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RESEARCH ARTICLE

AGRONOMIC CHARACTERISATION OF UNDERGROWTH YAM (*DIOSCOREA* SP.,) FARMS IN COTE D'IVOIRE

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Abstract

Yam, the staple food of the Ivorian people, is the leading food crop in Côte d'Ivoire. Today, with the expansion of perennial crops, especially rubber, yams face the problem of a scarcity of arable land, which threatens food security. To solve this problem, farmers are increasingly growing undergrowing yams as part of their perennial crops. This study aims to characterize understory yam production systems in Côte d'Ivoire. To do this, data was collected from 127 understory yam producers in four main perennial crop regions (Centre/Centre-East, East, West and South-West). The study showed that the main systems practised are the association of yams with cocoa trees (54%) and cashew trees (28%). The average age of the trees is 20.13 years for cocoa and 12.85 years for cashew. White Cocoassié, Red Cocoassié, Yellow Cocoassié and Bolodja are the undergrowth yam varieties grown. Most of these undergrowing yams are grown on gravelly soils on plateaux. The density of yam associations varies greatly depending on the system. These systems need to be improved to increase yam yields and contribute to food security.

Introduction:-

In intertropical zones, yam (*Dioscorea* sp.) is an essential food crop and plays a major role in the food security of millions of people (Adeniji et al., 2012; Cornet, 2015). In Côte d'Ivoire in particular, yam is the leading food crop (Dibi et al., 2014; Kouakou, 2012). It plays a major role in agricultural food production, accounting for 63.72% of the area under food crops (FAO, 2010), with production of 7,391,131 t in 2018-2019 (FIRCA, 2020). This production is mainly located in the North-East, Centre and East, above the 8th parallel North, where it is a staple food for the population (N'Goran et al., 2007). Unfortunately, at a national level, yam production is falling as soil fertility declines and cultivable land becomes scarcer (Kouakou et al., 2019). Given this situation, urgent solutions are needed to remedy the situation and improve yam production in Côte d'Ivoire. To this end, Maliki (2013) has developed alternative improved fallow systems and technologies combining shrub and herbaceous legumes. However, adoption of these technologies remains low and very mixed due to technical and socio-cultural constraints

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(Saïdou et al., 2007a and 2007b). In Côte d'Ivoire, undergrowing yams are grown in association with perennial crops (Ocren, 2022). It therefore makes sense to study these perennial crop-undergrowing yam production systems to improve their yields.

Materials and Methods:-

Study area

This study was conducted in Côte d'Ivoire, in 4 regions where yams are grown in association with perennial crops (Figure 1). These were the Centre and Centre-East, South-West, East and West regions. Several towns were visited in these different regions. In the Centre and Centre East, the towns visited were Yamoussoukro, Toumodi, Dimbokro and Bongouanou. In the South-West, Gagnoa, Soubré, Méagui and San-Pédro were selected. Those in the East included Abengourou, Bondoukou and Bouna. In the West, Daloa and Issia were selected (Table 1).

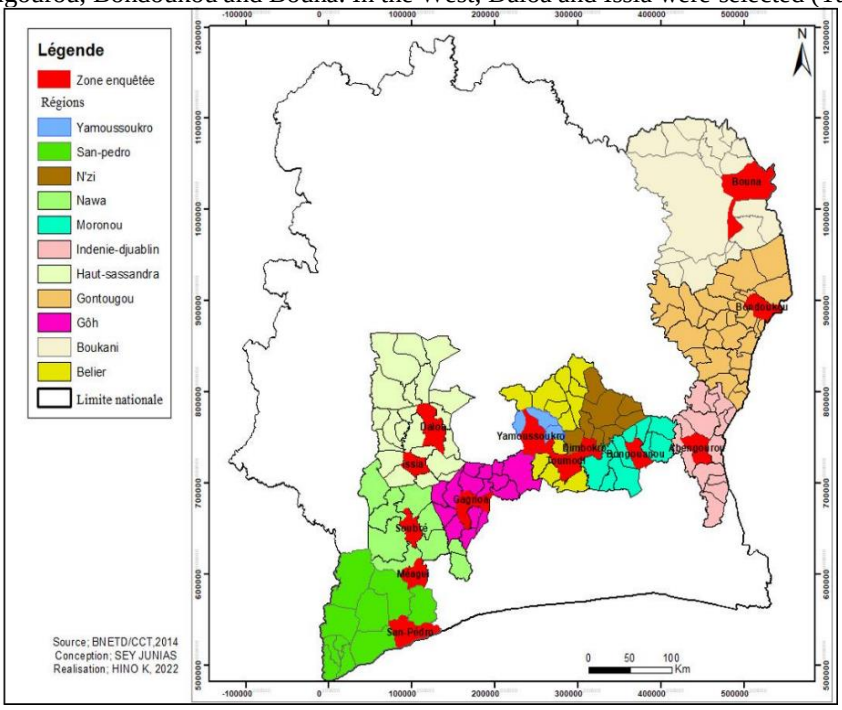

Figure 1:- Survey regions.

Table 1:- Distribution of understorey yam producers in the regions and localities surveyed in Côte d'Ivoire.

Regions	Localities	Number of producers surveyed	Percentage of respondents (%)
Centre/Centre-East	Yamoussoukro, Toumodi, Dimbokro and Bongouanou	30	23.62
East	Abengourou and Bouna	29	22.83
West	Daloa and Issia	36	28.35
South-West	Gagnoa, Soubré, Méagui and San-Pedro	32	25.20
Total	12	127	100

Plant material

The plant material consisted of undergrowth yam accessions.

Methods:-

To carry out this survey, localities were targeted from the outset based on the cardinal axes in each study region. Then, each locality for the study by region was chosen by a systematic random draw from the database of selected localities. The plantations were chosen based on their accessibility in all seasons.

Individual face-to-face interviews with the producers and visual observation of the plantations enabled us to gather information and gain an overall idea of the undergrowth yam production systems. The survey consisted of interviewing the farmers directly, using a questionnaire sheet that had been drawn up in advance.

The questionnaire variables focused on the characteristics of the cropping systems used, in particular the different understory yam-based systems, the areas under perennial crops, the age of the trees, the number of yam mounds, the type of soil, the topographical position of the farms, the yam varieties used, the production cycle of the varieties and the yam harvesting period.

Surveys were carried out both in the fields and in family yards, from 8 a.m. to 6 p.m., by appointment with the producers. The surveys were carried out from March to August 2022.

Statistical analysis

The data collected during the survey were entered in to an Excel spreadsheet and then analysed using STATA 14 softwares. The analysis was based on descriptive statistics (frequency calculations and averages). Charts and curves were produced using this spreadsheet.

Results:-

1.Cropping systems used

The cropping systems used by farmers in all the areas visited were: yams grown in association with cocoa trees (54%), cashew trees (28%), coffee trees (7%), fruit trees (5%), rubber trees (4%) and oil palms (2%) (Figure 2).

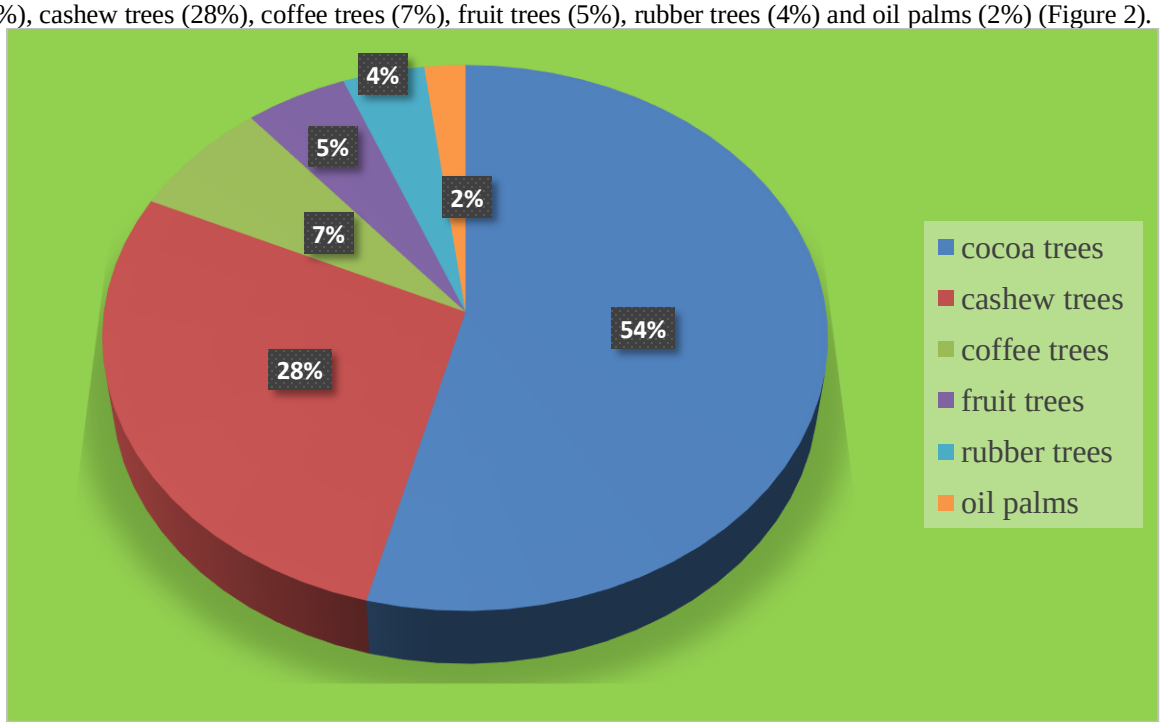

Figure 2:- Yam-based systems practised in Côte d'Ivoire.

Analysis by region shows that the most common cropping systems in Côte d'Ivoire are combining yams with cocoa trees (94.44% of growers in the West, 93.75% in the South-West and 70% in the Centre/Centre-East) and cashew trees (96.55% in the East, 33.33% in the West and 23.33% in the Centre/Centre-East). Moderately practiced cropping systems are the association of yams with coffee trees (16.67% of producers in the Centre/Centre-East and 13.89% in the West), fruit trees (15.63% in the South-West) and rubber trees (16.67% in the West). The least common system is combining yams with palm trees (3.13% in the South-West, 3.33% in the Centre/Centre-East and 3.45% in the East). Combining yams with rubber trees is mainly practised in the West, while cashew nuts are grown more in the East (Figure 3).

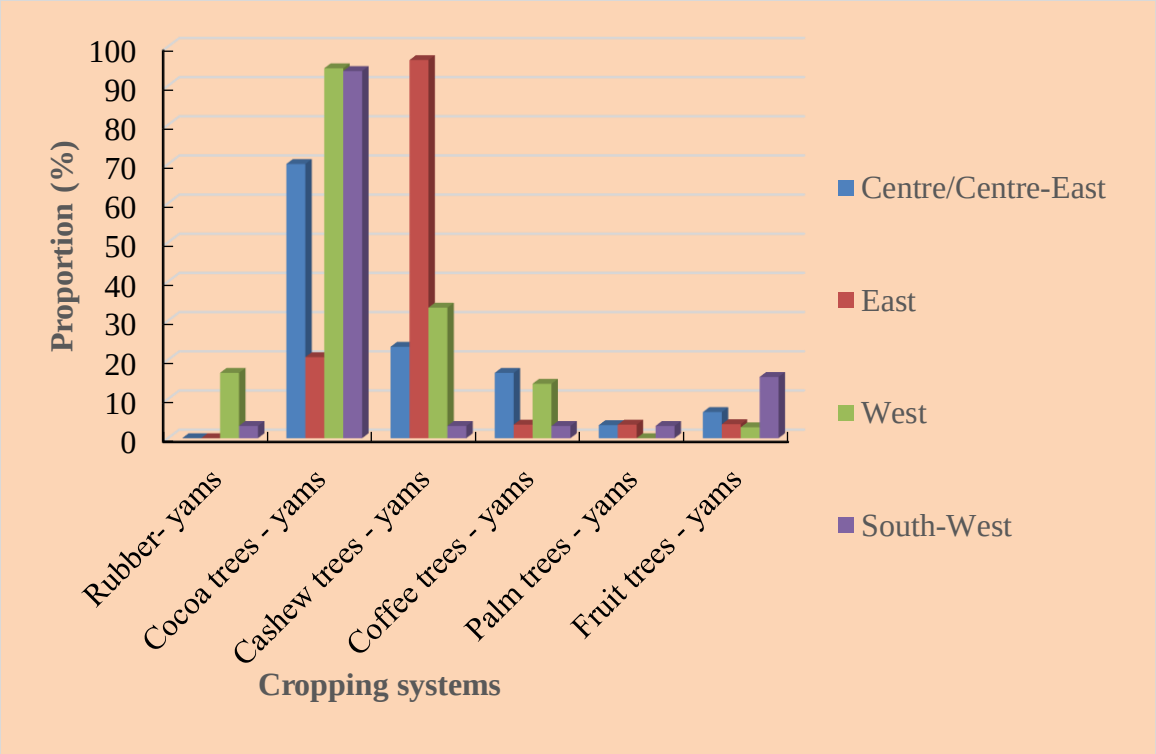

Figure 3:- Proportion of cropping systems practised by study region.

Plantation characteristics

Age of perennial crop trees

The age of perennial crop trees in association with under story yams varies according to the system (Table 2). On average, the trees are 20.13 years old for cocoa trees, 12.85 years old for cashew trees, 7.63 years old for rubber trees, 30.97 years old for coffee trees and 29 years old for palm trees. Analysis by region shows that in the cocoa-yam system, the association of undergrowing yams is practised in old cocoa plantations (25.30 years in the South-West and 21.75 years in the East) or mature plantations (15.71 years in the Centre/Centre-East and 17.76 years in the West). In the cashew-yams system, yams are grown in old cashew orchards (21 years in the East), mature plantations (12.6 years in the Centre/Centre-East) or younger plantations (8 and 9.81 years in the West). In the rubber-yam system, undergrowing yams are grown in association with young rubber trees (5.25 years old in the South-West) or mature yams (10 years old in the West). For coffee trees, undergrowing yams is practised in old coffee plantations (47 years in the South-West and 28.40 in the Centre/Centre-East) or mature plantations (17.50 years in the West). In the palm-yams system, undergrowing yams are grown in association with young palm trees (8 years old in the South-West) or old palm trees (50 years old in the Centre/Centre-East).

Table 2:-Tree ages in understory yam cropping systems.

Age of perennial crop trees (years)						
Systems/Regions	Rubber-yams	Cocoa trees - yams	Cashew trees - yams	Coffee trees - yams	Palm trees - yams	Fruit trees - yams
Centre/Centre-East	-	15.71	12.60	28.40	50.00	-
East	-	21.75	21.00	-	-	-
West	10.00	17.76	9.81	17.50	-	-
South-West	5.25	25.30	8.00	47.00	8.00	-
Average	7.63	20.13	12.85	30.97	29.00	-

Area under perennial crops and density of associations of yams in the understorey

Table 3 shows that the area under perennial crops and the density of yam associations vary according to the systems and regions surveyed. With an average area of 4.10 ha for rubber, farmers planted 337.37 mounds of yams in the

undergrowth, giving an association density of 74.15 mounds/ha. In the cocoa trees-yam system, the average density of association of yams with cocoa trees is 42.71 mounds/ha. With the cashew trees-yams system, the density of yam associations with cashew trees is 30.20 ridges/ha. The coffee trees-yams undergrowth association occupies an average area of 1.38 ha, with a density of 57.96 mounds/ha. The density of the yam-palm association is 40.00 mounds per hectare, with an average area of 0.5 ha. As for fruit trees, the density of yam associated is 27.22 mounds/ha and the area occupied is 2.25 ha. The density of yam associations is higher under the rubber trees. However, the density varies widely between regions (4.71 mounds/ha in the West and 143.59 mounds/ha in the South-West).

Table 3:- Areas under perennial crops and densities of undergrowth yam associations in the regions surveyed

Cropping systems/regions	Rubber-yams	Cocoa trees - yams	Cashew trees - yams	Coffee trees-yams	Palm trees - yams	Fruit trees - yams
Area under perennial crops[1] (ha)						
Centre/Centre-East	-	2.52	3.80	2.40	0.50	-
East	-	2.25	6.61	-	-	
West	6.33	2.88	2.31	0.75	-	-
South-West	1.87	3.74	4.00	1.00	0.50	2.25
Average	4.10	2.85	4.18	1.38	0.50	2.25
Number of yam mounds [1]						
Centre/Centre-East	-	146.60	92.40	63.00	30.00	3.50
East	-	53.75	205.76	-	-	-
West	29.83	138.61	122.09	67.25	-	-
South-West	644.91	152.00	50.00	-	10.00	61.25
Average	337.37	122.74	117.56	65.12	20.00	32.37
Yams density [2] (No. of mounds/ha)						
Centre/Centre-East	-	58.17	24.32	26.25	60.00	-
East	-	23.89	31.13	-	-	-
West	4.71	48.13	52.85	89.67	-	-
South-West	143.59	40.64	12.50	-	20.00	27.22
Average	74.15	42.71	30.20	57.96	40.00	27.22

[1] Average values, [2]Estimated values (Number of ridges/Area of perennial crops)
Source: Survey data, 2022

Types of soil and topographical position of farms

On the basis of the growers' responses, the understorey yam cropping systems were broken down according to soil type and topographical position of the farms. The analysis shows that, apart from the palm-yam system, which is grown only on sandy surface soil, most of the other systems are grown on gravelly soil (Figure 4). In terms of the topographical position of farms, cropping systems are predominantly located on plateaux compared with mid-slope and low-slope positions (Figure 5).

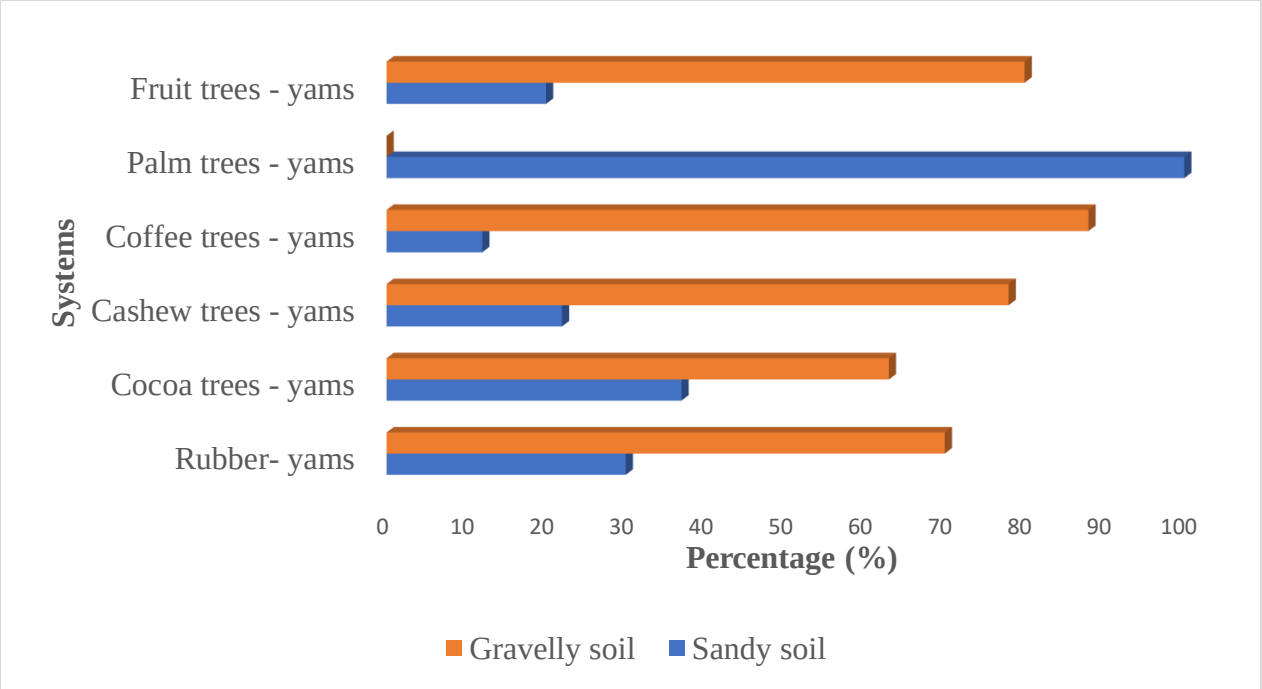

Figure 4: Soil types used for associations with under growth yams

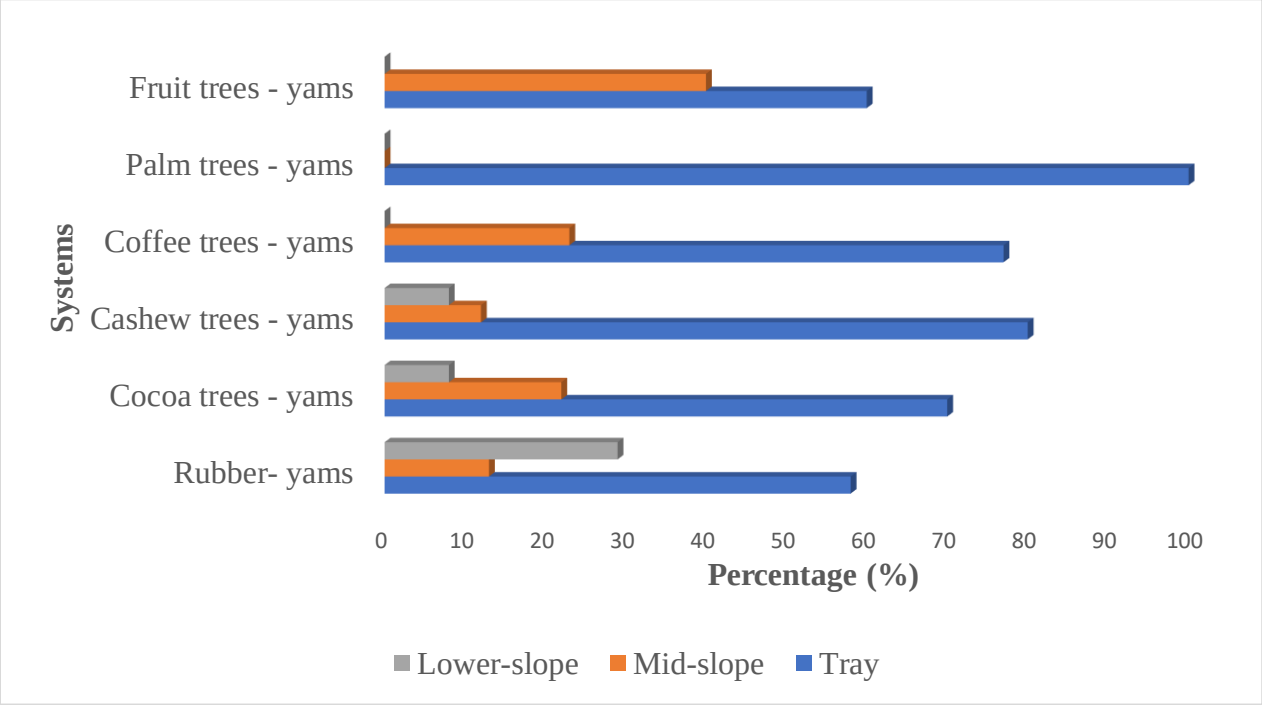

Figure 5:-Topographical position of undergrowth yam farms.

Undergrower yam varieties grown

Table 4 shows the varieties of undergrowth yam grown by producers. There is great diversity (22 varieties) and several vernacular names are given to these yams. The most widely grown are white Cocoassié (29.76%), red Cocoassié (14.88%), yellow Cocoassié (8.30%), Bacoué (7.61%), Soupkataloa (6.92%) and Bolodja (5.19%).

Table 4:-Varieties of undergrowth yam grown.

N°	Undergrowth yam	Percentage (%)
1	Akakli	0.35
2	Bacoué	7.61
3	Bolodja	5.19
4	Cocoassié assobailai	1.73
5	White Cocoassié	29.76
6	Cocoassié ble	3.46
7	YellowCocoassié	8.30
8	Yellow-violet Cocoassié	2.77
9	Black Cocoassié	2.08
10	Cocoassié okloue	3.46
11	Cocoassié oufoue	1.73
12	Red Cocoassié	14.88
13	Cocoassié violet	1.38
14	Cocomiséné	3.46
15	Dapa	1.04
16	Foufoue akassi	0.69
17	Gnaranbolor	0.35
18	Kouadio kouadio	1.04
19	Kounougbe	1.38
20	Kpossoko	1.73
21	Soupkataloa	6.92
22	Wawa	0.69

Main varieties of undergrowth yams grown under perennial crops, their production cycle and harvesting period

Table 5 shows the main undergrowth yam varieties grown under perennial crops and their production cycles. White Cocoassié varieties are associated with cocoa, cashew, rubber, coffee, palm and fruit trees. Red Cocoassié varieties are associated with cocoa, cashew, rubber and coffee trees. The yellow Cocoassié variety is associated with cocoa and coffee trees. Bacoué is generally associated with cocoa and rubber trees, while Soupkataloa and Bolodja are associated with cocoa and cashew trees respectively.

The association of undergrowing yams with perennial crops has a longer cycle length with cocoa, rubber, coffee, palm and fruit trees (12 months). The cashew-yam association lasts between 8 and 12 months. Harvests start in August/September and end between October and January.

Table 5:-Harvesting cycles and periods for the main varieties of undergrowing yam grown in association.

Cultivated yam varieties	Associated crops	Cycle length (months)	Harvest period
White Cocoassié	Cocoa	12	August to January
	Cashew nuts	8 to 12	August to October
	Rubber	12	August to October
	Coffee	12	August to January
	Palm	12	August to January
	Fruit trees	12	August to January
Red Cocoassié	Cocoa	12	August to January
	Cashew nuts	8 to 12	August to October
	Rubber	12	August to October
	Coffee	12	August to January
Yellow Cocoassié	Cocoa	12	August to January
	Coffee	12	August to January
Bacoué	Cocoa	12	September to January
	Rubber	12	September to January
Soupkataloa	Cocoa	8	August to January
Bolodja	Cashew nuts	8 to 11	August to January

Discussion:-

The cropping systems observed in the regions visited were the association of undergrowing yams with cocoa trees (54%), cashew trees (28%), coffee trees (7%), fruit trees (5%), rubber trees (4%) and oil palms (2%). These systems are advantageous because they enable farmers to solve the problem of staking, which is essential for good plant growth and yam tuber productivity. In addition, these systems provide diversified food resources, additional income and help restore soil fertility. Maliki (2013) and Cornet (2015), could state that the practice of crop associations enables producers to ensure food security (availability, stability, access and use of different agricultural products), diversify income sources and sustainably manage the soil. Moreover, for Balogoun et al. (2014), the association of annual crops with trees has several advantages, including food security for households, income generated by the sale of both products and weed control. The results also show that the proportion of the cocoa-yam system (54%) is higher than the other systems encountered. Our results corroborate those of Kouakou et al. (2019) who state that in Cameroon as in Côte d'Ivoire, the association of yam with cocoa is the most frequent.

The age of perennial crop trees in association with under growing yams varies from system to system. On average, the trees are 20.13 years old for cocoa trees, 12.85 years old for cashew trees, 7.63 years old for rubber trees, 30.97 years old for coffee trees and 29 years old for palm trees. The association of under growing yams is practised in adult plantations of perennial crops (cocoa, coffee, palm and cashew). According to Hamon et al. (1986), undergrowing yam cultivars such as Cocoassié (*D. rotundata*), Cocomiséné (*D. cayenensis*) and Bolodja (*D. cayenensis*) are mostly grown under adult cocoa, coffee or cashew orchards by farmers in Côte d'Ivoire, with satisfactory yields. As for the rubber-yam systems, they are generally grown in immature rubber trees so that the yams can benefit from a certain amount of light penetrating the plantation to carry out photosynthesis and develop better. Our results are in line with those of Sey et al. (2024), who assert that the presence of large rubber trees, whose dense foliage creates a shady microclimate, prevents the proper diffusion of light and slows down the yam growth and development process.

In addition, among the systems used, the density of yam association is higher under the rubber trees (74.15 mounds/ha). However, this density varied considerably between regions (4.71 mounds/ha in the West and 143.59 mounds/ha in the South-West). Compared with the rubber-yam system, the density of the Cocoa trees-yams association (42.71 buttes/ha) and the cashew-yams association (30.20 buttes/ha) varied less between regions. These results show that the density of yam associations with perennial crops, especially rubber, is not well controlled.

The undergrowth yam cropping systems were broken down according to soil type and the topographical position of the farms. The analysis showed that, apart from the palm-yam system, which is grown on sandy or sandy topsoil, most of the other systems are grown on gravelly soils. These results show that yam tolerates and adapts to a diversity of soils. Our results are in line with those of Cornet (2005), who states that yam is tolerant of a wide range of soils. However, it prefers light, deep, well-drained soils with a sandy loam or sandy loam texture. Furthermore, Kouakou (2005) states that a sandy-clay texture on the 0-20 cm fringe is favourable to yam cultivation. In terms of the topographical position of farms, cropping systems are predominantly located on plateaux compared with mid-slope and low-slope positions. This could be explained by the fact that staple crops generally prefer flat or gently sloping ground. This is particularly the case for cocoa (Kouamé, 2007) and rubber (APROMAC, 2018; Essehi, 2019). As for yam, a secondary crop, it can only adapt to the environment in which it is grown. Adifon et al. (2019) showed that 26.70% of farmers in north-west Benin and 47.10% in central Benin grow yams in lowlands, flood plains and riverbeds, building large mounds a metre or more high to protect the tubers from hydromorphy.

The results also revealed that there is a huge diversity of undergrowth yams cultivated by growers (22 varieties). Vernacular names were given to these yams. Our results are in line with those obtained by N'Goran (2023). Indeed, the author discovered a diversity of undergrowth yams, notably 40 accessions in Côte d'Ivoire, and studied their agromorphological diversity. The most widely grown undergrowth yam varieties are white Cocoassié, red Cocoassié, yellow Cocoassié, Bacoué, Soupkataloa and Bolodja. This choice could be justified by the taste quality and high yields of these yams.

The production cycle of undergrowth yam varieties associated with perennial crops varies between 8 and 12 months. Our results are in line with those of Cornet (2015) and Adifon et al. (2019). For these authors, the yam production cycle extends over a period of 8 to 12 months. The results presented show that under growth yam harvests start in August/September and end between October and January. Our results are more or less identical to those obtained by

Kouakou et al. (2005) for early yams. Harvests are spread out from July to September for the first harvest and from December to January for the second harvest.

Conclusion:-

The study revealed that the cropping systems practised are the association of yams in the undergrowth with rubber trees, cocoa trees, cashew trees, coffee trees, palm trees and fruit trees. Among these systems, the main ones are yam cropping systems under cocoa and cashew trees, which are widespread in the West, South-West and Centre/Centre-East for cocoa trees, and in the East, West and Centre/Centre-East for cashew trees. The coffee-yam association is more widespread in the Centre/Centre-East, while the fruit tree-yams association is more prevalent in the South-West. The association of undergrowing yams with rubber trees is much more widespread in the West region. The average age of trees associated with undergrowing yams is 20.13 years for cocoa trees, 12.85 years for cashew trees, 7.63 years for rubber trees, 30.97 years for coffee trees and 29 years for palm trees. The undergrowth yam varieties grown are generally white Cocoassié, red Cocoassié, yellow Cocoassié, Bacoué, Soupkataloa and Bolodja. These undergrowth yams are mostly grown on gravelly soils and the farms are located on plateaux with very variable densities. These systems, which combine yams with perennial crops, therefore need to be improved to increase yam yields and contribute to food security in rural and urban areas.

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Conflicts of interest

The authors declare no conflict of interest regarding the publication of this article.

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