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Impact Evaluation of the Use of PBR Cowpea in Nigeria

Baseline Process Evaluation Report

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ACRONYMS

AATF	African Agricultural Technology Foundation
ADP	Agricultural Development Project
FGD	Focus group discussion
GM	Genetically modified
IE	Impact evaluation
IFPRI	International Food Policy Research Institute
ISAAA	International Service for the Acquisition of Agri-biotech Application
LGA	Local government area
OPV	Open pollinated variety
PBR	Pod-borer resistant
PE	Process evaluation
PIP	Program impact pathway
RCT	Randomized controlled trial
SSA	Africa South of the Sahara
SSI	Semi-structured interview

EXECUTIVE SUMMARY

This process evaluation (PE) is part of a five-year (2021–2026) impact evaluation (IE) of the use of a new pod-borer-resistant (PBR) cowpea variety in Nigeria, a project led by the International Food Policy Research Institute (IFPRI) and funded by the United States Agency for International Development (USAID). While the IE draws from a representative sample of 1,399 farmers to determine the causal impacts of the use of PBR cowpea, the PE complements the IE by exploring in detail the potential adoption of the PBR cowpea variety and the reasons for adoption or non-adoption, including its potential impacts on actors throughout the value chain.

A program impact pathway (PIP) is the basis of this PE. The PIP identifies how impacts emerge from program inputs, processes, outputs, and outcomes to highlight barriers and facilitators of adoption. Given that this PE was conducted before the rollout of PBR cowpea in the IE, the analysis focuses on the potential of this innovative seed to achieve positive outputs and outcomes based on the PIP. Qualitative data were gathered from eight focus group discussions with farmers and 180 semi-structured interviews conducted with farmers, extension agents, seed dealers, and cowpea traders from eight local government areas (LGAs) in the states of Adamawa and Kwara. Given that the data are qualitative, the data are not representative. However, important insights were found that can help guide the IE.

The analysis of the PE data yielded the following major finding:

- **Information about PBR cowpea:** Farmers, input dealers, cowpea traders, and extension agents in the study area—at this time, early in the dissemination process of this new variety—have little or no knowledge about the PBR cowpea variety.
- **Non-availability of PBR cowpea:** None of the farmers in the study area were cultivating the PBR variety in early 2023. Nonavailability of the seed in the market was cited as the main reason for non-adoption. However, farmers expressed their willingness to adopt the PBR variety if seeds were readily available.
- **Seeds:** Farmers in the study areas plant mainly conventional (noncertified) cowpea varieties, with a very small percentage growing improved certified hybrid varieties. Most of the seeds planted are recycled and shared among farmers. Farmers stated that the primary reasons for using mainly recycled seed were affordability and ease of access.
- **Farmer seed trait preferences:** Farmers' preferred seed traits are high yield, pest resistant, marketable, early maturing, better tasting, require less cooking time, and drought tolerant. Given that the new PBR cowpea seed meets several of these criteria, farmers expressed interest in it.

- **Production constraints:** The most important cowpea production challenge cited by farmers is high pest infestation, followed by high costs of seeds and pesticides, inadequate financial capital, poor soil fertility, lack of storage facilities, limited extension service, and weather-related factors such as flooding and drought. With poor access to credit and the high cost of pesticides, farmers find it difficult to purchase these inputs. Some of these factors, such as high pest infestation and rising pesticide costs, could increase the future demand of PBR seeds.
- **Health impacts:** Despite the high cost of insecticides, because of the high insect infestation and the use of varieties that are not insect resistant, farmers need to spray numerous times. Most farmers reported a general increase in health-related symptoms associated with their insecticide use. In addition to men farmers applying pesticides (i.e., herbicides and insecticides), youth apply pesticides, which raises concerns for their health as well.
- **Commercialization:** Farmers earn income from the sale of cowpea, as most of the cowpea produced is sold as whole beans rather than processed product, suggesting that value addition is very minimal (in support of the production–income pathway).
- **Importance of cowpea in diets:** Cowpea has an important subsistence role in household diets, contributing to food and nutritional food security (in support of the production–consumption pathway). The sale of cowpea as a food grain dominates that of fodder on the market, suggesting that cowpea is very important for human consumption. For instance, farmer households prepare cowpea grains for different meals, such as moin-moin (bean pudding) and kosia or akara (bean cake), which are consumed at home. Given that the PBR cowpea seed shows improved yields, it has the potential to positively affect food security among cowpea-producer households.
- **Gender:** Women have less decision-making power compared with their male counterparts in cowpea production, such as about how much cowpea to produce and decisions on input use (e.g., the variety to grow and how much money and household labor to devote to cowpea production). However, in some cases, women have decision-making power regarding how much cowpea to keep for home consumption and use of the money from the sale of cowpea.

On the basis of these findings, the following recommendations are put forward to guide the implementation of the PBR cowpea intervention:

- **PBR adoption:** To increase PBR cowpea adoption, it is critical to highlight the variety's benefits for pest resistance to the legume pod borer (and thus reduced pesticide use),

higher yields, and potential improved marketability. Given that women play an active role in many activities in the production and sale of cowpea, it is important to get their buy-in as well.

- **Soil health:** Given the challenge with soil fertility in the study areas, any intervention to provide PBR cowpea seeds should include fertilizer to maximize the potential gains of PBR cowpea through increased yields.
- **Farmer awareness:** Limited awareness and access to information on PBR cowpea seeds are major adoption constraints. Therefore, providing more awareness about the PBR cowpea variety and its benefits through extension platforms is critical to ensure its adoption.
- **Availability of PBR cowpea seeds:** Given that there are no PBR cowpea seeds available in the markets in the study areas as at the time of the interviews in early 2023, it is paramount to improve producers' access to this new variety.
- **Low existing adoption of certified seeds highlights the need for lower input costs:** Farmers plant mostly recycled seeds because of the high cost they associate with buying certified seeds. Any intervention aimed at providing certified seeds, such as PBR cowpea, should consider the cost implications for farmers and emphasize that while the upfront costs are higher compared with recycled seeds, farmers will spend less on pesticides and may have higher yields that contribute to increased marketability of their product. In addition, in the long term, farmers who adopt PBR cowpea may face lower health costs and more productive working days because of reduced pesticide application.
- **Like any other technology, PBR cowpea is not a silver bullet:** Farmers indicated that pests and diseases are their major production constraints. While PBR cowpea is resistant to the devastating *Maruca vitrata*, it is important to keep in mind that it is not resistant to other types of pests and diseases affecting cowpeas, such as aphids, flower bud thrips, and the cowpea weevil.

In conclusion, through qualitative insights, this PE uncovered some facilitators and barriers to adopting the PBR cowpea variety. Insect and pest infestations remain a major challenge for cowpea production in the study area. The use of insecticides to control these insects is on the rise, which farmers associate with adverse health effects and additional production costs. Therefore, providing the PBR cowpea variety will aid in not only improving farmers' cowpea yield, household income, and food security, but also may reduce insecticide use, with some potentially associated health benefits, for one of this crop's major insect pests. However, the PBR variety is not readily available on the market, and knowledge about the variety among

key actors, such as farmers, is very low. Farmers indicated a willingness to adopt PBR cowpea if the seeds were available. Improving awareness about the variety among key actors and making the variety easily accessible will improve their understanding and adoption of the variety.

1. INTRODUCTION

This section provides a brief background on genetically modified (GM) crops and seed systems in Africa and, more specifically, in Nigeria, and it introduces the pod-borer resistant (PBR) cowpea and motivation for the study. The section ends with the study's research objectives and questions.

1.1 A brief background on genetically modified crops and seed systems in Africa

In many developing economies, households still depend on the agricultural sector for livelihood support. However, persistent low agricultural productivity and limited transformation of food systems are significant hurdles to improving welfare (Fuglie, Wang, and Ball 2012; Martey, Etwire, and Mockshell 2021). Several development interventions prioritize increasing agricultural productivity as a viable pathway to improving farmers' welfare, including increasing access to technologies, such as fertilizer, improved seed varieties, and technical knowledge (Martey, Etwire, and Mockshell 2021). GM crops offer one additional solution to food insecurity and low agricultural productivity in sub-Saharan Africa through increasing crop yield, reducing input use, and improving crop quality (Arthur and Yobo 2014; Brookes and Barfoot 2014). However, their commercialization in some developing and developed countries has been slower. Despite substantial evidence that GM crops are beneficial to farmers and for the environment (Brookes and Barfoot 2018) and pose minimal safety concerns for consumers (WHO 2023), political and regulatory issues, often including mis- and disinformation about this technology, have affected progress in some countries (Arthur and Yobo 2014; Gbadegesin et al., 2022; Mabaya et al. 2015; Smyth 2017).

Despite the benefits that GM crops could provide for African economies, only seven countries have currently commercialized GM crops: cotton in South Africa, Sudan, Ethiopia, Kenya, Malawi, Nigeria, and Eswatini; soybeans and maize in South Africa; and cowpea in Nigeria. Indeed, based on data from the International Service for the Acquisition of Agri-Biotech Applications' (ISAAA) annual reports from 1997 to 2020 (ISAAA 2023), the adoption of GM crops is very limited in SSA and accounts for only 1.4% of the global area of GM crops. Several challenges, such as weak seed systems, weak intellectual property rights protection, institutional challenges (e.g., access to credit and complementary inputs), and the length of time it takes for policies, laws, and regulations on GM crops (e.g., biosafety bills), affects the commercialization and adoption of GM crops in Africa (Falck-Zepeda, Gruère, and Sithole-Niang 2013; Gbadegesin et al., 2022; Rock and Schurman 2020; Wafula et al. 2012). However, there are ongoing investments aimed at increasing access to and adoption of GM crops in Africa. These have focused on technical capacity building, regulatory expertise, and harmonizing of regional frameworks via groups like

the African Union, the African Agricultural Technology Foundation (AATF), and national research institutions (Gbadegesin et al., 2022).

Seed systems face several challenges despite their being integral to achieving food and nutrition security (McGuire and Sperling 2016). However, the seed systems in most countries in Africa South of the Sahara (SSA) are still relatively underdeveloped. Farmers typically rely on informal seed systems dominated by open- pollinated varieties and seed-saving practices (McGuire and Sperling 2013; Ragasa et al. 2013). The story is not different in Nigeria, where most farmers rely on the informal system (i.e., own-saved seeds and exchange with friends or relatives) to obtain their seeds (see, e.g., Wossen et al. 2017). Limited access to improved seeds due to underdeveloped and weak seed systems is partly responsible for low use of improved cowpea seeds in Nigeria (Iorlamen et al. 2021).

Studies have shown that factors such as variety-specific attributes, farmer characteristics (e.g., age, education, income, and gender), institutional factors (e.g., extension visits and group membership), and access to credit and financial resources are the key drivers of adoption of improved seed varieties (Timu et al. 2014; Melesse et al. 2023). Fisher et al. (2015) also identified factors such as limited availability of improved seed, lack of resources, high seed price, and perceived attributes of different varieties as main barriers to the adoption of improved seed in Africa. Preferences for seeds may differ by gender. However, differences may arise where men and women face different constraints, different roles and responsibilities in the production system, and different crop production goals, or if crops are grown predominantly by men or women (Anja et al. 2017).

For instance, reviewing gender preferences for maize attributes in Africa, Voss et al. (2021) found minor variations in the trait characteristics by gender. Also, in identifying gender varietal and trait preferences for maize in Nigeria, Benin, and Mali, Tegbaru et al. (2020) did not find any clear differences in preferences for drought-tolerant maize varieties and hybrids by men and women farmers. In most cases, they found that characteristics preferred by men are also valued by women. However, men tend to value characteristics such as marketability, while women focused more on food security traits such as grain color, taste, and appearance. In light of the literature, this study will examine differences in seed and trait preferences by socioeconomic characteristics.

1.2 Pod-borer-resistant cowpea

In 2019, Nigeria was the first country in the world to approve the commercial release of an insect-resistant, GM cowpea crop, the PBR cowpea (Addae et al., 2020; Akinbo et al. 2021). This commercial release was the first for a food crop in SSA, and it was a significant occurrence,

considering the importance of cowpea in Nigeria's agricultural economy (Nwagboso et al. 2024). Nigeria's commercial release of PBR cowpea may have set an example to be followed by other countries in SSA. PBR cowpea was approved for general environmental release in Ghana in 2022 and is now awaiting registration as a commercial variety (Abutu 2023). PBR cowpea expresses insecticidal proteins from the soil bacterium *Bacillus thuringiensis* (Bt) (Popelka et al. 2006). This soil bacterium is commonly used as a biopesticide in conventional and organic agriculture for its safe insecticidal properties. The Bt genes are used to control various insect pests, including lepidopterans such as the legume pod borer (*Maruca vitrata*). These Bt lepidopteran proteins are highly specific and not toxic to other insect classes, other organisms, animals, and humans. Legume pod borers are devasting to cowpea production because they reduce the size and quality of the harvest. Reductions of yields by up to 80% have been reported (AATF 2021). In addition, to combat legume pod borers, farmers spray their fields 6 to 10 times during the growing season, which aside from being often ineffective because the chemicals do not reach the pest larvae inside the plant structure), entails increased input costs and farmer-associated adverse health effects (AATF 2021). Given this cowpea variety's resistance to the legume pod borer, it has the potential to improve yields, reduce input costs, and reduce the adverse effects from pesticide use for cowpea farmers.

Ex-ante estimations of the benefits of Bt cowpea find high net returns for both consumers and producers (Gbègbèlègbè et al. 2015; Phillip et al., 2019). Applying an economic surplus partial equilibrium model, Gbègbèlègbè et al. (2015) estimated that assuming an efficient seed system with no trade barriers, the adoption of PBR cowpea could increase social welfare in Nigeria by US$625 million annually. The study also found that female-headed rural households in Nigeria are more likely to adopt PBR cowpea compared with male-headed households. Using an economic surplus model, Phillip et al. (2019) estimated that planting PBR cowpea could result in US$350 million net present-value benefits for producers and consumers over a 25-year period, with 70 percent of the benefits accruing to producers. These two studies estimate that adopting PBR cowpea could accrue positive outcomes. However, the nuanced factors affecting the adoption of PBR cowpea and the potential socioeconomic impacts on different value chain actors, including men and women, remain limited.

1.3 The motivation for this study

To gather evidence on the factors affecting adoption of PBR cowpea and potential impacts on value chain actors, USAID provided funding for a five-year (2021–2026) impact evaluation (IE) led by the International Food Policy Research Institute (IFPRI) to examine the impacts of

planting the new PBR cowpea variety and its effects on a variety of economic and food security conditions (Andam et al. 2023). As part of the IE, this process evaluation (PE) seeks to understand factors influencing the uptake of the PBR variety and its potential to influence a variety of socioeconomic factors among various actors. Given the importance of cowpea in Nigeria and the benefits associated with the PBR cowpea, such as increased yield, reduced pesticide use, and thus improved income, health, and food security, this study will help guide the IE by recommending measures that could lead to increased adoption.

The PE relies on qualitative data from semi-structured interviews (SSIs) and focus group discussions (FGDs) conducted with a variety of value chain actors, providing insights into these varying groups of people. For example, the PE not only examines the potential adoption of PBR cowpea among farmers, but also provides insights into the marketing of cowpea products and consumer preferences. Understanding consumer preferences is essential for assessing the market- driven impacts of cowpea production and targeting marketing campaigns to specific consumer groups. Furthermore, by interviewing men and women separately, gender-related aspects of cowpea production and intra-household decision-making regarding cowpea production are extensively explored. This gender-specific information is valuable for understanding the potential gender-disaggregated impacts of PBR cowpea adoption. To the best of our knowledge, this is the first study to date that uses a PE to examine the potential adoption of PBR cowpea variety in Nigeria since its commercial release in December 2019. The PE is critical to understanding the reasons behind adoption or non-adoption of PBR cowpea and how and why impacts may or may not occur from its adoption, which cannot be ascertained from an IE. This PE serves as an important addition to the IE because it explores the facilitators and challenges to adoption and can help improve the design of the PBR IE intervention. Overall, the IE can use the results from this PE to better assess the potential impacts of PBR cowpea adoption on women, men, and different value chain actors. The results can also be used to help guide future actions regarding the commercialization of PBR cowpea.

1.4 Study objectives

The main objectives of this PE are to understand farmers' preferences for cowpea attributes related to the PBR cowpea and the marketability of PBR cowpea in order to unravel the potential effects of the adoption of a PBR cowpea variety on farming households in Nigeria. More specifically, this study has the following five objectives:

1. Inform and complement the broader IE[1] conducted by IFPRI.
2. Establish a baseline program impact pathway (PIP) and gather insights for guiding

the subsequent rollout of PBR cowpea in Nigeria.

3. Examine the potential effects of the production and adoption of PBR cowpea at the farm and household level, including effects disaggregated by gender.
4. Examine the extent of the availability of PBR cowpea in the market and its performance and potential in local markets compared with conventional cowpea varieties.
5. Examine smallholder farmers' preferences for cowpea attributes, including preferences disaggregated by gender, and how these attributes align with the PBR cowpea variety.

1.5 Research questions

This baseline PE seeks to address the following research questions:

1. What are the effects of the potential production and adoption of PBR cowpea at the farm and household levels at different phases of production, such as cultivation, harvest, processing, and market preparation?
   Indicators: Pest infestation, costs of production including labor and other inputs, changes in production practices, production, profit/income, and food security.

2. How do smallholder farmers' preferences for cowpea attributes vary by gender, and how do these preferences align with the PBR cowpea variety's attributes?
   Indicators: Attribute preferences by gender, demand for PBR cowpea, and preferred preferences compared with the PBR cowpea's attributes.

3. Is PBR cowpea available in the market? If so, how does it perform in local markets compared with conventional cowpea? If not, what factors affect its market potential?

[1] The IE seeks to generate evidence on the impact of the newly introduced PBR cowpea variety SAMPEA-20T, developed by the USAID-funded "Feed the Future Innovative Maize and Cowpea Technologies to Increase Food and Nutrition Security in Africa, PBR Cowpea Sub-Activity (2020—2025)." The IE will collect from baseline, mid-line, and endline surveys. The IE will use a cluster randomized controlled trial (c-RCT) with two treatment arms and a control arm: PBR cowpea adoption (T1), PBR cowpea adoption plus inputs (T2), and conventional cowpea adoption (C).

Indicators: Availability in market, willingness to adopt among farmers, willingness to sell among traders, willingness to buy among consumers, preferred traits, and potential marketing campaigns.

Collecting data on the above research questions will provide baseline data to inform and complement the broader IE. To explore the above research questions, this study adopted a PE approach to uncover insights and nuanced findings from qualitative data. This approach is explained in detail in the following section.

2. METHODOLOGY

This section describes the methodology of the study, namely the PIP, which forms the basis of the PE, the study location, data collection, and data analysis process.

2.1 Program impact pathway

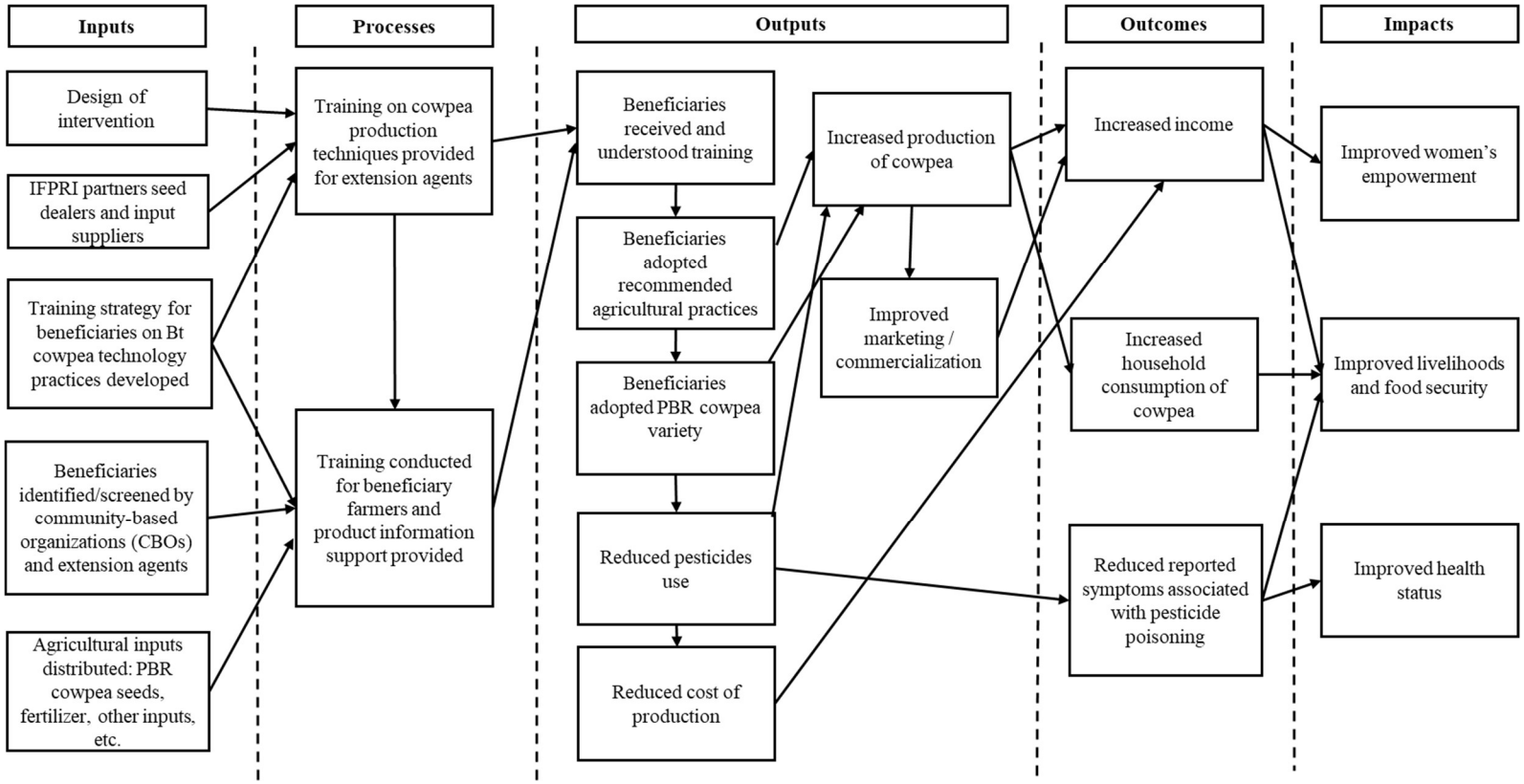
The methodological approach involves developing PIP models and linking data collection to PIPs using multiple data (Rawat et al. 2013). With the aid of PIPs, PEs identify how impacts emerge from program inputs and activities (Kafle and Benfica 2017) to understand the barriers and facilitators of participation and adoption.

The PIP presented in Figure 1 guided the design of the survey instruments, data collection, and analysis. The PIP visualizes and describes how inputs (the intervention) connects to processes, outputs, outcomes, and impacts to understand the rollout of the PBR cowpea technology and the fidelity of the intervention's operations (i.e., how the design of the program may or may not vary from reality). The PIP helps analyze the potential pathways to achieve impact. The PIP includes all intervention components, from inputs (interventions and their design), processes, outputs, and outcomes to impacts. *Inputs* include the design of the intervention, partnership with key stakeholders, training strategy, identification of beneficiaries, and distribution of agricultural inputs (PBR cowpea seeds, fertilizer, etc.). These inputs lead to *processes* (activities) that include providing training on PBR cowpea production techniques and providing product information support. The provision of training on PBR cowpea technologies equip beneficiaries with an understanding of PBR technology practices and other agricultural practices necessary for the adoption of the PBR cowpea. *Outputs* entail whether the training was understood, and the practices adopted, and whether production increased. The adoption of the technology is also expected to lead to reduced pesticide use, reduced production costs, increased production of cowpea, and increased market participation (commercialization).

For *outcomes*, three pathways are identified. Increased production likely contributes to increased availability of cowpea products for household consumption (production–consumption pathway) and increased income through the sale of surplus produce (production–income pathway). The third pathway is the production–health pathway. The adoption of the PBR cowpea variety leads to a reduction in self-reported health symptoms associated with pesticide use (reduced pesticide use creating a health-related pathway). The final step in the PIP is impacts. *Impacts* include improved livelihoods and food security (via increased income and consumption of cowpea products), improved health status due to reduced reported symptoms from pesticides poisoning, and

improved women's empowerment. Given that the IE's RCT is not yet rolled out, this PE aims to understand how the potential adoption may lead to impacts given the above steps outlined in the PIP.

Figure 1 Program impact pathway for the adoption of PBR cowpea

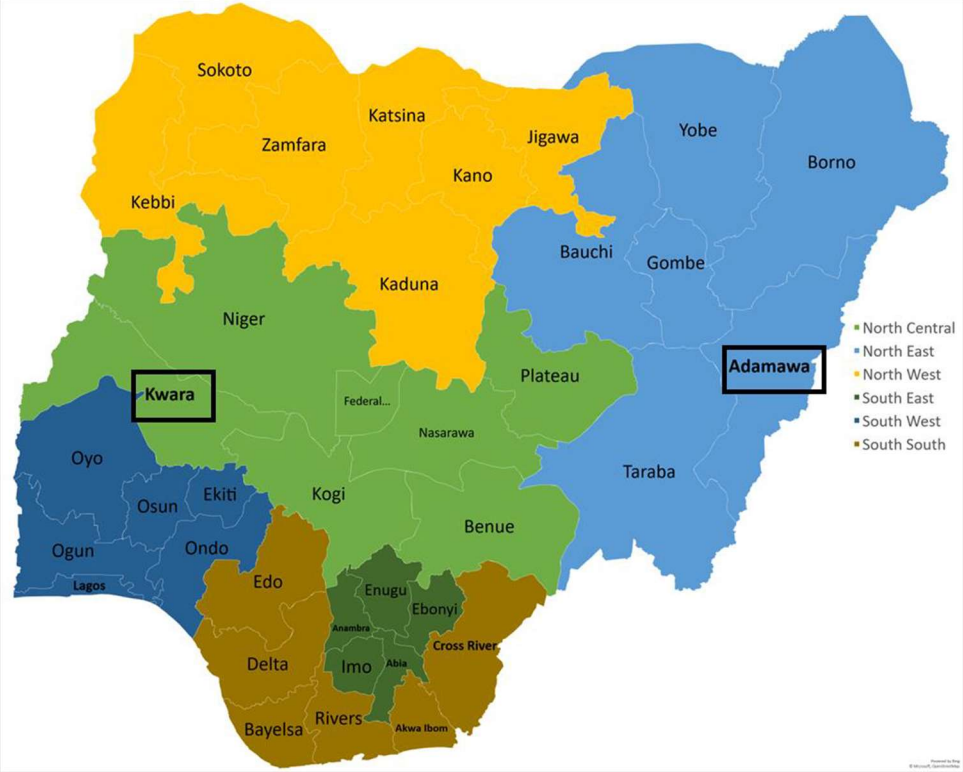


Source: Authors' own illustration.
Note: IFPRI = International Food Policy Research Institute; Bt = *Bacillus thuringiensis*; PBR = pod-borer resistant.

2.2 Study location

The states of Adamawa and Kwara were selected for the IE study's location (Figure 2) and thus for this study's location as well. Adamawa is in the eastern part of Nigeria, while Kwara is in the western part. These states were selected mainly because they are high cowpea-growing states (top 10 by production), have low penetration of the PBR cowpea variety, and have a relatively stable security situation. Using these criteria, the IE purposely selected four LGAs from each state, taking into account their low penetration and similar contextual factors (size, socioeconomic and agroclimatic conditions, and road and market access).

Figure 2 Map of federal states in Nigeria and selected study region



Source: Author's own illustration.

2.3 Data collection tools and respondent selection

The PE study relies on qualitative data to identify relevant, culturally sensitive attitudes and perceptions that can shape processes and outcomes. As such, qualitative methods are invaluable tools and resources to help formulate relevant questions to be examined by more structured approaches, such as surveys and RCTs) (Barrios and Costell 2004; Munoz 1998; Patton 2002). These include SSIs and FGDs.

SSIs use a combination of a small set of closed-ended questions with open-ended ones that the interviewer may change depending on the information collected at the time. SSIs are a valuable tool to gain insights and information from experts and other relevant stakeholders. Questions covered in the SSIs include general cowpea production practices, production challenges, preferences for cowpea attributes, awareness of PBR cowpea and adoption, gender roles and responsibilities in cowpea production, dynamics related to decisions about cowpea production, marketing of seeds and grains, and effects of cowpea on livelihoods. To gather information from a wide range of value chain actors, in addition to interviewing farmers, the researchers conducted SSIs with extension agents, cowpea traders, and agro-dealers. The intention was to conduct SSIs with equal shares of men and women with these other value chain actors, so that insights about gender dynamics in the cowpea value chain and in cowpea seed preferences could be better understood.

FGDs were conducted with men and women cowpea farmers. Farmers were separated into men- and women-only groups to understand the gender dynamics of technology adoption. We decided to conduct the FGDs separately, rather than with men and women together, so that each gender could speak more freely; we were concerned that social norms would inhibit women from speaking freely if men were also in the FGDs. It was intended to conduct FGDs with farmers who cultivate the PBR cowpea seed variety as well as those who grow other types of cowpea seeds; however, because the researchers were unable to find producers who had grown or were currently growing PBR cowpea, they conducted FGDs with cowpea farmers regardless of the type of variety grown. Questions in the FGDs covered topics such as cowpea production practices, cowpea seed attribute preferences, gender dynamics, decision-making in cowpea production, general knowledge, and awareness of the new PBR variety, and the impacts of cowpea on farmers' livelihoods and food security. FGDs and SSIs were audio recorded with participants' consent and later transcribed.

Data was collected between July 10 and August 3, 2023. There were two enumerator teams: the team in Adamawa had four research assistants, and the team in Kwara had 14 research assistants. The reason for the difference in the number of research assistants in the two states is that Hausa is the common language in Adamawa, whereas four different languages are spoken among the respondents in Kwara, namely Bokobaru, Yoruba, Nupe, and Hausa. There were two research team managers in both states.

Table 1 provides an overview of the data collection tools and number of respondents in each category. Four FGDs (i.e., two with men and two with women) were conducted in each state for a total of eight FGDs. Each FGD had between 8 and 10 farmers. For the SSIs, 81 cowpea farmers

(71 men and 10 women) were interviewed. The farmers in the FGDs and SSIs were randomly selected from a list compiled by IFPRI for the IE baseline study. The IE has two treatment arms that will be given PBR cowpea seeds and a control group that will grow the conventional cowpea seed. Because there were questions on perception and the willingness to adopt PBR cowpea, farmers in the control groups were not contacted or interviewed in this study to avoid potential influence. Direct phone communication was used for farmer outreach, covering introduction and scheduling details. The farmers interviewed in the SSIs were mainly smallholder farmers with an average farm size of 4.6 hectares. Most practice mixed cropping, with the remainder (nearly one-third) practicing monocropping. Farmers usually plant cowpea with other crops, such as maize, sorghum, groundnut, and sesame, to maximize the available land and for diversity to protect against crop failure.

In addition to farmers, SSIs were conducted with extension officers, cowpea traders, and agro-input dealers. A total of 40 extension agents were interviewed (32 men and 8 women). Extension agents were purposively sampled based on existing relationship to and expertise in cowpea production. A list of extension agents was provided by the Agricultural Development Project (ADP). From this list, five extension agents per LGA were randomly selected, except for Patigi and Kaiama, where six and four agents were selected, respectively. Collaborating with these extension agents, traders and agro-dealers were identified through a snowball sampling approach. The survey team visited markets and selected agro-dealers who sell cowpea using the snowball approach. A total of 18 agro-dealers were interviewed (17 men and 1 woman). The survey team could locate only one woman agro-dealer, despite trying to reach a more balanced representation of women. Most of the agro-dealers interviewed were from Kwara state because in Adamawa state, despite searching multiple markets, no cowpea seed sellers were found.

The snowball approach was used to collect cowpea traders. Identified traders who sold cowpea products to consumers referred the data collection team to other cowpea traders. A total of 41 cowpea traders (21 men and 20 women) were interviewed. The interviewed cowpea traders were found to have high levels of education, with nearly one-third having completed secondary education and one-third having completed tertiary education. The interviewed traders had an average of 17 years of experience. Just over half of the interviewed traders were also retailers, with others involved in wholesaling and production. This enabled us to collect additional insights from these value chain actors. The traders interviewed sold an average of about 1,300 kg of seeds, nearly 16,000 kg of grains, and 18 bags of cowpea fodder each week. This section describes how the data was analyzed.

Table 1 Data collection tools

									Total
State		**Adamawa**			**Kwara**				
Local government area (LGA)	Song	Hong	Mubi south	Maiha	Ifelodun	Patigi	Edu	Kaiama	
Focus group discussions (FGDs)									
	1	1	1	1	1	1	1	1	**8**
Semistructured interviews (SSIs)									
Farmers	10	10	10	10	10	10	11	10	**81**
Extension agents	5	5	5	5	5	6	5	4	**40**
Traders	6	5	5	5	5	6	4	5	**41**
Agro-dealers	0	0	1	0	5	5	5	2	**18**

Notes: One extension agent in Mubi south was also an agro-dealer. This respondent was interviewed twice in these different capacities.

2.4 Data analysis

Transcripts from the SSIs and FGDs were reviewed by the research team. Any questions or discrepancies were discussed via email and through biweekly meetings with the survey firm. Data from the SSIs with open-ended questions were analyzed by independent coders. The transcripts from the FGDs with producers and key informant interviews with other value chain actors (extension agents, agro-dealers, and traders) were analyzed using a thematic content

analysis. Content analysis is a tool for explorative studies, particularly for systematic examination and interpretation of the content to identify patterns, themes, assumptions, and meanings (Berg 2004; Lune and Berg 2017). The original texts were coded by two independent researchers/coders, and storylines were identified. The coding was done in different phases using the emergent coding (open coding) approach (Blair 2015). During the first phase, each coder created a list of codes based on the PIP and emerging themes from the broad set of questions asked during the interviews. In the next phase, the two coders compiled a master list of codes. After this phase, any additional codes that arose following discussions between the coders were aggregated with the initial codes to create a final list. The third phase involved the development of the final list of codes. Additional research staff read over the transcripts to gather more information and quotes. The analysis and presentation of the results followed the study's PIP.

3. RESULTS

This section presents the study results by the steps in the PIP: inputs, processes (training), outputs, outcomes, and impacts. The last subsection of this section focuses on gender and decision-making in cowpea production.

3.1 Inputs

The first step in the PIP is inputs, which examines awareness of PBR cowpea, farmers' seed trait preferences, availability and accessibility of cowpea seeds, and constraints in cowpea production. These factors are important to understand in designing an intervention targeting cowpea producers so that the intervention can be tailored to suit their needs and address their challenges.

3.1.1 Farmers' awareness of and willingness to adopt PBR cowpea

Most of the interviewed farmers are not aware of the PBR cowpea variety. PBR cowpea is largely unknown among most producers and other actors in the cowpea value chain, such as seed dealers and traders. Even after PBR cowpea seed traits were described, most farmers were unable to identify this variety and thus could not identify this variety with a local name or nickname. Few farmers indicated that they were registered to be given PBR cowpea seeds to plant, which is how they were made aware of the variety. However, none of the farmers interviewed are currently planting PBR cowpea seeds. Nearly all farmers indicated a willingness to adopt PBR seeds if they were made available to them. For example, a woman in an FGD in Kwara said: "Yes,

we will be glad to have the PBR seeds …. given that it is insect free and early maturing, planting it will reduce our expenses on the farm." In Adamawa state in Song Mubi LGA, a woman said: "When are we expecting the PBR cowpea variety to be made available? We would like to have this seed to plant so that we can boost our cowpea production and get high yield and more income."

Extension agents also spoke of farmer awareness and the willingness to adopt PBR cowpea. An extension agent in Hong LGA in Adamawa said: "Farmers are made aware through group training, where they were invited here in Hong for the training by ADP." An extension agent in Kaiama LGA in Kwara said: "Farmers were made aware of PBR through demonstration plots. We did PBR demo plots in four locations (Gwaria, Aboki in Kaiama LGA, and two locations in Baruten LGA)." Another in Kaiama LGA in Kwara said: "Farmers are very willing to adopt the PBR. In the community we did a demo [demonstration] in Baruten LGA, and the head of community saw the benefits (resistance to pest and high yield) and went to Zaria to get 100 kg of PBR cowpea and shared it to farmers in the community." An extension officer in Adamawa explained farmers' interest in the variety: "Many farmers are reaching out to us asking for the seed, and some have already cleared farmland allocated for the variety." An extension agent in Mubi LGA in Adamawa said: "Farmers are yet to start growing PBR cowpea-resistant variety. They are ever willing and ever ready to cultivate PBR cowpea. In fact, some of them are constantly asking us when the PBR seeds will be made available." In Kwara, an extension agent in Kaiama LGA said: "The PBR cowpea seed is yet to be available, but if the PBR cowpea seed is made available, it will be tested to see the outcome, especially the pesticide resistance and high-yield trait. This will inform farmers of their decision to adopt it." Another extension agent in Kwara summarized the above well: "If the PBR cowpea seeds are available, farmers will adopt it more." Therefore, extension agents believed that the PBR cowpea variety would benefit farmers through high yields, lower production costs, and increased incomes.

Traders too spoke of the demand for PBR cowpea if it were made available. A trader in Kwara state in Edu LGA said: "I recommend that the PBR cowpea should be brought to our town. There should be free samples because no one will buy things if they have never seen the result." In Patigi LGA, an agro input dealer expressed: "How I wish I can get the PBR cowpea next month for this production season." Last, an agro-input dealer in Kaiama LGA said: "The PBR seed should be made available to the market as soon as possible so that people (farmers) can have a trial and see the result output."

The above quotes and viewpoints from producers, extension agents, and traders all demonstrate a willingness and demand for PBR cowpea if they were made available.

3.1.2 Cowpea farmers' preferences by gender for cowpea traits related to production

Farmers grow several different types of cowpea varieties. Varieties commonly planted by farmers are Bosop, brown beans, iron beans, SAMPEA (specifically SAMPEA-11), and "kananado" (milk). The iron variety, according to the farmers, is high yielding, while the Bosop is easily marketable because it produces larger grains. The SAMPEA-11 is an early maturity variety and has a sweeter taste. Respondents throughout the study area spoke of specific varieties and traits they preferred. For example, both men and women in Kwara in Patigi LGA preferred the white cowpea (40-day maturing) and another called "capangi" that could be planted twice a year. Farmers claimed the latter was brought back by a farmer after a visit to the Northern states. Gender differences in trait preferences are further explored below.

The most common cowpea varieties women planted in Adamawa included the white cowpea, kananado, because of its availability, and the red cowpea. In Song LGA, women planted Bosop for high yield and "World Bank" for early maturity period. In Kwara, the women in Edu LGA had local names for the varieties planted: "Ndako sode," "Talba," "Danmisila," "Milik," and the "Red cowpea." They preferred these varieties because of their availability and affordability and because they had seen men planting it. In Ifelodun LGA, women and men in Mubi LGA and men in Patigi LGA preferred the "white", "milk" and "brown" cowpea for high yield and taste. Women liked "black nose," which was sometimes referred to as "iron beans" because it cooks quickly. In addition, women use the leaf to make soup. Women also liked black nose because of its high yield.

Particular traits preferred by men-only FGDs in Kwara revealed that the "milky" variety was the most planted cowpea variety because of its favorable characteristics, such as good taste, ease of marketing and cooking, and higher market price. This is captured in the following quote from a farmer: "We plant the white, brown, and milky colored variety of cowpea, but the cultivation of the milky colored variety is more because it is in higher demand in the market, it tastes better, it's easy to cook, and the market price is slightly higher than the white colored cowpea." The men in Kaiama LGA preferred to plant milky-colored, white, and brown cowpea varieties. The milky color variety was most preferred because of its taste and high commercial value. The men in Adamawa preferred iron beans and Bosop because of their high yield and volumes when processed. However, the erratic nature of rainfall caused them to switch to kananado and "banjara" varieties, which grow in drier climates. They also indicated that even though Bosop had commercial value, it produced larger pods than beans, thus requiring more beans to adequately fill sacks to sell. The men in Hong LGA prefer the conventional variety, "bumbalaster," which they found to give a high

yield. The men in Maiha LGA all preferred iron beans and Bosop over other cowpea varieties because of their higher yield and volume when processed. However, the increasing shortage in rainfall caused them to switch to kananado and banjara cowpea varieties. They did mention that even though Bosop had commercial value, it produced larger pods than beans, which again require more beans to adequately fill sacks to sell. A man farmer in Hong LGA also spoke of preferred traits in terms of market value: “We also have red beans, which is almost the same [as] black nose, and you can plant it anywhere and it will grow. The price is very good in the market when it comes to profit making, and the demand for it is very high.” Farmers in the study area look for certain characteristics or traits when choosing the type of cowpea variety to plant. Based on the FGDs and the individual farmer SSIs, the most preferred attributes include higher yield, early maturation, taste, ease of cooking, color, larger size of bean, drought tolerance, ease of harvesting, and marketability. Color is an important attribute for farmers, as cowpeas are used for different foods. For instance, in an FGD with women in Kwara, a respondent said: “The white (bean) is always fine when you use it for bean cake (akara), and moin-moin, but the brown (bean) is always fine for eating when it is cooked.”

As shown above, preferences for different cowpea attributes differed by gender. Men preferred traits such as high yield and marketability, whereas women preferred good taste and ease of cooking. However, there were similarities in their preferences. Both men and women preferred cowpeas with early maturity cycles. In addition, some other respondents indicated that both men and women preferred cowpea varieties that are high yielding. For example, an extension agent from Adamawa indicated: “Men prefer SAMPEA-11 due to its short time of grow[ing] and harvesting, while women prefer Bosop because of its size and [because] it produces bigger grains.” Having early maturing varieties is important because this prevents potential damage from terminal drought and late season insects.

3.1.3 Availability and accessibility of conventional and PBR cowpea seeds

Generally, farmers indicated that access to conventional cowpea seeds is not a major problem because most of them save and recycle their seeds. An FGD with men in Kwara revealed: “There are no difficulties in obtaining seeds because we do recycle seeds against the next planting season. The only time we may have to buy seeds is when our saved seeds are attacked by insects.” A man farmer in Adamawa in Song LGA said: “I recycle seeds because I want to use them for next year’s planting season, and I do not want to buy new seeds from the market.” In Maiha LGA, a man farmer reflected on the difficulty of finding seeds to buy as a reason for recycling

seeds by saying: “I recycle seeds because I do not want to suffer next year trying to look for seeds.” Concern about cost was another major reason for recycling seeds. A man farmer in Adamawa in Song LGA said: “I recycle cowpea seeds because buying new seeds is costly … so I prefer to use the one I stored.” Another man farmer in Kwara state in Kaiama LGA said: “I recycle seeds in order to have seeds for the next farming season. I also do not have money to buy new seed during next planting.” The above reflections from farmers show that the major reasons they recycled seeds were due to difficulties in finding seeds, as well as the cost of purchasing seeds.

The SSIs with individual farmers revealed a similar picture of farmers recycling seed: Nearly all farmers reported recycling seeds. The practice of seed sharing is also common among farmers. Reasons cited for these practices include ease of access, cost savings, and distrust for some seeds sold in the market, as some farmers reported unknowingly purchasing bad seeds. This shows that building trust in seed markets is important in the study area. In addition, farmers’ financial constraints should be addressed in an intervention promoting the purchase of cowpea seeds.

Regarding PBR seeds, the results show that they were not available to farmers, although PBR seeds have been allowed to be commercialized since the end of 2019. Farmers indicated that they did not know where to access PBR seeds. This was confirmed by extension agents in the study area. For example, an extension agent in Adamawa indicated: “Farmers are yet to start growing PBR cowpea-resistant variety.” Interviews with agro-dealers corroborated the assertion that PBR seeds were not available in the market. In addition, most agro-dealers had not heard of the PBR cowpea variety. As such, none of them sold PBR cowpea seeds.

Agro-dealers in the study area mostly sell a range of products, namely, pesticides (e.g., insecticides and herbicides), spray equipment, and seeds. Regarding seeds, many agro-dealers sold open pollinated varieties (OPV) and hybrid seeds, yet OPVs were much more common. Agro-dealers often source their seeds from wholesalers within their LGAs or from farmers. For example, an agro-dealer in Kwara stated: “I normally get my supplies from the market, such as Tsaragi market Edu LGA.” However, farmers buy seeds mostly from traders rather than agro-dealers. This is because compared to agro-dealers, traders are located closer to farmers. Agro-input companies and dealers are mostly situated at the state and LGA headquarters and not in villages where farmers reside. The retail outlets mostly sold rice, maize, soybeans, and vegetable seeds. Although access to conventional seeds was not a major problem in the study regions, farmers’ access to improved or hybrid cowpea seeds was hindered by many factors. Interviews with individual farmers revealed that more than half had difficulty buying seeds from the market. Major difficulties encountered include the high cost of seed, lack of good quality seed, limited availability,

and poor accessibility in terms of proximity to a seed market.

3.1.4 Cowpea production constraints

The interviewers revealed several barriers that farmers and extension agents mentioned in the production of cowpea. Respondents mentioned myriad challenges: pest infestation, high costs of seeds and pesticides, lack of credit (or inadequate financial capital), poor soil fertility, lack of storage facilities, drought, flooding, and limited extension services. A woman respondent in Kwara explained the difficulties with pests: “Our crops are being eaten up by insects …. We normally spray the farm with insecticides at least every four days, but this requires money. Therefore, if you have a large cowpea farm and you do not have money to buy chemicals, it looks as if you are growing weeds.” These challenges were not peculiar to a particular group of farmers because men, women, and youth were all affected. For example, a farmer in the FGD with men in Kwara also discussed pests: “The challenges of cowpea farming in our area revolve around the problem of pest control …. If you do not effectively control insect pests and you are not lucky enough, you may not gain anything from the farming of cowpea due to insect pest attack.” Regarding climate change, a woman farmer in Adamawa in Song LGA said: “Another problem is the climate change; sometimes we experience drought, while sometimes we experience flooding like last year, and it affected our crops.” When farmers were asked about changes, they have noticed in the last two years regarding the production of cowpea and specifically the use of conventional seed varieties, most reported that input use has generally increased over the last two years. For example, farmers indicated a major increase in the use of labor, fertilizer, herbicides, and insecticides. The increasing use of herbicides and pesticides is expected, as farmers reported a general rise in pest infestations over the years.

The challenges confronting cowpea farmers in the study area were also confirmed by extension officers, as captured in a statement: “Women lack adequate capital to buy pesticides, while the youth also lack adequate capital to cultivate large farms.” In sum, many constraints relate to the difficulty farmers have in obtaining the required inputs for cowpea production. Thus, having access to credit would play a major role in helping farmers acquire critical inputs, such as seeds, pesticides, fertilizers, and storage facilities. Lack of storage facilities often leads farmers to sell their grains at lower prices rather than risk losses during storage. On the other hand, inappropriate storage subjects the cowpea grains to insect attacks, which leads farmers to buy insecticides. As revealed by the results, farmers often lack financial capital to purchase these chemicals.

The above subsection on inputs in the PIP shows that the design of the PBR cowpea intervention

should highlight how the PBR cowpea addresses the major constraints reported by farmers, which revolve around pests. Promoting PBR cowpea as a variety that can drastically reduce pesticide use and input costs would be beneficial to the program.

3.2 Processes: Training and advisory services

The next step in the PIP processes covers training. Although the PBR cowpea intervention had not yet been rolled out in the study areas, this section provides insights into how effective the intervention may be, depending on whom is relied upon in the rollout process.

The results on training and advisory services highlighted how overextended extension agents are in the study area. On average, one extension agent in Adamawa works with 614 farmers, while in Kwara, one agent works with 207 farmers, and a few extension agents work with as many as 1,000 farmers. This shows that extension agents in the study area are spread thin by the high number of farmers they serve. In addition, the sheer variety of services agents offer—from providing information on good agricultural practices and establishing demonstration plots to advising on harvest and proper storage, fertilizer and pesticide application techniques, new technologies, and the measurement of farms—means they've built trust within the farming community. An extension agent in Adamawa elaborated on the training he provides by saying: "We train farmers on good agricultural practices… I train them on new technologies and innovations and also make sure they adopt to the new technologies introduced." Thus, the role of extension agents in promoting the adoption of new technologies such as the PBR cannot be overemphasized.

Regarding the PBR variety, some extension agents reported that they were first made aware of PBR cowpea through formal conversations with the IFPRI IE team on the IE of PBR cowpea. In addition, extension agents reported that the representative from the state ADPs made some farmers aware of PBR cowpea through one-on-one visits. An extension agent spoke about how farmers were made aware of the PBR variety: "We did a house-to-house sensitization exercise, and we registered some farmers, who are interested in the PBR cowpea … so they were made aware through the registration exercise." An extension agent in Adamawa indicated that he had planted the PBR variety and thus informed farmers about the benefits that are associated with it. He indicated: "I am advising farmers that they should adopt the PBR cowpea because I am a living witness; I have planted it, and I have seen the results." Although the majority of farmers had not heard about the PBR cowpea variety, the few who had heard about it received their information from extension agents and some from ADP representatives. For example, a woman in

an FGD with farmers in Adamawa said: “An extension agent came to our meeting and informed us about the PBR variety …. She promised us that she will bring the PBR cowpea seed to us if she gets access to it.” A farmer in Kwara state in Kaiama LGA said: “I heard from extension officer that the PBR cowpea seed is very nice.” This result further confirms the unavailability of the PBR cowpea to farmers in the study area, as well as the interest farmers have in planting the variety.

Extension agents also indicated that they provide other advisory services to cowpea farmers. These include information on seed selection, time, stages of input application, cropping systems, timing of harvest, pesticide selection, weed management, and tractor use. Despite efforts by extension officers to offer extension advice and information to farmers, the FGDs revealed limited advice from extension agents on the choice and use of inputs, suggesting a divergent view between extension agents and farmers regarding extension services provision. Farmers said that they felt that they were not visited frequently enough by extension agents. A farmer in a men-only FGD in Kwara said: “There are no extension workers who come to educate us on choice of chemicals or pesticides to use.” Thus, farmers may use their own knowledge or rely on colleague farmers for such advice, which often may lead to undesirable outcomes. An example of such outcomes is emphasized in the following statement from a farmer in a men-only FGD in Kwara: “Most of the chemicals we use are usually adulterated and do not effectively control insect pests. If you are not lucky enough, you may not get any cowpea due to insect pest attack.”

The results suggest that extension officers need to provide more information and training to farmers to guide their production decisions. But extension agents mentioned a number of challenges they encounter in the course of their work, especially in promoting new technologies. Some of the challenges include difficulty in reaching farmers, limited number of extension agents, inadequate funding to facilitate mobility, rejection from farmers, and farmers’ disbelief in new technologies.

3.3 Outputs

The outputs step in the PIP examines the adoption of recommended cowpea production practices, production costs, input use, and cowpea production marketing and commercialization.

3.3.1 Adoption of different cowpea varieties and changes in production costs

As the above results show, the PBR variety has not been adopted by any farmers in the study region because it is not yet available. Instead, the vast majority plant conventional (noncertified)

varieties, with a small proportion planting improved or hybrid varieties. Although most farmers grow conventional varieties, they highlighted the challenges they face with their use. Notable among them is the poor quality of the seeds as they are often stored in places exposed to moisture and insects. Women farmers in Kwara elaborated: “Like the conventional seed, sometimes you will even plant some and it will not geminate, and if it later germinates it will not produce well even if you apply insecticides to it several times.” These challenges farmers face regarding conventional seeds offer an opportunity to encourage the use of PBR cowpea seeds. Although farmers are not currently growing PBR cowpea seeds, some were made aware of the new PBR variety and were willing to adopt it. In this regard, extension agents suggested the need to create greater awareness, such as through public demonstrations, and provide incentives, such as offering credit and distributing free samples, to facilitate the adoption of PBR cowpea seeds.

3.3.2 Marketing of cowpea products—supply and demand

This subsection examines the supply and demand of cowpea products in the study regions. Results from the SSI with farmers, extension agents, and FGDs show that cowpea is produced for both commercial and subsistence purposes. However, most cowpea grown is sold in markets rather than consumed at home. For instance, results from the individual farmer interviews show that the majority of cowpea seeds are sold at the market, with about one-fifth kept for own consumption and one fifth for other purposes, such as saving for planting (i.e., seed recycling) and giving to family and friends as gifts. Wholesalers are the most common value chain actor farmers sell their cowpea to, followed by retailers, consumers, and other buyers. Only a few sell to processors.

Interviews with cowpea traders show that both seeds and grains are sold. However, the sale of certified cowpea seeds is rare, as conventional cowpea is sold by most traders. Only a handful of traders sold both conventional and certified cowpea seeds. In terms of cowpea products sold, traders mostly sell both grain and fodder compared with only fodder or grain. Most of the products are sold as unprocessed whole beans. The sale of processed cowpea products in both regions is very rare, due to the lack of processing facilities in the study area. The traders interviewed cited several reasons for selling cowpea products: demand for the product, income, and access to food for the family. The result suggests that traders serve a wide range of farmers, from small- to large-scale. Most traders across markets reported sourcing cowpea products primarily from farmers in nearby communities or within their LGAs. Traders also source cowpea products from other markets outside their area, their own production, other farmers outside their area, and other

traders. The results suggest that if farmers produce the PBR variety, there may be available markets within their locality for their cowpea grains. Traders face a variety of constraints in marketing cowpea, including high transportation costs, lack of storage facilities, and insecurity, in addition to limited funds, lack of availability of good cowpea varieties, insect attacks, and poor bagging. According to traders, consumers use different selection criteria to buy their cowpea products. Consumers generally look for certain characteristics, such as color, grain size, ease of cooking, and cleanliness of cowpea. Likewise, untreated, chemical-free products are also preferred by consumers. Traders used the word “neatness” to describe cowpea that was unbroken and free of infestation by insects and cited these qualities as being important to consumers.

The results in this section show that the PBR cowpea variety addresses several constraints in the market as well as consumer preferences. Adopting the PBR cowpea variety could affect several aspects in the outputs step in the PIP, such as by reducing pesticide use, reducing costs of production, increasing cowpea production, and leading to improved marketing of cowpea given consumer preferences for cowpea grown with less pesticide use. The next section describes the potential outcomes and impacts of PBR cowpea.

3.4 Outcomes and impacts

Outcomes examine whether household consumption and income would improve from the adoption of PBR cowpea, while impacts examine whether PBR cowpea production would lead to improvements in food security and livelihoods through increases in income and consumption of cowpea products. This section also discusses health-related outcomes and impacts from cowpea production. Since PBR cowpea products are not yet available on the market, the information presented here relates to other cowpea varieties cultivated by farmers, thereby setting the stage for potential impacts from PBR cowpea production.

Cowpea is grown for both household consumption and sale. Indeed, nearly all farmers indicated that cowpea production contributes to both household income and food security. This is also reflected in a statement from a woman respondent in an FGD in Adamawa: “Cowpea production has helped provide food in our houses that we manage throughout the year. Though we consume, we also sell it to buy some other household food staples.” This was also corroborated by men. For example, a farmer in Adamawa said the following during a men-only FGD: “For us, cowpea farming helps us a lot. The important thing is getting a good harvest, which is very helpful at home as we can use beans to prepare foods such as moin-moin (bean pudding), kosia (bean cake), etc. We also sell and use the money to buy other food items, such as maize and rice, for home consumption.” These results support the production-income and production-consumption

pathways in the PIP.

As cowpea is also grown for commercial purposes, farmers earn income from the sale of cowpea products. In the producer survey, the majority of the farmers indicated that their incomes have increased over the last two years even though they predominantly cultivate conventional varieties. Income generated from the sale of cowpea is used for multiple purposes, which include buying other food items, paying children's school fees, buying inputs, buying livestock, and building houses. For example, in one of the FGDs, a woman said: "We sell too and use money to pay our children's school fees … income generated from sale of cowpea, especially with farms, are used to build houses." Depending on how large a cowpea farm is, income generated can be used to acquire many things.

Regarding the effects of cowpea production on health, farmers were asked to indicate changes they have seen over the last two years from pesticides use due to growing conventional cowpea varieties. Results from the producer survey show that half of the respondents indicated an increase in self-reported symptoms associated with pesticide use. Given the farmer-indicated negative health effects of pesticides, using the PBR cowpea variety is expected to decrease use of some pesticides used to control the pod borer with potentially improved health and productivity outcomes, especially among men, who are mostly responsible for pesticide application.

3.5 Gender roles and decision-making in cowpea production

In the interviews, farmers were asked about whom in the household is responsible for activities and decisions about cowpea production. The results show that there are differences according to gender. In general, men are mainly responsible for hiring labor, preparing land, weeding, storing, and selling/marketing, while women are mainly responsible for harvesting, fetching water for spraying, and processing (threshing). Herbicide and insecticide applications are done by men, and in particular, male youth. The spraying of pesticides by male youth was discussed in most of the FGDs. A man farmer in Adamawa in Maiha LGA explained the division of labor: "Men help in land clearing, planting, pesticides application, and harvesting. Women help with planting, seed sorting, weeding, and threshing, while youth engage in pesticide application, weeding, planting, harvesting, and threshing." A man farmer in Kwara in Kaima LGA also explained the division of labor among family members: "Men and youth do the land preparation, planting, weeding, fetching of water, spraying and sales of cowpea produce, while the women are charged with the responsibility of harvesting and processing only, after the maturity of the crop, when the fruit of farm labor is out." About the division of labor between men and women only, a woman in an FGD in Kwara said: "Men take care of the planting, spraying, and fumigation, but women also help fetch

water used for spraying chemicals." Women perform the bulk of the picking and marketing of cowpea. An extension officer in Adamawa indicated: "Women are particularly into picking (harvesting), threshing, winnowing, and processing, while men are involved in land preparation, planting, weeding, and spraying of insecticides. The youth are into pesticide application and bagging." However, certain activities, such as planting and threshing, are also done by both men and women. Decision-making power also differs according to these different activities.

The results indicate that men are primarily responsible for most decisions regarding cowpea production and cowpea plots. For example, men are responsible for decisions related to where and how much cowpea to produce, as well as how much money and household labor to devote to cowpea production. This is especially the case in households with a married couple. In instances where the farm belongs to a woman, the husbands play a major role in managing the farm. This is explained in the following statement by a farmer during an FGD with men in Kwara: "Our women do not manage the farm even if she has the financial capability. It is the husband who is the head that will assist in managing the farm, and their [women's] responsibility would be assisting in harvesting and processing cowpea." A woman farmer in Kwara also elaborated: "Our husbands make the decision on what to do on the cowpea production because they are the ones that do hire laborers on the farm, and they are the ones that pay for the laborers, so definitely all the decision-making is from them." When discussing decisions about cowpea plots, a man farmer in Kwara in Kaiama LGA said: "The decision is taken by men since they are the head of the house. Women don't take decisions for us." These statements underscore the dominant role of men in decision-making on cowpea production in the study area. In female-headed households or where wives manage cowpea plots, women have most of the decision-making power in cowpea production. For example, a woman farmer in Adamawa in Song Mubi LGA said: "The family will sit together and deliberate on who will manage the cowpea plot. Sometimes if the husband and wife are sharing or cultivating the same plot of land for cowpea, the man will manage the farm. But if the woman is cultivating her own plot, she will be the one to manage it."

Regarding sales, the results indicate that men make the decisions, but in most cases, the women are consulted. There is also joint decision-making on how much of the produce to keep for household consumption and the use of money from the sale of cowpea. Most women indicated that their husbands make the cowpea production decisions, but in some cases, such as about the use of the money from cowpea sales, women are consulted. This is typified by a comment in one of the men's FGDs (in Kwara): "The men make the decisions, but, in most cases, they do discuss with the women, especially if an occasion [is] coming up that would involve money."

FGDs revealed that cultural and religious beliefs play a critical role in household decision-making

and cowpea production. Adamawa has more Christians than Kwara, which has a predominantly Muslim population. In general, Muslims in the study area tend to have more restrictive gender norms compared to Christians. Gender norms represent a major barrier for women. This is explained by a man farmer in Kwara: “One of the barriers for women’s participation in cowpea production is due to religious beliefs …. Some men do not allow their spouses to do farm work due to religious beliefs.” A man farmer in Kwara in Kaiama LGA said: “One of the barrier(s) for women’s participation is due to religious beliefs. Some men do not allow their spouses to do farm work due to religious beliefs.” The men in Adamawa acknowledged that these traditional norms which limit women’s direct participation in farming activities were a hindrance. In both states, norms required that women sought husbands’ permission to engage in any activity and permission to go outside the home. In some communities visited in Kwara, farming was deemed as an unusual occupation for women, with trading viewed as a more suitable activity. These cultural beliefs prevent women from making critical decisions about cowpea production, which can affect their adoption of technologies, like PBR cowpea. Last, women are overburdened by household and childcare responsibilities. A woman farmer in Adamawa in Mubi LGI said: “There is a lot of stress for women, especially during the raining season, where you are managing the farms as well as managing the house.” Thus, cowpea interventions targeting women farmers should be cognizant of their workloads. We discuss the above results in the following section.

4. DISCUSSION

This section first discusses the main findings from the PE in light of the existing literature, the PIP, and the study's objectives before providing insights into the IE.

Cowpea farmers interviewed in this study were mainly smallholder farmers who practice mixed cropping (or intercropping) with maize, groundnut, or sesame. This cowpea production system has been reported in other African countries, such as in Ghana, where the majority of cowpea farmers practice intercropping with maize, millet, and yam (Karikari et al. 2023). Conventional (noncertified) and mainly recycled cowpea seeds are the most common varieties planted in the study area, with only a few farmers growing improved or hybrid varieties. Major varieties grown include Bosop, iron beans, SAMPEA-11 (SAMPEA), and kananado (milky). These varieties are associated with farmers' preferred traits, such as high yielding, high consumer demand, better taste, and less cooking time. Planting of conventional varieties demands high use of insecticides to prevent insect attacks. Thus, farmers experience a high probability of heavy yield loss from pest infestation. Moreover, the excessive use of insecticides can have negative consequences on farmers' health. We found that half of farmers reported increases in reported symptoms due to insecticide use over the last two years (production–health pathway). The interviews revealed that in addition to adult males, male youth also spray the fields with pesticides. Farmers said that they plant conventional varieties and recycle seeds because of the lower cost associated with doing so (and mistrust of "seed distributors") compared with purchasing improved certified varieties. This has been found in other studies as well (e.g., Wossen et al. 2017). In addition, a study in Tanzania found that farmers choose to cultivate traditional varieties over improved ones if the rainfall is insufficient (Kassie et al. 2013). Cowpea farmers discussed drought as a major setback they have faced. Research confirms the increase of drought in Nigeria (Shiru et al. 2019) and that rainfall is projected to decrease in the southeast, northeast, and central parts of Nigeria, while the temperature is expected to increase throughout the country, which, in turn, would increase the frequency of droughts (Shiru et al. 2020). Weather-indexed crop insurance is a mechanism to reduce the impact from drought on farmers, yet its uptake is limited despite government support (Madaki, Kaechele, and Bavorova et al. 2023).

Production of cowpea in sub-Saharan Africa is affected by several abiotic and biotic stresses and socioeconomic factors (Horn and Shimelis 2020). Consequently, this study identified several constraints affecting the production of cowpea. Constraints that hinder cowpea production in the

study area includes low yield potential, high incidence of pest infestations, high input cost (i.e., pesticides), lack of financial capital or credit, lack of storage facilities, and weather-related factors such as flood and drought. Karikari et al. (2023) also identified similar challenges in Ghana. High pest infestation and high cost of pesticides is identified as a recurrent challenge faced by cowpea farmers. Insect pest infestations and high cost of pesticides are identified as major factors affecting cowpea production in West Africa, including Nigeria (Baoua et al. 2021; Haggblade et al. 2021; Kusi et al. 2019; Mbavai et al. 2015). With limited access to credit, and given the high cost of insecticides or pesticides, most farmers face difficulties purchasing these inputs. These factors could positively affect the future demand for PBR seeds, given that this cowpea variety is resistant to pod borers. Although the challenges farmers face cut across the gender spectrum, women farmers were particularly constrained by lack of financial resources. This suggests that women and men farmers in the study will likely have unequal access to PBR cowpea seed varieties,

The results also show that cowpea is a major economic activity and business in the study area. Farmers earn income from the sale of cowpea, as the majority of the cowpea produced is commercialized (production–income pathway). This earned income can be used to support household livelihood activities (e.g., pay children's school fees, build houses) and purchase other food items. Most of the produce is sold as whole beans rather than processed, suggesting that value addition is very minimal. Adding value to the crop can lead to the realization of the full potential of the crop through higher prices. Providing processing facilities would therefore help achieve this goal. Although much cowpea is sold, it has an important subsistence role in household diets, contributing to food and nutritional food security (production–consumption pathway).

The results revealed that farmers use cowpea primarily as a food source rather than fodder. Even on the market, the sale of cowpea as a food grain dominates, indicating that cowpea is very important for human consumption. For instance, farmer households prepare cowpea grains into different meals, such as moin-moin (bean pudding) and kosia or akara (bean cake), which are consumed at home. As such, farmers—especially women—prefer consumption-related traits, such as better taste and less cooking time.

A shift to alternative varieties, such as the PBR variety, is essential to reduce input costs, increase yields, increase profits, and reduce negative impacts on farmers' health. However, the results show that although the PBR variety has been commercialized in Nigeria, only a small number of farmers in the study area are aware of it. Because of the limited availability of PBR cowpea seeds in the

market, none of the farmers interviewed had grown or were growing PBR cowpea. Moreover, some agro-dealers, cowpea traders, and extension agents, were not familiar with this variety.

The fact that farmers in the study area are not planting the variety is not due to lack of interest, but rather lack of availability in the study areas. This was corroborated by extension officers, agro-dealers, cowpea traders, and the research team, who tried to find available PBR cowpea seed in the market. Also, there was lack of information about the new variety, as some farmers were not aware of its existence and thus its potential benefits. These factors block the adoption of the PBR cowpea variety. The fact that cowpea seeds planted by farmers are most commonly recycled from previous planting seasons suggests potential obstacles for market-valued PBR cowpea seeds.

We found that there are several traits preferred by farmers, some of which are addressed by the PBR cowpea variety. Farmers preferred cowpea traits such as high yield, early maturing, pest resistant, high consumer demand, better taste, less cooking time, and drought tolerant. The findings suggest that yield is an important characteristic farmers consider when making choices about which variety to grow, which is consistent with other studies (Asrat et al. 2010; Karikari et al. 2023). Early maturity and drought resistance are important characteristics famers prefer. Given the variability in rainfall and periods of drought, it is essential for farmers to cultivate varieties with traits that help address the negative consequences of these unpredicted events on yields. Likewise, farmers prefer pest-resistant varieties, given that one of the major constraints in the study area is the susceptibility of the cowpea to insects. These results suggest that farmers consider different traits when selecting cowpea varieties and are particularly concerned about pests and insects.

The results show the existence of cowpea gender-differentiated trait preferences. For instance, women were particularly interested in traits such as good taste, ease of cooking, and early maturing, while men prefer traits such as high yield, marketability, and early maturing. The results show that women's varietal preferences appear to be more related to food security traits, which is in line with the study by Weltzien et al. (2019). According to Christinck et al. (2017), differences in trait preferences between men and women occur when they are faced with different constraints, roles and responsibilities in production, and production goals.

Women and men have distinct roles in cowpea production systems in the study regions. Men are mainly responsible for hiring labor, preparing land, weeding, storage, and selling/marketing, while women are mainly responsible for harvesting, fetching water for spraying, and processing (threshing). Regarding decision-making, the results show that men farmers living in male-headed households are mainly responsible for making decisions about cowpea production, such as how

much cowpea to produce and decisions on input use (e.g., the variety to grow and how much money and household labor to devote to cowpea production). Most women indicated that their husbands make the cowpea production decisions, but in some cases, such as regarding the use of the money from cowpea sales, women are consulted. In female-headed households or where wives manage cowpea plots, women have most of the decision-making power regarding cowpea production. This implies that women farmers with their own plots, particularly in female-headed households, could independently adopt PBR cowpea seeds if they are made available. As such, marketing campaigns and knowledge creation about PBR cowpea should be sure to target not only men, but also women. The fact that women are often overburdened with household and child responsibilities should not be overlooked. Women were found to do more in cowpea production in Adamawa than in Kwara. An explanation for this difference, as discussed above, is the dominant religion and cultural beliefs in each state.

Insights for the IE

The PBR cowpea PE complements the IE of PBR cowpea adoption by shedding light on the how and why behind the results. For instance, this PE brings to the forefront the various challenges and constraints faced by cowpea farmers and traders. These constraints, including issues related to pest control, high cost of transportation, lack of storage facilities, insecurity, access to quality seeds, and the availability of credit, are critical to understanding the limitations on production and income.

The PE highlights that awareness of the PBR variety among farmers, agro-dealers and cowpea traders in the study area is limited. This lack of awareness, as well as farmers' preferences for specific cowpea traits and the lack of availability of PBR seeds, has a high potential to influence the pace of adoption of PBR cowpea and could impact the eventual rollout of the improved variety into these states and other areas where awareness is low. It is noteworthy, however, that farmers expressed enthusiasm for this new variety should it become available. Furthermore, the recurring use of recycled seeds due to cost considerations and ease of access emerges as a critical consideration for PBR cowpea adoption. Ensuring accessibility and promotion of PBR cowpea seeds to farmers is paramount to address this prevailing practice.

Furthermore, the PE brings to light the existing relationship between extension agents and cowpea farmers. Extension agents play a pivotal role in providing information and advisory services to farmers. This is evident in the fact that the few farmers who have heard of PBR cowpea received their information from extension agents. However, extension agents in the study area are spread thin, with high numbers of farmers to serve, leading to gaps in communication and service

provision. As such, we recommend that programs not rely solely on extension agents to provide input, such as seeds and training, to farmers. A multipronged approach is needed, such as using farmer field schools, farmer-to-farmer networks, mass media (e.g., TV, radio, online advertisements, Facebook groups where farmers could pose questions in a group), agro-dealers, village leaders, and model farms.

The PE shows that the majority of cowpea produce is sold in the market, emphasizing the economic significance of cowpea production. The adoption of PBR cowpea therefore has a potential to increase yields, food security, and marketability, leading to higher revenues for farmers, traders, and other actors in the cowpea value chain. As revealed by the gender roles, women tend to engage in processing, while men primarily engage in various production activities. However, with the adoption of PBR cowpea, there is potential for a shift in labor dynamics. This shift could lead to increased demand for labor in processing and value addition activities, potentially contributing to a more diverse and skilled workforce. The gendered trait preferences and inequalities in decision-making power also provide insights into tailoring communication strategies for promoting PBR cowpea, based on individual priorities. The PE also revealed that the PBR cowpea variety could improve the health of cowpea farmers and their families because spraying is done by men and male youth. Therefore, making farmers and their families aware of the harms of incorrectly using and spraying pesticides, which can be done upward of 10 times to combat the legume pod borer (AATF 2021), is critical to getting buy-in from all family members. The most significant contribution of the PE is its ability to identify specific areas where the implementation of the IE can be enhanced, such as addressing the deferential household impacts of adopting PBR cowpea and the influence that other actors in the value chain will have on the outcomes of the IE, and the fact that information about the PBR cowpea variety is not yet widespread in the study areas. The PE is also able to inform recommendations beyond the study, such as creating awareness of the PBR cowpea variety and introducing processing and storage facilities to enhance PBR cowpea's crop value and market potential.

5. CONCLUSION

Cowpea is the major food crop and an affordable source of protein for most households in Nigeria. Nigeria's commercial release of an insect- resistant, GM cowpea crop, the PBR cowpea, has prompted a five-year (2021–2026) IE led by IFPRI, with funding from USAID, to examine the impacts of using the new PBR cowpea variety and its effects on a variety of economic and food security conditions. As part of the IE, this study examined cowpea production, adoption of newly commercialized PBR varieties, and marketing in the two study sites of the IE in Adamawa and Kwara states of Nigeria using a PE approach. The baseline qualitative findings from this study have provided more insight into the IE by revealing the facilitators and barriers to adopting the PBR cowpea variety. Results were obtained using data from SSIs and FGDs conducted with farmers, in addition to SSIs conducted with extension agents, cowpea farmers, seed dealers, and cowpea traders. The analysis of results provides some justification to support the continued production and commercialization of insect-resistant cowpea varieties such as the PBR variety.

Pest resistance, higher yield, and marketability are important traits preferred by farmers. The promotion of the PBR cowpea seeds should emphasize the benefits of the variety's resistance to pests, yield potential, and marketability in terms of the characteristics that appeal to consumers. These attributes would be crucial in adoption of the PBR variety.

Several constraints were identified that affect the production of cowpea. These constraints include pest infestation, high costs of seeds and pesticides, lack of credit (or inadequate financial capital), poor soil fertility, lack of storage facilities, drought, and flooding. Compared with men, women farmers are more constrained by lack of credit or financial resources. This has an implication for the adoption of improved varieties, such as PBR cowpea seeds. For example, farmers require credit for agricultural production, which includes the purchase of inputs, such as seeds. Therefore, lack of credit will negatively affect their ability to buy PBR cowpea seeds. The issue of pest infestation was highlighted as a major constraint. This finding, therefore, underlines the importance of promoting the benefits of to the variety's resistance to pests. The emergence of the PBR cowpea is a timely response to tackling the issue of pest infestation in cowpea production. Given the challenge of soil fertility in the study area, any intervention to provide PBR cowpea seeds should include fertilizers to maximize the potential gains.

The findings highlight the presence of both common and specific characteristics of cowpea that appeal to men and women farmers and the diverse roles they play in cowpea production and decision–making. Given the gender dimension on decision-making and trait preferences, policies and programs aimed at promoting the PBR cowpea variety should capture gender dynamics in

agricultural decision-making and highlight the important traits that appeal to both men and women. Targeting men and women separately through different campaigns or demonstrations on PBR cowpea is necessary to improve adoption.

The study revealed that conventional varieties are the most planted cowpea varieties in the study areas. Although farmers were not cultivating the PBR variety, their interest suggests potential for its widespread adoption. Limited access to information on PBR cowpea seeds and availability on the market appeared to be the major adoption constraints. Providing more awareness about the PBR cowpea variety and its benefits through extension platforms is critical to ensure its adoption. However, given that the extension-to-farmer ratio is very low, having group training and demonstrations would be more effective in reaching a large number of farmers. Also, it is important to ensure that the seeds are made available to farmers at the right place and right time. Making extension agents and other value chain actors aware of the PBR cowpea will help to improve its adoption.

Since farmers reported yield loss due to pest and insect attacks, and given the importance of cowpea to farmers and other value chain actors, making readily available a variety that is pest and disease resistant will reduce the cost of cowpea production (through reduced pesticide use), boost cowpea production, and result in fewer health-related symptoms from pesticide use and in other benefits (e.g., improved incomes, improved food security) along the value chain. However, because farmers recycle seeds mainly due to the high cost associated with buying new seeds and their low income, any intervention aimed at providing PBR seeds should consider the cost implications and provide incentives and investments that would lower the cost of the seeds for increased adoption. Lastly, this PE was conducted before the rollout of the RCT under the IE. Future PEs conducted at the midline and endline will improve the understanding of the issues reviewed here, to shed light on why or why not impacts may or may not be realized.

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