Effect of a Smartphone-Based Diagnostic Application on Tomato Farmer Disease Identification Accuracy: A Controlled Field Evaluation in Northern Nigeria

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Abstract: Smallholder tomato farmers in Northern Nigeria correctly identify major fungal diseases only about 41% of the time using unaided visual inspection, contributing to fungicide misapplication and avoidable yield loss. This study evaluated the field impact of SmartfarmerApp, a smartphone-based diagnostic application built on a validated convolutional neural network, on farmer disease identification accuracy. A pre-test/post-test controlled design allocated 240 tomato farmers across eight Local Government Areas in Kano and Kaduna States to an intervention group (n = 120, received the application) or a control group (n = 120, continued with conventional information sources), using computer-generated random allocation stratified by location and gender. Disease identification accuracy was assessed with a standardised 10-item photographic test at baseline and after one growing season. Intervention-group accuracy rose from 41.0% to 78.0%, compared with 41.0% to 42.0% in the control group. Analysis of covariance, controlling for baseline score, farming experience, and smartphone ownership, confirmed a statistically significant intervention effect, $F(1, 235) = 94.28$, $p < .001$, partial $\eta^2 = 0.286$. A difference-in-difference estimate indicated a net improvement of 3.6 percentage points attributable to the intervention (95% CI [3.2, 4.0]), exceeding the pre-specified minimum meaningful difference of 2.0 points. Application usage logs showed sustained engagement, with 68.6% of intervention farmers scanning at least weekly over the five-month evaluation period. These findings indicate that a locally developed, offline-capable diagnostic application can produce a substantial, practically meaningful improvement in smallholder farmer diagnostic accuracy under real field conditions.

Keywords: *Mobile Application, Field Trial, Diagnostic Accuracy, Smallholder Farmers, Difference-in-Difference, Tomato, Nigeria.*

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I. INTRODUCTION

Effective tomato disease management depends on farmers correctly identifying the causal disease before selecting and applying a fungicide. In Kano and Kaduna States, Nigeria, baseline assessment found that unaided farmer visual diagnosis is correct only 41.0% of the time, consistent with documented farmer knowledge gaps and fungicide misuse across the same states (Balogun et al., 2023; Yakubu et al., 2024). This diagnostic gap is plausibly linked to broader documented economic losses from tomato disease in the region (Mohammed et al., 2023; Usman & Mohammed, 2023), since incorrect diagnosis leads to ineffective or unnecessary fungicide applications.

Mobile-based decision support tools have shown generally positive effects on farmer practice in developing-country contexts (Ahmed et al., 2023), and deep learning-based diagnostic applications for other crops have demonstrated field-relevant accuracy (Ramcharan et al., 2023). However, evidence on whether such tools measurably improve farmer diagnostic accuracy — as opposed to laboratory model accuracy alone — remains comparatively limited for West African smallholder tomato systems.

This study evaluated, in a controlled field design, whether access to a validated smartphone-based diagnostic application improved farmer disease identification accuracy relative to a control group receiving no such tool, and examined patterns of farmer engagement with the application over one growing season.

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II. METHOD

Design and Participants

A pre-test/post-test controlled design was implemented across eight LGAs in Kano and Kaduna States. A total of 240 tomato farmers (30 per LGA) were enrolled using stratified random sampling with a minimum 30% female representation per LGA, and randomly allocated to an intervention group (n = 120) or a control group (n = 120) using a computer-generated random sequence stratified by LGA and gender. At baseline, 168 (70.0%) participants were male and 72 (30.0%) female; mean age was 38.4 years (SD = 9.7); mean farming experience was 11.2 years (SD = 6.4); and smartphone ownership was 28.3%. Baseline disease-identification accuracy did not differ between groups, $t(238) = 0.43$, $p = .67$, supporting adequacy of randomisation.

Intervention

Intervention-group farmers received SmartfarmerApp, a Hausa-language, offline-capable Android application built on a MobileNetV2 convolutional neural network validated at 91.8% on-device diagnostic accuracy across ten tomato disease and health classes, with strong agreement with expert pathologist assessment ($\kappa = 0.89$) in prior validation work. Farmers photographed symptomatic leaves and received an on-device disease classification with corresponding management guidance. Control-group farmers continued using their usual information sources (neighbours, agrochemical dealers, extension agents, or unaided visual inspection) without access to the application.

Outcome Measurement

The primary outcome was disease identification accuracy, assessed using a standardised 10-item photographic test (laminated cards showing the five target diseases at two disease stages each) administered by trained enumerators at baseline and after one growing season (endline). Enumerators scoring the test were blind to group allocation where logistically feasible. Application usage (scans, module views) was logged automatically by the application for intervention-group farmers.

Statistical Analysis

Analysis of covariance (ANCOVA) compared endline accuracy between groups, controlling for baseline score, farming experience, and smartphone ownership. A difference-in-difference (DiD) estimate quantified the net improvement attributable to the intervention. Because only two measurement waves (baseline and endline) were available, the parallel-trends assumption underlying DiD could not be directly verified; results are therefore interpreted as indicative of relative improvement rather than as a strictly causal estimate, consistent with the intervention-effect heterogeneity documented in reviews of comparable mobile advisory tools (Ahmed et al., 2023). All analyses used IBM SPSS Statistics Version 26.0 (IBM Corp., 2022).

III. RESULTS

Baseline and Endline Accuracy

Intervention-group mean accuracy rose from 4.1/10 (41.0%, SD = 1.1) at baseline to 7.8/10 (78.0%, SD = 0.9) at endline, a gain of 3.7 points (37.0 percentage points). Control-group accuracy showed negligible change, from 4.1/10 (41.0%, SD = 1.3) to 4.2/10 (42.0%, SD = 1.2), a gain of 0.1 points (see Table 1).

Table 1 Baseline and Endline Disease Identification Accuracy (Scores out of 10), by Group

Group	Baseline M (SD)	Endline M (SD)	Change	Change (%)
Intervention (n = 120)	4.1 (1.1)	7.8 (0.9)	+3.7 (1.1)	+37.0%
Control (n = 120)	4.1 (1.3)	4.2 (1.2)	+0.1 (0.8)	+1.0%
Net DiD Effect	—	—	+3.6	+36.0%

Intervention Effect

ANCOVA confirmed a statistically significant intervention effect on endline accuracy after controlling for baseline score, farming experience, and smartphone ownership, $F(1, 235) = 94.28$, $p < .001$, partial $\eta^2 = 0.286$, adjusted $R^2 = 0.309$. The net difference-in-difference effect was +3.6 points (95% CI [3.2, 4.0]), exceeding the pre-specified minimum meaningful difference threshold of 2.0 points.

Application Usage

Usage logs were available for 118 of 120 intervention farmers (98.3% completeness). Farmers scanned suspected diseased leaves a mean of 14.3 times (SD = 2.2) over the five-month evaluation period, and 68.6% scanned at least weekly, indicating the application was integrated into routine farm monitoring rather than used only during the initial novelty period of the trial.

IV. DISCUSSION

Intervention-group farmers nearly doubled their disease identification accuracy over one growing season, while the control group showed negligible change, and the ANCOVA-adjusted effect was both statistically significant and, at 3.6 points, comfortably above the pre-specified threshold for practical meaningfulness. This magnitude of improvement is consistent with the generally positive intervention effects reported for mobile crop disease management applications in developing-country contexts (Ahmed et al., 2023), and with field deployments of mobile deep-learning diagnostic tools for other African staple crops (Ramcharan et al., 2023). High weekly engagement (68.6%) further suggests farmers found the tool sufficiently useful to incorporate into ongoing practice rather than abandoning it after initial curiosity.

The gap between farmers' post-intervention accuracy (78.0%) and the underlying model's validated on-device accuracy (91.8%) is worth noting: farmers did not simply

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defer to the application's output on every occasion, and the identification test measured farmer knowledge and recall rather than direct application use during testing. This gap may reflect partial adoption, situations where farmers did not have the application available, or genuine learning transfer that remains imperfect after one season; distinguishing between these explanations is a priority for follow-up work.

This study has limitations. The evaluation covered one growing season at prototype stage rather than a full multi-season randomised controlled trial, and while allocation was randomised, neither farmers nor enumerators could be fully blinded to group status given the visible nature of smartphone application use. The absence of intermediate measurement waves prevents direct verification of the parallel-trends assumption underlying the difference-in-difference estimate, so this figure should be read as indicative of relative improvement rather than a definitive causal effect. Generalisation beyond Kano and Kaduna States, and beyond the five target diseases, has not been established.

V. CONCLUSION

A controlled field evaluation found that access to a validated smartphone-based diagnostic application produced a statistically significant and practically meaningful improvement in tomato farmer disease identification accuracy, alongside high sustained engagement over one growing season. These findings support continued investment in, and scale-up piloting of, locally developed diagnostic applications as a complement to conventional agricultural extension in smallholder tomato systems, and justify progression to a full multi-season randomised controlled trial with yield and fungicide-use outcomes.

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