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ADOPTION OF COMPOST-BASED FERTILIZATION AMONG PEPPER FARMERS IN SOUTHWESTERN NIGERIA: EXTENSION APPROACHES AND YIELD OUTCOMES

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ABSTRACT

Declining soil fertility and escalating synthetic fertilizer costs in southwestern Nigeria have intensified interest in locally produced organic amendments, yet farmer adoption of compost-based fertilization remains constrained by knowledge gaps, labour requirements, and uncertain economic returns. This study assessed adoption patterns, yield outcomes, and extension delivery preferences among pepper farmers exposed to plantain peel compost technology in Irepodun/Ifelodun Local Government Area of Ekiti State, Nigeria. A mixed-methods approach combined a randomised controlled trial on 120 farmers' fields with structured interviews and focus group discussions during the 2022 and 2023 growing seasons. Four compost rates (0, 5, 10, and 15 t ha^{-1}) were evaluated on pepper (*Capsicum annuum* L. cv. Tatase) in a randomised complete block design. Parallel household surveys examined adoption determinants, while focus groups elicited feedback on extension delivery methods. Results showed that 68% of exposed farmers adopted compost technology by the second season, with adoption strongly associated with farm size, extension contact frequency, and perceived economic benefit. Compost at 10 t ha^{-1} increased marketable fruit yield from 8.6 to 11.4 t ha^{-1} (a 32% gain), raised soil organic carbon from 0.64% to 0.89%, and increased available nitrogen from 42.6 to 60.8 mg kg^{-1}. Farmers preferred demonstration plots and peer-farmer trainers over conventional extension lectures, citing visual evidence and trust as critical factors. The benefit–cost ratio of 2.3:1 at 10 t ha^{-1} (excluding family labour valued at opportunity cost) provided compelling economic justification. Labour requirements for compost production and initial scepticism about organic amendment efficacy emerged as primary adoption barriers. Integrating participatory demonstration with farmer-to-farmer extension accelerated adoption and offers a scalable pathway for sustainable pepper intensification and agricultural waste management in southwestern Nigeria.

Keywords: Adoption; Agricultural extension; Compost; Pepper; Plantain waste; Soil fertility

1 INTRODUCTION

Agricultural extension systems in sub-Saharan Africa face the dual challenge of disseminating productivity-enhancing technologies while ensuring their environmental and economic sustainability. In southwestern Nigeria, where smallholder farming dominates the agricultural landscape, soil fertility decline has emerged as a critical constraint to vegetable production, particularly for high-value crops such as pepper (*Capsicum annuum* L.) (Akanbi et al., 2020).

Decades of intensive cultivation without adequate nutrient replenishment have depleted soil organic matter, reduced microbial activity, and diminished the capacity of sandy loam soils to retain water and nutrients. Simultaneously, the rising cost and sporadic availability of synthetic fertilizers have rendered conventional input-dependent production increasingly precarious for resource-constrained farmers (Ojo & Adebayo, 2022).

The transformation of agricultural waste into organic fertilizer represents a convergence of environmental management and soil fertility restoration objectives. Plantain (*Musa paradisiaca*), a staple crop widely cultivated and consumed across southwestern Nigeria, generates substantial quantities of peel waste estimated at 35–40% of total fruit weight during processing (Nduwimana et al., 2020). Currently, this biomass stream is largely discarded in open dumps, landfills, or water bodies, contributing to environmental pollution, greenhouse gas emissions, and public health hazards. Composting these peels converts a disposal liability into a soil amendment asset, simultaneously addressing waste management and agricultural productivity challenges.

Pepper holds particular significance in Nigerian agriculture and food systems. As a vegetable, spice, and source of vitamins, antioxidants, and capsaicinoids, pepper commands consistent market demand and generates substantial income for smallholder households (Srinivasan, 2016). The crop's sensitivity to soil nitrogen and potassium availability makes it an ideal candidate for organic amendment interventions, while its relatively short growing cycle allows rapid feedback to farmers on technology performance. However, the gap between research-station demonstrations of compost efficacy and actual farmer practice remains substantial, with adoption rates for organic fertilization technologies rarely exceeding 20% in Nigerian smallholder systems without sustained extension support (Ayeni & Adeleye, 2018).

1.1 Statement of the Problem

Despite compelling biophysical evidence for compost benefits, farmer adoption of compost-based fertilization in southwestern Nigeria remains disappointingly low. Several interconnected factors contribute to this adoption gap. First, conventional extension approaches relying on classroom lectures and printed materials fail to address the experiential learning preferences of smallholder farmers, who prioritize visual evidence and peer testimony over technical prescriptions (Dahunsi et al., 2020). Second, the labour investment required for compost production chopping, turning, watering, and curing discourages time-constrained households, particularly where off-farm employment competes for family labour (Hargreaves et al., 2008). Third, the delayed nutrient release characteristic of organic amendments creates a perception of inferiority compared to the rapid response of synthetic fertilizers, undermining farmer confidence during initial trials (Gabhane et al., 2012). Fourth, the absence of local markets for compost and the lack of standardised quality indicators prevent commercial development that could reduce farmer labour burdens.

In Irepodun/Ifelodun Local Government Area of Ekiti State, these challenges are compounded by specific contextual factors. The local government, situated in the derived savanna agro-ecological zone, possesses sandy loam soils with inherently low organic matter and high leaching potential, making soil amendment particularly critical yet economically risky for farmers. Plantain processing is concentrated in the urban centres of Igede-Ekiti and Omuo-Ekiti, generating substantial peel waste within short distances of vegetable production areas, yet no organised composting enterprise has emerged to bridge this spatial proximity. Extension services in the area, delivered through the Ekiti State Agricultural Development Programme (EKADP), have historically emphasised synthetic fertilizer distribution over organic matter management, creating institutional inertia that favours status quo practices.

The specific problem addressed by this study was the low and stagnant adoption of compost-based fertilization among pepper farmers in Irepodun/Ifelodun, despite the availability of raw materials, biophysical suitability, and potential economic benefits. Without understanding why farmers reject or discontinue compost use, and without identifying extension approaches that overcome these barriers, the technological potential of plantain peel composting will remain unrealised, and soil degradation will continue unabated.

1.2 Significance and Justification for the Research

This study held significance at multiple levels. For farmers in Irepodun/Ifelodun and similar contexts, the research provided evidence-based guidance on compost application rates, economic returns, and labour-efficient production methods that could improve pepper productivity while reducing dependence on costly synthetic inputs. For extension policy, the study identified delivery mechanisms particularly demonstration plots and farmer-to-farmer training that proved more effective than conventional approaches, offering actionable recommendations for restructuring agricultural advisory services. For environmental management, the study quantified waste diversion potential and soil carbon accretion, contributing to climate adaptation and mitigation objectives at local and national scales.

The justification for focusing on Irepodun/Ifelodun Local Government Area was threefold. First, the area represented a typical derived savanna farming system with widespread plantain processing and intensive pepper cultivation, making findings transferable to similar contexts across southwestern Nigeria. Second, the EKADP had recently initiated a pilot organic farming programme in the area, creating institutional entry points and policy relevance for the research. Third, the concentration of plantain peel waste near vegetable production zones offered a natural experiment in waste-to-resource transformation that could model circular economy principles for Nigerian agriculture.

Objectives of the Study

The broad objective was to assess the adoption dynamics, yield outcomes, and extension delivery preferences associated with plantain peel compost technology among pepper farmers in Irepodun/Ifelodun Local Government Area. The specific objectives were to:

- characterize the socioeconomic profiles and current soil fertility management practices of pepper farmers in the study area;
- evaluate the effects of different plantain peel compost rates on soil properties, chlorophyll content, flowering, and yield of pepper (*Capsicum annuum*) under on-farm conditions;
- determine the factors influencing farmer adoption or non-adoption of compost-based fertilization over two growing seasons;
- assess farmers' preferred extension delivery methods and identify barriers to sustained compost use; and
- conduct economic analysis of compost production and application to establish profitability thresholds for farmer recommendation.

2 MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Irepodun/Ifelodun Local Government Area of Ekiti State, Nigeria, specifically in the farming communities surrounding Igede-Ekiti (latitude 7°40'N, longitude 5°18'E, elevation 460 m) and Omuo-Ekiti (latitude 7°45'N, longitude 5°42'E, elevation 480 m). The area falls within the derived savanna agro-ecological zone, characterised by a bimodal rainfall pattern with mean annual precipitation of 1,200–1,400 mm concentrated between April and October. Mean annual temperature ranges from 21°C to 32°C, with relative humidity averaging 75–85% during the growing season (see Table 1).

Ekiti State is located between longitudes 4°51′ and 5°51′ East of the Greenwich meridian and latitudes 7°15′ and 8°05′ North of the equator, with a total land area of 5,887.89 km^2. The state comprises 16 Local Government Areas and three senatorial zones (Ekiti North, Ekiti Central, and Ekiti South). The population was 2,384,212 at the 2006 census, with a projected annual growth rate of 3.2%. The state has abundant forest resources, and its climate supports diverse agricultural enterprises including maize, cassava, yam, pepper, and plantain cultivation.

The soils of the study area are predominantly sandy loam Alfisols with low inherent fertility, pH 6.0–6.8, organic carbon below 1%, and rapid leaching of applied nutrients. Farming systems are mixed crop–livestock enterprises. Plantain processing for local consumption and market sale generates substantial peel waste, particularly in Igede-Ekiti where a weekly plantain market serves surrounding communities.

Table 1: Monthly meteorological data at Igede-Ekiti, Irepodun/Ifelodun LGA, Ekiti State, during the 2022 growing season (July–November)

Month	Rainfall (mm)	Max Temp (°C)	Min Temp (°C)	RH (%)	Sunshine (hrs/day)
July	186.4	30.2	21.6	82.4	4.8
August	214.6	29.8	21.4	84.6	4.2
September	198.4	30.4	21.8	82.6	4.6
October	146.8	31.2	22.2	78.4	5.4
November	48.6	32.4	22.8	72.6	6.2
Total / Average	794.8 (Total)	30.8 (Mean)	22.0 (Mean)	80.8 (Mean)	5.0 (Mean)

Source: Ekiti State Agricultural Development Programme (EKADP), Igede-Ekiti Station, 2022. RH = Relative Humidity. Rainfall values are monthly totals; temperature, RH, and sunshine values are monthly means.

2.2 Experimental Design and Farmer Selection

A mixed-methods design combined quantitative on-farm trials with qualitative household surveys and focus group discussions. For the on-farm trial, 120 pepper farmers were selected through stratified random sampling from EKADP farmer registers in six communities (20 farmers per community). Stratification ensured representation across gender, farm size categories (small: <1 ha; medium: 1–2 ha; large: >2 ha), and prior exposure to organic farming practices.

The on-farm trial was arranged as a randomised complete block design (RCBD) with farmer as block. Each of the 120 farmers hosted all four compost treatments, each replicated three times on their field, giving 12 plots per farm (3 m × 3 m each) and 1,440 experimental plots in total across the six communities. Farmers were grouped into four blocks of 30, stratified by farm size, to control for inherent soil and management variation. The four treatments were:

- T_1: Control (no compost)
- T_2: 5 t ha^{-1} plantain peel compost
- T_3: 10 t ha^{-1} plantain peel compost
- T_4: 15 t ha^{-1} plantain peel compost

2.3 Compost Production and Quality

Plantain peels were collected from processing points in Igede-Ekiti market and transported to a central composting site. Farmers participated in compost production through a three-day hands-on training covering chopping, heap construction, moisture management, and maturity assessment. Each farmer produced their own compost under supervision, ensuring the method was replicable independently. The chemical properties of the finished compost are presented in Table 2.

Table 2: Chemical properties of plantain peel compost used in the study

Property	Value	Unit	Method
pH (1:5 water)	7.2	—	Electrometric (pH meter)
Organic carbon	28.6	%	Walkley–Black wet oxidation
Total nitrogen	1.84	%	Kjeldahl digestion
C:N ratio	15.5:1	—	Calculated
Available phosphorus	4.86	mg kg^{-1}	Bray-1 colorimetry
Exchangeable potassium	1.86	cmol kg^{-1}	Flame photometry
Moisture content	22.4	%	Gravimetric (105°C, 24 hr)
Bulk density	0.64	Mg m^{-3}	Core method

Analyses performed at the Soil Science Laboratory, Federal Polytechnic Ado-Ekiti. Moisture content of 22.4% is consistent with published values for mature vegetable-waste compost (15–30% range). The high potassium content (1.86 cmol kg^{-1}) reflects the characteristic K-richness of plantain peel biomass — a nutritionally important property for pepper, whose fruit development, water relations, and sugar accumulation are potassium-dependent processes.

2.4 Crop Management

Farmers transplanted pepper cv. Tatase seedlings at 60 cm × 45 cm spacing during the first week of July in both the 2022 and 2023 seasons. Basal NPK 15–15–15 was applied at half the recommended rate (60–30–30 kg ha^{-1}) to all plots, including the control, to isolate compost effects without confounding from absolute nutrient deficiency. Weeding was manual at 3 and 6 weeks after transplanting; pest control followed farmers' normal practice with synthetic pyrethroids. No irrigation was applied; crops relied entirely on rainfall.

2.5 Soil and Plant Measurements

Composite soil samples (0–15 cm) were collected from each plot at harvest and analysed for pH, organic carbon, available nitrogen, available phosphorus, and exchangeable potassium using standard methods. Leaf chlorophyll content was measured using a SPAD-502 chlorophyll meter (Minolta Camera Co., Japan) at 4, 8, and 12 weeks after transplanting. Days to 50% flowering, flower number per plant, and fruit set percentage were recorded. Marketable fruit yield was assessed at physiological maturity.

2.6 Farmer Survey

Structured interviews were conducted at three time points: pre-exposure (baseline), mid-first season, and end of second season. The questionnaire captured demographic characteristics, farm resources, current soil fertility practices, knowledge of composting, willingness to adopt, and perceived constraints. Adoption was defined as farmer-initiated compost production or purchase and application to at least 0.25 ha of pepper in the season following exposure.

2.7 Focus Group Discussions

Six focus groups (one per community, 8–12 participants each) were conducted at the end of the 2023 season. Discussions explored farmer experiences with compost production, yield observations, labour-sharing arrangements, preferred extension methods, and suggestions for scaling. Sessions were audio-recorded with participants' informed consent, transcribed, and thematically analysed.

2.8 Economic Analysis

Partial budget analysis computed costs and returns for each compost rate. Costs included hired labour for compost application and transport of raw materials. Family labour for compost production was costed separately and reported as a sensitivity analysis but excluded from the headline benefit–cost ratio (BCR), consistent with the standard partial budget convention used in Nigerian smallholder economics where family labour incurs no cash expenditure (IITA, 2014). Returns were based on marketable fruit yield and prevailing farm-gate prices (₦98,000 per tonne, 2023 season average). BCR and returns to labour were calculated to establish economic thresholds.

2.9 Statistical Analysis

On-farm trial data were analysed by ANOVA for a randomised complete block design with farmer as block, using GenStat 15th Edition (VSN International). Treatment means were separated by the least significant difference (LSD) at $p < 0.05$. Survey data were analysed by descriptive statistics, chi-square tests for association, and binary logistic regression for adoption determinants. Focus group transcripts were coded and thematically analysed using NVivo 12. Nagelkerke R^2 and model significance are reported for the logistic regression model (Table 7; n = 120).

3 RESULTS

3.1 Socioeconomic Characteristics of Respondents

Participating farmers were predominantly male (72%), with a mean age of 48.6 years and mean farming experience of 22.4 years. Farm size averaged 1.4 ha, with 68% of farmers cultivating less than 2 ha. Only 24% had received formal agricultural training beyond primary school, while 56% reported regular contact with EKADP extension agents. Prior use of organic amendments was limited: 18% had applied poultry manure, 8% had used crop residues, and none had produced or purchased compost before the study.

Current soil fertility management relied heavily on synthetic fertilizers (89% of farmers), with NPK 20–10–10 or urea applied at rates below recommendations due to cost constraints. Manure use was declining (12% in 2022 vs. 28% in 2015), attributed to reduced livestock ownership and labour scarcity for manure collection and transport.

3.2 Soil Chemical Properties at Harvest

Table 3: Effect of plantain peel compost on soil chemical properties at harvest (0–15 cm depth)

Property	T1 — 0 t ha^{-1}	T2 — 5 t ha^{-1}	T3 — 10 t ha^{-1}	T4 — 15 t ha^{-1}	LSD (p<0.05)
pH	6.2d	6.4c	6.7a	6.6b	0.2
Organic carbon (%)	0.64d	0.74c	0.89a	0.86b	0.06
Available N (mg kg^{-1})	42.6d	52.4c	60.8a	58.6b	4.8
Available P (mg kg^{-1})	6.8d	9.4c	11.6b	12.2a	1.4
Exchangeable K (cmol kg^{-1})	0.14d	0.28c	0.42a	0.40b	0.06

Means in each row followed by different letters differ significantly at $p < 0.05$ (LSD). T3 (10 t ha^{-1}) was optimal for all soil properties except Available P, where T4 produced marginally higher values. The 200% increase in exchangeable K (0.14 → 0.42 cmol kg^{-1}) at T3 reflects the high potassium content of plantain peel compost and is consistent with the documented K-rich composition of Musa spp. peel waste (Nduwimana et al., 2020).

Compost application significantly improved all measured soil chemical properties, with 10 t ha^{-1} generally optimal (Table 3). Soil pH rose from 6.2 in the control to 6.7 at 10 t ha^{-1}, reflecting the near-neutral to slightly alkaline reaction of the compost (pH 7.2). Organic carbon increased from 0.64% to 0.89%, available nitrogen from 42.6 to 60.8 mg kg^{-1}, available phosphorus from 6.8 to 11.6 mg kg^{-1}, and exchangeable potassium from 0.14 to 0.42 cmol kg^{-1}. The 15 t ha^{-1} rate showed marginal additional gains, indicating diminishing returns beyond 10 t ha^{-1}.

3.3 Chlorophyll Content

Chlorophyll content increased progressively with compost rate, peaking at 10 t ha^{-1} (Table 4). At 8 weeks after transplanting, SPAD values rose from 38.6 in the control to 45.8 at 10 t ha^{-1}, a 19% gain. The 15 t ha^{-1} treatment recorded 44.2, slightly below the optimum, suggesting that excess potassium at 15 t ha^{-1} may have induced mild nutrient imbalances that marginally suppressed chlorophyll biosynthesis. The sustained SPAD advantage through 12 weeks indicated delayed leaf senescence under improved nutrition.

Table 4: Effect of plantain peel compost on SPAD chlorophyll content of pepper at 4, 8, and 12 weeks after transplanting (WAT)

Treatment	SPAD at 4 WAT	SPAD at 8 WAT	SPAD at 12 WAT
T1 — 0 t ha^{-1}	32.4d	38.6d	34.2d
T2 — 5 t ha^{-1}	38.6c	42.6c	39.4c
T3 — 10 t ha^{-1}	42.8a	45.8a	43.6a
T4 — 15 t ha^{-1}	41.2b	44.2b	42.4b
LSD (p<0.05)	2.4	2.6	2.4

Means in each column followed by different letters differ significantly at $p < 0.05$ (LSD). SPAD values reflect relative leaf chlorophyll concentration; measurements taken on the third fully expanded leaf from the apex of five tagged plants per plot.

3.4 Flowering and Fruit Set

Compost accelerated flowering and improved reproductive success (Table 5). Days to 50% flowering shortened from 45.2 in the control to 41.0 at 10 t ha^{-1}. Flower number per plant rose from 24.6 to 32.6, while fruit set improved from 64.2% to 78.6%. The 15 t ha^{-1} treatment showed slight reductions in flower number and fruit set compared with 10 t ha^{-1}, confirming the optimal rate.

Table 5: Effect of plantain peel compost on days to 50% flowering, flower number per plant, and fruit set percentage of pepper

Treatment	Days to 50% Flowering	Flower No. per Plant	Fruit Set (%)
T1 — 0 t ha^{-1}	45.2a	24.6d	64.2d
T2 — 5 t ha^{-1}	43.6b	28.4c	70.8c
T3 — 10 t ha^{-1}	41.0d	32.6a	78.6a
T4 — 15 t ha^{-1}	42.2c	30.8b	75.4b
LSD (p<0.05)	1.2	2.2	3.4

Means in each column followed by different letters differ significantly at $p < 0.05$ (LSD). For days to flowering, lower values indicate earlier flowering — agronomically desirable. T3 (10 t ha^{-1}) was optimal for all three reproductive parameters.

3.5 Fruit Yield

Marketable fruit yield responded strongly to compost, with 10 t ha^{-1} producing the highest gain (Table 6). Total yield rose from 12.4 t ha^{-1} in the control to 16.2 t ha^{-1} at 10 t ha^{-1}, while marketable fruit yield increased from 8.6 to 11.4 t ha^{-1}, a 32% gain. Individual fruit weight improved from 102.4 g to 128.4 g. The 15 t ha^{-1} treatment produced lower marketable yield (10.2 t ha^{-1}) than 10 t ha^{-1}, indicating diminishing returns.

Table 6: Effect of plantain peel compost on total fruit yield, marketable fruit yield, individual fruit weight, and non-marketable fruit yield of pepper (t ha^{-1})

Parameter	T1 — 0 t ha^{-1}	T2 — 5 t ha^{-1}	T3 — 10 t ha^{-1}	T4 — 15 t ha^{-1}	LSD (p<0.05)
Total fruit yield (t ha^{-1})	12.4d	14.4c	16.2a	15.6b	1.2
Marketable fruit yield (t ha^{-1})	8.6d	9.8c	11.4a	10.2b	1.2
Individual fruit weight (g)	102.4d	114.6c	128.4a	122.6b	8.4
Non-marketable yield (t ha^{-1})	3.8d	4.6c	4.8b	5.4a	1.0

Means in each row followed by different letters differ significantly at $p < 0.05$ (LSD). Marketable fruit yield excludes damaged, undersized, or misshapen fruits. Non-marketable yield = Total yield − Marketable yield. T3 (10 t ha^{-1}) was optimal for marketable yield, individual fruit weight, and total yield; T4 showed highest non-marketable fraction, attributed to minor blossom-end disorder under excess potassium supply.

3.6 Adoption Patterns

By the end of the second season, 68% of exposed farmers had adopted compost technology. Adoption was significantly associated with farm size ($\chi^2 = 14.6$, df = 2, $p < 0.001$), extension contact frequency ($\chi^2 = 11.2$, df = 1, $p = 0.001$), and perceived economic benefit ($\chi^2 = 18.4$, df = 1, $p < 0.001$). Logistic regression results (Table 7) identified farm size, extension contact, and first-season yield gain as the three strongest predictors of adoption.

Table 7: Binary logistic regression of compost adoption determinants among pepper farmers (n = 120, Nagelkerke $R^2 = 0.54$, model $\chi^2 = 48.6$, $p < 0.001$)

Variable	Odds Ratio	95% CI	p-value	Significance
Farm size (>1 ha vs. ≤1 ha)	3.84	1.86–7.94	0.001	**
Extension contact (frequent vs. infrequent)	2.96	1.42–6.18	0.004	**
First-season yield gain observed	4.62	2.24–9.54	<0.001	***
Years of farming experience	1.06	0.98–1.14	0.148	ns
Gender (female vs. male)	0.84	0.38–1.86	0.664	ns
Prior organic fertilizer use	2.14	0.96–4.76	0.062	ns
Constant	0.08	—	0.002	**

** = $p < 0.01$; *** = $p < 0.001$; ns = not significant. Reference categories in parentheses. Nagelkerke $R^2 = 0.54$ indicates good model fit. The odds ratio for first-season yield gain (4.62) confirms that observed agronomic performance is the single strongest predictor of farmer adoption, exceeding the influence of socioeconomic characteristics.

3.7 Extension Delivery Preferences

Table 8: Farmer preferences for extension delivery methods and key advantages or limitations cited (n = 120)

Extension Method	Preferred by (%)	Key Advantage / Limitation Cited
Demonstration plots	82	Visual evidence; builds confidence before committing resources
Peer farmer trainers	74	Trust, local language, shared experience
Group training workshops	56	Efficient; facilitates peer discussion
EKADP extension visits	48	Official credibility, but infrequent and farm visits rare
Radio / audio messages	36	Wide reach; accessible during farm work
Pamphlets / posters	22	Low literacy limits effectiveness
One-on-one farm visits	68	Highly effective but labour-intensive for extension service

Percentages do not total 100% as farmers could select multiple preferred methods. The high preference for demonstration plots (82%) and peer farmer trainers (74%) aligns with established experiential learning theory in agricultural extension (Dahunsi et al., 2020).

3.8 Economic Analysis

The partial budget analysis (Table 9) demonstrated that compost application at 10 t ha^{-1} was the most economically efficient rate. Additional gross revenue at this rate was ₦274,400 ha^{-1} (2.8 t ha^{-1} yield gain × ₦98,000 t^{-1}). Total additional cash costs (compost transport and hired application labour) were ₦120,000 ha^{-1}. The benefit–cost ratio was 2.3:1, excluding family labour which incurs no cash expenditure in the smallholder context. When family labour for compost production is costed at the local opportunity wage (₦3,500 per person-day × 26 person-days ha^{-1} = ₦91,000 ha^{-1}), the adjusted BCR declines to 1.3:1 still profitable but below the threshold that typically motivates adoption without extension incentives. The 15 t ha^{-1} rate was not profitable under either cost assumption.

Table 9: Partial budget analysis of plantain peel compost application on pepper at prevailing 2023 farm-gate prices (₦98,000 t^{-1})

Item	T1 — 0 t ha^{-1}	T2 — 5 t ha^{-1}	T3 — 10 t ha^{-1}	T4 — 15 t ha^{-1}
Marketable yield (t ha^{-1})	8.6	9.8	11.4	10.2
Gross revenue (₦ ha^{-1})	842,800	960,400	1,117,200	999,600
Additional revenue over control (₦)	—	117,600	274,400	156,800
Compost transport cost (₦ ha^{-1})	0	36,000	72,000	108,000
Hired application labour (₦ ha^{-1})	0	16,000	48,000	96,000
Total additional cash cost (₦)	0	52,000	120,000	204,000
Net benefit over control (₦)	—	65,600	154,400	−47,200
Benefit–cost ratio (BCR)*	—	2.3	2.3	0.8
Marginal net benefit vs. lower rate (₦)	—	65,600	88,800	−205,000

*BCR = Additional gross revenue ÷ Total additional cash cost. Family labour for compost production (estimated at ₦91,000 ha^{-1} at local opportunity wage) is excluded from the BCR denominator because it incurs no cash expenditure in the smallholder farming context — consistent with the standard IITA partial budget convention for sub-Saharan African smallholder economic analysis (IITA, 2014). When family labour is included, BCR at 10 t ha^{-1} declines to 1.3:1. All costs and revenues are in Nigerian Naira (₦), 2023 season prices. The 15 t ha^{-1} marginal analysis shows a net loss of ₦205,000 relative to the 10 t ha^{-1} rate, confirming 10 t ha^{-1} as the economic optimum.

4 DISCUSSION

The 68% adoption rate recorded by the second season far above the sub-20% baseline typical of Nigerian smallholder organic technology adoption reflects the combined effect of two factors that are rarely simultaneously present in conventional extension programmes: a participatory demonstration design that allowed farmers to observe yield outcomes on their own fields before committing, and the peer farmer trainer model that provided locally trusted, linguistically accessible knowledge transmission. The logistic regression finding that observed first-season yield gain was the strongest predictor of adoption (OR = 4.62, $p < 0.001$) is consistent with Rogers' (2003) diffusion of innovation framework, which identifies observability and trialability as the two most critical attributes for accelerating technology adoption in smallholder contexts. The visual evidence of fuller canopies, earlier flowering, and heavier fruits on compost-treated plots, observed directly by participating farmers and their neighbours, provided a persuasive demonstration that no extension lecture could replicate.

The potassium response observed across soil and yield parameters a 200% increase in exchangeable K (0.14 → 0.42 cmol kg^{-1}) at 10 t ha^{-1} and a corresponding 32% gain in marketable fruit yield reflected the characteristic K-richness of plantain peel biomass and its particular alignment with pepper's potassium-dependent fruiting physiology. Potassium regulates stomatal aperture, phloem loading of sucrose for fruit filling, and cell wall integrity in expanding fruit tissue processes that directly determine fruit weight, firmness, and marketable grade (Marschner, 2012). The improvement in individual fruit weight from 102.4 to 128.4 g (a 25.4% gain) is likely attributable primarily to this K-mediated improvement in fruit cell expansion and sugar accumulation, corroborating the findings of Oladele and Aina (2021) on composted organic wastes in pepper production. The slight yield depression at 15 t ha^{-1} lower marketable yield (10.2 vs. 11.4 t ha^{-1}) and higher non-marketable fraction is consistent with research showing that excess potassium can antagonise calcium and magnesium uptake, inducing blossom-end disorder and reducing fruit quality at rates beyond the crop's uptake capacity (Cakmak, 2005).

The economic analysis confirmed that the 10 t ha^{-1} compost rate was the threshold at which benefits most clearly exceeded costs under current price conditions, but the sensitivity of this conclusion to the treatment of family labour is an important caveat for extension communication. A BCR of 2.3:1 excluding family labour communicates a compelling message of economic viability to farmers who have abundant family labour and no off-farm employment alternatives. However, for households where family members have access to wage labour at ₦3,500 per person-day or above, the adjusted BCR of 1.3:1 may not provide sufficient margin to justify the 26 person-days ha^{-1} that compost production requires. This duality points to an important segmentation in the recommendation: the compost technology in its current manually intensive form is best targeted at labour-surplus households, while the long-term scaling pathway requires investment in mechanised or semi-mechanised composting to reduce the labour burden to levels compatible with labour-constrained household adoption. The emerging role of community composting enterprises already informally operating in parts of Ogun and Lagos States provides a practical template for this transition.

5 CONCLUSION AND RECOMMENDATIONS

This study demonstrated that plantain peel compost applied at 10 t ha^{-1} significantly improved soil organic carbon, available nitrogen, available phosphorus, exchangeable potassium, chlorophyll content, flowering performance, and marketable fruit yield of pepper in Irepodun/Ifelodun Local Government Area, with a benefit–cost ratio of 2.3:1 (excluding family labour). Adoption reached 68% of exposed farmers by the second season, driven primarily by observed first-season yield gains, extension contact frequency, and farm size. Participatory demonstration plots and peer farmer trainers were the most preferred and effective extension delivery mechanisms. Labour requirements for compost production and initial scepticism about organic amendment efficacy were the primary adoption barriers.

The following recommendations are made:

- Plantain peel compost should be applied to pepper at 10 t ha^{-1} as the economically optimal rate under current price conditions, incorporating basal NPK 15–15–15 at half rate for phosphorus supplementation.
- The EKADP and state extension services should adopt participatory demonstration plots and peer farmer trainer networks as the primary extension delivery model for compost technology, replacing the conventional lecture-based approach that this study found to be significantly less effective.
- Future studies should evaluate the combined application of plantain peel compost with reduced-rate synthetic fertilizer to identify whether a partial substitution strategy can reduce input costs while maintaining the yield advantages documented in this study.
- Policy investment in community-scale composting enterprises leveraging the existing concentration of plantain peel waste in urban markets is recommended as the primary pathway for scaling compost adoption to labour-constrained farming households across southwestern Nigeria.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest with respect to the authorship, research, or publication of this article.

Statement of ethical approval

This study involved structured household surveys and focus group discussions with human participants. Ethical approval was obtained from Ekiti State Agricultural Development Program (EKADP) prior to data collection.

Statement of informed consent

All participating farmers provided written informed consent before enrolment. Participation was entirely voluntary, and participants were free to withdraw at any time without penalty. Farmer identities and plot locations have been anonymised in all tables and publications.

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