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Soil Management and Fertilizer Use Practices in Smallholder Plantain Production Systems

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Authors' contributions

This work was carried out in collaboration between both authors. Authors OJA and AAO designed the study and wrote the protocol. Author AAO wrote the first draft of the manuscript and author OJA edited the manuscript. Authors OJA and AAO managed the literature searches while author AAO performed data analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The depletion of soil nutrients and organic matter as accentuated by the non-adoption of appropriate soil management practices is one cause of the yield decline that compels farmers to abandon plantain orchards after two to three production cycles. Information on soil management and fertilizer use practices in plantain production systems was collected through questionnaire from 316 farmers, selected at five each from two major plantain-growing towns in the local government areas of Ekiti and Ondo States. The respondents were mainly males, 40-60 years old, married and fairly literate smallholders who intercropped False Horn and True Horn plantain cultivars with arable and tree crops. Few farmers (0.64%) identified poor soil fertility as a cause of orchard decline but 33.2% shifted from farms cultivated for five years and allowed the attendant fallows. Mulching was practiced by 45.9% of respondents and involved the use of sawdust while 35.8 and 47.2% applied fertilizer and manure to plantain respectively. Urea and NPK were the main products applied once or twice annually. Non-availability, high prices of the products and lack of nearby sales outlets affected fertilizer use. There is the need to strengthen the agricultural extension services in order to increase adoption of improved soil management practices, drive the demand for and influence access to fertilizers whose use would expand plantain output.

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1. INTRODUCTION

Nigeria's annual plantain output, estimated at 2.4 million metric tonnes (MT), comes from the southern states where it features regularly in the multi-storey homestead gardens and intercropping mixtures with food and tree cash crops on distant farms [1,2]. These traditional production systems and the few commercial-scale farms, being promoted in response to plantain's identified roles in the subsistence economy, employment generation and poverty alleviation, give low yields (5.5-12.0 $MT.ha^{-1}$) compared to 30-40 $MT.ha^{-1}$ cumulative yields obtainable under sole cropping in research farms [3].

Plantain production systems must attain these high yield levels. The requirement will be increased adoption of the improved husbandry packages recommended for the sole planted (parent) crop [4,5,3] and which should satisfy the management needs of subsequent ratoons. Unfortunately, fruits yields decline progressively necessitating abandonment of the orchards for new sites after two to three ratoon production cycles [2] implying that the package of recommendations was not intended to support perennial productivity.

The traditional production systems that are not targeted by these recommendations continue to produce plantain bunches and appear to attain perennial productivity, for some reasons. The household and kitchen wastes (including ashes) and domestic animals' droppings (manures) regularly disposed in the homestead gardens build up soil organic matter and supply large amounts of nutrients, especially nitrogen (N) and potassium (K), required for vigorous growth of plantain. Also, foliar diseases are low because the kitchen smokes act as fumigants against fungi pathogens while [6] observed that the activities of diverse microbial populations attracted to organic materials added to the mats reduce the population of plant parasitic nematodes. Plantain derives nutrients from the fertile soils in which tree cash crops, especially cacao (*Theobroma cacao*), are grown in Nigeria and benefits from the associated soil management practices [7]. The ensuing mixtures mimic the natural multi-storey forest in which the somewhat closed nutrient cycle between vegetation (litter) and topsoils maintains soil nutrients and ensures organic matter build-up and maintenance. The nutrients derived from fertilizers and other soil management practices applied to produce the component arable crops in the mixtures on the outlying fields also benefit plantain.

The foregoing implies that additional nutrients, especially N and K often deficient and most rapidly depleted in orchard soils [8], must be emphasized in order to sustain high productivity in plantain. The nutrients recommended for the planted crop are 200-300 kg N, 100 kg P_2O_5 and 350-550 kg $K_2O.ha^{-1}$ [5] which can be obtained from 1,000 kg NPK 20-10-10 and 420 kg muriate of potash (MOP).ha^{-1}. Unfortunately, fertilizer prices have continued to rise in response to persistent widespread scarcity of the products, as unintended consequences of the deregulating fertilizer market [9] which make adoption of this recommendation for plantain expensive and beyond the reach of resources-poor farmers. Besides, conscious addition of organic materials for soil and nutrient management in the orchards was not emphasized in the recommended husbandry packages even as soil organic matter decomposition would proceed rapidly under the humid conditions and associated shading of the orchard floor by plantain leaves.

Nutrient depletion is the major threat to the sustainability of crop production systems and a factor in the loss of perennial productivity of plantain orchards. [10] noted that poor yields on smallholder farms are often attributed to problems of poor soil fertility. The extent to which this threat has been a concern in plantain production systems in Ekiti and Ondo States has not been documented. Also, nutrient management practices being used to enhance the prospects of plantain perennial productivity should be recognized and focus given to the various aspects that require promotion for adoption by farmers. This study involved a survey of the plantain production systems in Ekiti and Ondo States to: (1) examine the phenomenon of orchard yield decline and abandonment from the farmers' perceptive (2) identify the soil management practices being adopted to reduce the problems that culminate in plantain orchard abandonment and (3) indicate the constraints to adoption of the soil management practices.

2. MATERIALS AND METHODS

The survey was carried out in the eastern portion of south-western Nigeria geo-political zone

comprising Ekiti and Ondo States located between longitudes 4º23'-6º02'E and latitudes 5º50'-8º05' N in June-August, 2010. The study area has a land mass of 21,254 km^2 and lies south of Kwara and Kogi States, east of Osun and Ogun States, west of Edo State and bordered in the south by the Bight of Benin (Atlantic Ocean). The population of 5.82 million according to the 2006 census [11] is distributed unevenly in 16 and 18 Local Government Areas (LGAs) of Ekiti and Ondo State respectively. The area experiences tropical climate with distinct rainy and dry seasons in March/April-October/November and November-March respectively. Mean annual rainfall decreases from 2,250 mm on the coast to 1,250 mm in the northern extreme while temperature range is 21-28^oC. The humid and sub-humid conditions impose natural vegetation types that consist of freshwater swamp forests near the coast, lowland rainforests in the central area and derived savannah/guinea savannah in the north and north-east portions.

Purposive sampling was used to obtain the samples for the study. The first stage involved selection of two main plantain producing towns in each LGA based on available crop production data and snowball sampling was used to randomly select five (5) plantain farmers in each town. Questionnaire was administered on the 340 respondents and additional information obtained through personal interviews. Information obtained from 316 respondents was subjected to descriptive statistical analysis of frequency counts and percentages.

3. RESULTS

Information on household characteristics of the 316 respondents is presented in Table 1. Majority of the farmers were males, belonged to the 46-50 year old bracket and had moderate literacy as 76.6% had at least formal education at the primary level. The marital status showed that 93.4% were married and mainly with 1-2 wives while 91.9% had up to 10 children.

Table 2 shows the features of the plantain production systems. Plantain was produced mainly in smallholdings (74.8% of respondents cultivated below 2.4 ha farms) that were mainly more than 15 years old (35.8%) and less than five (5) years (32.6%). Sole plantain was grown in 26.3% of the farms whereas intercropping was the main practice involving arable crops alone (18.9%), tree crops alone (33.5%) and mixture of tree and arable crops (47.6%). The commonest component arable crops were cassava (53.3%), maize (46.1%) and yam (41.5%) while the tree crops were cacao (76.1%), citrus (43.1%), kola (32.5%) and oil palm (29.3%). The number of pseudostems maintained/mat was three (3) (33.9%) and four (4) (38.6%).

Table 1. Information on the social features of plantain farmers in Ekiti and Ondo States

Characteristics		Frequency	Percentage (%)
Age (years)	<30	13	4.1
	30-45	80	25.3
	46-60	170	53.8
	61-75	45	14.2
	>75	8	2.5
Sex	Male	277	87.7
	Female	39	12.3
Marital status:	Single	7	2.2
	Married	309	97.8
Number of wives	1-2	296	93.7
	3-4	18	5.7
	>4	2	0.6
Number of children	1-5	162	51.3
	6-10	129	40.8
	>10	25	7.9
Education	Non-formal	74	23.4
	Primary	93	29.4
	Secondary	101	32.0
	Tertiary	48	15.2

Table 3 shows the respondents' recognition of production-related problems on plantain farms. Snapping of pseudostems was a feature of orchard yield decline which involved 2 and 3 and above.mat^{-1} in 36.7 and 32.6 % of the farms respectively. Poor soil fertility got a very low rating (0.6%) whereas 53.5, 21.5 and 16.8% gave consideration to wind, drought and weight of bunches respectively. Toppling was a problem involving 1-5 and 6-10 pseudostems in 78.2 and 91.5% the farms respectively with the causes being strong winds (52.9%), root damage by pests (26.9%) and shallow soils (13.9%).

Table 4 shows the soil management practices adopted in plantain production systems. Application of manure and mulching was practiced on 35.8 and 45.9% of the farms respectively. The mulching materials were sawdust (70.6%), other materials (mixture of weeded broad leaf and grass species) (19.0%) and oil palm bunch refuse (10.4%). Earthening up was practiced by 70.6% of the farmers at the frequency of 1-2 times (79.4%), 3-4 times (19.3%) and 5-6 times (1.3%) annually. High mat and/or toppling of pseudostems were the main reasons given for earthening up by 86.2% of the respondents while 32.6% of plantain farms attained five years and were shifted to allow for fallow.

The features of fertilizer use practices are shown in Table 5. Fertilizer was used regularly in 47.2% of the farms and involved urea (73.7%) and compound NPK (22.8%) while muriate of potash (MOP) was least (3.6%). Fertilizer quantities were mainly 1-2 bags (67.1%) and 3-4 bags (18.8%) applied once (83.2%) and twice (13.4%). The fertilizer application methods adopted were ringing and covering with soil (38.9%), band/hole placement (26.2%), ringing without covering with soil (22.2%) and side dressing (11.4%) while

Table 2. Characteristics of plantain production systems in Ekiti and Ondo States

Characteristics		Frequency	Percentage (%)
Farm age (years)	<5	103	32.6
	6-10	67	21.2
	11-15	33	10.4
	>15	113	35.8
Farm size (Ha)	<2.4	252	79.8
	2.5-6.0	52	16.5
	6.1-10.0	9	2.9
	>10	3	0.8
Cropping systems:	Sole cropping	83	26.3
	Intercropping	233	73.7
Plantain cultivar:	False horn	206	65.2
	False horn + Horn	48	15.2
	False horn + French	10	3.2
	False horn + Banana	37	11.7
	French + Banana	5	1.6
	All	10	3.2
Pseudostems/mat:	2	87	27.5
	3	107	33.9
	4 and above	122	38.6
Plantain intercropping:	Arable crops	44	18.9
	Tree crops	78	33.5
	Arable + Tree crops	111	47.6
Arable crops in mixture:	Cassava	81	53.3
	Maize	70	46.1
	Yam	63	41.5
	Vegetables	56	36.8
	Legumes	8	5.3
Tree crops in mixture:	Cacao	143	76.1
	Citrus	81	43.1
	Kola	61	32.5
	Oil palm	55	29.3

Table 3. Farmers' perception of the on-farm problems associated with plantain yield decline

On-farm problems		Frequency	Percentage (%)
Snapping (snapped plants/ mat):	1	97	30.7
	2	116	36.7
	>3	103	32.6
Causing of snapping:	Wind	169	53.5
	Drought	68	21.5
	Bunch Weight	53	16.8
	Pests and diseases	24	7.6
	Poor soil fertility	2	0.6
Toppling (toppled plants/farm):	1-5	247	78.2
	6-10	42	13.2
	11-15	17	5.4
	>16	10	3.2
Causes of toppling:	Wind	167	52.9
	Root damage by pests /diseases	85	26.9
	Shallow soil	44	13.9
	High mat	20	6.3

Table 4.Soil management practices adopted in plantain production systems

Management practice		Frequency	Percentage (%)
Manuring:	Yes	113	35.8
	No	203	64.2
Mulching	Yes	145	45.9
	No	171	54.1
Mulching materials:	Sawdust	102	70.6
	Oil palm bunch refuse	15	10.4
	Others (weeds)	28	19.0
Earthening up:	Yes	223	70.6
	No	93	29.4
Frequency of earthening up /year:	1-2	177	79.4
	3-4	43	19.3
	5-6	3	1.3
Reasons for earthening up:	(1) High mat	93	41.6
	(2) Toppling	70	31.4
	(3) Yield increase	16	7.2
	(1) + (2)	28	12.6
	(1) + (3)	4	1.8
	(2) + (3)	6	2.7
	(1) + (2) + (3)	6	2.7

broadcasting was least used (1.3%). The planted crop was most fertilized (95.3%) while the ratoons received less fertilizer (4.7%). The farmers attributed low fertilizer use more to non-availability of products (66.1%) and high cost (price) of fertilizers (17.4%) but less to the effects on fruit quality (5.7%), scarcity of labour for application (4.8%), lack of technical knowhow of application (3.8%) and promotion of weeds (2.2%). Fertilizers were not available because fertilizer sales outlets were not in the farming communities (88.3%) rather than the very far distance of fertilizer stores (3.8%) while others (7.9%) felt connection with government officials was often needed to get fertilizers.

Responses to some perception statements related to soil management practices are shown in Table 6. The farmers disagreed that inputs from government sources were generally adequate (74.1%) but agreed with the following: information dissemination from the extension services to farmers was adequate (51.9%); plantain yields increased on annual basis (78.8%) and adoption of improved management practices enhanced plantain productivity (92.1%).

Table 5. Fertilizer use and management practices in plantain production systems

Fertilizer use feature		Freqeuency	Percentage
Fertilizer use:	Yes	149	47.2
	No	167	52.8
Fertilizer type:	Urea	110	73.7
	Compound NPK	34	22.8
	MOP	5	3.5
Quantity applied (in bags):	1-2	100	67.1
	3-4	28	18.8
	5-6	10	6.7
	7-8	7	4.7
	>8	4	2.7
Number of applications/year:	One(1)	124	83.2
	Two(2)	20	13.4
	Three (3)	4	2.7
	Four (4)	1	0.7
Placement method:	Ringing and soil cover	58	38.9
	Band/hole placement	39	26.2
	Ringing no soil cover	33	22.2
	Side dressing	17	11.4
	Broadcasting	2	1.3
Fertilizer applied to:	Planted crops	142	95.3
	Ratoon crops	7	4.7
Reasons for not using fertilizer:	1. Non-availability of fertilizer	110	66.1
	2. High cost of fertilizer	29	17.4
	3. Lack of technical know how	6	3.8
	4. Negative effect of fruit quality	10	5.7
	5. Increased weediness on farms	4	2.2
	6. Scarcity of labour for application	8	4.8
Reasons for non-availability of fertilizer:			
	1. Lack of fertilizer sale outlets	97	88.3
	2. Lack of official connection	9	7.9
	3. Long distance to fertilizer store	4	3.8

4. DISCUSSION

The main cocoa belt in Nigeria is located in the eastern portion of the South-west geo-political zone. The humid to sub-humid features of forested lowlands and small hills in Ekiti and Ondo States are particularly suitable for cacao (*Theobroma cacao*) whose juvenile plantations require shade. Plantain is the choice nurse plant used to provide natural shade in cacao plantations and sometimes other tree crops like kola (*Cola* spp) and lowland coffee (*Coffea canephora*) [7]. The areas south of the cocoa belt in Ondo State, characterized by humid conditions and deep friable soils required for oil palm and rubber, also favour plantain production. These tree cash crop environments are male-dominated as earlier observed by [12] which explains the prominence of men in plantain production while the decision-making roles of women are in post-harvest handling activities [13]. The men's age at 40-60 years is similar to 41-60 years age reported for 60% of cacao farmers in Ondo State [14] and average 50 years and above for cacao farmers in West African countries [15]. However, with the youth (<30 years) at 4.1% and 18.3% of the respondents over 60 years old, the farming population is ageing. This and the disinterest of the youth have been identified as social constraints in the agricultural sector such that the need to make agriculture attractive to the youth through gainful employment, income generation and poverty alleviation is a focus of the agricultural transformation agenda [16]. The level of literacy was moderate with 47.2% having at least secondary school education and would enhance the adoption of improved husbandry especially when such technology being promoted requires that farmers read the labels and instructions on products [17].

The small sizes of plantain farms (<2.4 ha) make intercropping with tree crops and/or arable food crops the rule while the few sole farms are

Table 6. Perception of issues related to soil management practices in plantain production systems

Perception statements		Frequency	Percentage (%)
Agricultural inputs from government sources are adequate:			
	Strongly agree	11	3.5
	Agree	39	12.3
	Undecided	33	10.4
	Disagree	101	32.0
	Strongly disagree	132	41.8
Information dissemination from agricultural extension services			
adequate and relevant:	Strongly agree	48	15.2
	Agree	116	36.7
	Undecided	25	7.9
	Disagree	48	15.2
	Strongly disagree	79	25.0
Adoption of management practices enhances plantain			
productivity:	Strongly agree	121	38.3
	Agree	169	53.5
	Undecided	15	4.7
	Disagree	11	3.5
	Strongly disagree	0	0.0
Plantain production increases annually:	Strongly agree	115	36.4
	Agree	134	42.4
	Undecided	18	5.7
	Disagree	35	11.1
	Strongly disagree	14	4.4

probably in response to the growing awareness of plantain production as a profitable venture for rural income generation and food security. These sole plantain farms and the nurse plants in juvenile cacao plantations would probably be those cultivated for less than five years and shifted either due to yield decline in the former or destruction of mats to give way to complete canopy closure in the latter [7].

Farmers rated soil fertility constraints least in plantain production systems because it was possible to harvest fruit bunches continually in the farms without additional nutrients from fertilizers and so lends credence to the farmers' belief that the soils are fertile. The poor inherent nutrient status of soils in the humid zone of Nigeria has been attributed to parent materials low in mineral reserves and intensive weathering that accompanies the processes of soil formation [18]. Since the best lands with fertile soils are grown to cacao and other tree cash crops in the distant farms not subject to the existing land tenure and bush fallow systems, the nurse plantain gets enough nutrients. The multi-storey mixtures develop nutrient conservation mechanisms that involve closed cycles between vegetation (litter) and topsoils for nutrient and organic matter build-up and maintenance of soil quality. Besides, plantain derives nutrients from applied fertilizers and benefits from other soil management practices meant to enhance the yields of the companion arable crops grown on outlying fields.

There is growing awareness that plantain yields would increase with the adoption of soil management practices, especially those that ensure adequate supply of plant nutrients. More than 60% of respondents did not use manure which is similar to a report that 53% of cacao farmers rarely used organic fertilizer [14]. However, a distinction needs to be made that organic fertilizers are now produced in many factories and marketed whereas manure refers to the various organic wastes which are applied to the farms. Plant residues are wastes but the use would probably be considered as mulching to derive benefits rather than nutrient supply nutrients because the main material used- sawdust- contains little amounts of nutrients. [19] noted that sawdust contains 0.29, 0.13 and 0.02% total N, P and K respectively and has high lignin content which decomposes very slowly while the high C/N ratio (164.5) would encourage N and P immobilization and cause their deficiencies in plants. Although earthening up aims at preventing the toppling of pseudostems

due to high mat formation but since it involves scraping nearby topsoils rich in nutrients around the mat, nutrient availability would be enhanced.

The low adoption of chemical fertilizer was not due to lack of awareness of the benefits and techniques of application but more on availability and rising prices of fertilizer products [9,20]. [20] observed that the main constraint to fertilizer use in Nigeria is the non-availability of the needed products. The issue of shrinking supplies and attendant increases in prices, as unintended consequences of the deregulating fertilizer market, are enduring challenges in the agricultural sector. The inefficiency in fertilizer marketing is attested to by the availability and use of urea as against the more appropriate and popular compound NPK fertilizers. Besides, the critical roles of the extension services in influencing the adoption of improved technologies by driving the demand for inputs and providing easy access to fertilizers have suffered from poor funding, administrative tardiness and inadequate and poorly motivated staff [20]. These contributed to the rating of government as reliable source of inputs and extension information as largely inadequate to influence plantain production systems.

The foregoing make shifting from plantain farms experiencing yield decline to new sites inevitable as the ultimate soil management practice. Thus, one-third of respondents who actually reported shifting to other plots would use the consequent fallow vegetation of complex species of trees and shrubs to maintain soil fertility through continuous build-up of nutrients and soil organic matter. According to [21], the fallow guarantees ecological stability because the transfer of nutrients and organic matter across boundaries is relatively small compared to the internal fluxes between the soil pool and overlying vegetation.

5. CONCLUSION

Nutrient depletion is a major factor in the loss of perennial productivity of plantain but few farmers in Ekiti and Ondo States of Nigeria identified poor soil fertility as a cause of decline in orchard productivity. Rotation or shifting from plantain farms experiencing yield decline to new sites was identified as the ultimate soil management practice. Non-availability of fertilizer, its attendant high cost and lack of nearby sales outlets affected the optimal use of the input in plantain orchards. The agricultural extension services should be strengthened in order to increase information dissemination among farmers on the need to adopt improved soil management practices such as mulching, earthening up and use of manures. The activities would also drive the demand for and influence access to fertilizer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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