ABSTRACT

In 2019, Nigeria approved the commercial release of a transgenic pod-borer insect-resistant (PBR) cowpea variety. The new variety is expected to generate yield gains of at least 20 percent and can reduce the costs of and exposure to pesticide applications, with particular benefit to female-headed households that represent a relatively large share of households engaged in cowpea production. However, the dissemination of the PBR variety is still in its early stages, such that awareness and adoption are still limited. The primary objective of the study is to estimate the impact of PBR cowpea on key productivity, income, environmental, and social outcomes at the household and farm levels in Nigeria's main cowpea-producing regions. The study will use a cluster randomized controlled trial (c-RCT) with an encouragement design highlighted by two treatment arms. The evaluation will randomly select communities who receive PBR cowpea seed packages. There will be two treatment groups: Treatment 1 (T1) will receive PBR cowpea plus fertilizer and pesticide for 2 kg of PBR cowpea package; and treatment 2 (T2) will receive only 2 kg of PBR cowpea package. The control group (C) will receive conventional cowpea seed packages. The study will collect and analyze data from baseline, midline, and endline surveys of treatment and control farmers to estimate the causal impacts of the intervention on PBR cowpea adoption, yields, returns, pesticide use, refugia use, and other outcomes of interest. Additional analysis on the underlying mechanisms will be conducted with the help of qualitative data obtained from key informant interviews and focus group discussions with farmers, extension agents, market actors, and other stakeholders in the cowpea value chain. Findings will be used to inform an analysis of the cowpea value chain in Nigeria and the potential opportunities and constraints that may influence PBR cowpea adoption, production, and market sales.

INTERVENTION(S)

The study uses an encouragement design in a cluster randomized controlled trial (c-RCT) combined with qualitative research to estimate the impact of PBR cowpea on key productivity, income, environmental, health, and social outcomes at the household and farm levels in Nigeria's main cowpea-producing regions. The study will be conducted within randomly selected communities located in Local Government Areas (LGAs, or sub-state administrative units that are similar to districts or counties) in the two main cowpea-cultivating states of Nigeria. The intervention will be conducted during a single growing season in 2023.

Participants in selected communities will be randomly assigned to one of two treatment groups or the control group. There will be two treatment groups: Treatment 1 (T1) will receive PBR cowpea plus fertilizer and pesticide for 2 kg of PBR cowpea package; and treatment 2 (T2) will receive only 2 kg of PBR cowpea package. The control group (C) will receive conventional cowpea seed packages. This encouragement design will estimate the impact of PBR cowpea under somewhat optimal conditions, i.e., conditions that farmers may not necessarily face in the future when markets and services for PBR cowpea seed distribution, information provision, and complementary inputs expand in the future. These optimal conditions include providing farmers with cowpea seed (PBR cowpea seed for treatment group farmers, and non-PBR cowpea seed for control group farmers), information on cowpea cultivation and management (including the planting of refugia to discourage rapid emergence of resistance to the PBR trait), and complementary inputs (primarily fertilizer and pesticides). This is deemed necessary for the evaluation because the first PBR cowpea variety was released in Nigeria only in 2019 and promotion efforts are still at a very nascent stage, implying that most farmers are generally not yet aware of or familiar with the variety. These optimal conditions are standardized between treatment and control groups to incentivize uptake at levels and rates required to minimally detect the effects of the intervention.

While our research design will allow us to quantify the overall and relative impacts of the incremental treatment arms of the intervention, it will also facilitate further heterogeneity analyses on potential differential impacts across groups of individuals by gender and education. Identifying the relative,

heterogeneous and impacts of these interventions is crucial to designing cost-effective and scalable approaches to address gender gaps in PBR cowpea agricultural productivity in Nigeria.

PRIMARY OUTCOMES

Primary Outcomes (end points)

1. Cowpea productivity
2. Cowpea profitability
3. Pesticide use
4. Health outcomes related to pesticide use

Secondary outcomes

1. Adoption of PBR cowpea
2. Consumption of cowpea
3. Food availability and nutrition
4. Labor use and costs
5. Marketing and commercialization

Primary Outcomes (explanation)

1. Cowpea productivity: Cowpea yield (kg/ha), production index
2. Cowpea profitability: Gross revenue from cowpea output minus costs of cowpea production (NGN/ha; production cost/revenue indices)
3. Pesticide use and costs: measured in terms of number and type of pesticide products applied; labor-days used in pesticide application (days/household); quantity of pesticides applied (kg/ha or l/ha); and costs of pesticide use (NGN/ha)
4. Health care use and costs: visits to health facilities for symptoms related to pesticide exposure (no./person); cost of health services related to pesticide exposure symptoms (NGN/person); number of days lost due to pesticide exposure symptoms or accessing health care services (days/person); health care use and cost index

Secondary Outcomes (explanation)

1. Adoption of PBR: Farmer expected adoption of PBR varieties used in the intervention subsequent seasons, measured as: a binary variable (1=adoption; 0 otherwise); the share of total operated farm area under cowpea cultivation (%); and the share of total area under cowpea cultivation (%).
2. Consumption of cowpea: Consumption of own-produced cowpea (measured in terms of appropriate quantities per person, per household, and per adult equivalent for a selected time recall periods); consumption index.

3. Labor use and costs: measured in terms of number and type of labor use; labor-days used in planting, production and harvesting by gender and hired labor for cowpea production (number of days worked).
4. Marketing and commercialization: Cowpea output sold to market vs. saved for home consumption (kg/ha, %); gross revenue from cowpea sold to market and its share of total household farm revenue (NGN/ha, %); commercialization index.

EXPERIMENTAL DESIGN

1. Overview

The study uses an encouragement design in a cluster randomized controlled trial (c-RCT) combined with qualitative research to estimate the impact of PBR cowpea on key productivity, income, environmental, health, and social outcomes at the household and farm levels in two of Nigeria's main cowpea-producing regions (Adamawa and Kwara states). In this study, the unit of randomization is a community in a Local Government Area (LGAs or sub-state administrative units that is similar to districts or counties) and the unit of analysis is the farm-household.

LGAs will be randomly assigned to one of the three treatment or control groups as detailed below:

- Treatment Group 1 (T1) will receive PBR cowpea seed, associated information on its cultivation and management, and complementary inputs.
- Treatment Group 2 (T2) will receive PBR cowpea seed and associated information on its cultivation and management.
- Control Group (C) will receive conventional (non-PBR) cowpea seed, associated information on cultivation and management, and complementary inputs.

2. Sampling

The study uses a multistage sampling procedure to select the states, LGAs, communities and households included in the study. In the first stage, we purposively select Adamawa and Kwara state in North-East of Nigeria. Both states are among the top cowpea-producing states in Nigeria. Moreover, both states provide acceptable conditions to research because they currently enjoy a relatively stable security situation when compared to other major cowpea-producing states in Nigeria.

The second sampling stage involves the purposive selection of four LGAs from 25 LGAs of Adamawa state and four LGAs from the 16 LGAs of Kwara state. These eight LGAs from both states were chosen because there is no PBR cowpea penetration in these areas, and it is expected to remain unchanged by the time of the intervention. The four selected LGAs in each state are similar across important contextual factors including size, socioeconomic and agroclimatic conditions, and road and market access. From the eight LGAs, we select 240 communities that are also similar across contextual factors, with eighty communities for the control group and the remaining 160 communities for the treatment groups. Within each community, we then list all households, from which we randomly selected five cowpea farmers to participate in the study, including from the control communities, for the baseline and end line surveys. We estimate the sample size of 400 farm households for the treatment group 1, with 400 farm households for the treatment group 2, and with 400 farm households for the control group. To account for the attrition rate, we increased the sample size by 200 households. As all communities (treatments and control groups) are selected randomly, adding 200 households to either group has no effect. Thus, we added 200 households from communities in treatment 2 to our sample. Within each community, we then list all households that cultivate cowpea and randomly select 5 cowpea farming households to participate in baseline, midline, and endline survey rounds.

To minimize the possibility that our study design is compromised during the intervention rollout (e.g., units selected for treatment may not, in fact, receive the treatment, or may not receive it in the fashion that was intended by the intervention), a field team comprised of research assistants and extension agents will regularly visit the study sites, engage with the local staff of the study's

implementing partner, monitor progress, and report back to the evaluation team. To assist farmers in following the recommended PBR cowpea practices, dedicated extension agents will be contracted. The timely application of insecticides will require not only supervision but also training for safe handling and application.

The evaluation team has been working with technology developers, the African Agricultural Technology Foundation (AATF) and its partners (including private local seed companies) to ensure access to necessary data and cooperation for the evaluation team, while maintaining the independence of the evaluation team. We have closely collaborated and gathered inputs from a diverse set of stakeholders, including USAID, the Institute of Agricultural Research (IAR, Zaria), the National Biotechnology Development Agency (NABDA), the Open Forum on Agricultural Biotechnology (OFAB) Nigeria Chapter, the National Biosafety Management Agency (NBMA), the Federal Ministry of Agriculture and Food Security (FMAFS), the Adamawa and Kwara state ministries of agriculture, extension officers, and the seed companies operating in the project study area.

3. Timing and duration

In the Northern Guinea Savanna agro-ecological zones of Adamawa and Kwara states, which is where the study will be implemented, there are two cowpea cropping seasons: wet season, which runs from August to December and dry season, which runs from February to July. This study will be implemented during the wet crop season in late 2023, with the rollout of the intervention beginning just prior to the season.

4. Treatment Effects

The study's main outcome of interest—the effect of the pod borer-resistance trait on cowpea productivity and profitability—will be estimated by comparing average yields (kg/ha) and profits (NGN/ha)—between T2 and C. Additional outcomes include the incremental effect of providing treated farmers with an input package, which will be estimated by comparing the average household-level yield between T1 and T2. The additional outcomes described earlier (awareness, uptake, adoption, productivity, profitability, pesticide use and costs, health care use and costs, consumption, and marketing and commercialization) will be estimated to evaluate the study's underlying theory of change, impact pathways, and mechanisms behind the observed effects. This will be supplemented with qualitative research conducted in the study area and within the study communities.

5. Data Collection

The unpredictability inherent in rainfed smallholder agriculture, including factors like pest and disease pressures, temperature and precipitation fluctuations, and volatile input and commodity prices, often results in significant year-to-year variations in yields and prices. Consequently, outcomes such as yields and profits tend to exhibit moderate to low levels of autocorrelation.

Additionally, the trial conducted in a small plot area using two kilograms of cowpea seeds and the comparison between baseline and midline surveys may not be suitable for our analysis. Nevertheless, the baseline survey provided an opportunity to average out noise when measuring time-invariant characteristics, generate a detailed descriptive analysis of the study site, context, and

sample, and ensure that randomization was implemented according to the study protocol and that the sample is appropriately balanced.

The choice of variables for the baseline survey is based on those used by similar studies in their orthogonality tests. In particular, the study will collect data on variables that are commonly considered in prior studies that investigate the adoption of yield-improving and damage-abating agricultural technologies and practices using both RCTs and non-experimental studies (Duflo, et al., 2011; Karlan et al., 2014; Ashraf, et al., 2009; Bulte et al., 2014). The survey will collect data from the sampled households with 12 modules arrayed in a survey instrument based on computer-assisted personal interviewing. Modules will cover household demographics (household size, age, education of household members), agricultural and non-agricultural assets, access to markets and public services (distance to the nearest agro-input shop and road, access to extension services). In addition, detailed information will be collected on household cowpea cultivation (input use and management practices), consumption, and marketing, as well as health symptoms and care.

The midline survey will re-survey the same sampled households in 2024, approximately one year after intervention rollout, and will feature similar modules, with an emphasis on cowpea cultivation, consumption and marketing. Similarly, the endline survey will re-survey the same sampled households one year later after the midline survey to capture sustained adoption and dis-adoption dynamics (Abate et al., 2023) and to provide insight on impacts over a longer term. Both the midline and endline survey will also aim to collect data on unintended (positive and negative) consequences of the adoption of PBR cowpea, e.g., a decrease in pest pressure affecting cowpea across the community. Although we do not anticipate a significant or systematic attrition rate during the intervention or between survey rounds, the study will conduct tests to explore attrition bias resulting from households dropping out of the study during or after the intervention.

Heterogeneity and spillover effects

The study will also analyze heterogeneous effects among specific household types such as female-headed plots (a phenomenon that is relatively prevalent in the study site), youth-headed households, and households categorized by wealth (assets), education level, or other differentiating factors that are relevant to the sampled population and study context.

The study will also examine the potential spillover effects of the intervention whereby untreated community members may nonetheless benefit from the intervention. It is hypothesized that in this study context, spillovers are likely to occur for several reasons. First, because the randomization is conducted at the community (rather than individual) level, there is more scope for peer learning effects or information sharing that could benefit untreated community members in a similar manner as treated community members. Second, non-treated households may benefit from PBR cowpea because seed can be easily exchanged between community members at a nominal cost via social reciprocity mechanisms, through non-market channels, or through other mechanisms. Third, PBR cowpea can itself generate spillover effects by reducing pest pressures at a within-community/micro-landscape level, or in areas adjacent to or at a short distance from the plot in which it is initially cultivated.

To minimize spillover effects, we distribute only 2 kg of PBR cowpea and inputs within the treatment communities, establishing clear boundaries between clusters to restrict the potential for sharing these limited resources. Our extensive monitoring activities, from field preparation to harvesting, serve to further mitigate spillover effects. Additionally, the sample size within each cluster is increased to enhance statistical power and precision, enabling an accurate assessment of direct

effects while minimizing the risk of cross-cluster contamination. Furthermore, our survey includes questions on the utilization of these resources.. Through this c-RCT design, we minimize spillover effects, ensuring the study's internal validity and treatment comparisons' integrity.

Experimental Design Details

See details above

Randomization Method

We will randomize the level of community using a complete listing of communities that have that cultivate cowpeas for at least two seasons prior to the intervention. Communities will be randomly assigned to the three arms of the experiment (T1, T2, or C) using a random number generator.

Randomization Unit

Communities within Local Government Areas

Was the treatment clustered?

Yes

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