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Functional Trend in Leaf and Sucker Production of Plantain in Response to Paring and Organic Mulch

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Abstract:
The study investigated the functional trend in the response of leaf and sucker production in plantain to paring and two organic mulch materials: oil palm bunch refuse and sawdust in South Western Nigeria. A multifactorial experiment was laid out in a randomized complete block design. Mulched treatments received either oilpalm bunch refuse or sawdust mulches at 6 and 11 months after planting of either pared or non-pared suckers in the field. Time course responses for area of youngest leaf opened, number of leaves and suckers produced were fitted with regression models using exponential, linear and polynomial (up to the fifth level, Quintic) functions. Paring stimulated exponential production of leaves and leaf area expansion from 8 to 15 months after planting while the type of organic mulch employed further influenced the functional response. Sucker production had a best fit into the quadratic function in all the treatments implying that sucker production would follow a similar trend over time irrespective of treatment. This study established for the first time in Nigeria that soil management practices would modulate time course response of plantain to paring of sucker planting materials.

***Keywords**: growth response, leaves, plantain, trend analysis, sucker*

1. Introduction

Several factors have been identified as limiting factors in plantain production but in Nigeria, plant parasitic nematodes are the key constraints (Speijer *et al.*, 2001). Nematodes cause damage to the root system resulting in root and rhizome debility, weakening anchorage, and impairing water and mineral extraction from the soil. This predisposes plantain to toppling over, wilting and nutrient deficiency to mention a few (Blake, 1969; Robinson, 1996; Olaniyi, 2011). Other biotic agents like the banana weevil (*Cosmopolites sordidus*) also cause damage to the rhizome of plantain and when banana weevils are present, damage caused by plant parasitic nematodes is aggravated (Speijer and Gold, 1995).

The migratory endoparasites (*Radopholus similis*, *Pratylenchus coffeae*) cause similar root and corm damage (Speijer & De Waele, 1997). The migratory feeding behaviour of these nematodes in the root and corm tissues causes the formation of lesions, which may enlarge and coalesce, resulting in large necrotic areas. On roots, initial damage can be seen as small dark purplish-red lesions on the outer part of the roots. These lesions may enlarge into purplish-black necrotic areas that usually extend throughout the cortex but not into the stele. Primary, secondary and tertiary roots can be affected.

In addition to the damages directly caused by nematodes, nematode-induced root lesions and necrosis, create a food base for weak, unspecialized fungal parasites of banana and plantain (*Fusarium* spp., *Cylindroclaium* spp. and *Rhizoctonia* spp.), which enables these fungi to invade the stele and to extend the necrosis to this part of the root (Gowen and Quénéhervé, 1990). As a result, the affected section of the root dies, because *Helicotylenchus multicintus* often feeds on the cortical cells close to the epidermis, root lesions caused by this nematode are often shallow and superficial, reddish brown to black in colour. On rhizomes, blackish-purple lesions can be seen around the root bases and/or other part of the rhizome. Lesions around the root bases may enlarge and destroy the root bases killing the entire root. Lesions on the corm can be several centimeters deep.

The sedentary endoparasites (*Meloidogyne* spp.) cause galling of the primary and secondary roots. These symptoms can be seen as irregular swellings, often on the root tips. In thick, fleshy primary roots, swelling may not be obvious, however, length-wise slicing of the roots may reveal white and dark brown pit-like structures inside the root cortex that contain the swollen females (Speijer and Gold, 1995). Roots infected with *Meloidogyne* spp. often show stunted growth (Coosemans *et al.*, 1994). However, plantain sucker with healthy root (that is roots free from galls and lesions) establishes better in that they are able to transport nutrients and water to the main stem smoothly without any impairment. These allow them to have better vegetative growth and maximum fruit production.

These biotic agents are often transported into new fields through infested planting materials taken from infested fields. In Nigeria, more than 90% of farmers use planting materials directly without any further treatment (Speijer *et* al., 2001). It is also likely that suckers are taken from failed plantain mats, which have not been able to produce bunches as a result of toppling over caused my nematode infections. So rather than loose the mat completely, farmers would remove suckers from such stand to establish new field, thereby transferring the problem into the new environment.

The most effective means of controlling a biotic problem is to prevent its introduction into otherwise clean fields through the use of clean planting materials. Since the planting material most commonly available is the sucker removed from existing fields, which are more often than not, infected, physical disinfestations of these sucker planting materials is recommended. This can be done by removing infected and infested dead tissues of the roots and rhizome planting. According to Blake (1969), the external tissue of the rhizome, with purple or reddish-brown lesions, which are symptoms of nematode infection, together with root stumps and adhering soil should be removed with a machete until only white corm tissue is exposed. This process is referred to as paring. Similarly, deep lesions and tunnels caused by the weevil larvae (Speijer *et al.*, 1993) should be removed.

When paring was presented to farmers, they were sceptical in adopting the method because they could not trust that the productivity of the plants would not be compromised (Olaniyi, 2006). Also because information is limited on the establishment of the suckers after paring, it became necessary to investigate the effect of paring on the growth of plantain. Mulching is an age long practice which is known to improve plant growth and enhance plantation longevity (Akobundu, 1987; Salau *et al.*, 1992). Organic mulch has been reported to stimulate the development of natural enemies of plant pests and pathogens (Dwivedi and Pandey, 1992; Patrick and Toussoun, 1970), thereby making the mulched environment antagonistic to pest and pathogenic organisms. Combined effect of paring and mulch is expected to be complementary in protecting plantain from plant parasitic nematodes, banana weevils and other soil borne pathogens. Information is limited on the effect of these interventions on plantain growth. Therefore, this study investigated functional interaction of leaf production and growth, and sucker production of plantain cultivar Agbagba with time, as influenced by paring, oilpalm bunch refuse and sawdust mulches in South western Nigeria.

2. Materials and Methods

2.1. Experimental site

On an established plantain trial at the Teaching and Research Farm of the Federal University of Technology, Akure. Akure lies between latitude 5oN of the equator and is within the tropical rain forest belt, with an average annual rainfall of about 1613mm per annum and an annual mean temperature of about 27^{o}C. Data were collected from 8 months after planting to 15 months after planting. At flowering of mother plant, soil chemical analysis under the different mulch categories was done using composite samples collected from 20 x 20 x 20 cm excavations at the base of flowered plants.

2.2. Experimental Design

Details on experimental setup are provided elsewhere (Olaniyi, 2006; 2007). However, the experiment was a multifactorial with six treatment combinations arranged in a randomized complete block design (RCBD) in three replicates. Factors investigated were two (2) levels of paring (i.e. pared and not pared) and three (3) levels of mulching (oil palm bunch refuse, sawdust and no mulch). This gave a total of six treatment combinations. Each treatment was assigned to a plot making a total of six plots (representing the treatments) per block. Plants were arranged within plots at 2 m x 3 m spacing between and within rows respectively. Each plot was separated from the next by a 3 m alley while blocks were separated by 4 m alleys. Each plot had six plants.

2.3. Treatments and Trial Maintenance

Before the observation reported in this study began, mulch had been applied at the base of each plant six months after field establishment to plants that received the mulch treatments (Olaniyi, 2006). Five months after, mulches were renewed at the rate of 4.1cm^3 per plant, representing 9.7kg for the oil palm bunch refuse and 3.75kg for the sawdust. Earlier, chemical analysis of the mulch materials showed that oil palm bunch refuse had 7.71% N, 928.3 ppm P and 0.43 Cmol/kg K; while sawdust had 2.63% N, 361.9 ppm P and 0.13 Cmol/kg K (Olaniyi, 2008).

2.4. Data Collection and Analysis

- **Leaf and Sucker Production:** At each sampling date every month, number of functional leaves on the mother plant and number of suckers on the mat were counted. A leaf was considered to be functional if at least 75% of the surface area was green. The number of suckers (SUC) was also counted. The length of the youngest leaf opened was measured as the distance from the base to the apex of the youngest leaf opened and the width was measured at the widest portion of the leaf lamina. The leaf area of the youngest leaf opened (YLA) was calculated as length x width of the youngest leaf opened x 0.83 (Obiefuna and Ndubizu, 1983).
- **Data Analysis:** Trend analysis was carried out for each parameter, regression equations were fitted and regression coefficients were estimated.

3. Results

3.1. Trend Analysis of leaf production

The trend of leaf production over time was dependent largely on the mulch type. Paring encouraged exponential leaf production on the mother plant over the period of study, as the R^2 value was strongest for the exponential function in the pared plants that were not mulched (PMN) (Table 1). Application of oil palm bunch refuse made plantain to respond differently in the pattern of leaf production as the increase over time departed from the exponential trend, assuming a quadratic trend. However, paring made the sawdust mulched plants to produce leaves at a faster (exponential) rate.

Treatment	Function	Regression Equation	R^2
PMN	Exponential	$Y = 7.4934e^{0.1006x}$	0.9641
	Linear	Y = 1.2086x + 6.6737	0.95
	Quadratic	$Y = 0.0589x^2 + 0.6783x +7.5576$	0.9591
NPMN	Exponential	$Y = 7.0348e^{0.0994x}$	0.9096
	Linear	Y = 1.1025x + 6.3581	0.8972
	Quadratic	$Y = - 0.0026x^2 + 1.1263x + 6.3185$	0.8972
PMS	Exponential	$Y = 7.\ 363e^{0.1187x}$	0.9398
	Linear	Y = 1.5464x + 6.1116	0.9198
	Quadratic	$Y = 0.1122x^2 + 0.5363x + 7.795$	0.9392
NPMS	Exponential	$Y = 8.2344e^{0.0672x}$	0. 8331
	Linear	Y = 1.1081X + 7.5499	0.8254
	Quadratic	$Y = 0.0747x^2 + 0.4363x + 8.6696$	0.8404
PMO	Exponential	$Y = 8.7866e^{0.0672x}$	0.9552
	Linear	Y = 1.7378x + 7.4205	0.9415
	Quadratic	$Y = 0.1314x^2 + 0.5548x + 9.3923$	0.9631
NPMO	Exponential	$y = 8.2344e^{0.1026x}$	0. 9294
	Linear	y = 1.4973x + 7.067	0.9274
	Quadratic	$y = 0.081x^2 + 0.7685x + 8.2816$	0.9383

Table 1: The effect of paring and organic mulch types in the functional trend in leaf production on plantain in Southwestern Nigeria
y = number of leaves; x = time (months after planting)

PMN: pared and not mulched; NPMN: not pared and not mulched; PMS: pared and mulched with sawdust; NPMS: not pared and mulched with sawdust; PMO: pared and mulched with oil palm bunch refuse; NPMO: not pared and mulched with oil palm bunch refuse.

3.2. Trend Analysis of leaf area production

Exponential growth rate best fitted the leaf area production all treatments except the oil palm bunch refuse mulched plants (Table 2). Pared plants that were mulched with oil palm bunch refuse had a negative coefficient; hence leaf area expansion had a negative correlation with time.

Treatment	Function	Equation	R^2
PMN	Exponential	$Y = 769.91E^{0.2781x}$	0.8949
	Linear	Y = 732.08x – 17.405	0.8789
	Quadratic	$Y = -47.057x^2 + 1155.6x – 723.26$	0.8935
NPMN	Exponential	$Y = 683E^{0.2855x}$	0.854
	Linear	Y = 593.65x +3 6.631	0.8246
	Quadratic	$Y = - 33.844X^2 + 898.25X – 471.04$	0.8353
PMS	Exponential	$Y = 1032.7E^{0.2525x}$	0. 8907
	Linear	Y = 851.63X + 9.4735	0. 808
	Quadratic	$Y = -12.256X^2 + 961.93X - 174.36$	0.8087
NPMS	Exponential	$Y = 829.91E^{0.8201x}$	0.9027
	Linear	Y = 810.15x - 72.293	0.8874
	Quadratic	$Y = -44.261x^2 + 1208.5x – 736.21$	0.898
PMO	Exponential	$Y = 1988.8e^{0.2124x}$	0.8717
	Linear	Y = 1046.3X + 1126.6	0.8635
	Quadratic	$Y = -97.617x^2 + 1924.8x -337.66$	0.8936
NPMO	Exponential	$Y = 1526.8e^{0.2502x}$	0. 8399
	Linear	Y = 1029.3x + 390.4	0.8679
	Quadratic	$Y = 16.548x^2 + 880.39x +63 8.61$	0.8688

Table 2: The effect of paring and organic mulch types in the functional trend in the area of the youngest leaf opened on plantain in Southwestern Nigeria
y = number of leaves; x = time (months after planting)

PMN: pared and not mulched; NPMN: not pared and not mulched; PMS: pared and mulched with sawdust; NPMS: not pared and mulched with sawdust; PMO: pared and mulched with oil palm bunch refuse; NPMO: not pared and mulched with oil palm bunch refuse.

Exponential function could not be fitted to any of the treatments in the pattern of sucker production (Table 3). Rather, linear and quadratic functions. However, the quadratic function better explained probabilities for all the treatments. Pared plants that received oil palm bunch refuse also had a negative trend.

Treatment	Function	Regression Equation	R^2
PMN	Linear	$Y = 0.6485x – 1.2964$	0.8925
	Quadratic	$Y = 0.0439x^2 + 02534x +0.6379$	0.9089
	Cubic	$Y = -0.0468x^3 + 0.6754x^2+ 1.6777$	0.9746
	Quartic	$Y = -0.0084x^4 + 0.1049x^3 - 0.2408x^2- 0.0536x +0.2473$	0.981
	Quintic	$Y = 0.0073x^5 - 0.1729x^4 + 1.469x^3 - 5.3379x^2+ 8.2421x – 4.2313$	0.9931
NPMN	Linear	$Y = 0.3618x – 0.8849$	0.6877
	Quadratic	$Y = 0.0731x^2 – 0.296x + 0.2113$	0.7999
	Cubic	$Y = -0.0153x^3 + 0.2795x^2 - 1.0835x + 0.9683$	0.8173
	Quartic	$Y = -0.0186x^4 + 0.319x^3 - 1.7394x^2+ 3.5487x – 2.1835$	0.8954
	Quintic	$Y = -0.01x^5 + 0.2054x^4– 1.539x^3 + 5.2033x^2+ 7.7507x + 3.9167$	0.9507
PMS	Linear	$Y = 0.9226x – 1.7664$	0.8832
	Quadratic	$Y = 0.0637x^2 + 0.349x – 0.8103$	0.9001
	Cubic	$Y = -0.0658x^3 + 0. 9515x^2 - 3.0378x + 2.4449$	0.9636
	Quartic	$Y = -0.0222x^4 + 0.3334x^3 - 1.4592x^2+ 2.4933x – 1.3185$	0.9856
	Quintic	$Y = 0.0065x^5 + 0.1688x^4 – 6.0049x^3 + 6.0049x^2+ 9.8914x - 5.3125$	0.9902
NPMS	Linear	$Y = 0.8926x – 1.6183$	0.8105
	Quadratic	$Y = 0.0264x^2 + 0.6549x – 1.2221$	0.8134
	Cubic	$Y = -0.0871x^3 + 1. 2018x^2 - 3.8291x + 3.0878$	0.9224
	Quartic	$Y = -0.0267x^4 + 0.3941x^3 - 1.7043x^2+ 2.8386x – 1.449$	0.9538
	Quintic	$Y = 0.0101x^5 - 0.254x^4 + 2.28x^3 - 8.7511x^2 + 14.307x - 7.6406$	0.9648
PMO	Linear	$Y = 1.4954x – 1.8798$	0.9253
	Quadratic	$Y = -0.0711x^2 + 2.1353x – 2.9464$	0.9337
	Cubic	$Y = -0.1006x^3 + 1.287x^2 - 3.0455x + 2.0333$	0.9929
	Quartic	$Y = -0.00063x^4 + 0.0135x^3 + 0. 5977x^2- 1.464x + 0.9572$	0.9936
	Quintic	$Y = 0.0071x^5 - 0.1651x^4 + 1.3305x^3 – 4.3234x^2+ 6.5451x -3.3667$	0.9958
NPMO	Linear	$Y = 1.5461x – 2.8899$	0.8565
	Quadratic	$Y = 0.0521x^2 + 1.0774x – 2. 1086$	0.8604
	Cubic	$Y = -0.1416x^3 + 1. 1964x^2 - 6.2163x + 4.9018$	0.9621
	Quartic	$Y = -0.0342x^4 + 0. 7494x^3 - 1.7593x^2+ 2.3263x – 0.9107$	0.9802
	Quintic	$Y = 0.0154x^5 - 0.3798x^4 + 3.3417x^3 -12.471x^2+ 19.76x - 10.323$	0.9892

Table 3: The effect of paring and organic mulch types in the functional trend in sucker production on plantain mat in Southwestern Nigeria
y = number of leaves; x = time (months after planting), PMN: pared and not mulched; NPMN: not pared and not mulched; PMS: pared and mulched with sawdust; NPMS: not pared and mulched with sawdust; PMO: pared and mulched with oil palm bunch refuse; NPMO: not pared and mulched with oil palm bunch refuse.

3.3. Effect of paring and mulch types on chemical properties of the soil at flowering of mother plants

The mulch materials did have obvious effects on the chemical properties of the rhizosphere of the mats at flowering of the mother plants. The mulched rhizosphere had higher nitrogen, potassium, phosphorus, and magnesium contents. They also had higher organic matter content. The pH increased to a slightly acidic level; 6.52 and 6.38 for oilpalm mulched (MO) and sawdust mulched (MS) treatments respectively when compared to 6.04 for the non-mulched (MN). The phosphorus level for MO was particularly high compared to the level in MS and MN. The same trend was observed for phosphorus and potassium levels. However, the reverse was the case in calcium content level with the MN having the highest level (Table 4).

Mulch Treatment	N (%)	OM (%)	K (ppm)	P (cmol/kg)	Mg (cmol/kg)	Ca (cmol/kg)	pH
MO	1.22	10.23	6.82	9.93	2.2	4.13	6.52
MS	1.08	9.89	2.43	4.12	1.02	3.95	6.38
MN	0.66	8.7	1.37	1.68	0.8	5.11	6.04

Table 4: Chemical properties of the soil at flowering of mother plants
N: Nitrogen; OM: organic matter; K: potassium; P: Phosphorous; Mg: Magnesium; Ca: Calcium; MO: Oil palm bunch refuse; MS: sawdust; MN: Not mulched.

4. Discussion

Paring did not give any deleterious effect on plant growth. Exponential growth surpasses both linear and polynomial growth, it is indicative that paring supported rapid leaf production over time. However, it is not clear if the leaves were sustained longer or new leaves are produced faster or both were the case with paring. Knowledge of this may be useful to explain benefits that may accrue to paring at harvest time. The effect of paring on plantain leaf production was determined by the type of organic mulch as leaf production in the oil palm bunch refuse mulched treatment irrespective of paring followed a quadratic function. With sawdust mulch, leaf production did not follow an exponential pattern when not pared. Hence, response of plantain to paring and the level of benefit derived would be determined by the type of additional (organic) input provided. It seemed like the oil palm bunch refuse mulch treatment would have gone through the normal phases of the growth curve while the exponential response could mean that a limiting factor triggered quick expansion which would be detrimental at later growth stage, like the flowering stage. Earlier, Rotimi *et al.* (1999) reported that oilpalm bunch refuse mulch enhanced plantain's vegetative growth in South eastern Nigeria and related its effectiveness to the high level of potassium (K). The chemical analysis of the two mulch materials used in this study revealed that oilpalm bunch refuse contained more than three times the quantities of K and nitrogen (N) while at flowering of the mother plant, more than four times the level of potassium in the non-mulched treatments was obtained in the oilpalm mulched treatments.

Oil palm bunch refuse treatment probably supported a faster expansion of the leaves and had advanced to the reproductive phase faster. At the reproductive phase, expansion rate of foliage has declined because the plant is entering into the stationary phase before senescence. It is at this stage that the fruits fill. Considering the other treatments, it could be that the foliage was still expanding at the expense of fruit production, hence time to flowering would be delayed and time for fruit filling may also be prolonged. Therefore, the effect of this growth trend needs to be observed till harvest. Unpublished data revealed that pared plants that were mulched with oil palm bunch refuse flowered earlier than other treatments. This could explain the negative association observed here, while plants in the other four treatments were still in the expansion phase as it seem**.**

The negative trend for the pared oil palm mulched plants is a sign of regulated suckering, which may portend positive impact on yield. Results show that suckering did not proceed at a constant linear rate and the response gradually declined (turned negative) over time. The polynomial relationship is more strongly explained by the 4^{th} (Quartic) and 5^{th} (Quintic) order polynomial functions.

This study has shown that soil management practices modulate time course response of plantain to physical disinfestations by paring and this is the first report in Nigeria of this function. In a previous study, Olaniyi (2011) also reported the first concise observation of the contribution of soil mulching to varied time course plant growth and yield responses of plantain to nematode damage in South Eastern Nigeria.

The fact that the best fitted functions were not linear brings a note of caution that in trend analysis of such factors, care should be taken in the choice of statistical analysis as plant growth is not completely linear with time (Olaniyi, 2011). Trend analysis confirmed that growth indices investigated in this study were favoured by the application of oil palm bunch refuse and that paring has no negative impact on plantain growth. The fact that pared plants that received oil palm bunch refuse had better functions than the unpared counterparts that equally received oil palm bunch refuse revealed that given improved cultural practice, paring would greatly improve plantain performance and without additional input, paring would still help them plants perform well.

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