IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 12, Issue 6 Ser. II (June 2019), PP 16-25
www.iosrjournals.org

Biological Control of Weeds and Soil' Erosion in Industrial Banana Plantations in Côte d'Ivoire

Kouadio Yao Prosper[1], Mevanly Ouattara [1], Tiebre Marie-Solange[1, *], Boraud N'Takpé Kama Maxime[1], N'guessan Kouakou Édouard[1]
[1] *University Félix HOUPHOUËT-BOIGNY, Abidjan, Côte d'Ivoire.*

Abstract: *The use of cover plants in banana plantations in Côte d'Ivoire concerns, the imperative of maintaining the competitiveness level of bananas on the European Union market, in a context of free trade, regarding the question of European food security concerning the physical quality of banana without glyphosate residues. Sustainable bananas production, therefore, call for research in organic and sustainable improvement in the fertility of the banana plantation by the reduction or even the elimination of pesticides, particularly herbicides, harmful to producers and consumers health. The aim is to produce banana without herbicide and to perpetuate this culture by the suppression of the erosion, the aeration, the maintenance of the microbial activity and the pedagogical structure of banana plantations soils. To do this, the local flora was studied and species were selected from the ability to control weeds, to resist trampling, the non-competitiveness to banana trees and the adaptability to the general ergonomics of banana cultivation. Cutting from these species have been put in incubators and then cultured in association with young banana trees. Growth, ergonomic and economic data were observed throughout the crop cycle banana. The results of the first months indicate that 7 species of cover plants were thus associated with the banana crop of which Vignaadenantha gives the best results. Also, a chain of activities, logistics and labor requirements as well as their cost have been defined. Thus, it is currently possible to produce banana without herbicide in Côte d'Ivoire through the use of cover plants on an industrial scale.*

Keywords*: Sustainable banana, Herbicides, Cover plants, Soilerosion, Côte d'Ivoire.*

Date of Submission: 06-06-2019 Date of acceptance: 21-06-2019

I. Introduction

Bananas are grown in 120 countries, of which 17 produce 75% of world production. Most of the production takes place in tropical regions and plays a key role in the economies of many countries, mainly developing ones. In terms of volume and value, since 1960, bananas have been the most exported fresh fruit in the world, tied with grapes in the presence of citrus fruits, apples and pears. World production was 63,400,000 t in 2000 over 4,500,000 hectares with an average yield of 15.8 t per hectare. Because of its production, bananas are the fourth most important food crop in the world after rice, wheat and maize. The largest producers are India (23%) and Brazil (9%), Ecuador (9%), China (8%), Indonesia (6%) and Costa Rica (3%), which account for 58% of World Production. They are a staple and an export commodity, contributing to the food security of millions of people in a large part of the northern countries such as the United States and Canada (38%), European Union (27%) and Japan (8%) is 73%. Emerging markets (15%) are North Africa and the Middle East (6%) Russia (5%) and China (4%) [1].

Moreover, sold on local markets, they are a source of employment and income for local populations. This is the case for India and Brazil, which sell all their bananas in their domestic markets [2]. In addition to these two countries, local consumption in producing countries is low (11%): Canary Islands (74,686 t), Martinique 68 tons, Guadeloupe 786 tons, Madeira 4,315 tons, Côte d'Ivoire (10%). As an export commodity, they make a vital contribution to the economies of many low-income food-deficit countries, including Ecuador, Honduras, Guatemala, Cameroon, Côte d'Ivoire and the Philippines. Total exports were 14 000 000 tons, or 1.8 billion euro in 2003, making banana the most exported fruit, both in quantity and value. Ecuador, Costa Rica and Colombia provide 65% of the international market ("Banana Republics"). The European market consumes 63% of dollar bananas (Ecuador, Costa Rica, Colombia and Panama), 18% of ACP bananas and 19% of the outermost regions of the EU (Martinique and Gouadeloup (50% EU) in France, the Canary Islands (43% European Union (EU), Spain), Madeira (Portugal) and Crete and Laconia (Greece) and Cyprus (13,500 t in 2004). Bananas from these countries are protected by compensatory aid from the EU's Common Banana Market Organization (CBMO), in order to balance the differential between average revenue to production and the cost of production. . This is no longer the case for the small producer countries of Africa, the Caribbean and the Pacific (ACP) such as Cameroon, Côte d'Ivoire, Dominican Republic, Saint Lucia, Jamaica, Belize, Saint-

Vincent and the Grenadines, Dominica, Surinam, Ghana, Cape Verde, Madagascar Somalia and Grenada since the liberalization of the markets as defined by the WTO in 1998. These countries therefore rely on the quality of their products to maintain in this competitive market. This notion of quality which was observed from the physical point of view of the banana (beauty, grade, weight, length of the fingers) became rather chemical or biochemical with the notion of Average Residue Limit (ARL) of pesticides (Fungicides, insecticides, nematicides and herbicides) contained in bananas for export. Especially since the publication of the actions of glyphosate on the human health (skin irritation, attack of the central nervous system,[3] and that it has been classified probable or possible carcinogens by IARC, since March 2015. And that, its harmful effects on the environment such as the accumulation throughout the food chain toxicity for any plant that has not been genetically modified to tolerate it, the leaching of soils to streams, rivers and streams, groundwater, the modification of soil chemistry (binds to particles, which renders it inert) which disrupts chemical processes in the plant environment, including its ability to fix nitrogen, which makes it necessary to increase nitrate fertilizer rates and its contribution to the growth of the Fusarium fungus and other pathogenic fungi in plant roots. The consequence of all anomalies is the fall in yields in banana production due mainly to soil erosion of banana plantations observed from the 3rd cycle, which requires replanting in the fourth crop cycle of banana [2] in order to protect the health of their population. Have EU countries decided not to use glyphosate in the banana production chain by 2020, at the latest? It is therefore in response to this urgent concern that these works were carried out with the aim of finding an alternative to the chemical control against weeds of industrial banana plantations in Côte d'Ivoire, the leading producer country (380 000 t in 2017) and first banana exporter in Africa and 13th in the world with 7,000 ha of banana plantations, 17,000 direct jobs, 60,000 indirect jobs, 8% of Gross Domestic Product (GDP) and 3% of Gross Domestic Product to be protected (GDP) are to be protected [4]. Specifically, it involves the combination of cover crops and organic matter in banana cultivation to restore soil fertility, eradicate soil erosion and weeds, and contaminate banana aerosol products from pesticides.

Thus, some banana companies such as the Banana Culture Development Company (BCDC), Wanita SA, Canavese, etc are initiating individual actions to reduce pesticides, especially herbicides, in order to increase quickly organic production of banana. However, the expertise of such projects, which include basic research of suitable cover crops and sufficient seed production for large areas, is beyond its control and is a limiting factor for the project. It is precisely to overcome this difficulty that GuilgalAgronomie SARL is asked to deepen and popularize the achievements of research related to biological control by cover plants against banana weeds in an industrial environment. The general objective is to produce banana without herbicide on an industrial scale. It is specifically a question of looking for local species that can serve as cover crops, that is to say capable of: (1) controlling weeds; (2) removing surface erosion from plants; (3) maintaining the slope of the drains, (4) supporting trampling; (5) does not compete with banana plants. To do so, surveys of local species of plants were carried out on the site in Banacomé. Those with agronomic interests were selected and nursed before being cultivated in association with young banana trees on a plot of about 4.1 hectares. Growth data for banana and cover crops were obtained as well as ergonomic and economic studies related to the use of cover crops in the field. This resulting document includes introduction and conclusion, materials and methods, results and discussion.

II. Material And Methods

2.1. Study area

The research was conducted in the Domaine ofBanacomoé belonging to the Banana Development Company (BDC), a member of Compagnie Fruitière. The estate is located in the district of Akoupé in the south-east of Côte d'Ivoire, between the 6th parallel North and the 4th West and covers more than 1,000 hectares of banana trees. It is located along the Comoé River in a humid forest zone in a subequatorial climate. It is accessible by fully asphalted road on the Abibjan-Abengourou axis.

2.2. Equipment

The work required the use of two cars, one for the Abidjan Researcher's trip to the site, the other, the V4 motorbike for harvesting and transporting the cover plants from Abidjan to Banacomoé and for the removal Plant Researcher.

In addition, two notebooks, one for the researcher and the other for the nursery manager, pruner, newspaper papers and a camera were needed to record the names of the species present and record the data related to the species, nursery stock, collect certain species for identification, take photographs of the plant species and agronomic realities of the Banacomoé estate. Finally, a tractor was used to transfer topsoil for potting and to transport seedlings and nursery area staff to the 4.1 hectares experimental plot. Decameter and bamboo stakes were also used for picketing. Jute wire and a 1 m long wooden rod used as a stallion were utilized in planting the cover seedlings. A caliper and a mason meter were used to obtain growth data for banana and cover crops. A survey sheet made it possible to draw up a floristic list of the studied area. A chainsaw was

used to cut branches or tree trunks when preparing the nursery area. Bins, crates, plastic bags, pots and two wheelbarrows were used at the nursery as well as 5 hoes and 2 machetes.

2.3. Methods

Work began with direct observation of weeds on plots and fallows, in thickets along the banks of the Comoé river, under rubberwood plants contiguous to banana plots to identify species which meet the criteria of the company. Subsequently, specimens were collected for their botanical identification at the National Center for Floristics (CNF). A nursery area (80 mx 60 m) has been created for vegetative propagation of plants. These were harvested in Abidjan, on the Northern Highway and under the rubber trees in Banacomoé, put in bags (trash and / or polyethylene) and then transported by car (4 x 4, double cabins) or motorcycle. The plants are sprayed with water at night on arrival at the site, at the nursery level by an irrigation system. They are then cut the next day or the same day at each node, each 2 nodes or three internodes according to their size, their physiological state and the species. The cuttings thus obtained are planted by orienting the axillary buds in the direction of the sun and by sinking into the sachets and into pots filled with potting soil (arable soil coming from a long-term fallow).

After stuffing the cuttings, the bags are stored in the shade under the shade of the canopy of shrubs Neem (*Azadirachtaindica*) and regularly watered (7 am to 8 am) in the mornings and from 17 to 18 h, afternoons. The budbreak times of the cuttings were also observed. The plants are then sorted, counted and stored after 3 weeks in a so-called stimulation zone, which is sunny enough to pre-adapt to the sun's rays andaccelerate their growth in the ambient air. These plants are regularly watered by the irrigation system put in place. They are then counted by species. The success and death rates are determined weekly. A sign is then placed to indicate the name of the species, the number of plants and the date of cultivation of the cuttings. The maintenance of the nursery consists of watering the plants, or to put the cuttings back to the place when they were badly planted, to cut the longest ones, counting more new branches to replant them, to weed the paths and sometimes to make some thinning by cutting branches of neem using a chainsaw. In this case, it was not necessary to apply plant protection products because the cuttings grew normally and without pathology. Beginning in the fourth week, the seedlings were transported in bins or boxes at a rate of 15 per unit and stored in the trailer of a tractor that transported them to the place of cultivation. The planting plot has an area of 4.1 hectares. It was an old fallow of *Tithonia diversifolia* A. Gray (Asteraceae) freshly cultured with large Nana banana plants of the Cavendish variety. Four rows of cover plants were planted on 26 banana planks of varying lengths up to 200 m with a width of 10 to 11 meters over a period of 4 months (April to July 2017). The banana trees were planted in double rows with a spacing of 2 m on the line and1.80 m between the lines. The cover plants are planted in 4 rows, 2 on the outer edges of the planks 60 cm from the outer rows of banana trees and two other inner rows placed 90 cm each of the two inner banana rows. This gives a gap of 1.5 m between 2 rows of cover plants and 1 m on the line. In total, an average density of 5, 000 cover seedlings were thus for 1 800 banana trees per hectare. After picketing the lines, a burlap wire is laid along which 30 cm x 30 cm x 30 cm pockets are dug every m. The young plants of cover plants are then deposited, removed from their sachet or the pot then planted by making sure that the stems are well directed towards the sun in the holes which are immediately, well resealed. The plants are recounted the following week to determine success and mortality rates in the field. The irrigation system is then started to water the plot for 8 hours a day. Therefore, all the traditional operations related to the maintenance of the banana trees intervene according to the usual agronomic program of the company (fertilization, installation of weevil trap, cable-way ...). Only herbicide weeding has been formallyremoved. Only two seedlings were carried out at the 4th and 8th week after the cultivation of cover crops. Subsequently, growth data were obtained on weeds (global abundance index), on cover crops (development phase, length, height of the stems and diameter at the neck of the stems, the number of leaves and the overall recovery rate of the plot and on the banana trees.

III. Results

3.1. Invasive weeds

Species such as *Telosmaafricana* (Asclepiadaceae) and *Urerakeayi* (Urticaceae) and *Parquetinianigrescens* (Parquetiniaceae) are highly invasive and difficult to eliminate from plantations. They resist all the usual herbicides. In addition, *Ipomoea trilobata* (Convolvulaceae), *Merremia hederacea* (Convolvulaceae), *Adeniarumicifolia* (Passifloraceae), *Centrosemapubescens* (Fabaceae) are also invasive. They are strict voluble and choke in this respect the banana trees but sensitive to the usual herbicides.

3.2. Local species of agronomic interest

Of all the species encountered, only (1) *Vigna adenantha*(Legume), (2) *Ipomoea carica* (Convolvulaceae), (3) *Heterotisrotundifolia* (Melastomataceae), (4) *Desmodiumadscendens* (Legume), (5) *Merremia sp*. (Convolvulaceae), (6) *Axonopuscompressus* (Poaceae) and (7) *Oplismenusbenthamianum* (Poaceae) were selected based on the search criteria. *Vigna adenantha* has been identified on the banks of the Comoé. It has the same characteristics as those known in Abidjan and Dabou (soft stem, trifoliolate leaves and pods like those of beans). However, the leaf area and the size of the leaflets are relatively small compared to that of Abidjan and Dabou which are perfectly identical. It could therefore be a local variety of *Vigna adenantha* different for that purpose from that of Abidjan and Dabou. *Merremia sp*. was first harvested in Dabou and then on the banks of the Comoé (marsh area). As for *Heterotisrotundifolia*, it is the same as that encountered in Dabou and on the Northern Highway (Axis Abidjan-Yamoussoukro). It evolves here, under the shading of rubber plants together with *Desmodiumadscendens*, in places where the foliage of rubber trees is less dense (windthrow, on the edges of large rubber trees in production) often in association with *Axonopuscompressus*. The latter also evolves under old rubber plants where it forms tufts with long leaves (15 to 30 cm) or roadside or in sunny places where it tilts well on the ground. *Ipomoeacarica* has been identified here and in Dabou. It evolves on fallows where it stifles all weeds. It sometimes competes very closely with *Brachiarabrezentha* (Poaceae), suppressing surface erosion of planks and drains. Rooting is superficial, retains soil moisture and produces litter. The stems of the plants thus retained were put in nursery for cuttings.

3.3. Activities generated using cover crops

The objective being to cover a hundred hectares in 12 months maximum, it was necessary to put the financial, material and human means at stake for the intensive production of seeds and to constitute a working team by defining and assigning works to be carried out. Thus, the use of cover plants results in at least 69 tasks to be performed from the acquisition of the plant material to the maintenance of plants. This work can be grouped into 6 main activities namely: (1) the acquisition of plant material, (2) the realization of the shade, (3) the production of cuttings, (4) the stimulation of the growth of young plants, (5) the transport of these to the field followed by their cultivation and (6) their maintenance.

3.3.1. Acquisition of plant material

It consists of (1) harvesting plants (cutting, putting in bags of fertilizer or garbage bags, storing in the vehicle, attaching) - (2) transporting them to the nursery- (3) unload the harvesting plants- (4) store them well in a damp, not very sunny place.

3.3.2. Realization of the shade

To realize the shade you must: (5) clear - (6) pick up the straw - (7) clear - (8) transport the earth - (9) make thinning - (10) put the irrigation system.

3.3.3. Production of cuttings

The production of cuttings begins with the (11) filling of the bags or buckets of potting soil (potting) - (12) followed by their storage - (13) therefore, cuttings should be cut - (14) planted in bags or buckets - (15) watered - (16) checked for cuttings planted in place - (17) to count empty bags - (18) to count filled bags - (19) to count the number of bags planted - (20) to count the number of plants that grew - (21) count the number of live plants that were not broken - (22) to count dead cuttings - (23) calculate success rate (number of plants that have broken up / total seedlings planted) - (24) calculate the potential of live plants (open plants + green seedlings / total seedlings planted) - (25) calculate the mortality rate of cuttings (number of dead cuttings / total number planted cuttings) - (26) ensure the vitality of the plants (good growth of the plants: problems of irrigation, brightness, attacks of insects, snail mushrooms (phytosanitary monitoring)) - (27) weeding bags or pans - (28) weeding paths - (29) keeping nursery area clean - (30) putting up signs (species, date of harvest, date of planting, location of harvest, type of harvested seed (seeds, cutting) number), sun or shade plant, probable date of cultivation in the field).

3.3.4. Stimulation of growth and acclimation of seedlings

Here, it is necessary (31) to sort live plants from stage 2 to 3 leaves - (32) transport of seedlings (wheelbarrows, crates) - (33) store the plants under actual field conditions before they are transported to the field after 6 - 7 days.

3.3.5. Transport of the seedlings from the nursery to the field

It starts with (34) the conditioning of the plants for the transport in plantation (putting the plants in plastic lockers very resistant (15 plants per rack) or in bins) - (35) followed by storage lockers in trailers (tractors, trucks, cars) - (36) unloading of plants from trailers - (37) transport to place of cultivation and (38) depositing plants in planting holes.

3.3.6. Cultivation and maintenance of the plants

To carry out the cultivation it is necessary (39) to picket - (40) to dig the holes (pockets) - (41) to deposit the plants in the holes - (42) placed in effective culture seedlings (return the bucket, tap on it with relative force or split the bag longitudinally, remove the bucket or bag, compact the soil around the foot, raise the plant vertically, make sure it is well align on the line of cultivation) - (43) pick up bags or buckets - (44) store buckets in bins - (47) return bins to nursery or discard in recycling bin or incineration - (48) store them for future use - (49) enumerate effectively planted plants - (50) enumerate dead feet after planting - (51) replace dead plants after planting - (52)) calculate the success rate on planting - (53) calculate the rate of loss in planting - (54) The maintenance consists in following the vitality and the phenology of the plants - (55) the phytosanitary evolution of the banana and cover plants (attacks of insects, mushrooms or snails, activities of the workers, irrigation problem) - (56) establish the relationship between all agronomic activities and their relevance to the evolution of cover crops and banana plants.

3.4. Rate of success and mortality in the field and in the nursery

In four months, 20,516 seedlings belonging to 3 species of cover plant were planted on a useful area of 3.65 hectares. These are *Vigna adenantha* (6,556 plants), *Ipomoea cairica* (6,611 plants) and *Merremia* sp. (7,349 plants) with an average density of 0.5 plants per m² and an average loss rate of 2.7% (TABLE 1). The average success percentage is 97.3%. However, an average loss of 12% of cuttings was observed during the first months (April and May) corresponding replacement rate (13.19%) due to the death after planting of young seedlings from nurseries and dead cuttings in nurseries (14.7%,). This weakness is due to difficulties in harvesting and transporting plant material. The cuttings of Vigna adenantha come from the harvest of cut stems 2 or 3 days in Abidjan, kept in hot containers sheltered from the sun between the months of March and April. They arrived in Banacomoé at the end of the day (16 - 18 hours) after hot hours in polystyrene bags over 200 km of road. In addition, the irrigation system was embryonic and the workers were not very motivated to work which was a priori contradictory (planting grass in a field). In addition, some transported species had to wait days or even one to two weeks before being transplanted into pots or into bags. However, the main cause was the lack of mastery of the technique of cultivation of the cuttings: it was necessary to orient the axillary bud from the bottom to the top. This escaped the workers for reasons of morphological recognition of the apical bud which sometimes had unfamiliar peculiarities. The cuttings were planted in the wrong direction. Others would die without ever showing the slightest bud while some rots after a few days or weeks of vegetation. Because of irrigation, some cuttings, even if they were badly planted, managed to break up and produce a vegetative system that was often identical to the others, thus escaping the controls. But once planted in this position, these cuttings dry out and die very early, before the end of the week. The last consideration is that plants from 3 weeks had an underdeveloped root system (reduced number, little lengthened, no nodosity). In addition, during the planting, the pots had to be returned and typed which caused the breaking of the roots and the disintegration of theearth clod around the roots. It even happens that the cutting thus bare and planted without root dies as early (before the end of the week) after its cultivation. The diagnosis was made and corrections were made. The agents were recycled and a more rigorous control was instituted in the nursery during and after the transplanting but especially before the transport in plantation for the cultivation. At this level, the few that escaped this sorting are identified and planted on the spot. A delay of 6 weeks before field cultivation of seedlings from cuttings was instituted. So, the transplanted cuttings spend 3 weeks under the shade to encourage their budding and 3 others in accelerated growth zone to promote the growth of stems and roots. All these provisions led to the complete cancellation of the losses and particularly the losses after the cultivation which caused additional costs.

TABLE 1: Distribution of cover plants species cultivated on the plot Carré 8 Comoé 2

N°of boards	Length (m)	Width (m)	Surface (m²)	Nomber of trees	Density	Lost rate (%)	Especies
1	153	10	1530	610	0,39	0	*Ipomoeacairica*
2	204	10	2040	1189	0,58	5	*Vignaadenantha*
3	210	11	2310	1160	0,5	10,25	*Vignaadenantha*
4	202	11	2222	964	0,4	18,7	*Vignaadenantha*
5	192	10	1920	1237	0,64	14,95	*Vignaadenantha*
6	140	11	1518	828	0,54	17,09	*Vignaadenantha*
7	198	10	1980	1178	0,59	0	*Vignaadenantha*
8	140	10	1400	775	0,55	0	*Merremiasp.*
9	234	10	2340	1392	0,59	0	*Merremiasp.*
10	205	10	2050	1218	0,59	0	*Ipomoeacairica*
11	207	10	2070	1230	0,59	0	*Ipomoeacairica*
12	205	10	2050	1030	0,5	0	*Ipomoeacairica*
13	205	10	2070	1230	0,59	0	*Ipomoeacairica*
14	192	10	1920	1080	0,56	0	*Merremiasp.*
15	170	10	1700	1129	0,66	0	*Merremiasp.*
16	140	10	1400	849	0,6	0	*Merremiasp.*

17	116	10	1160	684	0,58	0	*Merremiasp.*
18	96	10	960	507	0,52	0	*Merremiasp.*
19	68	10	680	399	0,58	0	*Merremiasp.*
20	91	10	910	534	0,58	0	*Merremiasp.*
21	75	10	750	435	0,58	0	*Ipomoeacairica*
22	62	10	620	360	0,58	0	*Ipomoeacairica*
23	40	10	400	225	0,56	0	*Ipomoeacairica*
24	50	10	500	273			*Ipomoeacairica*
Averages	**149,791**	**10,125**	**1520,833**	**854,833**	**0,558**	**2,7495**	*6 boardsof Vigna adenantha*
Maximum	**234**	**11**	**2340**	**1392**	**0,66**	**18,7**	*10 boardsofIpomoeacairica =*
Minimum	**40**	**10**	**400**	**225**	**0,39**	**0**	*8 boards ofMerremia ps.*
Total			**36 500**	**20 516**			

3.5. Growth of cover plants

Bud burst of Vigna adenantha cuttings begin between 4 and 6 days after being cultured in the bags. That of Ipomoea cairica and Merremia sp. takes place a little earlier between 3 and 5 days of culture. The seedlings of Vigna adenantha are planted at the 3-leaf stage at 3 weeks of nurseries. After one week, the average size of the plants is 14 cm with a leaf area of less than 8 cm². The growth of the stems is first vertical then, they gradually approach the ground under the action of gravity and become horizontal on the ground from the third week. The bud burst of secondary buds started since the second week will increase the leaf area which rapidly increases to 1 m², then to 4 m² and then to 12 m² 26 JAP, 40 and 46 JAP under the action of the fertility of the soil of irrigation but also, good rainfall and weeding (TABLE 2). The tillering of the primary and secondary branches is horizontal. At this point, no rod was wrapped on the banana tree so close to the collar. Better, they emit roots at each node and stimulate the growth of aerial organs. They also fix the surface of boards and drains that they eventually compact. The banana planks will quickly cover with cover plants of banana leaves and weeds. The index of abundance dominance of the latter and their recovery will go from 5 to 1 and 60% to cancel after 6 weeks of culture after two weeding and under the combined action of the cover plants and the shade of the banana trees that cover the planks at about 60%. Meanwhile, the cover crop coverage rate is 95%. Their first, older leaves turn yellow and fall. After 90 days the planks and drains are completely covered by cover crops under the action of the tertiary branches, which will also result in a growth in height of the carpet of cover plants and their winding on themselves and on the first selected rejects. This volubility is occasional and can be explained by the absence of space to colonize. This differentiates the stems of Vigna adenantha from those of Ipomoea cairica which are strictly voluble. In effect, the stems of the latter species curl up on themselves from the nursery. In cultivation, they are very fast to sow and wrap after 3 weeks on the pseudostems of young banana trees. This necessitates a weekly or fortnightly check which is limited to making 1 m diameter rounds of banana rounds. Nevertheless, this plant, like Vigna adenantha, is very well tolerant of trampling, suppresses water erosion of the surface of planks and drains and suppresses weeds.

TABLE 2: Growing data of *Vigna adenantha* plants

Dates	Plants	Number of leaves	Heights (cm)	LBF (cm)	Number of branches
28/04/2017	1	3,37	14,62	8	0
	1	5,5	22,2	22,2	0
(15 JAP)	1	4,5	14,1	12	0
	1	3,7	20,3	10	0
	Total	**17,07**	**71,22**	**52,2**	0
	Average	**4,2**	**17,8**	**5,7**	0
11/05/2017	1	14	0	103	3
	1	14	0	182	7
(30 JAP)	1	14	0	102	6
	1	10	0	112	6
	Total	**52**	**0**	**499**	**22**
	Average	**13**	**0**	**124,7**	**5,5**
	Variations	10	**-15**	**16,7**	**5**

3.6. Banana growth

The neck diameter of the banana trees increased progressively from 3.3 cm to 13.67 cm after 2.5 months. The average value being 8.8 cm. Banana trees averaged 14.31 leaves or 1.43 leaves per fortnight, of these leaves, 9.73 remained functional, ie 67.43%. The banana trees have reached an averageheight of 144.49 cm on average during this period. Considering the shape of the different curves, it is to be observed that the evolution of the neck diameter, the total number of leaves issued and that of the functional leaves of the banana trees is linear while that of the height of the banana trees and the foliar and exponential bouquet Moreover, between the 33rd day and the 46th day after cultivation, the average value of the collar diameter, the total number of leaves issued and the number of functional leaves remains constant and equal to 7. During this period the height of the pseudo and the foliar bouquet continue to increase. This could well indicate a phenological

phase important in the development of the banana tree. This is the pre-run that is to say phase of the banana pseudo-trunks stretch in height and the leaves in length. The rate of variation or growth of the average pseudo-trunks passes abruptly from 100% to 200% and that of the leaf bouquet changes from 300% to 500%. The value of these last two variables then remain constant between the 46th day and the 59th day, about 2 weeks during which, the diameter at the collar, the total number of leaves emitted, and functional leaves increase again. Beyond the 59th JAP the variation of the dimensions of the leaves and stems become more remarkable 500% to 800% for the first and 200% to 300% for the last variable with the growth of the number of leaves issued and especially functional sheets. It follows that the neck diameter, the total number of leaves emitted and the number of functional leaves are linked while the height of the pseudo stem and the width of the leaf bouquet evolve together and the operation of the second group of variables derives from that of the first group. In the sense that the multiplication of the number of leaves increases the diameter of the neck due to the interlocking of the sheaths and the number of functional leaves which induces the growth in height of the pseudo-trunks and that of the foliar bouquet of the banana plants because of the photosynthesis.

TABLE 3 : Statistical analysis of banana growth variables

		DCm (cm)	Dates (JAP)	LBF (cm)	NTFm	NFFm	Htm (cm)
N	Valid	5	5	5	5	5	5
	Missing	0	0	0	0	0	0
Average		8,8080	46,40	165,1980	11,6540	7,2220	76,0120
Median		8,2700	46,00	145,5700	12,0700	6,7000	68,5700
Fashion		3,30[a]	20[a]	84,60[a]	8,50[a]	5,20[a]	24,90[a]
Standard deviation		3,83691	21,197	77,80015	2,23800	1,67804	47,31697
Variance		14,722	449,300	6052,863	5,009	2,816	2238,896
Asymmetry		-,332	,097	,891	-,454	,637	,650
Standard asymmetry error		,913	,913	,913	,913	,913	,913
kurtosis		,625	-1,043	,216	-,383	,820	-,430
Standard error of Kurtosis		2,000	2,000	2,000	2,000	2,000	2,000
Beach		10,37	54	198,21	5,81	4,52	119,69
Minimum		3,30	20	84,60	8,50	5,20	24,90
Maximum		13,67	74	282,81	14,31	9,72	144,59
percentiles	25	5,6500	26,50	100,1000	9,5000	5,9350	34,1000
	50	8,2700	46,00	145,5700	12,0700	6,7000	68,5700
	75	12,2350	66,50	240,1100	13,6000	8,7700	121,6450

a. Presence of several modes. The smallest value is displayed. DCM-Middle Diameter of the Collet; JAP-Day After Planting; LBF-Length of Foliar Bouquet; NTFm-Total Average Number of Sheets issued; NFFm-Average Number of Functional Sheets; Htm-average height of the pseudo-trunks

3.7. Saving the use of banana plant cover crops

An estimate of the cost of implementing the use of cover crops was necessary to facilitate the extension of their use in banana plantations. For an area of 4.1 hectares; on average, 6 people had to be mobilized permanently for the nursery and the cultivation of cover crops. In addition, a researcher, a casual help, a driver, a tractor driver, a supervisor and an assigned worker worked part-time, that is to say on average 3 days per week during 4 months under the supervision of the Director of the domain. and the Production Department, to carry out this work. This work involved expenditures of 794, 410 CFA francs (TABLE 4)for 854, 833 planted cover seedlings and for the cost of daily occasional labor committed to the nursery, planting and weeding or 184, 760 francs per year. hectare or 46,186 francs per hectare per month. It will be necessary to add to this the expenses of the Expert, fuel and other ancillary expenses: housing, food, insurance...

TABLE 4: Relative importance of cover plants activities

Activities	Cost (F CFA)	Cost (%)	Number of days	Times (%)
Nursery	573 235	72,15	58	72,5
Planting	157 235	19,79	20	25
Weeding	64 000	8,05	2	2,5
Total	**794 470**	**99,99**	**80**	**100**

IV. Discussion

Unrestrained species such as *Telosmaafricana*, *Parquetinianigrescens* (Periplocaceae) and *Urerakeayi* are known asafrican species in ivorian forests [5]. They are minors and common to industrial banana plantations in Côte d'Ivoire, especially in Dabou and Tiassalé. These plants are difficult to be manage in bananas plantation because of their volubility, the exuberance of aerial organs and especially because of their resistance to glyphosate [6]. Moreover, they are present in the flora of the banana plantations of Dabou. *Adeniarumicifolia* Engl. and Harms var. miegei (AKÉ-ASSI) of Wilde and *Merremia hederacea* (Burm., f.) Hallier f. appears to be endogenous to Banacomoé and controllable by the usual herbicides. The last two species, *Centrosemapubescens*

(*Centrosemamolle* Mart. Ex Benth.) And *Ipomoea triloba*, have a very rapid growth. Their aerial organs are very overlapping. They are very competitive with banana plants because they are strict voluble and choke on bananas. Nevertheless, they are sensitive to the usual herbicides. In addition, Centrosemapubescens can be used for regeneration of fallow fertility. It is used as a forage crop in agropastoral and is grown well in association with *Panicummaximum*, *Hyparrheniarufa*, *Melinisminutiflora*, *Chloris gayana*, *Pennisetum purpureum*, *Paspalumdilatatum*; with less success with *Brachiariautica* and *Digitariadecumbens*. It is sometimes planted with *Calopogoniummucunoides* and *Pueraria phaseoloides* to give rapid coverage in the first year. However, Centrosemapubescens has the disadvantage of dropping a significant amount of seed into the soil, which germinates very long afterwards, and necessitates weeding in crops, and invasion by its creeping habit leads to maintenance work [7, 8].Local species of agronomic interest such as *Vigna adenantha* are known in Côte d'Ivoire and internationally. Its capacity to control the weeding of industrial banana plantations [9, 6]and to cuttings [10]has been proven at the local level. Elsewhere, in Venezuela, studies have been conducted on its forage abilities and especially on the high protein and germination of its seeds. This latest work confirms and gives solutions related to seed utilization difficulties, the availability of which causes problems in terms of quantity and seasonality. What justifies this work which is a culmination of that of [10] and offers real possibility of popularization of this plant in an industrial environment?*Axonopuscompressus* is a perennial stoloniferous species. It is a forage plant and used to plant lawns. Often used as a cover crop mostly in shady environments [11]. Among the selected species, *Desmodiumadscendens* has long been recognized as a green manure and a perennial herb that can control weeds and has good resistance to trampling [7, 6]. On the other hand, *Heterotisrotundifolia* (Sm.) Jacq.-Fél. known for its therapeutic virtues [12]is a perennial bushy species with ascending or prostrate herbaceous stems and rooting from nodes, sometimes lignified at the base. Reproduction is carried out by seed and cuttings. It is a fast-growing, continuously flowering species for much of the year and is particularly suitable for use as groundcover on well-drained, neutral or slightly acidic soils and kept constantly moist in areas with a tropical and subtropical climate, resistant to temperatures of only a few degrees below zero for a short time. The ideal exposure is in full sun, but it also adapts to a light shade, although with less abundant flowering. Can also be grown in pots, especially hanging, in soil rich in humus with the addition of about 30% siliceous sand, for better drainage [13]. *Oplismenusburmanii* is a dense forest and savanna gallery species. It is present in secondary forests, clearings, edges and in fallows where it sometimes forms monospecific stands [11]. This plant is also a weed crop. It is therefore at once a kind of closed and open environment that can adapt to banana growing. Finally, the species *Merremiasp* is not yet fully identified. It is very colonizing wet places of the peat soils of Dabou and wet clay from the banks of the Comoé river atBanacomoé. It is a kind of sun, resistant to glyphosate and adapted to the shading of banana trees.

These local species besides *Axonopuscompressus* which is used for lawns, the others have not yet been the object of cutting. Their reproduction was until then ensured by seeds. The need for vegetative propagation has become apparent as soon as the control capacity of grass weeds of industrial banana plantations of legumes and mainly of *Vigna adenantha* has been demonstrated [9, 6]. In addition, the small amount of seeds available only in dry periods (July-August and November-March) associated with seeding difficulties (seeding depth less than one centimeter) and uncertain emergence, sometimes requiring the scarification of seeds before sowing if Seeds have led to this research to satisfy demand in the industrial environment. Thus, the first results showed the ability of *Vigna adenantha* to cut with long stems of 3 knots [10]. The present study resulted in the bud burst of a node. This is a significant advance that can lead to the production of a large amount of seed after 4 to 6 weeks maximum instead of 2 months in an irrigated system. Also, the number of species capable of being cuttings and controlling weeds increased from 2 to 7 belonging to several families (Leguminous (2 species), Melastomataceae (one species), Convolvulaceae (2 species) and Poaceae (2 species)). This gives a variety of opportunities based on ecological peculiarities and agronomic needs, especially with average success rates of 97 in and nursery and plantation. At the agronomic and technical level, this work has led to the definition of tasks whose sequence leads to making the use of cover crops an agronomic activity well integrated into banana growing in general. Admittedly, the cost remains relatively high 794, 470 F CFA for about 4 hectares over 4 months or 49, 654 F CFA / ha / month against 37, 000 F CFA / ha / year for glyphosate [6].This is partly explained by the partial use of the workers and their lack of knowledge of this activity. However, even though other work will be directed towards cost reduction, it should be noted that biological control is relatively more expensive than short-term chemical control. The economic benefits of this innovation are to be observed over the medium and long term in that in many banana growing cycles only light maintenance is likely to be required. There will be no herbicide treatments or replanting of cover plants to do especially since the plants spread freely to conquer new plots. In addition, the soil fertility being preserved the durability of the cycle is thus ensured. In addition, bananas from these plots are herbicide-free and therefore very useful for the health of consumers and will certainly have a higher market value than those produced with herbicides. At the current stage, the system put in place can produce an average of 60,000 plants per month and cover 10 to 12 hectares of banana per month with an average of 6 people. Furthermore, the comparison of banana growth data obtained

with those of Dabou [6]indicates that for the same variety of Cavendish banana, the average neck diameter is higher at Banacomoé (8.27 cm) at 46 JAP against 7.4 cm at 51 JAP observed in Dabou then approaches to 13.67 cm (74 JAP) against 14.2 cm (70 JAP in Dabou). The banana trees are on average smaller in Banacomoé (68.5 cm) at 46 JAP against 72.1 cm at 51 JAP in Dabou then become larger at Banacomoé (144.59 cm) at 74 JAP against 134.7 cm at 70 JAP in Dabou; the total number of leaves issued to Banacomoé is greater (12) at 46 JAP against 8.3 to 51 JAP Dabou or 14.31 leaves at 54 JAP against 14 to 70 JAP in Dabou. The number of functional leaves is 9.72 to 74 JAP in Banacomoé against 7.5 to 70 JAP in Dabou. The average diameter of the leaf bouquet is 145.5 cm at 46 JAP at Banacomoé against 160 cm at 51 JAP in Dabou or 282.82 cm at 74 JAP against 248.4 cm at 70 JAP. This analysis indicates that Banacomoé banana trees have growth values that are often higher or fairly close to those of Dabou. This reflects a clear advantage of using cover crops.

Also, it is necessary to note the synchronous evolution of the foliar bouquet and the height of the banana trees whatever the age of the banana trees, as well as the total number of functional leaves and that of total leaves emitted. On the other hand, the growth of the neck diameter seems to be periodic and could indicate growth phases of banana. It should be noted that the foliar emission rate was one leaf per week between the 20th and the 46th JAP, which is normal before decreasing during the rapid growth phase to 0.4 and 0.7 leaves per week. The ratio between the average height of banana and total banana doubled after 26 days and tripled after 54 days. At 70 JAP, the height of the banana trees is 10 times that of the average diameter of the banana neck and also 10 times the total number of leaves and the NTF / DC ratio is equal to unity which clearly indicates that the diameter of the neck is numerically equal to the total number of sheets issued. This observation is the same as that made by [6] in Dabou. Similarly, it should be noted that at the same date, the diameter of the leaf bouquet is 20 times the diameter of the neck and about 20 times also the total number of leaves. This amounts to saying that the diameter of the leaf bouquet is both twice the average height of the banana trees and the total number of leaves emitted on average by the banana trees. These observations are the same as those observed on bananas in Dabou [6]belonging to the Cavendish group's Grande Naine variety and can therefore translate a consistency in banana trees from the slow growth phase that is ie from 51 JAP where the physiological balance of banana plants is established between different growth parameters of banana. This allows to define 4 growth phase as the banana: the installation which ends at 30 JAP followed by the phase of slow growth which by the 30^{th} to the 50^{th} JAP, the phase of rapid growth which extends from the 50^{th} to the 70^{th} JAP and the run that starts from 70^{th} JAP to finish with blooming around the 130^{th} JAP. This division seems adapted and more simplified thus more usual than that based on the ratio length compared to the width of the leaves [2]. It must be concluded, in view of all these results that the present work confirms in part (apart from yield data) the positive effects of the combination of cover crops, especially *Vigna adenantha*, to the cultivation of Grande Naine bananas, such as observed by [14].

V. Conclusion

This work is a response to the concern of the Banana Crop Development Corporation (BCDC) to find an alternative to the chemical control of banana weeds on these facilities. The expertise of GuilgalAgronomie SARL was therefore solicited to find plants capable of controlling weeds, remove surface erosion of boards, maintain the slope of drains, withstand trampling and which do not compete with banana. After four months of activity, the flora of banana plots and riverbanks of the Banacomoé estate was studied. Fourteen plant species with agronomic potential were observed. Compared to the basic objectives, only *Vigna adenantha*, *Heterotisrotundifolia*, *Desmodiumadenantha*, *Axonopuscompressus*, *Merremia sp*. *Ipomoeacairica* and *Oplismenusburmanii* have been selected as effective cover crops for biological control of banana weeds. Accelerated vegetative multiplication techniques have been developed with a view to the abundant production of quality seeds and to cover large areas in record time by defining spots that can make the use of these plants a well-adapted professional activity of the general agronomy of banana plants within the SCB. All these studies coupled with economic investigations have given real satisfactions that make these species real opportunities for sustainable production of banana quality without herbicide good for the health of consumers. Already, *Vigna*'s abilities to meet all the objectives of this research have been confirmed. It follows that the popularization of these plants in industrial settings is a success.

Acknowledgments

The authors express their gratitude to the company GuilgalAgronomieSarl and to the managers of the SCB, and to whom contributed in one way or another to the success of this project.

References

[1]. F.A.O,The world economy of banana 1985-2002, 2003. http://www.fao.org/docrep/007/y5102f/y5102f00.htm#Content
[2]. A. Lassoudière, The banana tree and its culture, Quae editions, Savoir-faire collection, CIRAD, 2007, 382 p.
[3]. National Institute of Health and Medical Research INSERM, Pesticides: Effects on health, 2013, ipubli.Inserm.fr/bits

[4]. Ministry of Agriculture and Rural Development, Plant Production Department, Côte d'Ivoire, 2018.
[5]. R.H. Kouassi, M.S.Tiébré, H.K.Kouadio and K.E. N'Guessan, Floral diversity of Inselbergs Brafouéby and Mafa-Mafou (South-East of Côte d'Ivoire), Journal of Animal & Plant Sciences, 22(1), 2014, 3407-3418.
[6]. Y.P. Kouadio, Use of cover crops as a means of biological control against the adventitious flora of the industrial banana plantations of Dabou in southern Côte d'Ivoire, PhD thesis of Botanical University of Félix HOUPHOUËT-BOIGNY University, UFR Biosciences, Laboratory of Botany, Specialty Biology, Morphology and Vegetal Taxonomy, option Weed sciences, 2010, 229 p.
[7]. H. Botton,Cover plants in Côte d'Ivoire, National Museum of Natural History, Journal of Tropical Agriculture and Applied Botany, Volume IV (1957 and 1958), France, 1958, 194 p.
[8]. CABI,Invasive species Compendium Ipomoea triloba (three-lobe morning glory), 2017, 3p.
[9]. Y.P. Kouadio, W.M. Egnankou, K.E. N'guessan, M.Zouzou and L.Aké-assi, Control of grassland under banana plantations using leguminous cover in the area of Dabou, Côte d'Ivoire. African Agronomy, 21(3), 2009, 215-330.
[10]. B.W.Boué, Vegetative propagation of Leguminouss, License L3 of Systematics and Plant Biology, Botany Laboratory, UFR Biosciences, Félix HOUPHOUËT-BOIGNY University, Abidjan, Côte d'Ivoire, 2016,15 p.
[11]. P. Poilecot, The Poaceae of Côte d'Ivoire, Boisera volume 50, Geneva, Switzerland, 1995, 734 p.
[12]. L. Aké-assi, African medicine and pharmacopoeia abstract: some plants traditionally used in the coverage of primary health care; NEI-CEAD, 2011, 156 p.
[13]. P. Puccio,Heterotisrotundifolia (Sm.) 03Jacq.-Fél. Research Gate GmbH, 2017
[14]. Y.P. Kouadio, M.S Tiébré, N.K.M.Boraud and K.E N'guessan,Effects of leguminous cover crops on the growth of banana trees in the industrial plantation of Dabou in southern Côte d'Ivoire. REB PASRES Review of the Environment and Biodiversity (1),2017, 76-90.

KOUADIO Yao Prosper. " Biological Control of Weeds and Soil' Erosion in Industrial Banana Plantations in Côte d'Ivoire." IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 12.6 (2019): PP- 16-25.