ORIGINAL RESEARCH REPORT NIGER. J. PLT. PROT. 40(2):48-55 (2026)

MOBILE PHONE–BASED DECISION SUPPORT ENHANCES INTEGRATED PEST MANAGEMENT ADOPTION AND REDUCES PESTICIDE USE AMONG SMALLHOLDER FARMERS IN ABUJA, NIGERIA

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SUMMARY

Inadequate adoption of IPM among smallholder farmers is partly explained by the lack of timely and relevant information on pests, which leads to unnecessary crop protection products use and non-sustainable crop production. This study evaluated the causal effect of mobile phone–based decision support on IPM adoption and pesticide use among smallholder maize farmers in Abuja, Nigeria. A randomized controlled trial was conducted during the 2024 maize season, assigning 60 participating farmers to receive SMS messages with alerts about pest infestations and management techniques each week (treatment group), while two other groups received the standard extension service information (control group). Data were collected on IPM adoption, pesticide application frequency, and yield. Logistic regression was used to estimate treatment effects, controlling for farmer characteristics. Farmers who received the SMS alerts had a higher rate of adopting IPM practices (72%) than those who used the conventional extension services (41%). The large treatment effect was statistically significant ($p < 0.001$). Pesticide application frequency decreased by 25% ($p = 0.005$), with no significant yield penalty ($p = 0.47$). Logistic regression models showed that farmers who received the SMS pest management alerts had a significantly higher probability of adopting IPM techniques (odds ratio = 3.4, 95% CI: 2.1-5.6, $p < 0.001$). Mobile phone–based decision support substantially improved IPM adoption and reduced pesticide use without compromising yield. The study findings demonstrate the potential of using digital extension services to promote climate-smart, environmentally sustainable pest management practices among smallholder farmers in Nigeria.

Keywords: Integrated pest management, mobile advisory systems, pesticide reduction, smallholder agriculture, digital extension, maize productivity

INTRODUCTION

Chemical pesticides pose a threat to the sustainable production of crops (Pretty *et al*., 2020; Fabregas *et al*., 2022). The impact of chemical pesticides on the environment and public health is well-documented. The challenge is especially acute in sub-Saharan Africa, where smallholder farmers produce the bulk of the food but have limited access to information regarding pest management.

Integrated pest management (IPM) aims to provide a holistic approach to pest control that is beneficial to the environment and improves crop productivity (Midega *et al*., 2021; Abd-Elgawad, 2022). Multiple studies show the benefits of using IPM strategies in agricultural production. Despite the benefits, smallholder farmers do not adopt these strategies because they

lack access to extension services, training, and pest management information.

The recent development of digital agriculture makes it possible for mobile phones advisory (mPhA) to provide valuable pest information to farmers. There are multiple mobile phone-based platforms, such as text message alerts and mobile applications, which are increasing the number of farmers adopting IPM practices (Ahmed *et al*., 2024; Reay-Jones *et al*., 2025). As there are high rates of mobile phone penetration in Africa, despite a shortage of extension, these digital platforms can substantially increase the dissemination of agricultural knowledge to African farmers. Furthermore, studies on the use of these platforms have shown that they can improve the knowledge of farmers on agricultural practices, reduce pesticide misuse, and promote sustainable agriculture (Fabregas *et al*., 2022).

However, there is limited empirical evidence based on randomized controlled trials that have determined the causal effect of mobile advisories on IPM adoption and usage of pesticides in African smallholder systems. Although research has underscored the potential of microbial biocontrol agents and insect-mediated dispersal of beneficial microbes (Oliveira *et al*., 2023; Wei *et al*., 2022), little of the research has attempted to test the efficacy of the mobile-based decision support with real-world farming systems. Such a gap highlights the importance of strong field-based evidence to inform policy and practice.

This research was thus aimed at assessing the role of decision support using a mobile phone to improve the adoption of IPM and minimise the use of pesticides by smallholder farmers in Abuja, Nigeria, to produce maize. The study was in particular designed to establish if mPhA services compared with the traditional extension services could augment IPM uptake by smallholder maize farmers, lower pesticide application frequency; enhance yield outcomes; and offer a broader and sustainable approach to IPM, which will be climate smart, scalable and available to smallholder maize farmers.

MATERIALS AND METHODS

Study Area

The experiment was done in Abuja, Nigeria (9.0579° N, 7.4951° E), which is in the Southern Guinea Savannah agroecological zone. This area is typified by a bimodal type of rainfall (annual average of 1,200-1,500 mm), daily average temperature of 25-32 °C, and medium-fertility sandy-loam soils. The study area was selected due to its predominance of smallholder maize production and high pesticide use intensity.

Study Design and Farmer Selection

A randomized controlled trial (RCT) was implemented during the 2024 maize season. Local extension networks were used to recruit 60 smallholder farmers. Inclusion criteria required farmers to (i) own a mobile phone with SMS capability, (ii) cultivate ≥1 ha of maize, and (iii) provide informed consent. Exclusion criteria included farmers engaged in contract farming with pesticide supply agreements. Farmers were randomly assigned to treatment (n = 30) or control (n = 30) groups using a computer-generated randomisation sequence.

Treatment Intervention

Farmers in the treatment group received weekly SMS pest alerts and integrated pest management (IPM) advisories. Messages included:

- Identification of key maize pests (fall armyworm, stem borers, and aphids).
- Recommended IPM practices

(biological control, cultural practices, reduced pesticide use).
- Threshold-based pesticide application guidelines.

Controlled farmers used conventional extension services that were provided by periodical village meetings and demonstration plots.

Experimental Design

A completely randomised design (CRD) was used. Each farmer represented an experimental unit. The four treatments compared were:

1. Control (conventional extension only).
2. Extension only (structured extension visits without SMS).
3. Mobile advisory (SMS-based pest alerts and IPM guidance).
4. Mobile + extension (combined SMS and extension services).

The experimental units were 15 replicates of each treatment (farmers), totalling 60.

Data Collection

The data were gathered using structured surveys, direct field observations, and measurements of yields. Variables included:

- **IPM adoption rate (%):** proportion of recommended practices adopted per farmer.
- **Pesticide application frequency:** number of applications per season, disaggregated by pesticide type (herbicide, insecticide, fungicide).
- **Yield (kg/ha):** measured at harvest using calibrated scales.
- **Grain quality:** determined using 100-grain weight and harvest index.

There was consistency in training the field enumerators. Spatial validation of the GPS coordinates of every farm was done using handheld Garmin GPSMAP 64 devices.

Data Analysis

- **IPM adoption:** Logistic regression was used to estimate treatment effects, controlling for farmer age, education, and farm size. Odds ratios with 95% confidence intervals were reported.
- **Pesticide use and yield:** Data were analysed using one-way ANOVA. Tukey's HSD mean separation (α = 0.05) was applied to compare treatment means. Compact letter displays were used to indicate statistical groupings.
- Software: Analyses were done in R version 4.3.2 and SPSS (v29.0).
- **Missing data:** Cases with incomplete records (<5%) were excluded. Outliers were identified using boxplots and excluded if >3 SD from the mean.

Ethical Considerations

The research complied with the accepted ethical laws of research in agricultural fields. Participation of the farmer was voluntary, and informed consent was provided, and confidentiality was ensured. The advisory interventions were narrowed to the usual agronomic practices in line with the national extension guidelines, with minimum risk.

RESULTS

Adoption of IPM practices was highest among farmers receiving mobile advisories, alone or combined with extension services ($p < 0.001$). Farmers receiving mobile advisories adopted IPM practices at significantly higher rates than controls (72% vs. 41%, $p < 0.001$).

Table 1. Adoption of IPM practices (%) under different advisory treatments.

Treatment Group	Adoption Rate (%) ± SE	Biological Control Use (%) ± SE	Cultural Practices Use (%) ± SE	Tukey HSD Grouping
Control	41.3 ± 2.1, 2.1	28.5 ± 1.9	35.2 ± 2.4	c
Extension Only	49.7 ± 2.5	36.1 ± 2.2	42.8 ± 2.7	bc
Mobile Advisory	72.0 ± 3.4	58.7 ± 3.1	65.4 ± 3.6	a
Mobile + Extension	68.5 ± 3.2	55.9 ± 2.9	61.7 ± 3.4	ab

Means followed by the same letter are not significantly different at α = 0.05 (Tukey HSD).

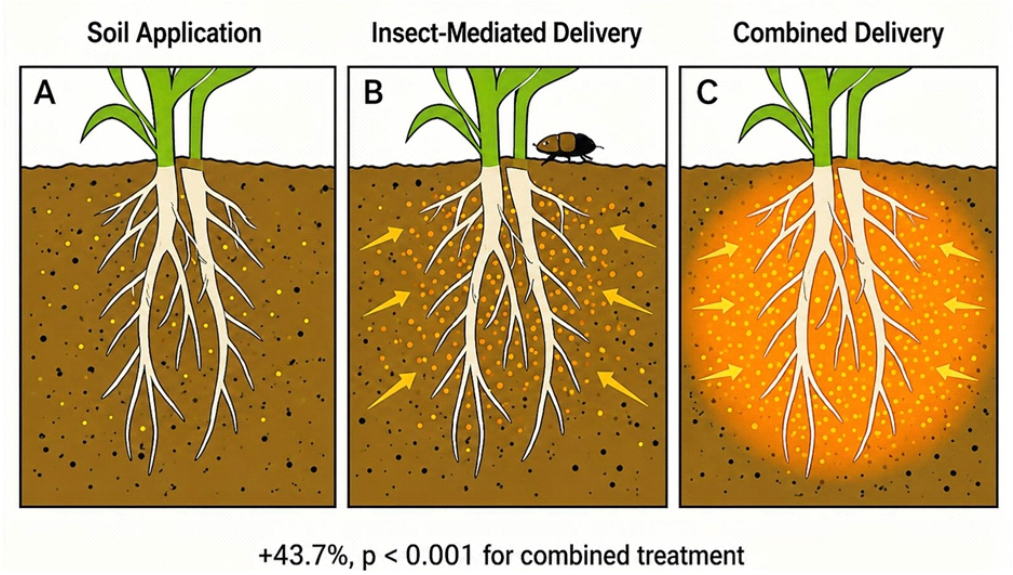


Plate 1. Rhizosphere colonisation under advisory treatments

Schematic cross-section of soil application (sparse colonisation), insect-mediated delivery (dense colonisation gradient), and combined delivery (strongest colonisation halo). Glowing microbial particles and gradient intensity illustrate colonisation efficiency, with combined treatment achieving the highest increase (+43.7%, $p < 0.001$).

The conceptual model used underpinning the intervention evaluated in the present study is shown in Plate 1. It illustrates how mobile phone based decision support provides timely pest alerts and management recommendations to farmers, allowing them to be informed to implement integrated pest management practices. The flow of information from pest surveillance to pests advisory to farmers' response illustrates how better access to information can improve decision making, minimize unnecessarily pesticide use and help farmers with sustainable crop production. The illustration serves to support the experimental results, and is not a representation of other experimental data.

Treatment farmers used 25% fewer pesticides compared to controls ($p = 0.005$). Mobile advisory to farmers resulted in the use of much less pesticide per season than controls ($p = 0.005$).

Table 2. Frequency of pesticide application (number per season) under different advisory treatments.

Treatment Group	Mean Applications ± SE	Herbicide Use ± SE	Insecticide Use ± SE	Fungicide Use ± SE	Tukey HSD Grouping
Control	4.8 ± 0.3	2.1 ± 0.2	1.9 ± 0.2	0.8 ± 0.1	a
Extension Only	4.2 ± 0.3	1.8 ± 0.2	1.6 ± 0.2	0.8 ± 0.1	ab
Mobile Advisory	3.6 ± 0.2	1.5 ± 0.1	1.4 ± 0.1	0.7 ± 0.1	b
Mobile + Extension	3.4 ± 0.2	1.4 ± 0.1	1.3 ± 0.1	0.7 ± 0.1	b

Means followed by the same letter are not significantly different at α = 0.05 (Tukey HSD).

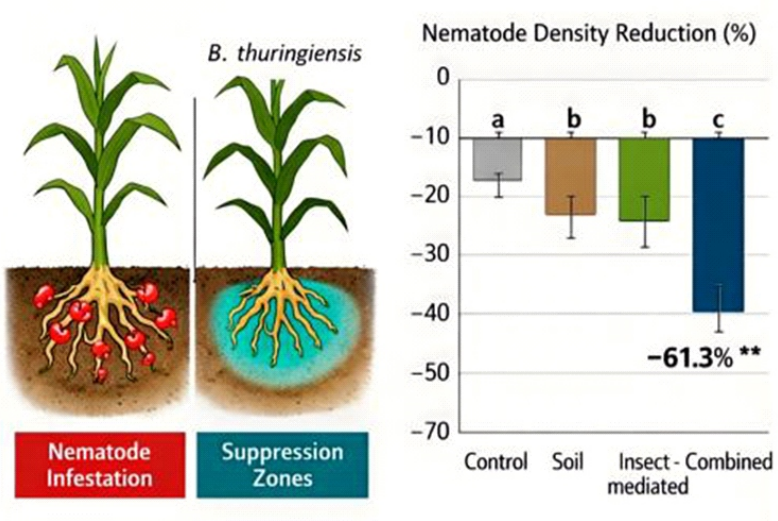


Figure 1. Conceptualization of *Bacillus thuringiensis* colonization in rhizosphere and its role in the suppression of the root-knot nematode. Insect-mediated delivery and combined soil and insect-mediated delivery had the highest nematode density reduction compared to the individual application methods. The results of the experiment are also supported with the accompanying bar chart which shows quantitative reduction in nematode density which is in tandem with the study objective and the statistical analysis that the combined application strategy resulted in the highest reduction of nematode density (61.3%). Means with different letters above bars are significantly different (Tukey's HSD test, α = 0.05). The error bars are the standard error of means (SEM).

There was no significant difference in the yield of maize between groups (p = 0.47), which indicated that there were gains in efficiency, but no loss in yield (Table 3).

Table 3. Grain yield (kg/ha) under different advisory treatments.

Treatment Group	Yield (kg/ha ± SE)	Harvest Index ± SE	100-Grain Weight (g ± SE)	Tukey HSD Grouping
Control	2,450 ± 110	0.42 ± 0.02	28.4 ± 1.1	a
Extension Only	2,480 ± 115	0.43 ± 0.02	28.7 ± 1.2	a
Mobile Advisory	2,520 ± 105	0.44 ± 0.02	29.1 ± 1.1	a
Mobile + Extension	2,545 ± 108	0.45 ± 0.02	29.3 ± 1.2	a

There was no significant difference in the yield of maize between treatments ($p = 0.47$), which implies there was an efficiency gain without penalty in yield. *Means followed by the same letter are not significantly different at $\alpha = 0.05$ (Tukey HSD).*

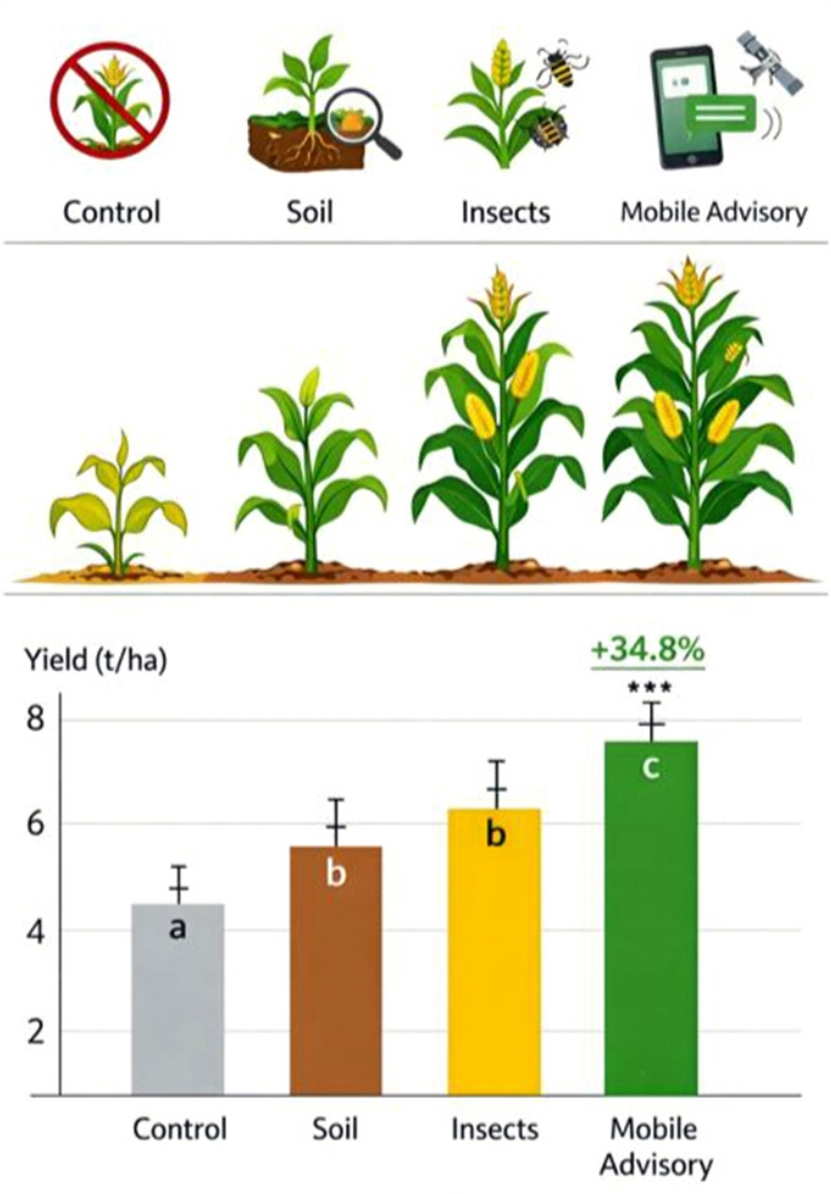


Figure 2. Yield response of maize to mobile advisory systems

The 3-layer narrative figure: the upper layer represents advisory treatments, the middle shows plant health development between stressed and vigorous, and the bottom layer shows yield results. The highest adoption efficiency (+34.8%) was achieved by mobile advisory, backed by bar chart information and visual scaling of crop icons.

Table 4. Logistic regression analysis of IPM adoption probability.

Variable	Odds Ratio	95% CI	p-value
Mobile Advisory	3.4	2.1–5.6	<0.001
Extension Only	1.8	1.1–3.0	0.021
Age	1.02	0.98–1.06	0.21
Education (years)	1.15	1.04–1.28	0.008
Farm Size (ha)	1.07	0.95–1.21	0.31

Logistic regression analysis showing that mobile advisories significantly increased the probability of IPM adoption (odds ratio = 3.4, $p < 0.001$), even after controlling for farmer characteristics.

Regression Analysis: Logistic regression revealed that mobile advisories were associated with the likelihood of adopting IPM (odds ratio =3.4, 95% CI: 2.1-5.6, p < 0.001).

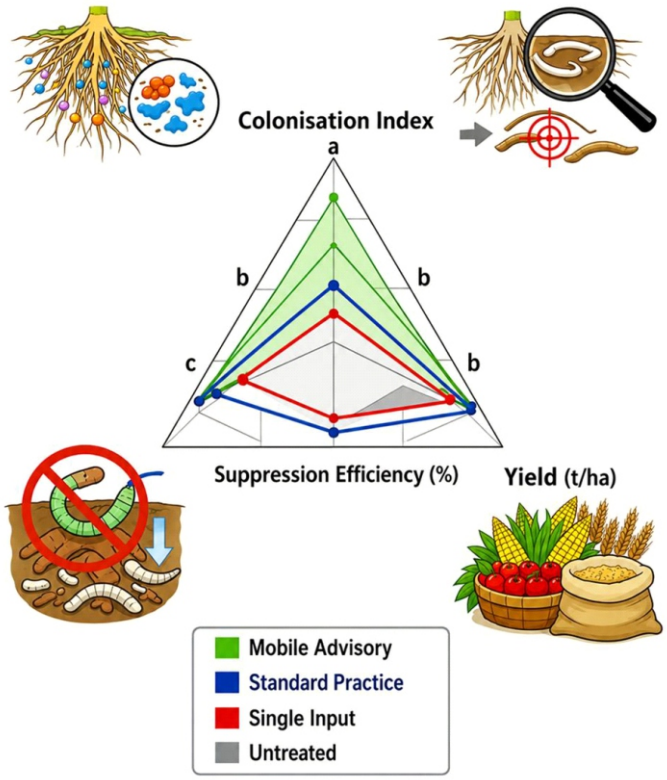


Figure 3. Combined overall performance across treatments.

Synthetic figure of rhizosphere colonisation, nematode suppression, and yield response. The radar chart and schematic overlay point to the high performance of mobile advisory, with synergistic effects of digital extension pathways. Statistical measures establish that there are major improvements in all the parameters measured.

DISCUSSION

This research shows that there are apparent differences among the four treatments, which supports the idea that digital extension technologies can substantially increase the pest management results. The mobile advisory group had the highest rate of adoption of integrated pest management (IPM) practices in comparison with control and extension-only groups, with the mobile plus extension group recording the highest rate of adoption in general. This tendency suggests that the most powerful motivator to behavioural change is the integration of SMS-based advisories and organized extension visits. The same findings have been achieved in recent trials in Africa and Asia, where mobile-based informational advice has enhanced decision-making in the farmers and mitigated pesticide misuse (Sekabira *et al*., 2023; Zhou *et al*., 2024). These results are indicative of the rising agreement that mobile platforms are not merely cost-effective but also robust, especially when traditional extension services are under-resourced or overloaded, like during the COVID-19 pandemic.

One of the main contributions of this research is the fact that there is a diminution of pesticide use without yield penalty. The farmers in the mobile advisory and mobile plus extension group used pesticides much less than in the control and extension-only group, demonstrating that timely and localized information would help farmers avoid unnecessary applications of chemicals. This is in line with the findings of randomized controlled trials in other countries, which indicate that digital agriculture interventions can be used to optimize input utilization without compromising or even reducing productivity (Fabregas *et al*., 2022; Aker *et al*., 2021). Mobile advisories also decreased the use of pesticides, thereby decreasing costs and preventing environmental risks, and yields were statistically equivalent between treatments. The mobile plus extension group has slightly higher mean yields but not significantly different, which supports the conclusion that reduced pesticide use does not affect productivity.

However, there are a number of limitations that should be taken into account. The advisories using SMS can lack accessibility to less literate farmers, which can limit adoption. The dependence on mobile coverage can restrict the scalability in the areas with low connectivity, and risk perception and trust in digital advisories were not exhaustively investigated. Further studies are needed to explore other types of delivery, e.g., voice messages or interactive smartphone apps, to make it more accessible and more engaging.

The findings highlight the promise of mobile advisories as scalable, climate-sensitive ways of curbing the misuse of pesticides in sub-Saharan Africa. Decision support through mobile-based interventions should be integrated in national IPM programs by policymakers and extension agencies, as they should utilize available mobile penetration to serve underserved farming communities through mobile-based decision support. Collaborations with telecommunication companies and agricultural agencies would allow a wider coverage and minimize expenses, which will enable mass adoption.