International Journal of Scientific Research and Management (IJSRM)
||Volume||07||Issue||06||Pages||EM-2019-1180-1199||2019||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v7i6.em02

Improvement of Soil Fertility in Industrial Banana Plantations of Côte d'Ivoire

KOUADIO Yao Prosper, ETIEN Dibiéthéodore, TIEBRE Marie-Solange, BORAUD N'Takpé Kama Maxime

Vorian Center for Economic and Social Research Cote d'Ivoire

Abstract
Côte d'Ivoire's banana-producing enterprises are confronted with declining plot yields as early as the third banana crop cycle. The main cause is soil erosion due to the destruction of the forest cover at the planting of the banana plantation in view of very high rainfall. In addition, the search for an alternative to harmful glyphosate on the health of producers and consumers requires innovative solutions to preserve the quality of bananas produced in order to ensure their competitiveness on the European Union market. 2020. In, this context, the expertise of Guilgal Agronomie SARL has been solicited for the development of a production system that can improve soil fertility, weed control in banana plantations without chemical inputs and fight against air pollution of water. A trial was set up on a 3-cycle plot with 7 covering plants and organic matter from plants for few months at Lumen, on a Wanita S A plantation. The first results indicate that test edbanana trees grow faster than control plots. The work carried out that it possible to control weeds bycovering plants, to produce banana without herbicide, to eliminate soil erosion and to stop drains' water pollution reaching the fifth crop cycle of banana.

Key words: Banana, Covering plants, improving fertility, soil erosion, Côte d'Ivoire.

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 are the most exported fresh fruit in the world, equal to grapes in comparison with 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%).

Moreover, sold on local markets, they are a source of employment and income for local populations. This is the case of India and Brazil, which sell all their bananas in their domestic markets (Lassourdière, 2010). In addition to these two countries, local consumption in producing countries is low (11%): Canary Islands (74,686 t), Martinique 68 tones, Guadeloupe 786 tones, Madeira 4,315 tones, 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 tones, 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 Guadeloupe

(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 (CMOB), 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, Ivory Coast 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 themselves 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 (MRL) of pesticides (Fungicides, insecticides, nematicides and herbicides) contained in bananas for export. Especially since the publication of the actions of glyphosate on human health (skin irritation, central nervous system involvement, ... (INSERM, 2013) and that it has been classified probable or possible carcinogens by IARC since March 2015 (Hakim, 2017 And that, moreover, its harmful effects on the environment such as the accumulation along the food chain toxicity for any plant that has not been genetically modified to tolerate it, the leaching of soils to the streams, rivers and groundwater, the modification of soil chemistry (binds to particles, which makes it inert) that disrupts chemical processes in the plant environment, including its ability to fix nitrogen, which forces to increase nitrate fertilizer rates and its contribution to the growth of the Fusarium fungus and other pathogenic fungi in plant roots (Hakim, 2017) .The consequence of all anomalies is the lower yields in banana production due mainly to soil erosion of banana plantations observed from the 3rd cycle, which requires replanting as early as the 4th banana crop cycle (Lassourdière, 2009). Also, in order to protect the health of their population, EU countries have 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 (GDPA) and 3% of Gross Domestic Product to be protected (GDP) are to be protected (Ministry of Agriculture, 2018). Specifically, this involves combining cover crops and organic matter with banana cultivation to restore soil fertility, eliminate soil erosion and weeds as well as contamination of banana aerosol products from pesticides.

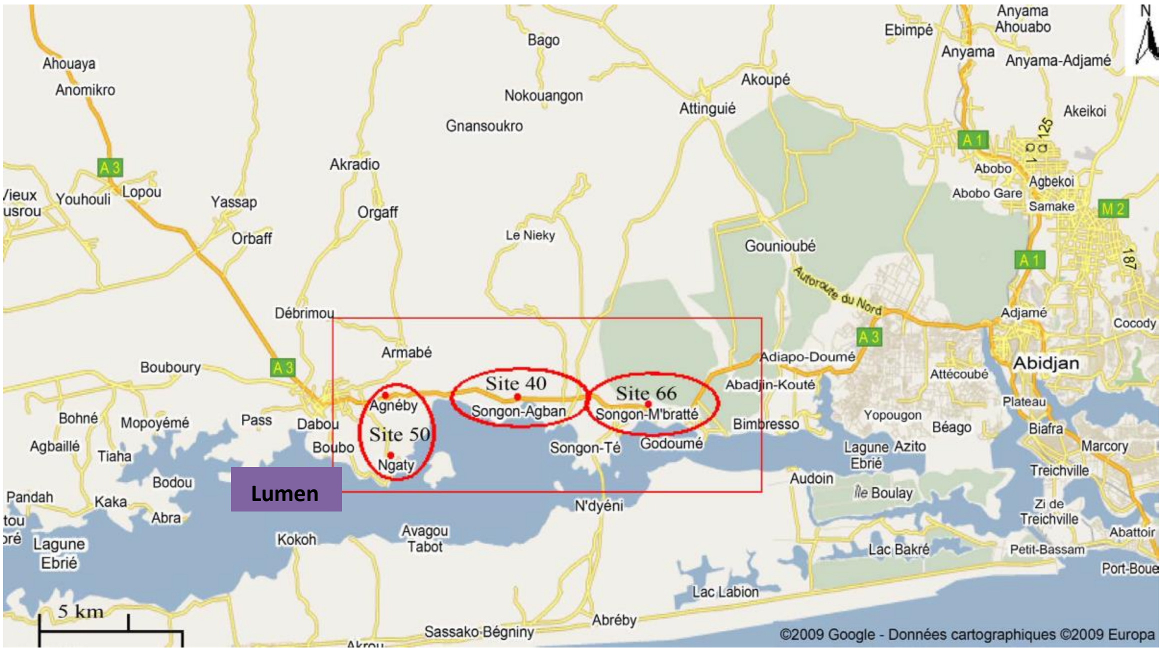

Figure 1: Study area (Lumen, Wanita S A plantation, Dabou, South of Côte d'Ivoire)

Materials and methods

Description of the study area
The study area is located at the entrance of the city of Dabou, located about thirty kilometers from Abidjan, in the Great Bridges Region, bordering the Ébrié Lagoon and in the spillway of the Agnéby River. It is one of the major areas of banana production in Ivory Coast. The climate is of the Attiean-facies subequatorial type (Tapsoba, 1995) with an average annual precipitation of 1557 mm. The mean annual temperature is 26.3 ° C and an insolation is estimated at 163.3 Lux. The relative humidity is 92.6% and the evapotranspiration estimated at 1.1 mm 3 / cm 2. The average wind speed is 0.5 m / s. The relief consists of low quaternary plateaus at low altitudes varying between 8 and 12 m with 2 and 6 m quaternary sands (Tapsoba, 1995). The hydrographic network consists essentially of Ébrié Lagoon and Agnéby River, (Dibi, 2002). It is in this seaside area that is the Lumen plantation belonging to the company Wanita SA which served as a framework for this work. It is accessible by asphalt road and located between the villages of Agnéby and N'gatty at the entrance to the town of Dabou (Figure 1).

Experimental plot and research objectives

The trial was held on plot 4 of the Lumen plantation owned by Wanita SA, located 1 to 3 km from the city of Dabou. This is a lower yielding banana third cycle plot that had to be fallowed for this reason (Figure 2 and Figure 3). It was chosen for a fertilization and biological control test against soil erosion, weeds and drainage water contamination under an old banana plantation.


Figure 2: Banana planks in the parcel Figure 3: Access road and parcel overview

Materials
The biological material consists of weed banana and 7 species of cover plants: *Desmodium trifoliata* (Figure 4), *Desmodium trifolium* (Figure 5), *Desmodium adscendens* (Figure 6), *Heterotis rotundifolia* (Figure 7), *Vigna adenantha* (Figure 8), *Crotalaria pallida* (Figure 9) and *Indigofera tinctoria* (Figure 10). The first five species are used against the weeds of the planks and the last two species were intended to close the light of the drains to avoid water contamination due to aerial chemical treatments, to provide lignin and organic matter by mulching and to fight against banana nematodes. In addition, the technical material includes two calipers for measuring the neck diameter of the banana trees, one meter of mason for the measurement of the height of pseudo stems and the diameter of the banana leaf bouquet, the bags for the banana trees. nurseries, 2 wheelbarrows, 2 hoes and a machete, 2 watering cans, 3 pairs of boots, 10 trash bags and a car for harvesting and transporting cover crops, a pruner to cut the stems of cover plants in cuttings, a roll jute wire for the jigs, a decameter, wooden and plastic lockers for the transport of seedlings, a 300-pages notebook and a pen for taking notes and a camera for shooting. Finally, mineral fertilizer (DAP and complexed fertilizer) and residues (cobs) of machined palm kernels used as organic matter were used for fertilization.

Methods
The work carried out can be summarized in the acquisition of cover crops, the production of nursery seed in nurseries, the preparation of test beds, the cultivation of cover crops, the monitoring and evaluation of the system put in place and data analysis.

Acquisition of cover plants

The cover plants were harvested in Abidjan either as seeds (Crotalaria pallida, and Indigofera tinctoria) or seeds and cuttings (*Vigna adenantha*) or cuttings only (*Desmodium trifolium*, *Desmodium trifoliata*). The branches of *Heterotis rotundifolia* were obtained on the northern highway. Finally, the stems of *Desmodium adscendens* were harvested on the Abidjan-Dabou axis and on the fallow lands of Lumen in Dabou.

Choice of test boards

The plot selected for the trial consists of aged banana trees in the third crop cycle (Figure 13), with a decline in production. It should be fallow. The work began with the diagnosis of the banana planks and the determination of the experimental device. In order to identify the causes of the decline in banana yield, a diagnosis was made by visual and direct observation of the soil and banana, in the absence of foliar diagnosis or soil samples considered too expensive. These analyzes concern the appearance, the size, the coloration, the position of the bulb, the pseudostems and the leaves of banana trees and the rejections but also on the state of the soil (trace or absence of erosion, coloration, firmness, organs decaying plants or remains of fertilizer, ...). Following this analysis, 6 boards of 100 m x 12 m size of banana were chosen for the test. Three were considered as controls (without cover plants, were fertilized with mineral fertilizers (DAP and complexed fertilizer) at the usual doses (Figure 11).

Figure 4 : *Desmodium trifoliata*

Figure 5 :*Desmodium trifolium*

Figure 6 : *Desmodium adscendens*

Figure 7 : Mulch abondant *d'Heterotis rotundifolia*

Figure 8 *:Vigna adenantha*

Figure 9 *:Plants de Crotalaria pallida*

Figure 10 : *Indigofera tinctoria*

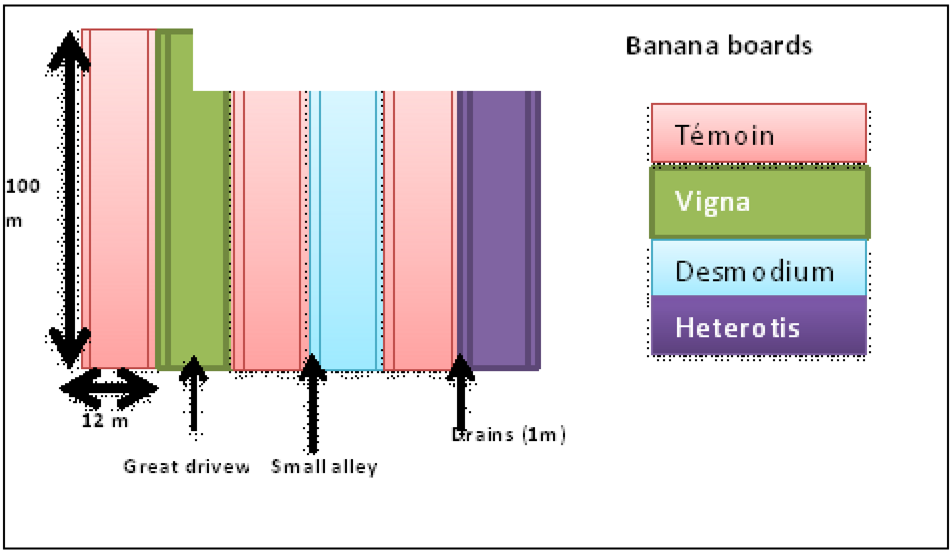

Figure 11 Experimental

The other 3 are the test boards, on which the cover plants have been planted (a plate of Vigna adenantha, one of Heterotis rotundifolia and one of Desmodium adscendens). The control boards alternate with the test boards.

Preparation and device of the test

The planks chosen were weeded with a machete (Figure 12 and Figure 14). The old pseudo stems of banana have been cut to the bulb. And all the straw consisting of weeds, leaves and false trunks of dead banana was collected in the middle of the large paths at 1 m from the banana plants (Figure 15, Figure16 and Figure17). The drains were parish priests. The leaves of the banana trees have been cleared of all traces of Sigatoka (whole leaves and necrotic or cut yellow parts). The irrigation system has been rehabilitated. The banana plots from the control plots were fertilized again (Figure 18 and Figure 19) with the usual doses of DAP (50 g per foot in week 1, 30 g urea per plant in week 3 and 5, and then maintenance with complexed fertilizer 12.3.22 (N-P2O5-K2O) + 5MgO5 + 11.5CaO + 2S). Guying has been resumed on the feet in production. A supply of palm seed cobs was spread at 243 bags on the test boards (Figure 20 and Figure 21). There was no mineral fertilization on these during the entire observation period.

Realization of the nursery

The cultivation of cover crops under the banana trees began with the direct cultivation of the cuttings. The selected species produce seeds whose availability and biology do not allow their direct installation on the boards. Also, the first trials of direct planting of cuttings of *Vigna adenantha* and *Heterotis rotundifolia* were not conclusive especially for the first. It was necessary to produce nursery seedlings (*Vigna adenantha*, *Crotalaria pallida* and *Indigofera* tinctoria) or cuttings (*Vigna adenantha*, *Desmodium adscendens*, *Desmodium trifoliata*, *Desmodium trifolium* and *Heterotis rotundifolia*). This work required 3 workers: a man and 2 women. The former was tasked with work requiring more physical force such as clearing the bag filling area (Figure 22 and Figure 23), building the shelter (Figure 24 and Figure 25), and setting up the shelter seedling culture. The ladies were responsible for filling the bags, sowing the seeds, cultivating the cuttings (Figure 26), watering and maintaining the seedlings and also planting the plants. The land used for the nursery is peat. Seed maintenance consisting of manually removing snails, disinfecting the nursery with fungicide and insecticide applications 15 days after seed and cuttings emergence, and exposure to sunlight 30 days later their lifting to accelerate growth. The establishment of the nursery and the preparation of the test planks took place at the same time, from November 2016 to February 2017 (Figure 27, Figure 28, Figure 29 to Figure37).

Figure 12 : Clogged drains

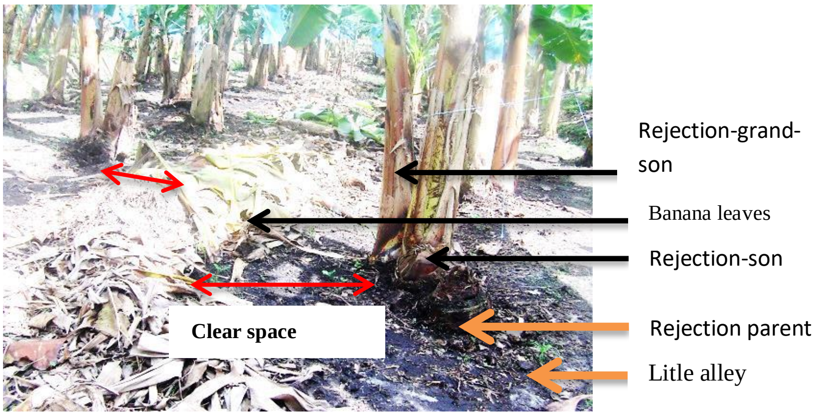

Figure13 : Bananiers au 3e cycle cultural

Figure 14 : Weeding of drains

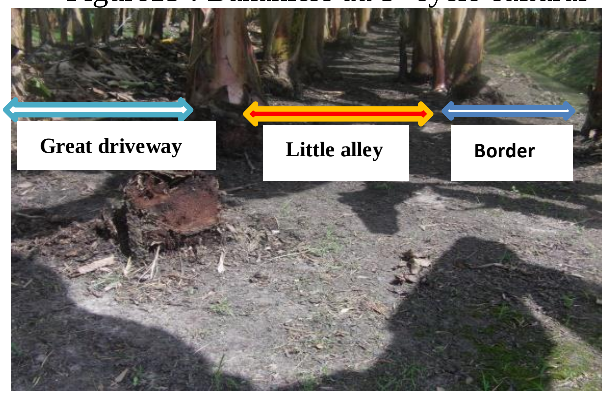

Figure 15 : Dégagement des allées des bananiers

Figure 16: Clearing the edges of the planks

Figures 17: Gathering of residues in the big driveway

Figure18 : Mineral fertilizer (DAP) Figure 19 : Complexed fertilizer

Figure 20: Palm seed cake serving Figure 21: Banana slab fully covered with organic material of palm kernel

Figure 22 : Filling sachets with peat Figure 23 : Packing area

Figure 24 : Construction of the nursery Figure 25 : Storage of bags at the nursery


Figure 26: *Desmodium trifolium* cuttings Figure 27: *Desmodium trifolium* cuttings ready to be planted


Figure 28 : Nursery of cuttings of *Heterotis rotundifolia* Figure29 : Cuttings of *Heterotis rotundifolia*


Figure 30: Young *Vigna adenantha* seedlings grown from cuttings Figure 31: Young seedlings from seeds of age to be plantedJeunes plants issus de graines en âge d'être plantés


Figure 32 : Resumption of cuttings of *Desmodium trifoliata* Figure 33: *Desmodium trifoliata* cuttings

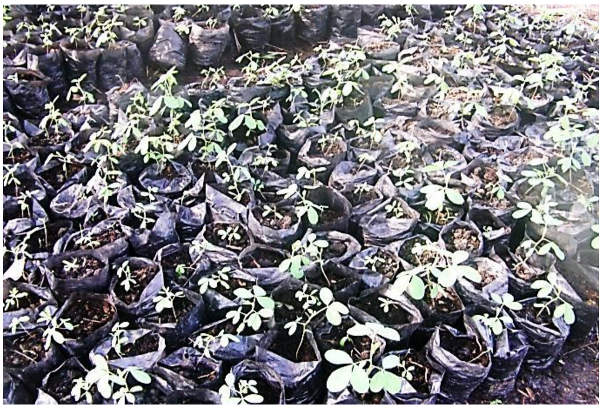

Figure 34: *Crotalaria pallida* stage 4 leaves

Figure35 : Plants of *Crotalaria pallida* at bloom

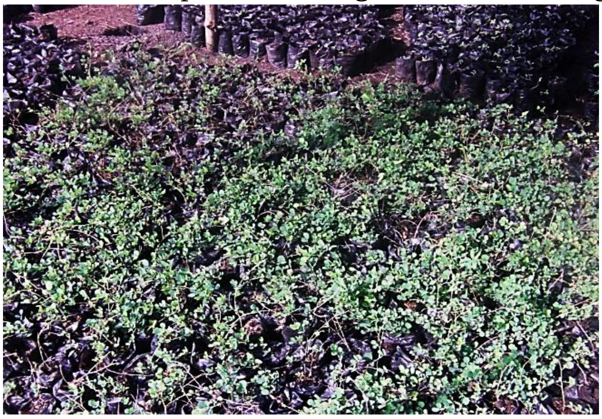

Figure 36 : Resumption of cuttings of *Desmodium adscendens*

Figure 37 : Cuttings of *Desmodium adscendens* ready to be planted

Direct cultivation of cuttings

Vigna adenantha stems were cut with a machete at each knot. The cuttings thus obtained were planted on the edges of the drains at each meter on the set line 0.5 m from the banana trees at the rate of one cutting per pocket. axillary buttons facing upwards. Cuttings of *Heterotis rotundifolia* were planted 0.5 cm from the irrigation pipes and at 1 m intervals on the line (Figure 38 to Figure 41).

Cultivation of cuttings from the nursery

At the end of a month and a half of the nursery the seedlings stemming from cuttings and seeds were put in culture on the test boards already prepared at the rate of 4 rows per board: one row in each small alleys and two rows bordering the 2 large aisles; the cover plants are 0.5 m from the banana line and 1 m apart on the line for *Vigna adenantha* and 0.5 m on the line for *Heterotis rotundifolia* and for *Desmodium adscendens* in 10 cm deep pockets and 20 cm in diameter. The plants of Indigofera tinctoria and *Crotalaria pallida* were planted 30 cm on the edges of the planks and 1 m on the line in pockets 30 cm deep and 20 cm in diameter. In practice, the seedlings are transported from the nursery to the board in lockers, then a line of template is erected between 2 stakes and using the decameter to determine distances. The pockets are then dug at the hoe. One person then plants the plants and another breaks the bags and closes the holes (Figure 42 and Figure 43).

Care of cover plants

To maintain the cover plants, two weeding sessions were carried out, one at the hoes and the other with a machete. The irrigation system was started to water the planks according to the usual program of the irrigation service in addition to the rains.

At maturity, plants of Crotalaria pallida and Indigofera tinctoria were pruned and foliage was used to mulch curbs and small alleys (Figure 83).

Banana growth data

The effects of treatments on banana were observed from the growth data taken in the 6th month after the start of the work. This information concerns the Foliar Bouquet Width (LBF) of the banana trees which corresponds to the distance between the tip of the 2nd and 3rd leaf from the top of the banana tree; the number of functional leaves (FF, green leaves without necrosis), the total number of leaves emitted by the banana (NTF, counted from the base to the top), the height of the Pseudo-Trunk (HT, measured with the meter of the intersection of the first two leaves to the ground) and the Collet Diameter (DC) which is the ground diameter of the base of the banana trunks. Growth data were observed for a total of 98 banana plants, 49 of which are control planks and 49 of which belong to the test plots. In each case, these banana trees were chosen from the two inner rows to avoid edge effects. Then a banana tree was chosen out of 10 on the row. It is this random method that has been used to obtain fairly objective average results representative of reality.


Figure 38: Direct cultivation of Vigna Figure 39: Cultivation line for cuttings


Figure 40 :*Vigna adenantha* cuttings planted Figure 41 : Direct cultivation of cuttings of *Heterotis rotundifolia*


Figure 42 : Plant plastic locker Figure 43 : Cultivation of *Vigna adenantha* plants


Figure 44: Roots and nodules of Crotalaria pallida Figure 45: Roots and nodosity of
at 4 weeks of nursery *Roots and nodules of Crotalaria pallida more than 6 weeks of nursery*

3. Results

Fertility of the plot and condition of the banana trees at the time of the trial

Visual observations on soil and banana indicate that after 3 crop cycles, the soil is compacted and often covered with a thin layer of greenish iron oxide (Figure 52 and Figure 53). In addition, the base of the pseudo stems is eroded and the rhizome is exposed, as are the discards, which are therefore almost all (80%) aerial (Figure 49, Figure 50 and Figure 51). Only the rejects of the banana trees at the edge of the planks (Figure 46 and Figure 47) and those of the two internal rows bordering the large alley have subterranean bulbs and can ensure the succession of crops (Figure 48). The part of the soil that is not eroded and fertile is the large alley where plant debris is constantly deposited during leaf stripping and eye catching in addition to the abundant straw and organic matter (parches of cocoa, chicken droppings) timing of soil preparation (Figure 54, Figure 55 and Figure 57). Under these conditions, all the fertilizers especially, the mineral fertilizer brought to the two outer rows of banana trees are easily leached and transported in the drainage channels of the water. The best-preserved areas are the immediate edges of the large driveway (Figure 56 and Figure 57).

Nursery work

The nursery and cultivation of the cover plants lasted about 103 days and cost the sponsoring company a total of 402,000 CFA francs, apart from the expertise and expenses related to the purchase of the grain stalks. of palm (Table1). The activities carried out are number 16 and concern the clearing of the filling area of the bags, the construction of shade, the filling of bags, ... The most expensive of these works are in descending order the cultivation of the plants which represents 26.87% of the total cost of the activities followed by the filling of bags which represents 15.92% of the expenses, the sowing of seeds and the putting in bags of the cuttings (10.94%) and the manual weeding with a cost of 40,000 CFA represents only 9.65% of the cost of the test. Other tasks are less costly in labor, time and expense (Table 1).

Success rate of cuttings after direct cultivation

The success rate is very low by less than 10 % for *Vigna adenantha*. For *Heterotis rotundifolia*, the success rate is 60 % (Figure 58 and Figure 59). However, growth is very slow and maintenance is tedious. In addition, the direct culturing of *Indigofera tinctoria*, *Crotallaria pallida*, *Desmodium adscendens*, *Desmodium trifolium* and *Desmodium trifoliata* is counterproductive. Thence it is necessary to make a cuttings nursery.

Growth of cover plants

Plant cover growth is relatively fast in nursery for all species. So that the cuttings produced can be planted from the 4th week to the 3 or 4 leaf stages. After 6 weeks of nursery, the plants are too large, the root system can be damaged when transporting the nursery to the plantation, which reduces the success rate and leads to replacement work (Figure 44 and Figure 45).). In addition, in *Vigna adenantha*, the growth of seedlings from cuttings is twice as fast as that of seedlings (Figure 71 to Figure 74). The growth of seedlings under banana trees is a function of soil cover The less dense it is, the faster the cover plants settle because of the strong luminosity, all else being equal, the plants of Crotalaria pallida and Indigofera tinctoria evolve quite rapidly, flowering at the same time. after 4 weeks and close all the lumens of the drains after 3-4 months after planting where they effectively control weeds (Figure 75 to Figure 80 and Figure 85) .The plants of *Vigna adenantha* and *Desmodium adscendens* have average growth, covering all the planks between the 4th and 5th month after they are cultured (Figure 61a Figure 64 and Figure). weeds and colonize even the surrounding spaces, especially at *Vigna adenantha*. *Heterotis rotundifolia* grows slowly under the big banana trees, which requires 3 weeding before its installation. In addition, it supports very little trampling until the 3rd month after its cultivation (Figure 67). But it forms a thick layer of vegetation able to control weed and erosion from the 4th month (Figure 68 to Figure 70 and Figure 84). *Desmodium trifoliata* and *Desmodium trifolium* are very sensitive to the shading of banana trees and evolve very hard. Also, the first becomes sometimes lianescente and does not offer just like the second one, a satisfactory control of weeds.

Banana growth

The growth of banana is marked by a rather spectacular departure of the rejects 4 weeks after the soil amendment (Figure 81 and Figure 82). This is translated physically by the stretching of the internodes of the discharges with the diameters with the collar relatively more important than at the origin; accompanied by a proliferation of discards at the turn of the mother-palms and later (between the 2nd and ^{3rd} months) by the closure of the banana canopy followed by the flowering and harvesting of the banana bunches. As a result, the crop moved from the 3rd crop cycle to the 4th and 5th cycle.

The organic matter contributed and the presence of the cover plants have contributed to the suppression of soil erosion so that the bulbs of the suckers and those of the large banana trees are kept deep in the soil. In addition, the growth data taken on suckling in the 4th cycle indicate that, after 6 months of testing, the banana plants of the cover crop plots are larger overall than those of the control plots (Table 2 and Table 2). Table 3). Thus the width of the Foliar Bouquet (LBF) is relatively greater in the banana trees of the test boards: 208, 23 cm ± 62.242 against 205.96 cm ± 48.892. Similarly, the number of Fertile Leaves (FF) is slightly higher in banana test planks (7.33 ± 1.36 leaves) than in control planks (7.06 ± 1.126 leaves), despite that the latter emitted a few more leaves (16,3 ± 1.776 leaves) than the first (16.1 ± 2.284 leaves). Also, the height of Pseudo-Trunks (HT) is on average 188.96 cm ± 33.948 in banana test boards against 187.31cm ± 34.711 for control banana. Finally, the Test Banana Peel Diameter (CD) is relatively higher in test banana (18.36 cm ± 0.978) than banana in control plots (18.1 cm ± 1.223).

Tableau1 : Activités et coût des travaux de l'amélioration de la fertilité du sol des bananiers

Activités	**Number of days**	**PU(FCFA)**	**Number of de persons**	**Cost (FCFA)**	**%of cost**
Clearing the bag filling area	1	2000	1	2000	0.49
Shade Construction	3	2000	5	10000	2.48
Filling bags	16	2000	2	64000	15.92
Transport of bags	3	2000	1	6000	1.49
Unloading of bags	3	2000	2	12000	2.98
Storage of bags	3	2000	2	12000	2.98
Watering plants	6	2000	2	24000	5.97
Sowing of seeds and setting of cuttings	11	2000	2	44000	10.94
Plant maintenance	7	2000	2	28000	6.96
Filling bags of palm seed cake	2	2000	2	8000	1.99
Spreading of palm seed cake	7	2000	2	28000	6.96
Planting of the plants	27	2000	2	108000	26.87
Replacement of dead feet	3	2000	2	12000	2.98
Weeding the boards with a machete	10	2000	2	40 000	9.65

Stripping bananas	1	2000	2	4000	0.9
Total / Average	**103**	**2 000**	**2.06**	**402 000**	**99.56**


Figure 46: Rejection pink colored tortoiseshell whose bulb is in the ground Figure 47 : Ground opening for the release of good rejects


Figure 48 : Good bayonet rejection with underground bulb Figure 49 : Bad aerial scale rejection


Figure 50 : Bad aerial bulb rejection Figure 51: Bad aerial scale rejection

Figure 52 : Eroded soil, compacted, leachedFigure 53 : Presence of greenish mold on the floor

Figure 54: Space between the straw and the second row Figure 55:Large driveway (rows 2 and 3)

Figure 56: Fertilizer protected by straw of banana leaves Figure 57 : Erosion of banana planks

Figure 58: *Vigna* cuttings *adenantha* issue Figure 59: *Resumption of Vigna de adenantha*
directly planted under the great banana trees   cuttings from direct cultivation cuttings

Figure 60: Start of installation of Desmodium adscendens Figure 61: Ground cover of *Desmodium adscendens*

Figure 63 : Good ground cover Figure 64 : Good control of *Desmodium adscendens* *Desmodium adscendens*

Figure65: Start of installation *of Heterotis rotundifolia* Figure 66: Good weed control by *Heterotis rotundifolia*

Figure 67: Path in foliage of Figure 68: Good ground covering of *Heterotis rotundifolia* *Heterotis rotundifolia*

Figure 69: suppression of erosion by *Heterotis rotundifolia*

Figure 70 : Good growth of banana trees in association with banana trees

Figure 71 : Start of installation *de Vigna adenantha*

Figure 72 : Weed control by *Vigna adenantha*

Figure 73 : Suppression of soil erosion *par Vigna adenantha*

Figure 74 : Good growth of banana associated to *Vigna adenantha*

Figure 75:Plants of *Crotalaria pallida* on the drains

Figure76 : Plants of *Indigofera tinctoria* on the borders of borders of drains

Figure 77: Drain cover by aerial plants of *Crotalaria pallida* 78: Protection against drains water pollution by *Indigofera tinctoria*

Figure79: Closure of drains by plants Figure 80: Weed control of drains
of *Crotalaria pallida* and *Indigofera tinctoria* by *Indigofera tinctoria and Crotalaria pallida*

Figure 81: Discards and banana at the beginning of the test Figure 82: Releases and banana 3 months later

Tableau 2 : Statistical data of banana from control plots

		DC	HT	NTF	NFF	LBF
N	Valide	49	49	49	49	49
	Missing	0	0	0	0	0
Average		18,149	187,31	16,37	7,06	205,96
Median		18,200	184,00	16,00	7,00	210,00
Model		17,3[a]	210	16	8	210
Ecart type		1,2232	34,711	1,776	1,126	48,892
Minimum		15,3	114	13	5	80
Maximum		20,2	257	20	9	336
Percentiles	25	17,250	162,50	15,00	6,00	176,00
	50	18,200	184,00	16,00	7,00	210,00
	75	19,100	210,00	18,00	8,00	240,00

a. a. Presence of several modes. The smallest value is displayed.

Tableau 3 : Statistical data of banana test plots

		DC	HT	NTF	NFF	LBF
N	Valide	49	49	49	49	49
	Missing	0	0	0	0	0
Average		18,357	188,96	16,10	7,33	208,39
Median		18,300	190,00	16,00	7,00	200,00
Model		17,2	210	16	8	190[a]
Ecart type		,9777	32,948	2,284	1,360	62,242
Minimum		16,0	120	11	5	100
Maximum		20,2	250	21	11	330
Percentiles	25	17,650	164,50	14,50	6,00	162,50
	50	18,300	190,00	16,00	7,00	200,00
	75	19,100	214,50	18,00	8,00	267,50

a. Presence of several modes. The smallest value is displayed.


Figure 83: Straw of *Crotalaria pallida* Figure 84:Absence of weeds at the end of the 4th cycle


Figure 85: Soil stabilized by *Desmodium adscendens* 86: Drains stabilized in the 5th cycle

Discussion

The decline in the soil fertility of the plot and the numerous aerial discharges observed during the 3rd cycle at the time of implementation of the trial is one of the characteristics of Ivory Coast banana plantations whose duration rarely exceeds the 4th crop cycle in the area of Dabou (Lassoudière, 2007 and Kouadio, 2010). In addition, the aerial rhizomes lead to compaction work, common falls of banana production, grassing and finally the fallowing of plots for short periods followed by replanting. All this raises the cost of banana production. The nursery and cultivation of cover crops in the soil fertility improvement project is original. Until then chemical or organic amendments (chicken dung, cocoa parches) have often been used. The presence of cover crops helps to eradicate erosion, which is the main cause of the decline in soil fertility, to control weeds and to ensure aeration, the microbiological activity of the soil and the permanent deposition of organic matter. All the selected species behaved well in the nursery, producing in 6 weeks maximum cuttings or plants ready to be planted in the field. Only Crotalaria pallida showed sensitivity to fungi in nursery leaves. The others have been attacked by snails and locusts in the aerial parts. In addition, *Vigna adenantha* cuttings grow faster in the nursery than seedlings. In all cases, the production of nursery plants must be recommended compared to sowing or direct cultivation especially under large banana trees and in the dry season. In addition, the planting of the plants under the large banana trees was rather slow (4 to 5) months against 3 months under the young banana trees. This can be explained by the canopy of large banana trees that does not allow the sun's rays to reach the growing cover plants. However, thanks to the cutting of banana trees, the luminous radiation stimulated the growth of the cover plants, which eventually covered the planks at 100% and colonized other areas. Especially *Vigna adenantha*, which supports trampling, offers the highest speed of installation, controls weeds and the best recovery rate also leaving a litter quite abundant. These results confirm them from Kouadio *et al*. in 2009. It is followed by *Desmodium adscendens* and *Heterotis rotundifolia*. The use of these plants is an alternative to the chemical control of banana growing (Kouadio *et al*., 2014). On the other hand, *Desmodium trifolium* and *Desmodium trifoliata* are not suitable for bananas. Their growth is slow and their ability to control weeds is low. The straw produced by *Crotalaria pallida* is abundant and allows the production of organic matter as well as *Indigofera tinctoria*. The installation of these species is fast especially if they are planted at the 4 leaf stage. Since these plants are nématicides, they can also contribute to the biological control of banana nematodes. These two species have already covered 90% of the light of the drains, the control of weeds along the drains and to avoid the pollution of the waters of the drainage channels of the water of the plot and thus, the protection of the quality of the waters and aquatic species (fish, crabs, frogs,...). These plants are less aggressive against banana than *Stenotaphrum secundatum* (Koudio, et al., 2016. They can be used on primary and secondary drains.) *Stenotaphrum secundatum* is more useful on collectors. Growth shows that the average values of the banana variables in the test plots are higher than those of the control planks. The observed data are characteristic of fast-growing banana trees, except for the average number of functional leaves that are the same (7.33 vs. 7.5) and leaflet diameters are slightly weak (208 cm vs. 248.4 cm), the observed values are generally higher than those of early-growing banana trees. earlier to those of undergraduate or second cycle bananas in flowering phase (Kouadio, 2010), which shows a positive impact of the use and non-harmful effects of cover crops on banana growth as observed by Kouadio et al. (2017). In addition, the relatively higher functional number of banana leaves in the test plots reflects a higher health of the test plots compared to the control plots and, on the other hand, a relatively higher banana production test plots compared to banana plots.

Conclusion

Research on improving the soil fertility of banana trees in Lumen, Dabou, in the south of Côte d'Ivoire, tested 7 species of leguminous plants for their cultivation, installation speed, ability to control grass cover, maintain slope of drains, suppress soil erosion, produce organic matter and affect banana growth. As well as the ability of the palm kernel crop to fertilize banana plantations, with a view to introducing them into the general ergonomics of banana growing in Côte d'Ivoire. The first results observed over a period of 6 to 12 months are satisfactory at the technical, scientific and agronomic levels. Thus, at the technical level, the method of producing cover plants is known. At the scientific level *Vigna adenantha*, *Desmodium adscendens* and *Heterotis rotundifolia* have demonstrated their ability to control weeds and to be used as cover crops under aged banana. Likewise, *Crotalaria pallida* and *Indigofera tinctoria* produce abundant straw and help to prevent aerial pollution of banana plantations. At the agronomic level, a new method of producing banana without chemical inputs has just been developed. Above all, an alternative to glyphosate is found. However, considering the cost of this new system, it is to be hoped that a planting plant for the production of cover crops will be created for all the banana producing companies that will be responsible for the distribution and training of the workers. The present works could have analyzed more parameters (dynamics of soil fertilization, mineral analysis of leaves, production data,...). However, company-level constraints did not allow for the completion of these highly relevant activities. Nevertheless, the results obtained are results of the real industrial environment and must be used for the general agronomy of banana in Ivory Coast and beyond.

Acknowledgements

All the materials have been supported by Wanita SA from Côte d'Ivoire. The lead author and also Guilgal Agronomy SARL manager is very grateful to Wanita SA Management Team.

References

[1] Dibi B., 2002. Quantitative and Qualitative Assessment of Groundwater Resources in the Dabou Region. D.E.A. of Earth Sciences and Mineral Resources, option: Hydrogeology, U.F.R. of Earth Sciences and Mining Resources, University of Cocody, Abidjan, Ivory Coast, 67 p.

[2] INSERM, 2013. Pesticides: Effects on health: a collective expertise of Inserm12 June 2013, 6 p

[3] Kouadio Y P, 2010. Use of cover crops as a means of biological control against the adventitious flora of the industrial banana plantations of Dabou in the south of Côte d'Ivoire, PhD thesis of the Botanical University of Félix HOUPHOUËT-BOIGNY University, UFR Biosciences , Laboratory of Botany, Specialty Biology, Morphology and Vegetal Taxonomy, option; Malherbology, 229 p.

[4] Kouadio Y. P., TIEBERE MS1, BORAUD NKM, N'GUESSAN KE, 2017. 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): 76-90

[5] Kouadio Y. Prosper, Boraud N'Takpé Kama Maxime, Tiebré Marie-Solange, Djakalia Ouattara, Edouard Kouakou N'guessan 2016. Biological Control of Erosion of Banana Drains in Ivory Coast. Agricultural Sciences, 2016, 7, 493-501

[6] Published Online July 2016 in SciRes. http://www.scirp.org/journal/as http://dx.doi.org/10.4236/as.2016.77050

[7] Kouadio Y. P., Tiébré M.-S., Kouassi R.H., 2014. Limits of chemical weeding in industrial banana plantations of Dabou in the south of the Ivory Coast.

[8] Kouadio Y. P. EGNANKOU W. M., N'GUESSAN K.E., ZOUZOU M. and AKÉ-ASSI L.,2009. Weeding control under banana plantations using cover legume in the Dabou area, Côte d'Ivoire. African Agronomy XXI (3): 215-330.

[9] Lassoudière André, 2007. The banana tree and its culture, Quae editions, Savoir-faire collection, CIRAD, 382 p.

[10] Danny Hakim1er August 20017. Monsanto's secret documents released, Thursday, August 3, 2017, New York Times website, Christian Berdot, Friends of the Earth, 3 p.

[11] Ministry of Agriculture, 2018. Interview with the Director of Plant Production at the Ministry of Agriculture during the program "Made in Africa", February 2018.

[12] Tapsoba S., 1995. Contribution to the geological and hydrogeological study of the region of

[13] Dabou (Southern Ivory Coast): Hydrochemistry, Isotopy and cationic index of aging of groundwater. Dotorat Thesis 3rd cycle, Laboratory of Hydrogeology, UFR of Earth Sciences and Mining Resources, University of Cocody, Abidjan, Ivory Coast 201p.