The efficacy of improved *in-situ* mulch rows on sustaining yields in different plantain (*Musa spp.*) cycles in Rivers State, Nigeria

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Abstract: This study was destined to investigate the efficacy of improved *in-situ* mulch rows in improving and sustaining plantain yields up to the 4th crop cycle. The trial was conducted at the Rivers State University of Science and Technology Teaching and Research Farm, Port Harcourt, Nigeria using six different banana and plantain clones/cultivars and improved life mulch rows incorporated on the three meter inter-rows and were cut back periodically. The *in-situ* mulch rows were planted with selected grasses and legumes. Growth and yield parameters were taken. The results shows that the manure from the *in-situ* mulch rows significantly increased and sustained yields up to the 4th crop cycle at ($p<0.005$) level of significance other than in the circumference at the last finger. On the growth parameters, there was also a significant difference amongst the clones in plant height, number of leaves and sucker production in all the crop cycles with the triploids scoring higher owing to their increased number of chromosomes and cell sizes. Bunch weights were found to be independent of bunch hand but increased with increase in finger number and size. The higher bunch weight of the triploids was attributed to fruit size and not the number of fruits which was higher in the diploids. This study has shown the usefulness of *in-situ* mulch rows in increasing and sustaining yields of different *Musa spp* up to the 4th crop cycle.

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Introduction

Bananas and plantains are tropical giant perennial monocots in the genus *musa* of the family *musaceae*. The most important cultivated types used by famers include AAA and AAB dessert bananas, ABB cooking bananas and AAB plantains which are starchy. Plantains are mainly low-land crops grown in the humid forest regions (Swennen, 1990). Plantains can be grown on a wide range of soils provided it is deep, well drained with adequate fertility and moisture. Unlike Cassava, Yam and other starchy staples whose demand tend to fall with rising incomes, demand for plantain remains high despite rising incomes (Dury *et al*., 2002). In West Africa, plantain is not only the cheapest carbohydrate food but also the cheapest crop for labour requirement, especially in rural areas where lack of enough labour is constrained to sustainable and full production (FAO, 2013).

Presently, a major problem facing plantain production in humid tropics is poor yield and economic yield sustainability. For example, on the average, Horn plantain yields 4-6 tons per hectare as against 46-68 tons/ha of Cavendish banana (Swennen, 1990). Yield decline syndrome occurs after 1-2 years when the crop is grown on large scale field plantation. This is partly due to reduced soil fertility, pests and diseases build up and high mat development. In order to maintain high productivity, shifting cultivation and other forms of related bush fallow systems have been practiced (Ayanlaja *et al.,* 2010). But with increasing population pressure, fallow periods have become too short for soil fertility to be adequately restored. The use of inorganic fertilizer manure to boast yield is commendable but very expensive or may not always be available (Stover and Simmonds, 1987).

Owing to plantain corms growth pattern, the upper surface of corms in ratoon – plantain fields can be seen above soil level (High Mat). This can lead to roots dry out, reduction in sucker production and tip over (Swennen, 1990). Therefore, as an approach to these problems, this study employed the use of *in-situ* mulch strip rows as a source of mulch/manure when they are periodically cut back.

Materials and Methods

Experimental site

The field trials were conducted at the Teaching and Research farm of Rivers State University of Science and Technology located in the humid forest zone of Southern Nigeria (FAO, 1994). The soil is an acidic sandy loam which occurs over sedimentary rock. The acidic level is 4.8, it is deficient in macro nutrients N_2 -, Mg-, K-, but high in phosphorus, which is why there was need to improve the soil nutrient status. The University is on latitude $4^0 31$'to 5^0N and longitude $6^0 41$'to 7^0E, with an average temperature of 27^0C, relative humidity of 78% and average rainfall that ranges from 2500 –4000mm (Nwankwo and Ehirim, 2010).

Experimental Materials

The experimental materials were made of the following: Calcutta 4 (C4), a wild diploid dessert banana with AA genome; Yangambi (km5) a dessert diploid banana with AA genome; Agbagba a land race triploid false horn type plantain with AAB genome; Obinai Ewai, a land race false horn triploid plantain with AAB genome; An unknown plantain, a medium unidentified triploid plantain; and UST/P/02/01, a medium triploid plantain developed at Rivers State University of Science and Technology Port Harcourt, Teaching & Research Farm. The planting materials were sourced from the Teaching and Research Farm of the University. To ascertain trueness to type, planting materials (Sword suckers) were collected from flowering stands.

The Experimental Design

The design of the experimental field was a Randomized Complete Block design (RCBD). Each clone cross was replicated three times. Each replicate consisted of 20 cleared planting rows of 1 x 10m and 21 un-cleared *in-situ* mulch rows of 2 x 10m each. Each replicate was 10 x 60m with 100 stands and separated from other replicates by 3m latitudinal bush rows. The whole field contained 300 *musa* stands and measured 36 x 60m (2160m^2 or 0.216 ha). The suckers were trimmed to size 30 to 40cm high with at least one viable adventitious bud and roots. The peeling was to get rid of nematodes and banana rhizome borers (Swennen, 1990). Holes of size 30 x 30 x 30cm were dug along the 1m wide planting rows at 2m intra- rows spacing and at 0.5m from the 2m *in-situ* mulch strip rows. This gave the normal population density of about 1667 plants per hectare. Clearing and stumping were done one each of the 1 x 10m planting rows only**.** Planting was done in the rainy period of June/July. Top soil was put in the dug holes first before planting the suckers. After planting, the soil was firmly marched and well mulched. Legumes like Mucuna (*Mucuna utilis*), stylo (S*tylosanthes gracilis)* and calapo (*Calapogonium mucunoides)* were introduced to form a legume-grass mixture with Guinea grass (*Panicum maximum).* At 4 weeks after planting, the *in-situ* mulch rows were cut back and the biomas used as mulch and manure. Obnoxious weeds in the *in-situ* mulch rows were eliminated. Weeds were controlled by regular monthly weeding at approximately 0.5m radius round the plantain stands for the first few months after which they were done only when necessary. But the *in-situ* mulch rows were regularly cut back at intervals of 2 months. A typical proximate analysis of the main grasses and legumes on the *in-situ* mulch rows is shown below.

Data Analysis:

A randomized complete block design (RCBD) with three replications was used. The results of the different parameters were subjected to combined analysis of variance (ANOVA) using the General linear model (GLM), while the differences among the treatment means were separated using least significant difference (LSD) at 5% level. All data analyses were carried out according to the procedure of SAS (1999). Ploidy levels of the progenies were ascertained through chromosomal counting using Tel and Hargerty (1984) method while the growth components (plant height, girt, number of leaves) and the yield components (bunch weight, number of hands per bunch, number of finger per bunch and finger sizes) were calculated using meter tape and physical count.

Results

Table 1: Proximate Analysis of the main *in-situ* mulch materials

	N	P	K	Fe	Ca	Mg	Na
Calopogonium Spp.	3.02	0.43	1.25	2.00	1.67	1.75	2.36
Pueraria Spp.	2.38	0.25	2.30	1.16	1.25	1.52	2.13
Mucuna Spp.	2.96	0.32	1.57	1.9	1.61	1.66	2.00
Centrosema Spp.	2.94	0.14	1.30	1.35	1.50	1.32	1.53
Guinea grass	0.15	0.60	0.81	3.36	2.36	1.87	2.53

Growth Parameters

In Table 2, the plant height at flowering for Obino I'Ewai and Agbagba (2.68m and 2.61m respectively) were significantly higher than other clones. The two banana clones had a lower plant heights, km5 (1.95m) followed by the least Calcutta4 (1.88m).

There was also a significant difference on the impact of crop cycle on the plant heights of the clones in Table 3. The clones showed a steady increase in heights from the crop plant in 1st crop cycle (1.9m) up to 4th crop cycle (2.43m).

On number of leaves at flowering, Obino I'Ewai, a plantain cultivar produced the highest number of leaves at flowering (9.65) followed by the unknown plantain although not statistically significant. Agbagba (8.75) produced significantly more leaves at flowering than the two banana clones, Yangambi (7.17) and Calcutta4 (6.00). The clone, UST Px/02/01 had the least number of leaves at flowering (Table 2).

The crop cycle also had significant effect on the number of leaves at flowering as shown in Table 3. The number of leaves at 4th year cycle (8.64) was higher than previous cycles 8.2, 7.6 and 6.9 in the crop plant.

The number of leaves at harvest reveals that a higher number of leaves were retained in Unknown plantain clone (2.82). This was followed by Obino I'Ewai (2.53) which had the highest number of leaves at flowering (Table 2). Agbagba cultivar retained 2.08 leaves at harvest and was significantly higher than that of the banana clones Calcutta 4 (1.67) and km5 (1.47) which were not significantly different from each other.

The crop cycle had a significant positive impact on number of leaves at harvest. The highest number of leaves were retained in the 4th crop cycle (2.52) followed by the 3rd cycle (2.2). Crop cycle had no significant impact on the number of leaves at harvest in the crop plant and the cycle following as shown in Table 3.

The number of suckers at harvest in Table 2 showed that Yangambi (km5) a banana clone significantly produced the largest number of suckers at harvest (7.52). This was followed by Obino I'Ewai (4.12) and Unknown plantain (3.05). Agbagba (2.73), Calcutta 4 (2.72) and UST/px/02/01 (2.55) were not significantly different from each other, although the latter produced the least number of suckers at harvest. There was also a significant difference on the impact of crop cycle on the number of suckers produced at harvest. There was a steady increase in sucker number (2.6) in crop plant till the 4th crop cycle (5.00) in Table 3.

Table 2: Effects of *in-situ* mulches on agronomic performance of the experimental clones

Clones	Plant height at flowering (m)	Number of leaves at flowering	Number of leaves at harvest	Number of suckers
ObinoI'Ewai	2.68^{a}	9.65^{a}	2.53^{a}	4.12^{b}
Agbagba	2.61^{a}	8.75^{b}	2.08^{b}	2.73^{d}
Unknown plantain	2.15^{a}	9.4^{a}	2.62^{a}	3.05^{c}
Yangambi (km5)	1.95^{cd}	7.17^{c}	1.47^{c}	7.52^{a}
Calcutta 4	1.88^{d}	6.00^{d}	1.67^{c}	2.72^{d}
UST/Px/02/01	1.99^{c}	6.00^{d}	1.80^{bc}	2.55^{d}

Means with the same letter (s) in a column are not significantly different at 5% level of probability.

Table 3: The impact of *in-situ* mulches on agronomic performance of crop cycles on the experimental clones

Crop cycle	Plant height at flowering (m)	Number of leaves at flowering	Number of leaves at harvest	Number of suckers
1	1.90^{d}	6.9^{d}	1.61^{c}	2.60^{d}
2	2.15^{c}	7.6^{c}	1.78^{c}	3.47^{c}
3	2.31^{b}	8.2^{b}	2.2^{b}	4.12^{b}
4	2.43^{a}	8.64^{a}	2.52^{a}	5.00^{a}

Means with the same letter (s) in a column are not significantly different at 5% level of probability.

Yield Parameters

Table 4 shows the yield components of the experimental clones. On the bunch weight there was a significant difference on yield with ObinoI'Ewai producing the highest bunch weight (5.10kg). This was significantly higher than Agbagba cultivar (4.48kg), Yangambi (2.4kg), Calcutta (4 0.56kg) and UST/px/02/01 (0.40kg). The crop cycle (Table 5) had a positive significant impact on bunch yield increase up till year 4 (3.45kg). Year 3 had 3.11kg while years 2 and 1 had 2.71kg and 2.13kg respectively in the crop plant.

At each harvest the number of hands counted per bunch from the various clones was shown on Table 4. ObinoI'Ewai (7.45) had the highest mean number of hands and showed a significant difference among the cultivars followed by Agbagba (6.35). There was no significant difference between Calcutta 4(5.63) and unknown plantain (5.57). Yangambi had the least (5.00) number of hands per bunch at harvest. There was equally a significant difference on the effect of crop cycle on number of hands per bunch. The highest hands per bunch were recorded in the 4th crop cycle and were significantly different from 3rd year (5.87). The crop plant and first ratoon crop number of hands per bunch were not significantly different (Table 5).

The number of finger per bunch varied significantly amongst the different cultivars (Table 4). The unknown plantain (64.33) had the highest number of fingers. UST Px/02/01 (60.87) did not significantly vary with Calcutta 4 (58.57). But km5 (53.95) had a higher number of fingers than ObinoI'Ewai (48.05) while Calcutta had the least number of fingers per bunch. Crop cycle had a positive significant impact on finger number per bunch. While the 3rd and 2nd year crops did not differ but were significantly higher than the crop plant (51.61) as in (Table 5).

On Table 4 Agbagba cultivar produced the highest first finger length of 22.54cm which was significantly followed by ObinoI'Ewai (18.63cm). Unknown plantain clone first finger length of 11.78cm was also significantly higher than that of Yangambi (8.00cm) while Calcutta 4 (4.6 cm) first finger length did not significantly vary from UST Px/02/01 (4.15cm) which was the least. The crop cycle impact was positive. The crop plant first finger average length of 10.15cm was significantly surpassed by the ratoon crops up to the 4th crop cycle although the increase was not significant.

The length of mid-finger (cm) as in Table 4 showed that there was a significant difference amongst the clones. The trend followed exactly as that of the first finger length. Agbagba (19.5cm) was the longest followed by ObinoI'Ewai (17.73cm) while Calcutta 4 (3.25cm) did not significantly vary from UST Px/02/01 (3.07cm) which was also the least. The crop cycle showed a continuous significant increase in the length of mid finger from the crop plant (9.18) to the 4th crop cycle (10.35) as in Table 5.

In Table 4, it showed the mean lengths of the last fingers of the clones just like the length of the first and mid fingers, the same trend followed and Agbagba cultivar (12.23) was also significantly higher and followed by ObinoI'Ewai (10.00cm). Unknown plantain (7.78cm) and km5 (6.63cm) had no statistical difference but were significantly higher than Calcutta 4 (2.8cm) and UST Px/02/01 (2.61cm) which were statistically the same. On the impact of crop cycle in Table 5, there was a statistical increase in the length of last finger in the 3rd (8.00) and 4th (8.35) crop cycles although significantly the same over the crop plant (7.15) and 2nd (7.46) crop cycles which also had no significant difference.

Table 4 showed that ObinoI'Ewai (11.97cm^2) and Agbagba (11.84 cm^2) cultivars first finger circumference were not significantly different but higher than that of other cultivars while unknown plantain (10.81cm) was higher than Yangambi (7.7cm^2). Calcutta 4 and UST/px/02/01 were not statistically different. On the impact of crop cycle after the crop plant (7.77), there was a slight steady but no statistical increase in the size of the first finger circumference up to 4th crop cycle (Table 5).

The performance of the clones in terms of the mid-finger circumference was presented in Table 4. Agbagba (11.15cm^2) and ObinoI'Ewai (10.80cm^2) are significantly the same but higher than other clones. Unknown plantain record was higher (10.00cm^2) than Yangambi (7.70cm^2) but UST/px/02/01 (3.34cm^2) and Calcutta 4 (3.20cm^2) were the least. In Table 5, the impact of crop cycle was significantly positive throughout the 4 year period. There was a steady increase of mid finger circumference from crop plant (7.21cm^2) to the 4th crop cycle 8.05cm^2.

The Agbagba (12.23 cm^2) last finger circumference was statistically significant than the rest of the clones followed by ObinoI'Ewai (9.58cm^2). Unknown plantain (7.80cm^2) and Yangambi (6.63cm^2) are significantly different from Calcutta 4 (2.80 cm^2) and clone 5 (2.60cm^2) in Table 4. Based on Table 5 result, crop cycle had no impact on the circumference of the last fingers of the clones.

Table 4: Effect of *in-situ* mulches on yield components of the experimental clones

Clones	Bunch weight (kg)	Number of hands	Number of fingers	Length of 1st finger (cm)	Length of mid finger cm	Length of last finger (cm)	Circumference at First finger (cm^2)	Circumference at mid finger (cm^2)	Circumference at last finger (cm^2)
ObinoIEwai	5.10^a	7.42^a	48.05^d	18.63^b	17.73^b	10.00^b	11.97^a	10.8^d	9.58^b
Agbagba	4.48^b	6.35^b	34.70^e	22.54^a	19.51^a	12,23^a	11.84^a	11.15^a	12.23^a
Unknown	4.15^c	5.57^c	64.33^a	11.78^c	8.32^c	7.78^c	10.81^b	10.00^b	7.80^c
Yangambi	2.40^d	5.00^d	53.95^c	8.00^d	7.00^d	6.63^c	7.7^c	7.70^c	6.63^c
Calcutta 4	0.56^e	5.63^c	58.57^b	4.60^e	3.25^e	2.80^d	4.21^d	3.20^d	2.80^d
UST/PX/02/01	0.40^e	5.03^d	60.87^b	4.15^e	3.07^e	2.61^d	4.82^d	3.34^d	2.66^d

Means with the same letter (s) in a column are not significantly different at 5% level of probability.

Table 5: The impact of *in-situ* mulches on yield components of crop cycle on the experimental clones

Crop cycle	Bunch weight (kg)	Number of hands	Number of fingers (cm)	Length of 1st finger (cm)	Length of mid finger	Length of last finger (cm)	Circumference at First finger (cm^2)	Circumference at mid finger (cm^2)	Circumference at last finger (cm^2)
1	2.13^d	5.66^c	51.61^b	10.156^a	9.18^c	7.15^b	7.77^b	7.21^c	7.03^a
2	2.70^c	5.64^c	53.37^{ab}	11.62^a	9.66^b	7.46	8.56^a	7.55^{bc}	7.00^a
3	3.11^b	5.87^b	53.63^{ab}	12.15^a	10.04^{ab}	8.00^a	8.80^a	7.80^{ab}	7.00^a
4	3.45^a	6.14^a	55.03^a	12.58^a	10.35^a	8.35^a	9.11^a	8.05^a	7.00^a

Means with the same letter (s) in a column are not significantly different at 5% level of probability.

Discussion:

After a short period of fallow, fragile humid tropical soils can only effectively sustain plantain crop plants and not subsequent ratoon crops. The Mulch materials effectively sustained the soil nutrient status throughout the four year period. Mulch materials are known to increase soil biological life and moisture content while gradually releasing the need soil nutrients from the decaying materials. According to Rukazambuba, *et al.,* (2002), *M. pruriens,* and *C. Pubescens* showed rapid nitrogen release and a relatively high release of calcium and magnesium thereby increasing soil exchangeable calcium and magnesium levels. The *in-situ* mulch components were relatively high in potassium which is the most abundant mineral in plantain mother plant and bunch (Gold *et al.*, (2006).

Mulching equally is useful in keeping the soil temperature low and in keeping down weeds. During the course of the work, the mulch materials also protected roots from drying out and improved the root ramification and stability of the ratoon crops especially in plantain clones which have high mat propensity. The mulch materials also supplied varying types of nutrients unlike the use of deep-rooted legumes shrubs like *Flamingia congesta* and *F. macrophylla* which are not only difficult to establish (takes up to 2 years) but they continuously supply the same type of nutrients year after year (Swennen, 1990).

There was a vast variation amongst the different cultivars. Although variation in heights and yield could be attributed to soil type, moisture regime plant density and other environmental factors, genetic difference is the main contributing factor in addition to environmental factors. Vuylsteke, *et al.,* (1993) reported that tetraploids and triploids have significantly higher heights, leaves number and area, and bunches than their respective full rib diploids in segregating euploid plantain-banana hybrids. Even in natural banana germ plasm, triploids have higher vegetative and fruit yields than diploids (Simnonds, 1983). This is because of increased cell sizes caused by increased number of chromosomes of tetraploids (4x) and triploids (3x).

In conclusion, this work has showed the usefulness of the improved i*n-situ* mulch strip rows of legume grass mixture in increasing and sustained plantain yields up to the 4th crop cycle.

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