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Depth of Planting and Mulching: Critical Agronomic Aspects (Cultural Practices) in Late-season Plantain Establishment in Rainforest Agroecology of South-eastern Nigeria.

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Abstract

The experiment examined the influence of six mulch sources (trash, wood shavings, palm frond, saw dust, black polythene sheet and no mulch (control) and three planting depths (60x60x60 cm, 60x60x80 cm and 60x60x100 cm) on soil macro biological life, soil moisture content and soil temperature during late season plantain establishment. A 3x6 factorial experiment was fitted into a Randomized Complete Block Design (RCBD) with three replications. The land was cleared manually. Planting depths were prepared, treated with poultry manure at 10 tha^{-1}. Each planting depth received 4 tha^{-1} of appropriate mulch except black polythene. After two weeks, plantain sword suckers were planted in December 2010. Core soil samples were collected at each planting depth for pre and post experimental soil physico-chemical analyses, soil macro biological life count and percentage soil moisture determination. Soil temperature was monitored at each depth using soil thermometers. All data for plantain were collected and analysed using Genstat. Mean separation was done using the least significant difference (LSD) at 5 % level of probability. Planting depths and mulches significantly ($P<0.05$) reduced soil temperature during 1 - 4 months after planting. The 60x60x80 cm depths mulched with saw dust recorded lowest soil temperatures at 1 and 2MAP (28.67^{0}C and 28.69^{0}C). Trash mulched plots of same dimension recorded lowest temperature (29.33^{0}C) at 3 MAP respectively. Percentage soil moisture content, soil macro biological life and plantain sucker sprout were significantly ($P < 0.05$) influenced within 3 months after planting. The 60x60x100 cm plots mulched with black polythene sheets conserved the highest soil moisture (20.12, 21.95 and 24.41 %) at 1-3 MAP respectively. The 60x60x80 cm and 60x60x100 cm planting depths mulched with same mulch types recoded 100 % sucker sprout at 3MAP respectively.

1.0 Introduction

In Southeastern Nigeria, plantain is usually established during the early and late planting seasons (Obiefuna, 1983). However, early season plantain establishment results in abundance of plantain fruits between July and December and then, plantain becomes scarce from January through June. This coincides with the natural hunger gap. Subsequently, the prices of available plantain rise. As a determinate all season crop, need arises for dry season plantain cultivation to bridge the hunger gap. The major limitation of the late season plantain planting is poor crop establishment and low survival percentage, especially when the rains end unexpectedly early (Obiefuna, 1989). The sword suckers for plantain establishment store for at least eight (8) weeks at ambient temperatures (Obiefuna, 1989). This unique attribute like yam tubers could be exploited for the December to March dry season especially when appropriately mulched. Therefore mulching is essential (Swennen,1990; Obiefuna*, et al,* 1983), and/or irrigation (Morton, 1987) during the dry season. Soils (ultisol) of Owerri, Southeastern Nigeria are

characterized by low nutrient reserve, high subsoil acidity and related constraints (Onweremadu, *et al,* 2007). Thus, soil improvement through the application of environmentally friendly and sustainable organic amendments such as mulch and poultry manure is advocated. This is particularly important in plantain which requires very fertile soil and high organic manure for establishment, growth and yield.
Organic mulch provides numerous benefits to the soil ranging from soil temperature amelioration, increased soil life, infilterability, nutrient and water retention in the soil (Salau*, et al*, 2003; Clatterbuck, 2010; Obiefuna, 1985; Shiyam, *et al,* 2010). Mulch materials are diverse in type, function, availability, and in characteristics. Common mulches in rainforest agroecology including saw dust, wood chips, palm frond, palm bunch refuse, tree litter and trash are cheap and readily available (Obiefuna, *et al,* 2014). Plastic mulch is completely impermeable to water and therefore prevents soil evaporation and limits water losses and erosion (Wikipedia, 2012). Soil diurnal temperatures vary with soil depth and influence crop growth in diverse ways. Thus while high soil temperatures inhibit, moderate temperatures enhance crop growth. This paper investigated the critical aspects of planting depth and mulching on late season establishment of plantain in the rainforest agroecology of Southeastern Nigeria.

2.0 Materials and Method

The experiment was conducted in the late planting season (November) of 2010 and terminated in the next early season (March) of 2011 at the Teaching and Research farm of the Federal University of Technology, Owerri located between latitudes 5^{o} 27',50.23´´ and 5^{o} 29´ 44. 18´´ North and longitude 7^{o}20´ 19.35´´ and 7^{o}02´ 56.12´´East at an elevation of 55.6m above sea level. The climate of Owerri is a humid tropical type characterized by wet and dry seasons. The wet or rainy season begins from mid – March to November with a little dry spell (called August break) occurring in August. The dry season is from mid November to mid March. The mean annual rainfall is 2500 mm and is bimodal with peaks in July and September (Nwosu and Adeniji, 1980). Minimum and maximum temperatures are 20^{0} C and 32^{0} C respectively. The soils are deep, porous and derived from sand deposits in the coastal plains which are highly weathered, low in mineral reserve and natural fertility (Ofomata, 1995; Onweremadu *et al,* 2007; Ononiwu, 1990).

Land was manually cleared, stumped and the trash packed. Core soil auger samples were collected randomly from experimental site, at 0 – 60 cm, 60 – 80 cm and 80 -100cm respectively, bulked and analyzed for physical and chemical properties in the laboratory. All mulch materials except black polythene were sampled for laboratory analysis. The treatments were three plantain planting depths viz: 60x60x60cm, 60x60x80cm, 60x60x100cm and six types of mulch materials namely: sawdust, wood shavings, palm fronds, trash, black polythene sheet and no mulch control. Thus, the treatments were laid out in a 3 x 6 factorial in a Randomized Complete Block Design (RCBD) fashion with three replications. The plantain sword suckers Musa AAB, Ogoni Red obtained from the University plantain orchard were pruned and planted at appropriate depths. Five plantains in single row spacing pattern was adopted. Blanket poultry manure was applied to each planting depth hole at 10 tha^{-1} (6kg/plant) in two equal split doses applied at one week pre-planting and four months after planting respectively. At planting, each planting depth was mulched with 4 tha^{-1} of appropriate mulch at 2kg/hole except black polythene where single layer sheet was used. Core soil samples were collected at each planting depth at monthly intervals, from January to March for macro biological life count (Moriera, *et al,* 2008) and percentage soil moisture content determination. Soil temperature which was recorded at 1300 hours daily and averaged for months was monitored from January to March at each depth using soil thermometers. The percentage sucker sprout was determined three months after planting. All empirical data on biological life, soil temperature, percentage soil moisture and plantain were collected and analyzed using Genstat (2005) statiscal software package. Treatment means were separated using least significant difference (LSD) at 5% level of probability according to Obi (2002).

3.0 Results

The pre-planting soil physico-chemical analyses (Table 1) at the different planting depths (60, 80 and 100cm) respectively showed that soil pH in H_20 (5.10, 4.82, 4.40), organic carbon (0.42, 0.21 and 0.05), organic matter (0.72, 0.37, 0.10), total nitrogen (0.30, 0.01 and 0.10) contents were low. This indicates a slightly acidic and infertile soil. Also the base saturation suggests the dominance of 1:1 clays, indicating a hjgh level of acidity. The soil showed poor fertility and as such, it belongs to the textural sandy clay loam class.

The analysis of the mulch materials (Table 2) indicated that the highest nitrogen, magnesium and sulfur contents were recorded in palm frond mulch (1.03%, 2.68 cmol kg^{-1} , ,2.13 cmol $kg^{-1,}$ respectively) while potassium and available phosphorus contents were highest in wood shavings (5.17 $cmolkg^{-1}$ and 10.08 mg kg^{-1} respectively). Palm frond mulch had the highest content of lignin (16.12 %). Wood shavings had the highest content of zinc (5.80 $cmolkg^{-1}$), copper (1.34 $cmolkg^{-1}$) and carbon (51.23 %), while trash had the highest content of iron (2.6 $cmolkg^{-1}$), manganese (2.19 $cmolkg^{-1}$) and water (3.62 %). The highest cellulose content was recorded in wood shavings and saw dust (34.90 %, 34.90 %) respectively and calcium was highest in saw dust (1.83 $cmolkg^{-1}$). The chemical analysis of poultry manure indicated an alkaline pH (8.20), high contents of organic matter (50.53), nitrogen (2.74%), potassium (0.95 cmol kg^{-1}), phosphorus (0.34 $cmolkg^{-1}$), calcium (3.62 $cmolkg^{-1}$), magnesium (1.82 cmol kg^{-1}) while the carbon: nitrogen ratio was 10:1.

The populations of soil macro biological life at one month after planting (Tables 3 and 4) indicated highly significant ($P<0.05$) effect of planting depth and mulch materials ($P<0.05$) on populations of big black ants and termites while millipede population was significantly ($P<0.05$) influenced by mulch materials at one month after planting (MAP). The 100 cm depths mulched with trash recorded the highest number (4.65) of big black ants (*Doryllus nigiricans*) while control plots (manured but unmulched) of 60x60x60 cm recorded the least (0.33). Highest termite (*Macrotemes bellicoccus*) population (22.67) was recorded in 60 cm plots mulched with trash, followed by 60 cm plots mulched with palm frond (20.00). Planting depths of 60cm and 80cm mulched with palm frond recorded the highest (1.0, 1.0) populations of millipedes (*Julius spp*). No termites and millipedes were found in all depths mulched with wood shavings, saw dust and black polythene. Populations of crickets (*Gryllus bimaculata*), snails (*Achatina fulica*) and earthworms (*Eudrilus eygeniea*) were not significantly influenced by planting depth, mulch sources and their interaction.

At two months after planting (Table 5), mulch materials and planting depth significantly ($P<0.05$) favoured large population of big black ants. However, plantains planted at 100 cm depth and mulched with trash recorded the highest number of big black ants (4.33), whereas the control (manured but unmulched) plots of 60cm depth recorded the least number of big black ants(0.32). Planting depth, mulch materials and their interactions showed non significant ($P>0.05$) differences for population of crickets and earth worms. Furthermore, at two months after planting (Table 6), millipede and termite populations showed significant ($P<0.05$) differences with regards to mulch materials only whereas termite population was significantly ($P<0.05$) influenced by mulch materials and planting depth. Thus, plantains planted 80 cm and 100 cm deep and mulched with palm frond recorded the highest population of millipedes (0.67 and 0.67) respectively. All plantains planted deep and mulched with wood shavings, saw dust, black polythene and control plots recorded no millipedes. The highest number of termites was recorded at 60 cm depth mulched with trash (20.00), closely followed by 80 cm depths mulched with trash (18.67). Shallow (60 cm deep) planting and medium (80 cm deep) plantings mulched with palm fronds also recorded high populations of termites (17.57 and 16.66) respectively. At all planting depths mulched with saw dust, wood shavings or black polythene totally inhibited termite habitation. At three months after planting (Table 7), cricket and earthworm populations were significantly ($P<0.05$)

influenced by planting depth, mulch materials and their interactions while big black ant population was significantly (P<0.05) favoured by planting depth and mulch materials. The 100 cm deep plantings mulched with palm frond recorded the highest (3.01) populations of big black ants, followed by 100 cm depth mulched with trash (2.65). Table 8 contains effect of mulch materials on the populations of millipedes, termites and snails at three months after planting. The shallow (60 cm) plantings mulched with trash and palm frond recorded similar (0.67 and 0.67) number of millipedes respectively, while planting depths mulched with saw dust, wood shavings, black polythene and control plots were uninhabited by millipedes. Plantains planted 60 cm deep and mulched with trash recorded the highest (13.70) number of termites. However, no termites were found in planting depths mulched with saw dust and wood shavings. The highest number of snails (1.00) was recorded in shallow 60 cm depths mulched with palm frond whereas no snails were recorded in deeper planting depths (80 and 100 cm) irrespective of the mulch source.

Planting depth and mulch (Table 9) significantly (P<0.05) affected monthly soil temperature level. The lowest soil temperature was recorded in 80 cm plantings mulched with saw dust in January (28.67^{0}C) and February (28.67^{0}C) while the 60 cm control (no mulch) plots recorded the highest soil temperatures from January (33.33^{0}C) to April (32.17^{0}C). The 100cm trenches mulched with black polythene recorded the lowest soil temperature in March (30.50^{0}C) while 80cm trenches mulched with trash recorded lowest soil temperature in April (29.33^{0}C) respectively. The moisture content (%) at the various planting depths and mulches in late season plantain during experimentation (Table 10) showed that the effect of planting depth and mulch materials were significant (P<0.05) within and between months (January to March). The 100cm depths mulched with black polythene recorded the highest moisture content (%) at one (20.12%), two (21.95%) and three (24.41%) MAP respectively while the lowest percentage soil moisture (7.13%, 8.83%) at one and two MAP was recorded at 60cm trenches of the control plots and 80cm trenches of the control plots were most dry at three MAP.

Percentage sprout of plantain suckers was significantly (P<0.05) influenced by mulch materials and planting depths at three MAP (Table 11). The plantains at 80 cm and 100 cm planting depths and mulched with black polythene recorded 100 % sucker sprout followed by those at 80 cm depth mulched with wood shavings (81.87 %).

4.0 Discussion

The soil is acidic and infertile, acidity increased with depth (60, 80 and 100 cm), and associated low organic matter content, carbon, total nitrogen and available phosphorus. Thus, the base saturation suggests the dominance of characteristic 1:1 clays of tropical ultisol of the University farm. The increase in soil pH with depth is indicative of illiniation of basic cations translocated after intensive leaching from the surface horizons (Onweremadu *et al.,* 2007). However, the recorded indices for soil fertility parameters were below the recommended levels for optimal crop productivity in Nigerian tropical soils (FDALR, 1985; Enwezor, *et al,* 1990).

The high populations of big black ants and termites recorded early (1-2MAP) in planting depths mulched with trash and palm fronds may be attributed to the fact that tropical termites preferably feed on timber, leaf, grass, or other crop residues (Wikipedia, 2012) when available. The low C:N ratio of trash and palm frond were preferred and rapidly degraded by termites (Becker, 2003; Wikipedia, 2012) within few weeks after planting. This report is corroborated by Obiefuna (1985) that grass mulch used in late season plantains was rapidly degraded by termites, hence offering poor protection to plantain further into the dry season. Mommer *et al.* (2013) reported that as detrivores, termites clear away leaf and woody litter. This rapid degradation of vegetation used as mulch may have resulted in the gradual reduction in termite and big black ant populations at three MAP. The absence of termites and big black ants in plots

mulched with saw dust and wood shavings may be attributed to the high C:N ratio, cellulose and lignin contents of the woody cells, reducing the ability of termites to efficiently digest the cellulose (Wikipedia, 2012). Termites have also been reported to migrate to the surface in search of food in the dry season (Wikipedia, 2012), hence the higher populations of termites in 60x60x60cm plots mulched with trash and palm fronds at one and two MAP. The significant abundance of millipede population was due to the cooling effect (Tables 9 and 10) sought by these organisms (USAF, 1991) resulting from moisture control and termite galleries.

The non significant response of cricket, snail and earthworm populations at one to two MAP, and crickets at three MAP may be attributed to high temperatures from January to March with little rainfall to provide sufficient moisture (Tables 9 and 10). This is in line with Chikezie *et al.* (2008) who reported that earthworms are most abundant in the rainy season (Kale and Kermegam, 2010). According to some reports, abundance and species diversity of earthworms are dependent on climatic conditions, especially occurrence of dry or cold periods and regional variations in vegetation, soil texture and nutrient content (Kale and Kermegam, 2010). In this regard high surface temperature and dry soils are limiting factors to earthworms than low temperature and water logged soils (Kale and Kermegham, 2010). Wikipedia (2012) reported that crickets are cold blooded scavengers and feed on organic materials, decaying plant materials, fungi and some seedling plants. Low rainfall, soil moisture and high daily and diurnal soil temperatures may have resulted in little or no decay and low microbial activity on the mulch materials at one to three MAP, hence very low cricket populations. Snail population did not respond significantly to mulch sources or trench depth at one to two MAP. This may be attributed to unfavourable soil and environmental conditions. NEARLS (2012) reported that snails are cold blooded animals and are therefore sensitive to changes in atmospheric humidity and thrive best at temperatures between 10 and 23^0C (Nwachukwu, 2013). When temperatures are too cold or too hot, snails withdraw into their shells, seal their shells, depend on stored food reserve in their body and aestivate (Nwachukwu, 2013). Although suitable mulch may have been available (trash, palm frond), unfavourable weather conditions adversely affected snail population in January and February 2011 (one to two MAP). However, as the rains came gradually from March, conditions became more favourable. Generally as the rains set in and stabilized larger population of millipedes, crickets, snails and earthworms were observed in most of the plots. This observation has been reported by many workers (Nwachukwu, 2013: .Wikipedia, 2010) among others.Organic matter is a source of energy for soil biota and thus, influences many of the biologically mediated processes of soil (Wikipedia, 2011; Mullongy and Merckx, 1999; FAO, 2005).Thus, the presence of poultry manure and various organic mulches under more favourable environmental conditions of higher rainfall and lower soil temperatures, provided the energy source needed for the sustenance and activities of crickets, earthworms, snails and millipedes

The significant influence of mulch materials, and the interaction of planting depth and mulch sources on percentage sucker sprouting of plantain at three MAP confirmed that mulching enhances sprouting and growth (Shiyam *et al.*, 2010; Obiefuna *et al.*, 2014). Furthermore, Obiefuna (1986) noted that the use of quality late sword suckers which are vigorous and healthy enhanced late season plantain establishment. The 100% sucker sprout recorded in 80 and 100cm trenches mulched with black polythene may be due to the high moisture conserving property of polythene sheet mulch (Wikipedia, 2013).

5.0 Conclusion

The current study showed that application of $4tha^{-1}$ of trash and palm frond in 60 to 100 cm planting depths significantly influenced populations of big black ants, termites and millipedes in late season plantain at 1 to 3 MAP and earthworms at 3 MAP respectively. Soil temperature and percentage soil moisture were significantly affected by application of different mulches and trench depths. Mulching with

black polythene sheets in 60x60x100 cm trenches conserved the highest percentage soil moisture from January to March, 2011 (1 to 3 MAP) and mulching with same in 80 to100 cm trenches recorded 100 % sucker sprout.

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Table 1: Pre-planting soil physico-chemical characterization of the experimental site in 2010.

	Planting depth (cm)		
Characteristics	60	80	100
pH in H_20	5.10	4.82	4.70
pH in KCl	4.98	4.71	4.52
Exchangeable hydrogen ($cmolkg^{-1}$)	0.30	0.60	0.50
Total nitrogen (%)	0.30	0.01	0.10
Available phosphorus ($mg\ kg^{-1}$)	0.62	0.21	1.15
Aluminium ($cmolkg^{-1}$)	0.40	0.80	0.60
Exchangeable cations ($cmolkg^{-1}$)			
Calcium ($cmolkg^{-1}$)	1.80	1.20	0.80
Magnesium ($cmolkg^{-1}$)	1.00	0.80	0.80
Potassium ($cmolkg^{-1}$)	0.12	0.21	0.17
Sodium ($cmolkg^{-1}$)	0.15	0.16	0.13
Total acidity ($cmolkg^{-1}$)	0.70	1.40	1.10
ECEC ($cmolkg^{-1}$)	3.77	3.77	3.00
Soil organic matter (%)	0.72	0.37	0.10
Soil organic carbon (%)	0.42	0.21	0.05
Base saturation	81.40	62.80	61.33
Percentage silt (%)	2.00	2.00	2.00
Percentage clay (%)	21.20	21.20	21.20
Percentage sand (%)	76.80	76.80	76.80
Textural class	SCL	SCL	SCL

SCL= Silt clay loam

Table 2: Chemical properties of mulch sources and poultry manure for the experiment in 2010

Sample	N %	Ca cmolkg^{-1}	K cmolkg^{-1}	P ppm	Mg cmolkg^{-1}	Lignin %	S colmkg^{-1}	Ash %	Cu colm/kg^{-1}	Fe cmolkg^{-1}	Zn cmolkg^{-1}	Mn cmolkg^{-1}	C %	H_2O %	Cellulose %	OM	C:N Ratio	pH H_2O
Poultry manure	2.74	3.62	0.95	0.39	1.82	0.51	1.14	0.82	0.04	0.39	0.19	0.31	27.15	0.54	0.72	50.53	1:4	8.2
Wood shavings	0.14	1.82	5.17	10.08	1.61	11.19	0.41	5.02	1.34	2.25	5.80	1.71	51.23	1.92	21.12	NA	NA	NA
Palm frond	1.13	0.93	3.06	3.95	2.68	16.12	2.13	2.56	0.04	0.06	0.03	0.08	31.40	2.79	34.90	NA	NA	NA
Trash	0.17	1.31	3.26	0.24	1.65	6.36	1.26	3.76	1.19	2.61	2.53	2.19	11.31	3.62	34.90	NA	NA	NA
Saw dust	0.14	1.83	5.16	10.06	1.59	11.12	0.42	4.90	1.33	2.24	5.71	1.72	51.20	1.892	1.10	NA	NA NA	NA NA
Black Polythene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		

NA= Not applicable (black polythene), NA= Not available (other mulch materials)

Table 3: Effect of planting depth and mulch materials on the population of big black ant (*Doryllusnigiricans*),crickets (*Gryllusbimaculata*) and earth worms (*Eudriluseygeniea*) at 1 month after planting in late season plantain (Jan, 2011).

Soil biological life Earth worms					Big black ants							Crickets
	Planting depth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	2.00	3.67	4.65	3.44	0.68	0.68	0.33	0.56	0.34	0.00	0.00	0.11
Wood shaving	0.68	0.67	1.00	0.78	0.33	0.32	0.33	0.33	0.00	0.00	0.00	0.00
Palm frond	1.67	1.68	3.00	2.11	0.32	0.31	0.33	0.33	0.33	0.00	0.00	0.11
Saw dust	0.68	0.66	1.00	0.78	0.69	0.35	0.00	0.33	0.00	0.00	0.00	0.00
Black polythene	1.00	1.34	1.35	1.22	0.65	0.00	0.00	0.22	0.32	0.00	0.00	0.11
No mulch	0.33	0.67	1.33	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	1.06	1.44	2.06	1.52	0.44	0.28	0.17	0.29	0.17	0.00	0.00	0.06
$LSD_{(0.05)}$ Mulch		0.75				NS				NS		
$LSD_{(0.05)}$Planting depth		0.53				NS				NS		
$LSD_{(0.05)}$Mulch x planting depth		NS				NS				NS		

NS= Not significant ,60 cm = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 4: Effect of planting depth and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemesbellicosus*) and snails (*Achatinafulica*) in late season plantain at 1 month after planting (Jan, 2011).

Soil biological life	Millipedes				Termites				Snails			
	Plantingdepth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	0.34	0.34	0.67	0.44	22.67	19.68	19.00	20.43	0.00	0.33	0.00	0.11
Wood shaving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palm frond	1.00	1.00	0.33	0.78	20.00	17.66	17.32	18.33	0.00	0.00	0.00	0.00
Saw dust	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black polythene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
No Mulch	0.00	0.00	0.00	0.00	1.00	0.67	1.00	0.89	0.00	0.00	0.00	0.00
Mean	0.22	0.22	0.17	0.20	7.28	6.33	6.22	6.61	0.00	0.06	0.00	0.02
$LSD_{(0.05)}$ mulch		0.26			1.13				NS			
$LSD_{(0.05)}$ plantiong dept		NS			1.80				NS			
$LSD_{(0.05)}$ mulch x planting depth		NS			NS				NS			

60 cm = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 5: Effect of planting depth and mulch materials on the population of big black ant (*Doryllusnigiricans*),crickets (*Gryllusbimaculata*) and earth worms (*Eudriluseygeniea*) in late season plantain at 2 months after planting (February, 2011).

Soil biological life	Big black ants				Crickets				Earth worms			
	Planting depth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	2.00	3.00	4.33	3.11	0.68	0.32	0.35	0.45	0.36	0.34	0.00	0.23
Wood shaving	1.00	1.00	1.00	1.00	0.31	0.34	0.33	0.33	0.00	0.00	0.00	0.00
Palm frond	1.68	1.67	3.00	2.11	0.67	0.36	0.33	0.45	0.00	0.00	0.00	0.00
Saw dust	1.00	1.00	1.67	1.22	0.33	0.30	0.00	0.21	0.00	0.00	0.00	0.00
Black polythene	1.00	1.35	1.33	1.23	0.66	0.33	0.00	0.34	0.00	0.00	0.00	0.00
No mulch	0.32	0.65	1.34	0.78	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.10
Mean	1.17	1.44	2.11	1.57	0.44	0.28	0.17	0.30	0.11	0.06	0.00	0.05
$LSD_{(0.05)}$ Mulch				0.97			NS				NS	
$LSD_{(0.05)}$Plantingdepth				0.68			NS				NS	
$LSD_{(0.05)}$ Mulch x planting depth				NS			NS				NS	

NS = non significant; 60cm=60x60x60cm dimension, 80cm= 60x60x80cm dimension, 100cm=60x60x100cm dimension

Table 6: Effect of planting depth and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemesbellicocus*) and snails (*Achatinafulica*) in late season plantain at 2 months after planting (February, 2011).

Soil biological life	Millipedes				Termites				Snails			
	Planting depth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	0.00	0.33	0.00	0.11	20.00	18.67	l815.33	18.00	0.00	0.00	0.00	0.00
Wood shaving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palm frond	0.35	0.67	0.67	0.57	17.57	16.66	13.68	15.97	0.00	0.00	0.00	0.00
Saw dust	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black polythene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No mulch	0.00	0.00	0.00	0.00	0.33	0.67	0.67	0.56	0.00	0.00	0.00	0.00
Mean	0.11	0.17	0.06	0.11	6.33	6.00	4.94	5.76	0.00	0.06	0.00	0.00
LSD $_{(0.05)}$ Mulch		0.26				1.08				NS		
LSD$_{(0.05)}$Planting depth		NS				0.76				NS		
LSD$_{(0.05)}$Mulch x planting depth		NS				NS				NS		

NS = not significant, 60 cm = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension.

Table 7: Effect of planting depth and mulch materials on the population of big black ant (*Doryllusnigiricans*),crickets (*Gryllusbimaculata*) and earth worms (*Eudriluseygeniea*) in late season plantain at 3 months after planting, (March, 2011).

Soil biological life	Big black ants				Crickets				Earth worms			
	Planting depth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	1.69	2.00	2.65	2.11	0.69	0.32	0.30	0.44	0.36	0.00	0.00	0.12
Wood shaving	0.65	0.67	1.35	0.89	0.35	0.33	0.31	0.33	0.00	0.00	0.00	0.00
Palm frond	1.68	1.66	3.01	2.12	0.33	0.35	0.36	0.34	0.36	0.37	0.00	0.24
Saw dust	0.00	0.00	0.00	0.00	0.67	0.36	0.35	0.46	0.00	0.00	0.00	0.00
Black polythene	1.00	1.34	1.32	1.22	0.66	0.30	0.00	0.32	0.00	0.00	0.00	0.00
No mulch	0.32	0.67	1.34	0.78	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.11
Mean	0.89	1.07	1.61	1.19	0.44	0.31	0.22	0.32	0.18	0.06	0.00	0.08
$LSD_{(0.05)}$ Mulch			0.79				Ns			ns		
$LSD_{(0.05)}$Planting depth			0.56				NS			NS		
$LSD_{(0.05)}$ Mulch x planting depth			NS				NS			NS		

NS = not significant, 60 cm = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 8: Effect of planting depth and mulch materials on the population of millipedes (*Julius spp*), termites (*Macrotemesbellicocus*) and snails (*Achatinafulica*) in late season plantain at 3 months after planting, (March, 2011).

Soil biological life	Millipedes				Termites				Snails			
	Planting depth (cm)											
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	0.67	0.65	0.00	0.44	13.70	11.34	10.35	11.79	0.00	0.00	0.00	0.00
Wood shaving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palm frond	0.67	0.35	0.33	0.45	11.30	11.66	9.02	10.66	1.00	0.68	0.00	0.56
Saw dust	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black polythene	0.00	0.00	0.00	0.00	0.64	0.33	0.31	0.43	0.00	0.00	0.00	0.00
No mulch	0.00	0.00	0.00	0.00	1.03	1.00	0.65	0.89	0.00	0.00	0.00	0.00
Mean	0.22	0.16	0.05	0.15	4.45	4.06	3.39	3.96	0.17	0.11	0.00	0.09
$LSD_{(0.05)}$ Mulch			0.29				0.99			0.26		
$LSD_{(0.05)}$ Planting depth			NS				0.70			NS		
$LSD_{(0.05)}$ Mulch x planting depth			NS				NS			NS		

NS = not significant, 60 cm = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 9: Soil temperature under late season plantain as affected by planting depth and mulch materials at 1-4 MAP, Jan-April, 2011.

Month after planting	January				February				March	April						
Plantingdepth (cm)																
Mulch sources	60	80	100	Mean	60	30	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	30.67	30.17	30.17	30.33	30.33	29.83	29.83	30.00	31.17	30.83	32.00	31.33	30.17	29.33	30.00	29.83
Wood shaving	31.50	31.33	30.33	31.00	31.17	30.67	30.17	30.67	31.67	30.83	31.17	31.22	31.00	30.00	30.33	30.44
Palm frond	31.33	29.50	29.67	30.17	30.17	29.50	29.50	30.06	31.83	32.17	30.83	31.61	31.50	31.00	30.17	30.89
Saw dust	30.00	28.67	30.83	29.83	30.00	28.67	30.33	29.67	32.00	31.00	32.33	31.78	31.00	30.67	30.67	30.78
Black polythene	31.00	30.50	30.00	30.50	30.50	29.50	29.50	29.83	31.00	31.00	30.50	30.83	30.00	30.00	30.00	30.00
No mulch	33.33	29.50	30.50	31.11	31.33	29.50	30.17	30.37	34.00	32.67	30.67	32.44	32.17	31.50	31.00	31.56
Mean	31.31	29.94	30.25	30.50	30.75	29.11	29.92	30.09	31.94	31.42	31.25	31.54	30.97	30.42	30.36	30.58
$LSD_{(0.05)}$ Mulch			0.95				ns			0.99				0.76		
$LSD_{(0.05)}$ Planting depth			0.67				0.75			NS				0.54		
$LSD_{(0.05)}$Mulch x planting depth			NS				NS			NS				NS		

NS.= Not significant, 60 = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 10: Effect of planting depth and mulch materials on the mean moisture content at 0-15 cm of the various planting depths in late season plantain at first 3 months after planting, January - March, 2011.

Month after planting	January				February				March			
Planting depth (cm)												
Mulch sources	60	80	100	Mean	60	80	100	Mean	60	80	100	Mean
Trash	9.00	9.56	8.03	8.86	11.08	12.39	9.84	11.10	14.49	17.25	16.53	16.24
Wood shaving	7.92	11.29	9.53	9.58	9.84	11.47	13.65	11.65	15.42	20.40	18.60	18.14
Palm frond	9.00	11.00	9.40	9.80	11.14	13.25	11.52	11.97	17.21	19.10	20.48	18.93
Saw dust	10.08	10.41	9.37	9.95	11.98	12.39	11.19	11.85	15.18	17.70	21.16	18.01
Black polythene	9.21	11.83	20.12	12.68	12.36	14.08	21.95	16.13	15.11	22.32	24.41	20.61
No mulch	7.13	8.72	7.78	7.87	8.83	9.80	9.89	9.50	20.48	14.28	17.96	17.51
Mean	8.72	10.18	11.00	9.97	10.87	12.23	13.01	12.04	16.39	18.51	19.86	18.25
LSD $_{(0.05)}$ Mulch		1.37	1.72			ns						
LSD $_{(0.05)}$Planting depth		0.97				1.22				2.16		
LSD $_{(0.05)}$ mulch x planting depth		NS			NS		5.2					

NS = not significant, 60 = 60x60x60 cm dimension, 80 cm = 60x60x80 cm dimension, 100 cm = 60x60x100 cm dimension

Table 11: Effect of planting depth (cm) and mulch sources on the percentage sucker spout of late season plantain at 3 months after planting

Mulch sources	Planting depth (cm) 60	80	100	Mean
Trash	48.11	70.50	50.30	56.53
Wood shaving	70.50	81.87	70.67	74.34
Palm frond	49.44	50.32	80.62	70.53
Saw dust	81.60	70.60	59.40	55.56
Black polythene	50.33	100.00	100.00	83.44
No mulch	46.30	49.31	38.43	44.68
Mean	63.21	70.43	66.57	64.14
$LSD_{(0.05)}$ Mulch	19.15			
$LSD_{(0.05)}$ Planting depth	NS	$LSD_{(0.05)}$ Mulch x planting depth	3856	