Côte d'Ivoire. Specifically, it will: (i) determine the agronomic performance of the four taro morphotypes (M1, M2, M3 and M7) of the *Xanthosoma* genus and (ii) determine the spatial occupancy of each of these four morphotypes.

2. Material and Methods

2.1. Plant Material

Plant material consists of plants from four morphotypes of taro *Xanthosoma* spp. (M1, M2, M3 and M7). The four morphotypes are distinguished based on the recognition criteria used by farmers in rural areas. These include leaf shape, leaf blade color, petiole color (including sheath), and tuber flesh color [9]. These morphotypes are easily identified by the coloration of the base of the petiole, according to the work of Koffi *et al*. in 2024 [8] (Figure 1). The samples were collected in the region of Mé in Ivory Coast. 132 samples were collected at the rate of 33 samples per morphotype for the four morphotypes. Plants of each of the four were deterred in the fields of producers. Then the leaf blade and petiole top of the plants were cut. Thus, the base of the plant was used as seed (Figure 2).

Morphotypes	Color and shape of leaf blade	Color of the petiole and sheath	Color of the petiole base	Color of the tuber flesh
M1				
M2				
M3				
M7				

Figure 1 Description of the four taro morphotypes *Xanthosoma spp.* [8 ; 9])

Figure 2 Plant without the leaf blade and the top of the petiole were used as seed

2.2. Methods

2.2.1. Study Site

The trial for the comparative study of agronomic performance and spatial occupancy of four morphotypes of taro *Xanthosoma* spp. was carried out at Soubré. Soubré's a town in the southwest of Côte d'Ivoire. This part of Côte d'Ivoire is characterized by high humidity. The average annual temperature is moderate, hovering around 25.8°C. The Soubré region has four seasons, including a long rainy season (April to mid-July), a short dry season (mid-July to mid-August), a short rainy season (mid-August to November) and finally a long dry season (December to March) [10].

The vegetation of Soubré is characterized by a dense humid forest [11; 12; 13]. The soils of the study site are typically highly leached ferralitic soils under hygrophilous forest, characterized by a low base saturation rate (often between 15% and 30%). Chemically, they are acidic and poor in nutrients. Physically, they are distinguished by their ability to retain water, although highly leached soils can be found on basic rocks [14].

2.2.2. Experiment Design

This trial was launched on June 9, 2020, on a plot 39 m long and 7 m wide, covering an area of 273 m^2. A Fisher block experimental design was adopted. The plot was divided into three blocks (11m x 7m) spaced 2 m apart. The blocks were arranged perpendicular to a slight slope (heterogeneity gradient) observed on the plot. With the morphotype (M1, M2, M3, and M7) as our comparison factor, each block received 11 samples of the four morphotypes, for a total of 44 taro samples per block, and 132 samples for the test.

Each block consisted of four sub-blocks (11m x 1m) with one morphotype per sub-block. The four morphotypes were distributed randomly across the blocks using a random draw method. The samples were planted on mounds spaced 1 m apart in rows in each sub-block. The trial was conducted during the rainy season, so we did not need to irrigate the plot. Similarly, no fertilizer was applied. To control weeds, manual weeding was carried out at regular intervals of two to three weeks throughout the experiment. As for pests, no major or significant damage requiring special treatment was observed. Therefore, no specific pest control measures were taken.

2.2.3. Data Collection and Analysis

Data collection was based on 13 quantitative variables [15]. Five variables were measured during the vegetative stage to determine the spatial occupation of the four morphotypes (Table 1). These five variables were collected between 5 and 6 months after planting. The other eight variables, including tuber yield per plant and edible tuber yield per plant, were measured after harvesting the tubers to assess the agronomic performance of the four morphotypes (Table 2). The harvest took place at the end of the crop cycle 10 months after planting. With a density of 1 m between rows and 1 m within rows (1 m x 1 m), yields in tonnes per hectare were obtained by dividing the tuber weight harvested per group by the density multiplied by the number of plants per group, using the following formula:

$$\text{Yield}\left(\frac{\text{tonne}}{\text{hectare}}\right) = \frac{\text{Tuber weight harvested by group (kg)}}{\text{Harvested area [density (1m x 1m) x number of plants by group (33)]}} \text{ x } 10$$

m: meter, kg: kilogram

132 samples divided into four groups (morphotype) were used for the test; 33 samples per group. With this sample size, the statistical power analysis for an ANOVA test calculated with the software R using the pwr library is less than 80% (power=65%, k=4, n=33, f=0.25, sig.level=0.05). However, the sample size of 33 per group was maintained due to lack of M7 morphotype samples in the sampling area.

The collected data was subjected to multivariate analysis of variance (MANOVA) to determine the overall variation between the four morphotypes of *Xanthosoma* spp. taro. Before applying for the MANOVA test, the following assumptions were verified: independence of observations, normality (QQ-plots) and equality of variances (Levene test). The whisker plots below show the dispersions of the 13 variables considered in our study (Figures 3 and 4).

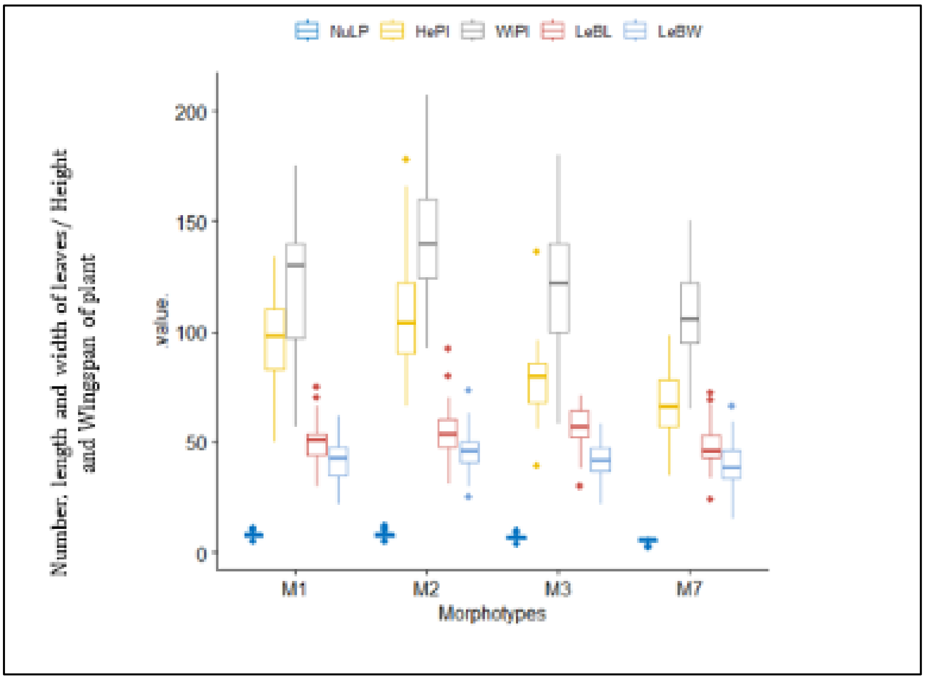
If a significant effect is found, then univariate results (ANOVA) or post-hoc tests can be examined to identify specific dependent variables and affected groups. Preliminary analyses found negligible differences between the three blocks. Therefore, ANOVA was performed according to the fixed model. After the ANOVA test revealed a significant difference between the four morphotypes, Tukey's HSD test was used for pairs of group means that are significantly different from each other. It compares all possible pairs of means and identifies significant differences but also allows for control of the risk of type I errors in multiple comparisons. These analyses were performed using R software with the following packages: library (dplyr) et library (agricolae) [16].

Table 1 List of 5 quantitative variables measured on plants for the analysis of spatial occupancy of the four taro morphotypes of taro Xanthosoma spp

Variables	Codes	Descriptions
Wingspan of plant	WiPl	Maximum horizontal distance reached by leaves, measured 5 to 6 months after planting
Height of plant	HePl	Maximum vertical distance reached by leaves from the crown, measured 5 to 6 months after planting.
Number of leaves per plant	NuLP	Total number of leaves per plant measured 5 to 6 months after planting
Leaf blade length	LeBL	Length of longest blade measured 5 to 6 months after planting
Leaf blade width	LeBW	Length of widest part of blade, measured 5 to 6 months after planting

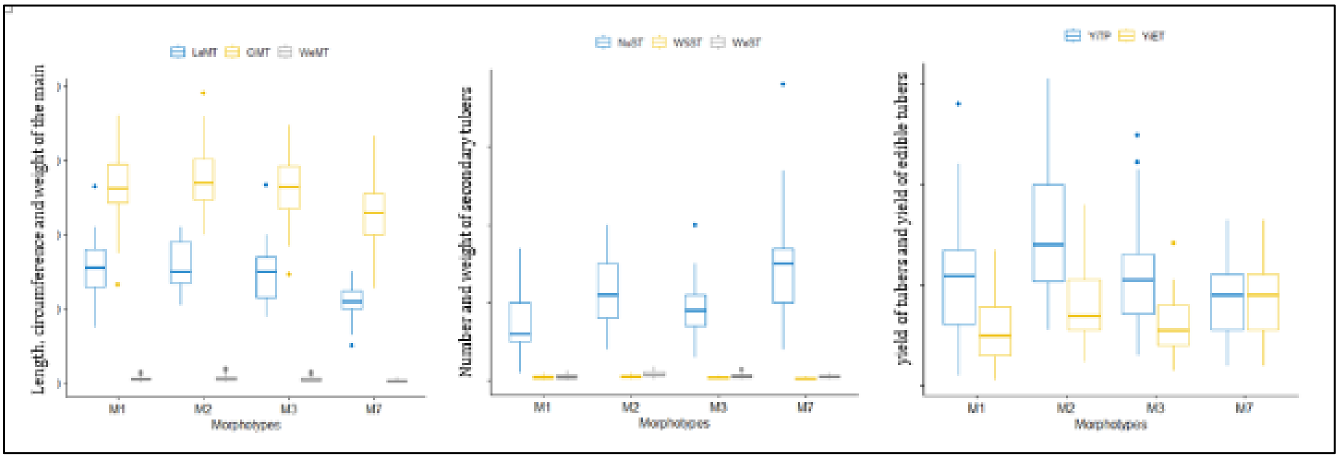
Table 2 List of quantitative variables measured for the analysis of agronomic performance of the four taro morphotypes *Xanthosoma spp*

Variables	Codes	Descriptions
Circumference of the main tuber	CiMT	Circumference of the main tuber, measured at the median level after harvest at 10 months
Length of main tuber	LeMT	Length of the main tuber from the point of contact between the base of the petiole and the top of the tuber measured 10 months after cultivation
Weight of main tuber	WeMT	Weight of main tuber harvested at 10 months
Number of secondary tubers per plant	NuST	Number of secondary tubers harvested at 10 months
Weight of 5 secondary tubers per plant	W5ST	Weight of the 5 largest secondary tubers harvested at 10 months
Weight of secondary tubers per plant	WeST	Weight of secondary tubers harvested at 10 months
Yield of tubers per plant	YiTP	Yield of tubers harvested at 10 months
Yield of edible tubers per plant	YiET	Yield of edible tubers harvested at 10 months



WiPl : wingspan of plant; HePl : height of plant; NuLP : number of leaves per plant; LeBL : leaf blade length; LeBW : leaf blade width; M1: morphotype 1; M2: morphotype 2; M3: morphotype 3; M7: morphotype 7

Figure 3 Dispersion of 5 quantitative variables for the analysis of spatial occupancy of the four morphotypes



CiMT : circumference of the main tuber; LeMT : length of main tuber; WeMT : weight of main tuber; NuST : number of secondary tubers per plant; W5ST : weight of 5 secondary tubers per plant; WeST : weight of secondary tubers per plant; YiTP : yield of tubers per plant; YiET : yield of edible tubers per plant; M1: morphotype 1; M2: morphotype 2; M3: morphotype 3; M7: morphotype

Figure 4 Dispersion of 8 quantitative variables for the analysis of agronomic performance of the four morphotypes

3. Results

3.1. Spatial occupation of the four morphotypes (M1, M2, M3 and M7) of taro *Xanthosoma* spp.

Preliminary verifications revealed negligible differences between the blocks, the analyses focused entirely on the fixed factor (morphotype). The spatial occupation of taro *Xanthosoma* spp. differ according to morphotype (P <0.001) (Tables 3 and 4). Except for leaf blade width (LeBW) (P>0.05), variation was observed between morphotypes for wingspan of plant (WiPl), height of plant (HePl), number of leaves per plant (NuLP) and leaf blade length (LeBL) (Table 5).

Table 3 Overall variation of 5 quantitative variables measured on plants for spatial occupancy of the four morphotypes

	Df	Pillai	approx F	num Df	den Df	Pr(>F)
Morphotypes	3	1.1959	16.704	15	378	$<2.2^{e-16}$ ***
Residuals	128					

***: significant Pr < 0.001

Table 4 Univariate variation of 5 quantitative variables measured on plants for spatial occupancy of the four morphotypes

		Df	Sum Sq	Mean Sq	F value	Pr(>F)
WiPl (cm)	Morphotypes	3	22712	7570.7	11.176	1.454^{e-06} ***
	Residuals	128	86711	677.4		
HePl (cm)	Morphotypes	3	31016	10338.7	24.584	1.254^{e-12} ***
	Residuals	128	53830	420.5		
NuLP	Morphotypes	3	142.33	47.444	28.354	3.988^{e-14} ***
	Residuals	128	214.18	1.673		
LeBL (cm)	Morphotypes	3	1408.3	469.44	3.94	0.00997 **
	Residuals	128	15250.7	119.15		
LeBW (cm)	Morphotypes	3	585.3	195.093	2.094	0.1042
	Residuals	128	11925.3	93.167		

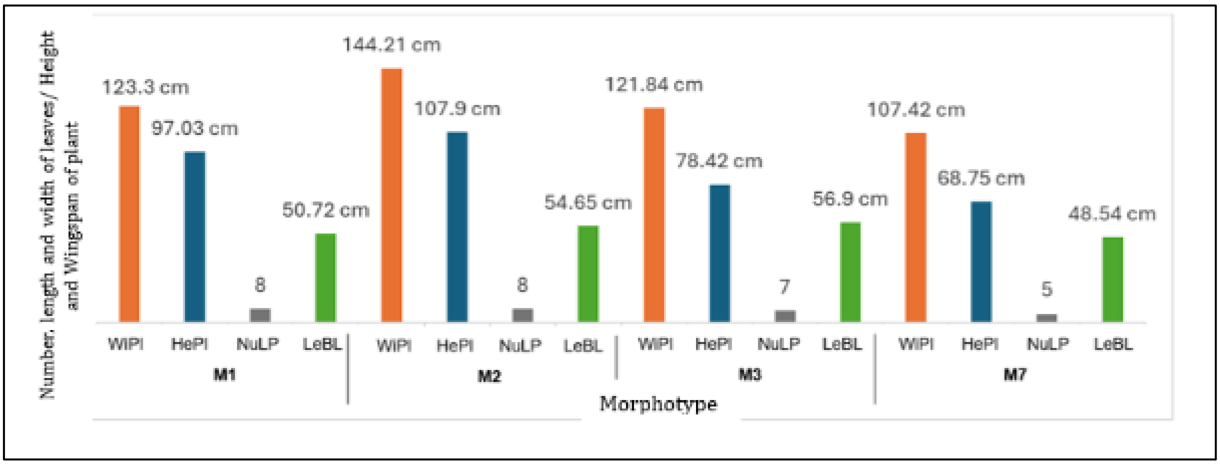
WiPl : wingspan of plant, HePl : height of plant, NuLP : number of leaves per plant, LeBL : leaf blade length, LeBW : leaf blade width, ***: significant Pr < 0.001, **: significant Pr < 0.01, cm: centimeter

Table 5 Means and standard deviation of variables differentiating the spatial occupancy of the four taro morphotypes Xanthosoma spp

Variables	M1	M2	M3	M7	Pr(>F)
WiPl (cm)	123.30 ± 28.98^{b}	144.21 ± 28.31^{a}	121.84 ± 25.07^{b}	107.42 ± 20.95^{b}	***
HePl (cm)	97.03 ± 21.56^{a}	107.90 ± 26.56^{a}	78.42 ± 16.65^{b}	68.75 ± 15.29^{b}	***
NuLP	8 ± 1^{a}	8 ± 2^{a}	7 ± 1^{b}	5 ± 1^{c}	***
LeBL (cm)	50.72 ± 10.40^{ab}	54.65 ± 12.36^{ab}	56.90 ± 10.04^{a}	48.54 ± 10.69^{b}	**
LeBW (cm)	42.93±8.84	45.62±10.33	41.34±8.37	39.95±10.83	> 0.05

WiPl : wingspan of plant, HePl : height of plant, NuLP : number of leaves per plant, LeBL : leaf blade length, LeBW : leaf blade width, M1: morphotype 1, M2: morphotype 2, M3: morphotype 3, M7: morphotype 7, a-b-c-d: ranking in descending order of the different averages, >0.05 : not significant Pr >0.05, ***: significant Pr < 0.001, **: significant Pr < 0.01, cm: centimeter

M2 recorded the largest average wingspan (WiPl) (144.21 ± 28.31 cm). The greatest average plant height (HePl) and the highest number of leaves per plant (NuLP) were observed at M1 (97.03 ± 21.56 cm; 8 ± 1) and M2 (107.90 ± 26.56 cm; 8±2). Leaf blade length (LeBL) was highest at morphotype M3 (56.90±10.04 cm). This was followed by those of morphotypes M1 (50.72±10.40 cm) and M2 (54.65±12.36 cm) (Figure 5).



WiPl : Wingspan of plant; HePl : Height of plant; NuLP : Number of leaves per plant; LeBL : Leaf blade length, cm: centimeter; M1: morphotype 1; M2: morphotype 2; M3: morphotype 3; M7: morphotype 7

Figure 5 Difference between spatial occupation of the four taro morphotypes *Xanthosoma spp*

3.2. Agronomic performance of the four morphotypes (M1, M2, M3 and M7) of taro *Xanthosoma* spp.

Multivariate analysis of variance (MANOVA) of the four morphotypes (M1, M2, M3 and M7) of taro *Xanthosoma* spp. based on the eight agronomic variables considered in this study, revealed a very significant difference (P<0.001) (Tables 6 and 7).

Table 6 Overall variation of 8 quantitative variables for the analysis of agronomic performance of the four morphotypes

	Df	Pillai	approx F	num Df	den Df	Pr(>F)
Morphotypes	3	1.0211	7.933	24	369	$<2.2^{e-16}$ ***
Residuals	128					

***: significant Pr < 0.001

Table 7 Univariate variation of 8 quantitative variables for the analysis of agronomic performance of the four morphotypes

		Df	Sum Sq	Mean Sq	F value	Pr(>F)
CiMT (cm)	Morphotypes	3	420.57	140.19	5.9001	0.00083 ***
	Residuals	128	3041.33	23.76		
LeMT (cm)	Morphotypes	3	460.51	153.502	13.529	1.009^{e-07} ***
	Residuals	128	1452.34	11.346		
WeMT (kg)	Morphotypes	3	2.2039	0.73465	7.8235	7.778^{e-05} ***
	Residuals	128	12.0196	0.09390		
NuST	Morphotypes	3	986.03	328.68	14.455	3.628^{e-08} ***
	Residuals	128	2910.48	22.74		
W5ST (kg)	Morphotypes	3	0.9987	0.33291	12.217	4.41^{e-08} ***
	Residuals	128	3.4880	0.02725		
WeST (kg)	Morphotypes	3	1.5778	0.52595	4.8574	0.00311 **
	Residuals	128	13.8594	0.10828		
YiTP (tonne per hectare)	Morphotypes	3	604.6	201.546	6.7374	0.00029 ***

	Residuals	128	3829.1	29.915		
YiET (tonne per hectare)	Morphotypes	3	250.76	83.588	6.1708	0.00059 ***
	Residuals	128	1733.86	13.546		

CiMT : circumference of the main tuber, LeMT : length of main tuber, WeMT : weight of main tuber, NuST : number of secondary tubers per plant, W5ST : weight of 5 secondary tubers per plant, WeST : weight of secondary tubers per plant, YiTP : yield of tubers per plant, YiET : yield of edible tubers per plant, ***: significant Pr < 0.001, **: significant Pr < 0.01, cm: centimeter, kg: kilogram

This variation was observed at the level of each agronomic variable related to the main tuber (CiMT, LeMT and WeMT), secondary tubers (NuST, W5ST and WeST) and yield (YiTP and YiET) (Table 8). Average lengths of the main tuber (LeMT) (15.60 ± 3.88; 15.76 ± 3.19 and 14.91 ± 3.88 cm) and weights (WeMT) (0.57 ± 0.30; 0.70 ± 0.38; 0.53 ± 0.29 kg) respectively of M1, M2 and M3 were statistically identical and higher than those of the M7 (11.17 ± 2.22 cm; 0.34 ± 0.20 kg). As for the circumference of the main tuber (CiMT), morphotypes M2 (27.63 ± 4.21 cm) and M3 (26.43 ± 4.72 cm) had on average statistically identical and highest values, followed by morphotype M1 (25.83 ± 5.14 cm). Morphotype M7 had the smallest circumference (22.79 ± 5.33 cm).

The highest average number of secondary tubers (NuST) was recorded at the morphotype M7 (15 ± 7). Morphotypes M2 and M3 produced an average of 11 ± 4 and 9 ± 3 secondary tubers per plant respectively. Morphotype M1 produced the lowest average number of secondary tubers per plant (7 ± 4). As for the average weight of secondary tubers per plant (WeST), morphotypes M1, M3 and M7 performed less well (0.55 ± 0.36; 0.61 ± 0.2 and 0.56 ± 0.23 kg) than M2 (0.82 ± 0.40 kg). Similarly, the average weight of the five largest secondary tubers per plant (W5ST) of the M2 morphotype (0.53 ± 0.19 kg) was higher than the average weights of the five largest secondary tubers of the other three morphotypes (M1: 0.44 ± 0.2; M3: 0.41 ± 0.13 and M7: 0.29 ± 0.1 kg).

Table 8 Means and standard deviation of variables differentiating the agronomic performance of the four taro morphotypes Xanthosoma spp

Variables	**M1**	**M2**	**M3**	**M7**	**Pr(>F)**
CiMT (cm)	25.83±5.14[ab]	27.63±4.21[a]	26.43±4.72[a]	22.79±5.33[b]	***
LeMT (cm)	15.60±3.88[a]	15.76±3.19[a]	14.91±3.88[a]	11.17±2.22[b]	***
WeMT (kg)	0.57±0.30[a]	0.70±0.38[a]	0.53±0.29[a]	0.34±0.20[b]	***
NuST	7±4[c]	11±4[b]	9±3[bc]	15±7[a]	***
W5ST (kg)	0.44±0.20[ab]	0.53±0.19[a]	0.41±0.13[b]	0.29±0.10[c]	***
WeST (kg)	0.55±0.36[b]	0.82±0.40[a]	0.61±0.29[b]	0.56±0.23[b]	***
YiTP (tonne per hectare)	10.95±6.19[b]	14.76±6.19[a]	11.23±5.17[b]	8.79±4.02[b]	***
YiET (tonne per hectare)	5.52±3.62[c]	8.23±4.00[ab]	6.11±2.96[bc]	8.79±4.02[a]	***

CiMT : circumference of the main tuber, LeMT : length of main tuber, WeMT : weight of main tuber, NuST : number of secondary tubers per plant, W5ST : weight of 5 secondary tubers per plant, WeST : weight of secondary tubers per plant, YiTP : yield of tubers per plant, YiET : yield of edible tubers per plant, M1: morphotype 1, M2: morphotype 2, M3: morphotype 3, M7: morphotype 7, a-b-c-d: ranking in descending order of the different averages, ***: significant Pr < 0.001, cm: centimeter, kg: kilogram

The highest average tuber yield (YiTP) was recorded for the M2 (14.76 ± 6.19 tonnes per hectare). Soit 32% contre 23.94% (10.95 ± 6.19 tonnes per hectare), 24.56% (11.23 ± 5.17 tonnes per hectare) et 19.22% (8.79 ± 4.02 tonnes per hectare) for M1, M3 and M7 respectively. For edible tubers (YiET), morphotype M7 recorded the highest average yield (8.79 ± 4.02 tonnes per hectare), followed by morphotype M2 (8.23 ± 4.00 tonnes per hectare). The lowest average yields of edible tubers were observed in morphotypes M1 with 5.52 ± 3.62 tonnes per hectare and M3 with 6.11 ± 2.96 tonnes per hectare (Figures 6 and 7).

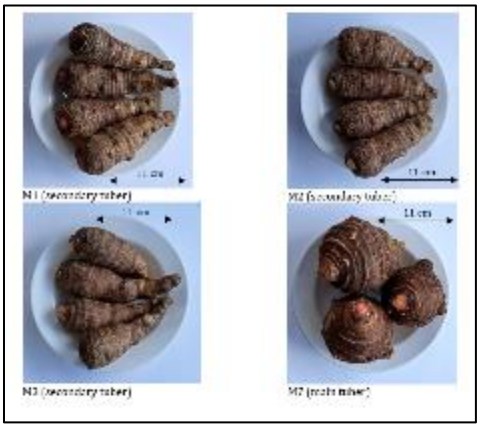


Figure 6 Edible tubers of the four taro morphotypes Xanthosoma spp

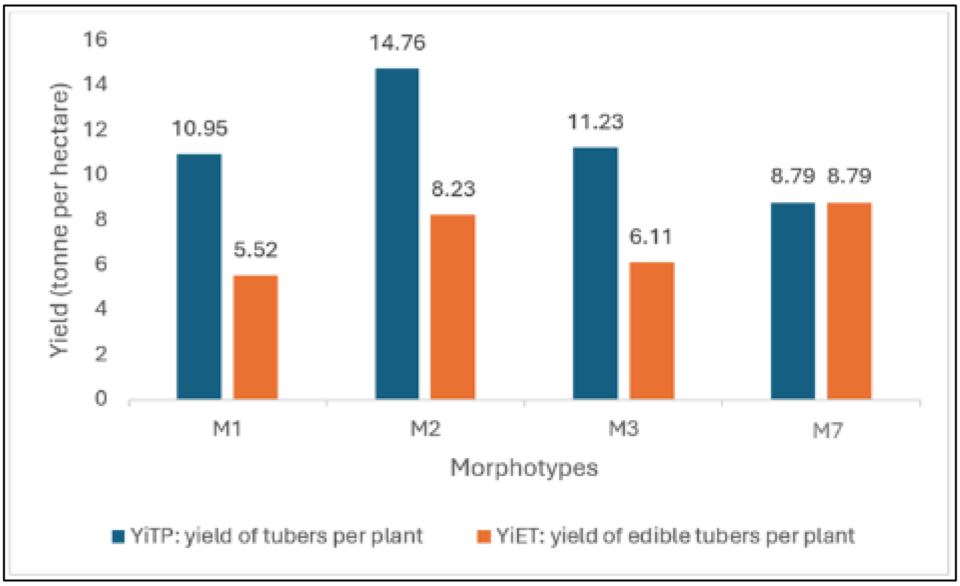


Figure 7 Difference between yield of tubers per plant and yield of edible tubers per plant of the four morphotypes of taro *Xanthosoma* spp

The spatial occupation (NuLP, HePl, WiPl, LeBW and LeBL) of taro *Xanthosoma* spp. is strongly correlated (NuLP:0.7, HePl:0.79, WiPl:0.82, LeBW:0.78 and LeBL:0.78) with yield of tubers per plant (YiTP), with a correlation coefficient greater than or equal to 0.7. On the other hand, the yield of edible tubers per plant (YiET) is weakly or moderately correlated (NuLP:0.36, HePl:0.44, WiPl:0.55, LeBW:0.58 and LeBL:0.63) with the variables of the spatial occupation with a coefficient of correlation less than 0.7 (Table 9).

Table 9 Correlation between the spatial occupation and yield

	NuLP	**HePl**	**WiPl**	**LeBL**	**LeBW**
YiTP	0.70	0.79	0.82	0.78	0.78
YiET	0.36	0.44	0.55	0.58	0.63

YiTP : yield of tubers per plant, YiET : yield of edible tubers per plant

4. Discussion

This study was carried out to increase knowledge of taro morphotype *Xanthosoma* spp. but above all to gain insight into their agronomic performance and spatial occupancy. The data obtained based on the quantitative variables considered enabled us to evaluate the variations between the four morphotypes of taro *Xanthosoma* spp. These variations are well marked in terms of both spatial occupancy and agronomic performance.

About the spatial occupancy of the four morphotypes, variation was observed for all variables considered, except for leaf blade width (LeBW). The results show that morphotype M7 occupies the least space in cultivation. In fact, morphotype M7 recorded one of the lowest average heights (HePl) (68.75 ± 15.29 cm) and average spans (WiPl) (107.42 ± 20.95 cm), as well as the lowest average leaf blade length (LeBL) (48.54 ± 10.69 cm) and the lowest average number of leaves (NuLP) (5 ± 1). This characteristic of the M7 morphotype is an important criterion for crop association. In many traditional contexts, taro is grown mainly in association [17]. Thus, the M7 morphotype could be easily associated in culture with high densities, which would optimize yield. Such an observation has already been made in Ethiopia by Tsedalu *et al.* [18] in their density study carried out on *Colocasia esculenta*. The cultivation of the M7 taro morphotype can therefore be practiced on small areas of land, in association with other food crops. Its cultivation is therefore possible for small farmers or women with limited resources.

To compare agronomic performance, attention was paid to the length, weight and circumference of the main tuber (LeMT, WeMT and CiMT), the number and weight of secondary tubers and the weight of the five largest secondary tubers (NuST, WeST and W5ST), as well as tuber yield and edible tuber yield (YiTP and YiET). Morphotypes M1, M2 and M3 respectively produced main tubers whose mean length (LeMT) (15.60 ± 3.88; 15.76 ± 3.19; 14.91 ± 3.88 cm), mean weight (WeMT) (0.57 ± 0.30; 0.70 ± 0.38 ; 0.53 ± 0.29 kg) and mean circumference (CiMT) (25.83 ± 5.14 cm; 27.63 ± 4.21 cm; 26.43 ± 4.72 cm) are statistically similar and superior to the M7 morphotype [11.17 ± 2.22 cm (LeMT); 0.34 ± 0.20 kg (WeMT); 22.79 ± 5.33 cm (CiMT)]. The similar characteristics of main tubers in M1, M2 and M3 suggest that they share genetic factors influencing tuber size. Paul and Bari [19] made similar observations for certain traits such as the size, weight and length of the main tuber among *Xanthosoma* genotypes.

The highest mean weight of secondary tubers (WeST) (0.82 0.40 kg) and the five largest secondary tubers (W5ST) (0.53 0.19 kg) were recorded at morphotype M2. Similarly, M2 obtained the highest average tuber yield (YiTP), with a production of 14.76 ± 6.19 tonnes per hectare. M2 therefore appears to be the taro morphotype *Xanthosoma* spp. with the best agronomic performance. These results may be linked to the high spatial occupancy of morphotype M2. Indeed, the variables measured to determine spatial occupancy are strongly correlated (NuLP:0.7, HePl:0.79, WiPl:0.82, LeBW:0.78, and LeBL:0.78) with yield of tubers per plant (YiTP). Thus, as the morphotype M2 has the greatest spatial occupancy, this would explain its agronomic performance. As noted in this study, the work of Tsedalu *et al*. [18] could help explain this result. These authors reported a strong positive correlation between tuber yield, leaf area index, and taro plant height. The performance of M2 could therefore be explained by this factor.

Although the M2 morphotype performs well agronomically, it does not appear to be the most important in terms of edible tuber yield (YiET). Indeed, M2 recorded an average edible tuber yield of 8.23 ± 4.00 tonnes per hectare, while M7 gave an average edible tuber yield of 8.79 ± 4.02 tonnes per hectare. This result can be explained by the fact that the main tuber of the M2 morphotype is unfit for consumption. The same applies to the main tuber of morphotypes M1 and M3. Only secondary tubers of M1, M2 and M3 are consumed. This assertion is shared by Owusu-Darko *et al*. [20]. These authors reported the non-consumption of the main tuber of *Xanthosoma* spp. in a study carried out in Ghana. In contrast to the M1, M2 and M3 morphotypes, the M7 morphotype produces consumable main tubers. Unfit main tubers have a considerable impact on the yield of edible tubers (YiET). However, the latter are generally used as seeds for the initiation of new crops. This practice is observed in several African countries, notably Ethiopia, according to [21].

A descendant combining the qualities of the M7 form and the three other forms (M1, M2, and M3) would have better agronomic performance. Indeed, M7 has the best yield of consumable tuber because of its main tuber which is edible. On the other side, M1, M2 and M3 whose main tuber is unsuitable for consumption have the best yield of secondary tubers. Thus, a cross between the form M7 and the forms M1, M2 or M3 would allow to obtain offspring with a high production of edible tuber, combining at the same time the qualities of each morphotype.

The M7 morphotype is the least known among the four that are treated in this manuscript. It is cultivated in very few areas in Côte d'Ivoire. In the areas where it is cultivated, the M7 morphotype is well known to farmers. However, it would be important to extend the knowledge of M7 so that all taro producers benefit from these advantages. Like other taro morphotypes, M7 contributes enormously to the food security of vulnerable households, especially those made up of women, and is a good source of carbohydrates for the nutritional satisfaction of children.

The present study having been conducted on a single site during a single season this would limit its generalization. It would be necessary to conduct the study again to refine the results. This requirement is all the more important given the low statistical power (65%).

Implications

In Côte d'Ivoire, local markets actively contribute to the manufacture of products with added value from many speculations. However, products such as taro chips, powder or taro-based drinks are little known by the populations. Taro is generally consumed in a porridge, foutou and braised. However, there are local systems for the processing of other taro morphotypes into flour and bread [22;23]. Only M7, which is little known to producers, does not currently benefit from a local technical system for processing and preserving quality food products.

The *Xanthosoma* taro is in general a rustic plant adapted to sunlight as well as shading. However, in Côte d'Ivoire by 2050, the work of Diomandé *et al*. [24] predicts a temperature increase of +1°C and +1.5°C respectively according to the RCP 4.5 and RCP 8.5 scenarios. As for precipitation, the projections associated with these previous studies are subject to numerous uncertainties, but they indicate a decrease in cumulative rainfall. This situation could compromise the yields of crops such as taro. It therefore appears necessary to develop varieties that are tolerant to thermal and water stress in order to ensure sustainable food security in Côte d'Ivoire.

5. Conclusion

With the scarcity of arable land and, above all, the reduction of space for food crops in favor of certain industrial crops, the identification of high-performance varieties occupying less space in cultivation is an essential priority. The present comparative study of the four morphotypes of taro *Xanthosoma* spp. in Côte d'Ivoire has enabled us to determine their spatial occupancy and agronomic performance. Results showed variations between morphotypes in both spatial occupancy and agronomic performance. Of the four taro morphotypes compared in this study, morphotype M7 recorded the highest edible tuber yield, with an average of 8.79 ± 4.02 tonnes per hectare. It is also the morphotype that takes up the least space in cultivation. These two properties make M7 the most efficient morphotype in terms of edible yield. Following on from M7, the M2 morphotype showed good agronomic performance, despite taking up the most space under cultivation. This morphotype produced higher yields than the M1 and M3 morphotypes. In the end, M7 is the morphotype of taro *Xanthosoma* spp. best suited to integration into food crop association systems in Côte d'Ivoire. However, the results obtained in this study are specific to the conditions of the study site. Thus, it would be necessary to repeat this study in other environments to refine the results.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] FAO, IFAD, WHO, WFP, & UNICEF. (2023). Summary of The State of Food Security and Nutrition in the World 2023. Transforming food systems to make food security, improved nutrition and healthy diets affordable for all. Rome, Italy, 42 p. https://doi.org/10.4060/cc6550f

[2] Jacquemot P. (2023). From food insecurity to food sovereignty in Africa. Willagri-UM6P. hal-04314189. Accessed: December 17, 2024. https://hal.science/hal-04314189

[3] IPGRI. (2002). Neglected and underutilized plant species: strategic action plan of the International Plant Genetic Resources Institute, Rome, Italy, 30 p.

[4] Lewu M. N., Adebola P. O. & Afolayan A. J. (2009). Effect of cooking on the proximate composition of seven accessions of Colocasia esculenta (L.) Schott tubers growing in South Africa. International Journal of Food Sciences and Nutrition 60(4):81–86.

[5] Nguimbou R. M., Boudjeko T., Njintang N. Y., Himeda M., Scher J., & Mbofung C. M. (2014). Mucilage chemical profile and antioxidant properties of giant swamp taro tubers. Journal of Food Science and Technology, 51(12), 3559–3567.

[6] Opara L. U. & Mejía D. (2003). Edible aroids: post-harvest operations. AGST/FAO: Danilo Mejía, PhD, FAO (Technical) pp. 1-8.

[7] Koffi J.-M. N., Koffi K. K., Bonny S. B. & Zoro B. I. A. (2021). Genetic Diversity of Taro Landraces from Côte d'Ivoire Based on Qualitative Traits of Leaves. Agricultural Sciences, 12 (12): 1433-1446. https://doi.org/10.4236/as.2021.1212091

[8] Koffi J.-M. N., Bonny B. S., Komenan A. O., Angui, C. M. V., & Koffi, K. K. (2024). Morphological diversity of taro genus Xanthosoma collected in four geographical areas in Côte d'Ivoire based on qualitative traits. African Journal of Agricultural Research, 20(2) : 184–198. https://doi.org/10.5897/ajar2023.16429

[9] Koffi K. K. & Koffi N. J.-M. (2021). Phenotypic diversity of cultivated and/or wild "taro" consumed in Côte d'Ivoire. Journal of Applied Biosciences, 3–10.

[10] Sorokoby V. M., Saley M. B., Kouamé K. F., Djagoua E. M. V, Affian, K. & Biemi, J. (2013). Spatio-temporal variability of climatic parameters and its impact on drying up in the Bô and Debo watersheds (Soubré department in southwestern Côte d'Ivoire). International Journal of Innovation and Applied Studies, 2(3), 287–299.

[11] Guillaumet J.-L. & Adjanohoun E. (1971). The vegetation of Côte d'Ivoire. In: The natural environment of Côte d'Ivoire. Paris: ORSTOM, (50): 166-262.

[12] Guillaumet J.-L. & Kahn F. (1979). Description of tropical forest vegetation. Morphological and structural approach. Candollea, 34 (1): 109-131.

[13] Monnier Y. (1983). Vegetation map of Côte d'Ivoire. Atlas of Côte d'Ivoire. 2nd ed., Jeune Afrique, Paris. 72pp.

[14] Blé O.L., Soro T.D., Hien M.P. & Degny G.S. (2022). Effect of agricultural input application on the water-sediment relationship in cocoa-growing areas of Yabayo in the Soubré department in southwestern Côte d'Ivoire. Ivorian Journal of Science and Technology, 40:43–56.

[15] IPGRI (1999). Descriptors for taro (Colocasia esculenta). International Plant Genetic Resources Institute, Rome, Italy, 56 p.

[16] R Core Team (2024). R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

[17] Onwueme I. C., Charles W. B. & FAO. (1994). Tropical root and tuber crops - Production, perspectives and future prospects. FAO, Rome, Italy, 228 p.

[18] Tsedalu M., Tesfaye B., & Goa Y. (2014). Effect of Type of Planting Material and Population Density on Corm Yield and Yield Components of Taro (Colocasia Esculenta L .). Journal of Biology, Agriculture and Healthcare, 4(17), 124–138.

[19] Paul K. K. & Bari M. A (2012). Estimates of genetic components for yield and related traits in Cocoyam. Agriculturists Scientific J. Krishi. Found. 10(2):127-132.

[20] Owusu-Darko P. G., Paterson A. & Omenyo E. L. (2014). Cocoyam (corms and cormels)—An underexploited food and feed resource. Journal of Agricultural Chemistry and Environment, 03(01), 22–29. https://doi.org/10.4236/jacen.2014.31004

[21] Eyasu W., Zemede A., Tileye F., & Kassahun T. (2017). Farmers perception of agromorphological traits and uses of cocoyam (Xanthosoma sagittifolium (L.) Schott) grown in Ethiopia. African Journal of Agricultural Research, 12(35), 2681–2691. https://doi.org/10.5897/ajar2017.12465

[22] Amon A. S., Soro R. Y., Assemand E. F., Dué E. A. & Kouamé L. P. (2014). Effect of boiling time on chemical composition and physico-functional properties of flours from taro (Colocasia esculenta cv fouê) corm grown in Côte d'Ivoire. Journal of Food Science and Technology, 51(5), 855-864. DOI 10.1007/s13197-011-0578-7

[23] Anon A. H., Fagbohoun J. B., Yapi J. C., Dabonne S. & Kouamé L. P. (2018). Bread characteristics and descriptive analysis of taro (Colocasia esculenta, Cv Fouê): Wheat composite bread and some fritters. International Journal of Food Science and Nutrition, 3(3), 41-45.

[24] Diomandé M., Akpa L., Ouattara A. L.-Y., Kpan G. O., Koffi A., Yao B. K., Yapi A. F., Soro D., Agbri L., & Biémi J. (2023). Climate and agriculture in Côte d'Ivoire: Perception and quantification of the impact of climate change on cocoa production by 2050. International Journal of Environment and Climate Change, 13(6), 328–344. https://doi.org/10.9734/ijecc/2023/v13i61832