Growth and Yield Increases Induced by Soil Cover during the First Plantain Crop Cycle in DR Congo

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Abstract: Plantains are a staple crop in the DR Congo. Their production is low and not perennial despite they produce suckers like other banana subgroups. This study examines the growth performance of plantain in the first growing cycle, in different cropping systems. This study was conducted during two different periods in two experimental fields at Kisangani, DR Congo, whereby the soil was covered or not covered. The performance was tested by burning the fallow residue or not and by growing plantain as a monocrop or as part of an intercrop system (with groundnut and/or cocoyam). The working hypothesis is that the very superficial and fragile root system in plantain needs continuous cover to allow water and nutrient uptake and guarantee anchorage and sucker production and therefore sustainable production. As during the first cycle this cannot be achieved by the plantain foliage, we studied the effect of soil cover by the cut fallow that was not burned or by different crops in association that cover the soil with their leaves. The yields of intercropped plantains were significantly higher than those of plantains in monoculture, while plantains grown on both burned and not burned fields had significantly improved yields in association. The smallest vegetative growth and yield was measured in a monoculture of plantain and with a burned residue, showing that soil cover either by fallow residue or associated crops is crucial for good growth in this potential perennial crop.

Key-Words: Intercropping, plantain, slashes and burn, soil cover, yield, DR Congo.

1 Introduction

Bananas (*Musa* spp.) and plantains (a particular subgroup of AAB *Musa*) constitute a major staple food crop for millions of people and serve not only as a fruit crop but also as energy-rich food in many parts of the tropical world [1, 2 and 3]. Ninety per cent of the production is consumed locally and mainly in the poorest countries of Africa, Latin America and Asia.). Sixty per cent of the world's plantains are produced and consumed in Central and Western Africa, where they are a key factor in the diet [2, 4 and 5].

In the Democratic Republic of Congo (DR Congo), plantains are cultivated in the central basin [6] Bananas and plantains are key components of food security in the country, with a production of 1.42 million t/year [7]. Bananas and plantains are ranked second in terms of production after cassava according to national statistics, and the Oriental provinces ranks first with about 30 % of production [8]. Bananas and plantains rank high in DR Congo, not only because of their genetic diversity [9 and 10] but also because of its consumption rates [11]. The rapid decline in soil fertility is one of the major constraints causing yield decline [12]. [13] report that the productivity of plantain in traditional agriculture is severely limited by soil depletion, wind-induced lodging, diseases and pests, and socio-economic constraints.

Shifting cultivation in the tropical rainforests of Africa is very common [14]. Traditionally, the practice consists of 2 to 3 years of agricultural activity, followed by 10 to 20 years of fallow [15] with the sustainability assured by long fallow periods [16]. However shorter periods of fallow periods and increasing overexploitation of land due to population growth have resulted in reduced soil fertility and the shortening of the fallow [17 and 18]. In such cropping systems, yields are still high in the first years, but then decrease quickly due to

decreased soil fertility and the difficulty in controlling weeds [19]. The decline in plantain production is fast with about 80% decline after 3 cropping cycles [20].

The yield decline in plantain can be avoided or much reduced by mulching, which protects the soil [21] or row cultivation of trees that provide foliage [22 and 23]. This is most often not practiced as mulching is expensive because it must be collected from other fields and transported into the plantain field while the trees take a long time for establishment and need regular pruning.

Alternatively the soil can be protected with crops grown in association like cocoyam [7] groundnut, yam and maize [4], taro, cassava, yam, and sweet potato [24], legumes [25 and 15]. The most common practices in the Ituri and North-Kivu provinces in DR Congo include banana-bean, banana-bean-taro, banana-maize-bean and banana-coffee intercrops [26 and 27] and plantain-maize, plantain-maize-rice, plantain-maize-casava, plantain-casava, plantain-casava-rice, plantain-rice, in Tshopo Province. This is common practice but gramineae crops associated with plantain are often considered harmful because of competition.

Sustainable farming systems are seen as a necessary condition to guarantee continuous access to arable land for rural populations [28]. Therefore we investigated an agronomic system adapted for plantain in the forest environment of Kisangani region as a basis for perennial plantain cultivation with a sustainable high yield. As previous research has shown that the high yield during the first cycle is indicative of perennial cultivation in plantain [21], we analyzed different soil cover treatments during the plant crop in two experimental fields and at two periods of cropping.

2 Materiel and Methods

2.1 Experimental Design and Plant Material

This research was conducted in two experimental fields and during two growing seasons at Simi Simi (388 masl, 00 ° 33'04 .6 " N, 025 ° 05 '15.6' 'E) village located 15 km from Kisangani city, in the DRC. The two experimental fields were separated by 800 m. The first experiment started in March 2015 until May 2016, while the second one ran from July 2016 to August 2017. Planting material were suckers of the false horn plantain cultivar, Libanga Lifombo (*Musa* spp. subgroup AAB), suckers of a local cocoyam variety (*Xanthosoma sagitifolium*) and seeds of a local groundnut variety (*Arachis hypogea*).

2.2 Experimental Treatment and Growth Conditions

To perform these two tests, two experimental fields were set up with a randomized block design, with 8 treatments and 5 replicates. Half of the field representing 20 randomly selected plots was burned while the other 20 plots were not burned. The 8 treatments (T) consisted of T1: plantains on unburned but slashed fallow; T2: plantains on burned fallow; T3: T1 + cocoyam; T4: T2 + cocoyam; T5: T1 + groundnut; T6: T2 + groundnut; T7: T1 + groundnut + cocoyam; T8: T2 + groundnut + cocoyam.

Plantains were planted at 3 m x 2 m spacing. Gap filling was done one month after planting (MAP). Cocoyam suckers and groundnut seeds were planted at a spacing of 1 m x 1 m and 20 cm x 20 cm respectively one month after plantain planting.

2.3 Data Collection

The same data were collected for the both first and second tests. These data concerned the growth and the production parameters. About growth, the diameter at the base, the height of the pseudostem at harvest was the measured parameters. For the production parameters, the measurements focused on cycle length, the weight of bunch and yield per ton per hectare.

The diameter of the pseudostem was measured at the base of the pseudostem and its height from the base to the level of the insertion of the two latest functional leaves. The plantain cycle length was determined by counting the number of days between planting and harvesting. The yields per ton per hectare per year were calculated from the weight of the bunch of the first cycle, planting density and the cycle length.

2.4 Statistical Analysis

The statistical analysis of the variance and the comparison of the means were done by the Bonferroni multiple tests using the software Statgraphics Plus.

3 Results

3.1 Vegetative Growth

The best vegetative growth (diameter and height of the pseudostem) was recorded in the 3 treatments where the soils were covered either due to no burning, or no burning with intercropping or burning with intercropping (Table 1). Intercropping, a proxy for soil cover generally had a positive effect

on plantain diameter growth for all of these two crop essays during the first crop cycle.
However, only treatment with the best and the fastest soil cover (plantain with cocoyam and groundnut) was significantly better than a monoculture of plantain for pseudostem diameter.
Regarding the height of the pseudostem, plantains grown in intercrop system showed no significant difference compared to those in monoculture. In addition, plantain growth in both diameter and height was significantly better in unburned fields and burned fields with intercropping than in the burned fields for the two experiments (Table 1).

Table 1. Diameter of pseudostem at the base and height of the plantain at harvest for two experimental fields

	Diameter at the base			Height of the plantain		
Cropping system	First experience	Second experience	Average of 2 experiences	First experience	Second experience	Average of 2 experiences
PA	16.94^{b}	17.13^{a}	17.05^{b}	273.13^{a}	263.49^{a}	267.68^{a}
PC	17.78^{ab}	18.11^{a}	17.98^{ab}	289.4^{a}	267.59^{a}	275.67^{a}
PG	17.40^{ab}	18.21^{a}	17.86^{ab}	284.00^{a}	275.38^{a}	278.09^{a}
PCG	18.41^{a}	18.07^{a}	18.26^{a}	286.71^{a}	273.37^{a}	280.81^{a}
p-value (p)	0.011^{*}	0.155^{NS}	0.006^{**}	0.243^{NS}	0.300^{NS}	0.114^{NS}
U	17.46^{ab}	17.84^{ab}	17.68^{ab}	$283.^{5ab}$	275.23^{a}	278.71^{ab}
B	16.34^{b}	16.21^{b}	16.27^{c}	261.29^{b}	248.29^{b}	254.16^{c}
UI	17.33^{ab}	17.32^{b}	17.33^{bc}	278.65^{ab}	262.39^{ab}	269.09^{bc}
BI	18.24^{a}	18.52^{a}	18.41^{b}	291.8^{a}	278.16^{a}	283.40^{a}
p-value (p)	0.001^{**}	0.000^{***}	0.000^{***}	0.012^{*}	0.001^{**}	0.000^{***}

Legend: PA, Plantain alone; PC, Plantain + cocoyam; PG, plantain + groundnut; PCG, plantain + cocoyam + groundnut. U, Unburned; B, Burned; UI, Unburned + Intercropping; BI, Burned + Intercropping. The Averages with the same letter did not differ statistically according to the Bonferroni test (p = 0.05).

3.2 Cycle Length of Plantain

The cycle length of plantain in monoculture was significantly longer than in any other treatment with soil cover (Figs. 1 A and B) (plantain with different intercrops).

On the other hand, plantains had early production when they were planted on burned or unburned field but with intercropping (Figs. 1 C and D).

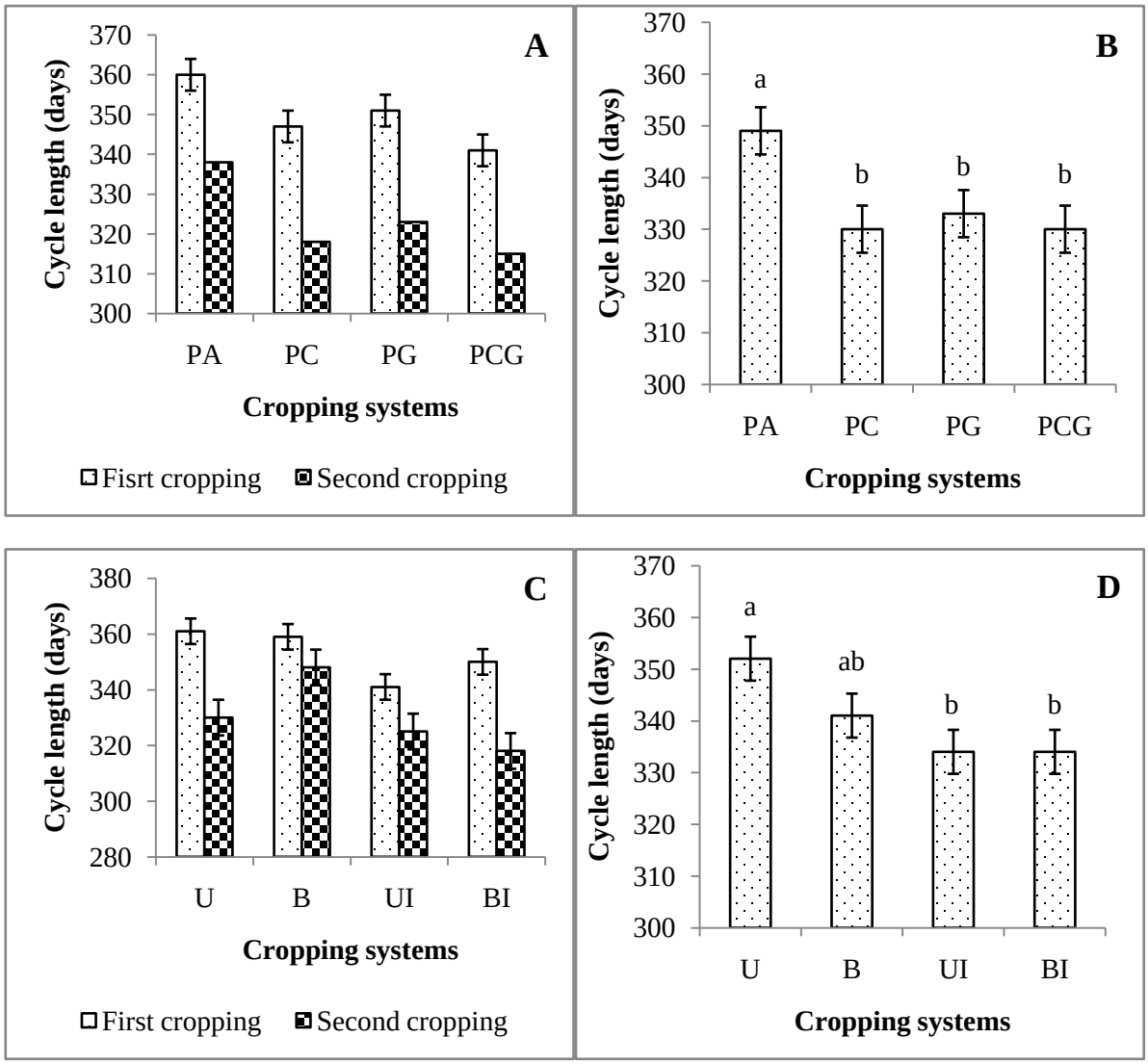

Fig.1. Cycle length of plantain with or without intercropping (A) in first and second experience; (B) average of two experiences, cycle length of plantain with or without burning (C); in first and second experience; (D) average of two experiences. PA, Plantain alone; PC, Plantain + cocoyam; PG, plantain + groundnut; PCG, plantain + cocoyam + groundnut. U, Unburned; B, Burned; UI, Unburned + Intercropping; BI, Burned + Intercropping. Bars with the same letter did not differ statistically according to the Bonferroni test (p = 0.05).

3.3 Plantain Yield

The yield of plantain was almost a mirror image of cycle length. Indeed longer cycles results in lower yields both in cropping system with or without intercropping (Fig. 2 A) and in the system with or without burning (Fig. 2 B). Plantain Monoculture, whether in first or second cropping resulted in the lowest yields (Fig. 3 A), while those in intercropping gave significantly higher yields (Figure 3 B). The plantain yield was improved when the soil below it was covered by cocoyam, groundnut and even more by both crops at the same time. This improvement was most remarkable in the plantain-cocoyam and in the plantain-cocoyam-groundnut combination, which increased the yield respectively by 1.98 t/ha/year and 2.3 t/ha/year relative to the monocropping system for the two tests combined. Generally, burned and unburned fields have similar yields of plantains (Figs. 3 C and D). However plantains were significantly more productive on burned or unburned intercropped fields than on burned without intercropping for all two tests conducted (Fig. 3 D).

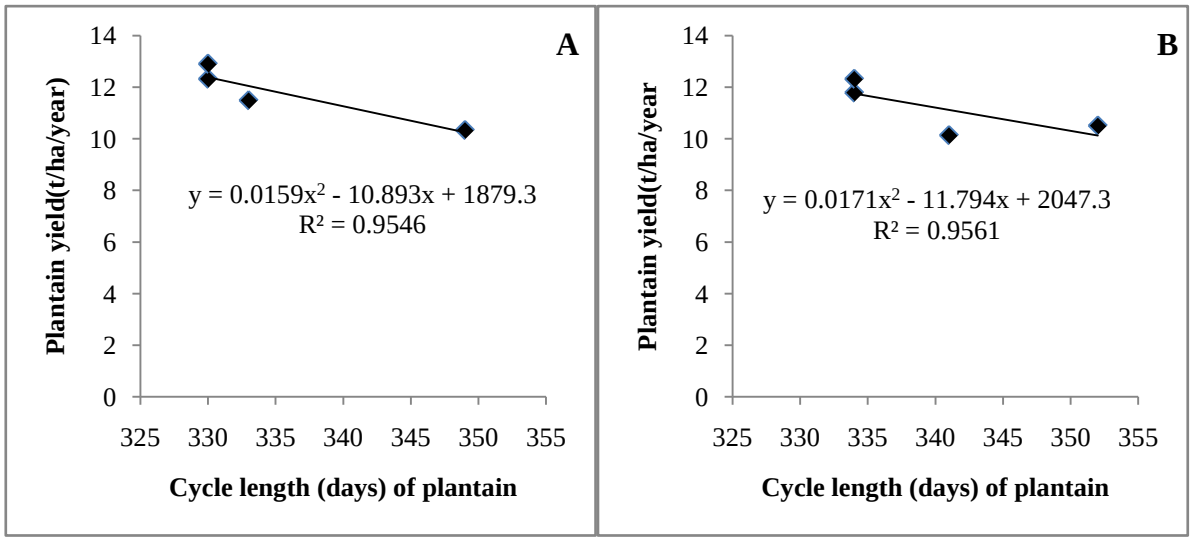

Fig.2. Correlation between cycle length and plantain yield (A) with or without intercropping; (B) with or without burning.

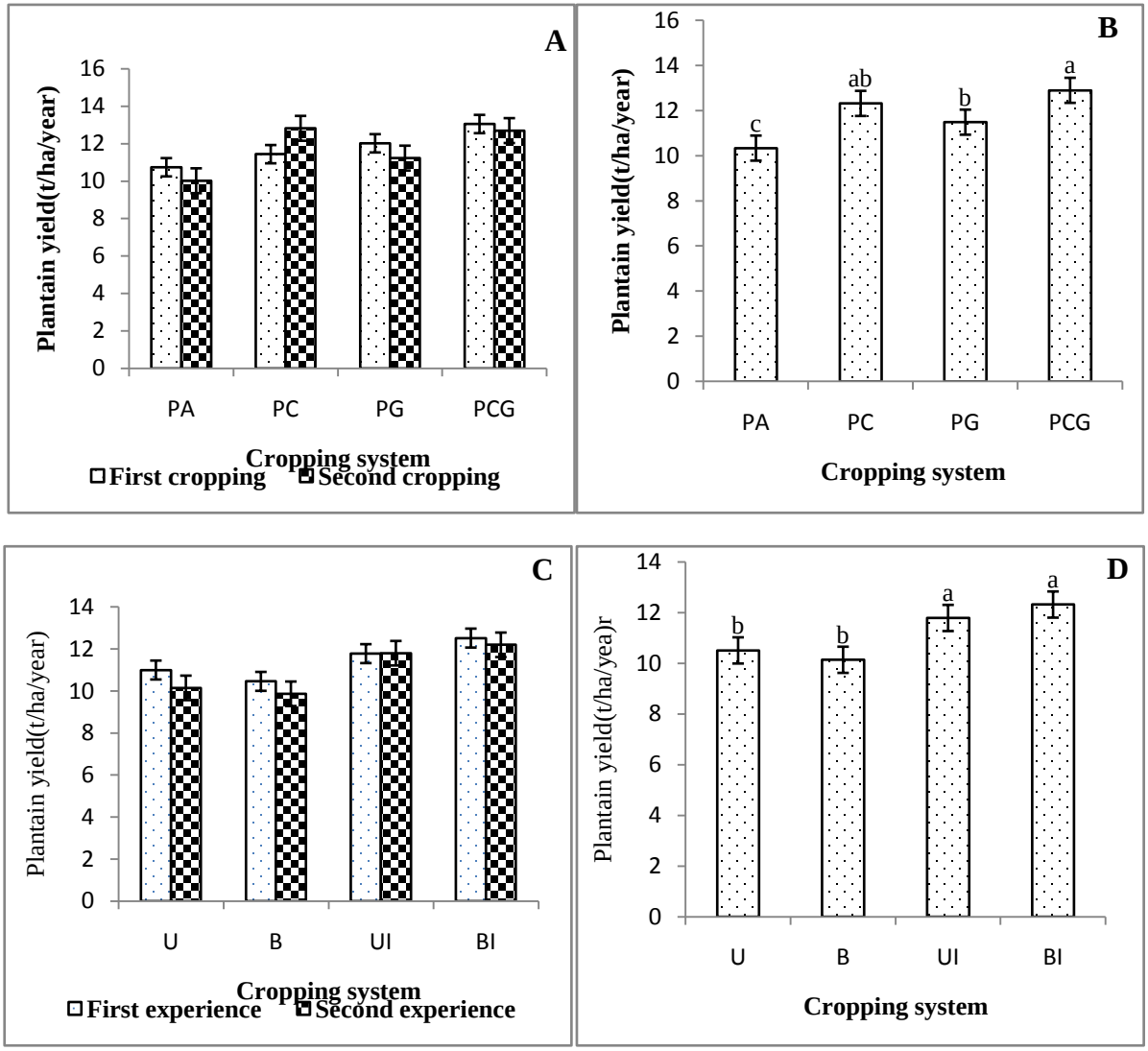

Fig.3. Yield of plantain with or without intercropping (A) in first and second experience ; (B) average of two experiences and Yield of plantain with or without burning (C); in first and second experience ; (D) average of two experiences. PA, Plantain alone; PC, Plantain + cocoyam; PG, plantain + groundnut; PCG, plantain +

cocoyam + groundnut. U, Unburned; B, Burned; UI, Unburned + Intercropping; BI, Burned + Intercropping. Bars with the same letter did not differ statistically according to the Bonferroni test (p = 0.05).

4 Discussion

Plantain as a monoculture on burned fields gave the lowest vegetative growth and yield. Any treatment that covers the soil, whether by no burning, or by covering the soil with crops in association, resulted in a better vegetative growth and a higher yield with significantly higher yields on burned and intercropped fields, and with plantains intercropped with cocoyam and groundnut. The plantains produced faster on burned fields with intercropping while those without intercropping had a longer cycle length. Our research demonstrates that the associations of plantains with certain crops that provide fast soil cover reduce the plantain cycle length. Previous studies such as those of [29] already demonstrated that plantains produce faster when soils were covered with mulch. Among all treatments, plantains associated with cocoyam and groundnut produced earlier and has also the highest yield. A higher vigor of the pseudostem and the larger leaf area was observed in these intercropped plantains. This leads to a rapid growth of plantains and consequently bigger bunches as shown by [30].

Growth and yield are highest when the slashed fallow vegetation is burned and immediately followed by a maximal soil cover from the groundnut grown with cocoyam. Clearly by no burning and intercropping, the superficial root system of plantain is protected against high soil temperatures and dehydration from the associated crops, while burning followed by crop association results in a fast supply of nutrients from the ashes [31]. The cocoyam with groundnut gave the best results as this maximizes a quick soil cover from the groundnut and the longest soil cover coming from the cocoyam, explaining why their combination is better than either crop alone. These intercrops covering the soil potentially returned organic matter to the soil during plantain production, thereby improving or maintaining its soil structure [32]. This is in line with earlier studies whereby it was documented that mulched plantain produce better than plantain without soil cover [33, 22 and 21]. Mulch provides both a physical effect (by covering the soil) as well as a nutritional effect (when it starts decomposing) and [29] have shown that in the first cycle the physical effect of mulch seems to prevail over the chemical effect.

This would explain that plantain with groundnut and cocoyam alone or in combination, gives a better plantain yield, because of the obtained soil cover, and that under the presented cultivation these intercrops are not to be considered as competing with plantain.

According to [34] the production of plantain with associated crops is almost four times higher than in monoculture, because of nutrients recycling from deep rooted perennial tree crops to plantain. But, [35] did not show that cocoyam improved the yield of plantain but their fields where not established on a field with a long fallow and in a region with a 8 month growing season, hence the soil cover by cocoyam and by plantain was presumably much slower than under the growing conditions in Kisangani. [36] demonstrated that plantain yield benefits from soil cover, while testing the positive effect of different tree densities. Similarly, [25] signal that agroecological practices such as the integration of shade- and drought-tolerant crops, nitrogen-fixing and cover crops could potentially improve soil fertility and moisture retention reduce the weed burden, narrow yield gaps and increase overall plot/farm productivity in these systems.

5 Conclusion

Unlike dessert bananas, the perennial cultivation of plantain is a challenge under field conditions in the poor soils of Africa. Plantain shows a perennial behavior in backyards where the soil is continuously covered by the very high density of plantain plants, the continuous enrichment with organic wastes and ashes from the homestead. However under field conditions, plantain fields last for 2 or 3 cycles, with the third cycle already showing a very big yield decline. Plantain cultivation can last for many years when mulching is applied, but this is economically not feasible as the mulch has to be carried into the field at frequent intervals. Alternatively plantains should thus be cultivated with a cover crop but this is not attractive to farmers who are not interested to maintain cover crops that offer no immediate return. Hence plantains need to be intercropped with crops that cover the soil very quickly, cover it for a long time until the plantain leaves protect the soils, and explore the soil profile other than where the plantain roots growth. Unlike cereals, groundnut and cocoyam offer these advantages to plantain and provide in addition some extra yield for the farmer.

The obtained higher yields after burning and plantain in association with some crops, seems to support the current crop husbandry methods applied by farmers. However higher yields results in higher

nutrient exports, hence the need to follow up the plantain yield over different crop cycles, and to study the effects of the applications of inorganic fertilizers to compensate the nutrient exports.

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