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Andrew M. Johnson, Tahirou Abdoulaye, Bamikole Ayedun,
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Andrew M. Johnson
Joan R. Fulton, Nicole J. Olynk Widmar,
Dept. of Agricultural Economics, Purdue University
West Lafayette, Indiana 47907-2056
johns993@purdue.edu, fultonj@purdue.edu, nolynk@purdue.edu

Tahirou Abdoulaye, Bamikole Ayedun ,Akande Adebowale,
Ranajit Bandyopadhyay, Victor Manyong
International Institute of Tropical Agriculture
PMB 5320, Oyo Road, Idi-Oshe
Ibadan, Nigeria
t.abdoulaye@cgiar.org

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Abstract

Aflatoxin is a potent mycotoxin that can cause cancer, stunted growth, and (in extreme instances) rapid death. Aflatoxin can contaminate many staple crops, including maize and groundnuts. As many as 4.5 billion people in the developing world may be chronically exposed. Scientists at the United States Department of Agriculture – Agricultural Resource Service, International Institute of Tropical Agriculture (IITA), and African Agricultural Technology Foundation have developed a biological control product called Aflasafe. IITA is currently working with the AgResults initiative to promote widespread adoption of Aflasafe in Nigeria and with the Aflasafe Technology Transfer and Commercialization Program to promote Aflasafe adoption in 11 African countries. In the fall of 2016, 902 oral surveys were administered to smallholder maize farmers in Nigeria. The survey was developed to obtain data regarding farmer awareness of aflatoxin and Aflasafe. At least 88% of farmers who head heard of aflatoxin claimed to recognize the negative health impacts of aflatoxin consumption on human and animal health. Private sector players were critical sources of information about Aflasafe for farmers. First-time users of Aflasafe persisted more frequently in purchasing the product in future growing seasons in some states than others. Stronger relationships between farmers and input suppliers seemed to increase the likelihood a farmer would repurchase. Farmers who purchase Aflasafe bundled with other inputs appeared more likely to repurchase than farmers who purchase Aflasafe stand-alone.

Keywords: aflatoxin; Aflasafe; AgResults; maize farmers; Nigeria

JEL Codes: D19; I15; O13

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Introduction

Aspergillus flavus, a fungus commonly found in soils and on grain and legume crops, produces "aflatoxin", a highly carcinogenic mycotoxin (Williams et al., 2004). The Centers for Disease Control and Prevention (2012) claim that about 4.5 billion people in the developing world are chronically exposed to dangerous levels of aflatoxins through their diet. Countries situated between the 40ºN and 40ºS latitude with "hot, humid, draught-prone climates" are most at risk (Narayan, 2014, p.2).

Chronic aflatoxin ingestion has been shown to cause liver disease and, in high concentrations, death in both humans and domestic animals (Williams et al., 2004). Aflatoxin is strongly linked to immune-system suppression, increased susceptibility to diseases, and growth retardation, notably stunting (Gong et al., 2002; Turner et al., 2003; Williams et al., 2004). Recent research suggests an association between consumption of aflatoxin contaminated maize ("corn" in the US) and the susceptibility to, and progression and severity of HIV/AIDS and opportunistic infections (Obuseh et al., 2011). Hepatitis B infection is believed to substantially increase the risk of liver cancer resulting from aflatoxin consumption (Groopman, Kensler, & Wild, 2008). Aflatoxin consumption also reduces the growth rate and productivity of farm animals (Williams et al., 2004).

There are two crops, maize and groundnuts ("peanuts" in US), that are particularly susceptible to aflatoxin contamination (Liu & Wu, 2010). These crops are significant sources of human food and animal feed in sub-Saharan Africa. Aflatoxin contaminated maize or groundnuts represent a significant risk to human health and a threat to trade in domestic and international markets (Otsuki, Wilson, & Sewadeh, 2001). Furthermore, toxic residues have been found in dairy, meat, and poultry products of animals fed aflatoxin-contaminated feed (Iqbal et al., 2014; Keyl & Booth, 1971).

The International Institute of Tropical Agriculture (IITA), in partnership with the United States Department of Agriculture–Agriculture Research Service (USDA–ARS), and national partners in Africa have developed a biological control technology to control aflatoxin. The product is named Aflasafe.

Aflasafe (www.aflassafe.com) is a safe product composed of natural strains of *Aspergillus flavus* that do not produce toxins (Bandyopadhyay et al., 2016). When Aflasafe is introduced in a farm field, the non-toxic strains outcompete the strains that produce the toxins, through a process known as competitive exclusion (Atehnkeng et al., 2008). Aflasafe is currently the most effective technology for aflatoxin mitigation in maize and groundnut at the pre-harvest stages (Bandyopadhyay et al, 2016). The protection continues even when the grains are in storage (Bandyopadhyay et al, 2016).

The core biocontrol technology was developed by the United States Department of Agriculture–Agricultural Research Service (USDA–ARS). IITA has taken the lead in adapting and improving the technology for Africa and is spearheading its adoption under the name Aflasafe. It is currently in use in Nigeria, Kenya, and Senegal.

The product is registered as Aflasafe^{TM} in Nigeria. Efforts are being made to scale out the technology in Nigeria through the AgResults Nigeria Aflasafe pilot project. The goals for that pilot project are to improve consumer health outcomes, generate economic benefits for smallholder farmers, and build a sustainable market for Aflasafe^{TM} (AgResults Initiative, 2015). A group of "implementer" that are private companies are enrolled in the pilot project to provide Aflasafe to farmers and aggregate the resulting production of "aflatoxin-safe" maize (i.e. maize with a sufficiently low aflatoxin concentration to be safe for human consumption and animal feed). Pilot project staff conduct tests to verify the levels of aflatoxin and Aflasafe in the maize those farmers produce. If the prevalence of Aflasafe is sufficiently high, a premium of US$18.75 (₦3,000) per metric ton is paid (AgResults Initiative, 2017). In the typical range of maize prices, this represents a premium of 5-13%, the anticipated long-term premium for aflatoxin-safe maize (AgResults Initiative, 2017). During Year 1 of the pilot project in the 2014 growing season, around 3,200 farmers worked with the nine implementers enrolled in the program (AgResults Initiative, 2017). Of the maize plots treated with Aflasafe in Year 1, 97% tested for less than 2 parts per billion (ppb), a level below both the US standard of 10 ppb and the EU standard of 4 ppb (AgResults Initiative, 2017).

IITA is in the process of developing and registering unique Aflasafe products in other African countries. In 2016, IITA – with funding from the Bill and Melinda Gates Foundation and United States Agency for International Development – launched the Aflasafe Technology Transfer and Commercialization (ATTC) Program. ATTC is a five-year project to promote Aflasafe registration and adoption in eleven African countries: Nigeria, Kenya, Senegal, The Gambia, Zambia, Burkina Faso, Ghana, Mozambique, Tanzania, Malawi, and Uganda (Partnership, n.d.).

Two fundamental questions need to be answered: What are the economic incentives for farmers to adopt the new technology? Are the economic incentives similar for human food, animal feed, and export markets? To address these question, economists from IITA and Purdue University are working together on a project known as ChoiceAflasafe. ChoiceAflasafe is funded by a grant from the United States government's Feed the Future Initiative through the Research Program on Agriculture for Nutrition and Health (A4NH) of CGIAR.

ChoiceAflasafe is intended to analyze users' acceptance of Aflasafe in Nigeria. The study targets two types of uses of aflatoxin-safe maize: human food and animal feed in the poultry industry. The target audience for human food use is smallholder farmers, and the target audience for poultry feed use is agribusiness enterprises (i.e. enterprises that produce poultry, feed, or a combination of poultry and feed). Separate surveys were developed and administered to each group. For both groups, survey respondents completed a discrete choice experiment and answered demographic questions and questions about their understanding of aflatoxin.

This paper presents the preliminary results from the farmer survey. Information about farmer demographics, understanding of aflatoxin, and Aflasafe usage are presented below.

Consumer Perceptions of Aflatoxin

Researchers have previously accessed the level of understanding about aflatoxin in sub-Saharan African countries. In a non-representative sample of eastern Ugandan groundnut farmers in 2014, 61% of households knew of aflatoxin by name (Jelliffe, Bravo-Ureta, Deom, & Okello, 2016). An additional 31.5% of groundnut farmers indicated hearing about “rotten nuts, moldy, bitter taste,” leading Jelliffe et al. to conclude that 92.5% of the sample group recognized aflatoxin as a problem in groundnut production (2016, p.24).

Daniel et al. (2011) found that 75% of Kenyan consumers surveyed from 2005-2007 in the counties of Makueni and Kitui, which have high incidences of aflatoxicosis, claimed to be aware that eating moldy maize could cause jaundice. De Groote et al. (2016) discovered that while 64% of consumers in their Kenyan sample were awareness of aflatoxin, only 16% understood its health risks.

From 2001-2004, Rotary International and IITA conducted public awareness campaigns on the topic of aflatoxin in Ghana, Togo, and Benin (James et al., 2007). They conducted a baseline survey in 2000 and a post-campaign survey in 2005. These survey results showed that awareness of aflatoxin among maize farmers during 2000 was significantly and substantially higher in Ghana (44%) than in Benin (11.6%) and Togo (6.8%) (James et al., 2007, p. 1287). After the campaign, maize farmer awareness levels were significantly higher than beforehand in Benin (58% of maize farmers informed) and Togo (46.1% of farmers informed) (James et al., 2007, p. 1287). The level of awareness about aflatoxin among maize farmers in Ghana also increased during the time of the campaign but this was not statistically significant.

Data and Methodology

Primary data was collected for this study. IITA and Purdue personnel collaborated to develop a survey using the latest methodology for choice experiments. To ensure full coordination, Purdue staff made two visits to IITA operations in Nigeria. Dr. Joan Fulton visited in May 2016 to help initiate survey development. Dr. Fulton and Andrew Johnson visited again in September 2016. They were centrally involved in the roll out of the survey interviews. Working with IITA staff the team developing and delivering training to the enumerators who were conducting the surveys. Enumerators were trained from September 28-29, 2016, at IITA’s station in Abuja, Nigeria. Fulton and Johnson also participated with IITA staff in the initial testing in a village by the enumerators. IITA staff recruited a team of 15 enumerators. Every enumerator holds a bachelor’s degree, and some have more advanced degrees.

The surveys were conducted during October and November of 2016 in six Nigerian states. The precise locations of the surveys are shown by the dots in Figure 2. Respondents were selected following a joint stratified and cluster approach. First, three strata were identified based on the level of experience farmers had with Aflasafe: those who had used Aflasafe in the past, those who were aware of Aflasafe but had not used the product, and those who were not aware of Aflasafe. Then, clusters of two states were assigned to each group based on the general level of experience of farmers in those states. In Kaduna and Oyo States, most farmers were current or former Aflasafe users. In Kwara and Benue States, most farmer were aware of Aflasafe but had never used it. In Nassarawa and Bauchi States, most farmers were not aware of Aflasafe.

For Benue, Kwara, Kaduna, and Oyo States it was essential to draw on the experiences of IITA to recruit the farmers for the two strata with at least some awareness of Aflasafe. Specifically, implementers enrolled in the AgResults Nigeria pilot project provided ChoiceAflasafe with a list of farmers in each appropriate control group. The IITA staff carrying out the survey randomly selected villages from this list and then randomly selected 15 farmers from each village. In Kwara and Oyo States, villages sometimes held fewer than 15 farmers, in which case all the farmers in the given village were surveyed. In Bauchi and Nassarawa States, where implementers were not present, information about villages and farmers was provided by extension services.

The survey received Internal Review Board approval from Purdue University and IITA (IRB Protocol #1606017881). Enumerators explained to respondents that participation was voluntary. Enumerators received verbal consent before proceeding with surveys. Responses to questions were recorded in CSPro 6.3. After conducting the discrete choice experiment, respondents were asked a series of questions about the characteristics of their household and farm. The farmer survey, excluding the choice experiment, is provided in Appendix A. Nine hundred two survey responses were recorded.

Results and Discussion

General Farmer Characteristics

Surveys were conducted in six Nigerian states as noted above. Farmers were divided into three treatment groups based on their level of experience with Aflasafe. The three experience groups were those farmers who are not aware of Aflasafe, those farmers who are aware of Aflasafe but have never use it, and those farmers that have experience using Aflasafe. The numbers of farmers from each state placed in each experience group are shown in Figure 1. In total, 297 farmers were not aware of Aflasafe, 285 farmers were aware of Aflasafe but had never used it, and 320 farmers were current or former Aflasafe users.

The six states were chosen to create approximately equal experience groups. IITA staff knew the general level of Aflasafe experience in each state *ex ante*. Oyo and Kaduna were the two states where many farmers have experience using Aflasafe due to the past demonstration efforts and work of the AgResults implementers. In Oyo State, surveys were primarily conducted around Oke Ogun, which is renowned for maize and grain production. In Kaduna State, surveys were primarily conducted in the northern parts of the state known for maize production. Because maize is produced proficiently in these regions, Aflasafe was purposefully introduced to them first.

Researchers targeted 150 farmer surveys responses in each state. Due to the small number of farms with experience using Aflasafe in Oyo State, researchers could not survey 150 farmers in a cost and time efficient manner. To make the Aflasafe user experience group approximately equal in size to the other experience groups, more than 150 farmers were surveyed in Kaduna State to compensate for the small sample group in Oyo State.

Figure 1. Farmer State and Information Type

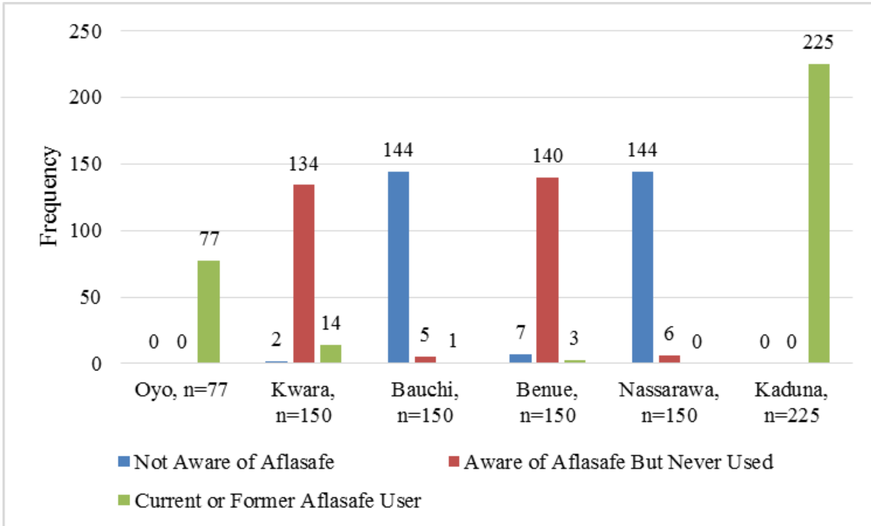
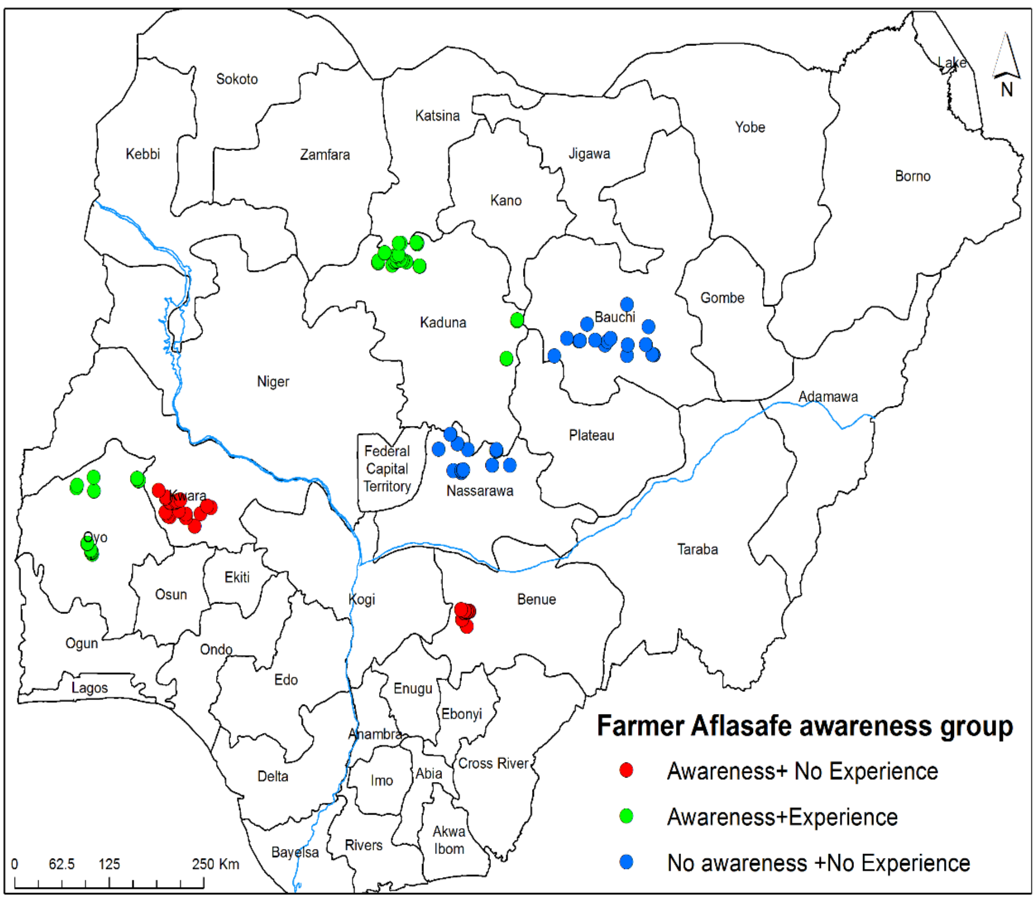


Figure 2. Location of Farmer Surveys



Summary statistics for the entire sample group are presented in Table 1. Three farmers did not disclose their age. Three other farmers did not report their household size. Seven farmers did not report the highest years of education of a member of their household.

The average farmer age was 44 years old. The average household size was 12.6, while median household size was 10 people. The average total cultivated land area was 7.8 hectares. The standard deviation of total cultivated land was larger than the mean, showing that there is considerable variation in the size of farming enterprises. The average area of maize cultivated land was 3.8 hectares, almost half of the area of total cultivated land.

The average score on the Progress out of Poverty Index (PPI®) was 53.4. The PPI® is a quick measure to describe various aspects of poverty, as demonstrated in Appendix C (Schreiner, 2015a). If a farmer scored 53.4 on the PPI®, there was approximately a 43.5% likelihood that the per capita consumption of his/her household was less than US$2.00/day in 2005 purchasing power parity (PPP) dollars (Appendix C). There was a 96.6% likelihood that the per capita consumption of his/her household is less than $5.00/day.

Table 1. Summary Statistics For Full Sample Group, n=902

	mean	median	sd	min	max	n
Age of Farmer	44.1	42.0	12.6	20.0	85.0	899
Household Size	12.6	10.0	10.0	1.0	80.0	899
Highest Years of Education Attained by Household Member	13.0	14.0	3.7	0.0	30.0	895
Years of Farming Experience	21.5	20.0	12.0	3.0	64.0	902
Size of Total Cultivated Land (Hectares)	7.8	5.0	8.8	0.4	99.0	902
Size of Maize Cultivated Land (Hectares)	3.8	2.5	4.7	0.1	50.0	902
PPI® Index Score (Range: 0-100)	53.4	52.5	13.4	20.0	98.0	902

Average responses to demographic questions are decomposed by gender in Table 2. One hundred and six survey respondents were women (11.8% of sample). Men represented at least 98% of the responses in Bauchi and Kaduna States, and 83% or less of responses in the other four states (see Figure 7). Therefore to reduce confounding between gender variations with geographic variations, responses from Bauchi and Kaduna States are excluded from the two rightmost columns of Table 2. These two columns are used to compare male and female responses in the two following paragraphs.

Women farmers had household sizes approximately 16% smaller than men on average (8.0 compared to 9.5). The average female farmer had essentially the same number of years of education as the average male farmer. The average female farmer had almost five fewer years of farming experience than the average male. Woman farmed 2 hectares less than men on average.

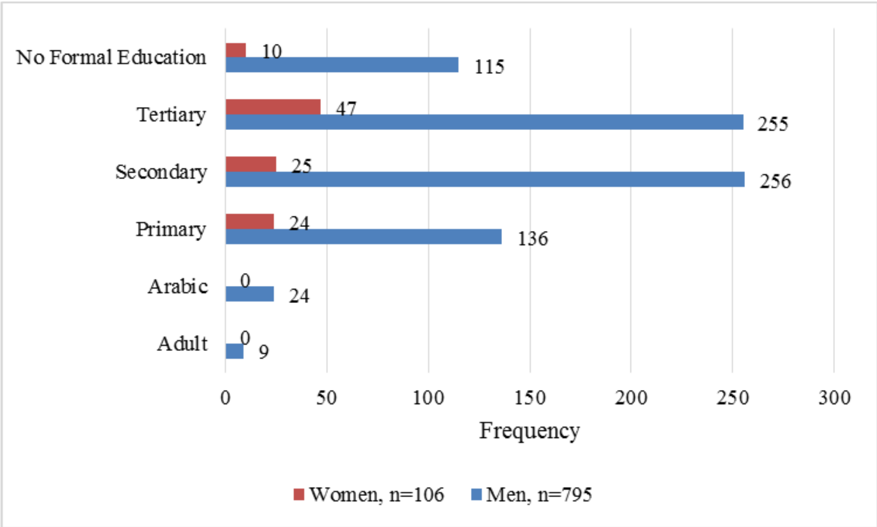
On average, women scored 3.4 points higher than men on the PPI®. The primary drivers of the difference in average PPI® scores were that women's households tended to have more sophisticated toilet facilities and tended to have fewer members.

Table 2. Mean Summary Statistics by Gender

	Full Sample		Excluding Bauchi and Kaduna	
	Men, n=796	Women, n=106	Men, n=426	Women, n=101
Avg. Age of Farmer	44.3	42.8	45.1	43.4
Avg. Houshold Size	13.2	8.1	9.5	8.0
Avg. Highest Years of Education by a Houshold Member	12.9	13.8	13.9	13.8
Avg. Years of Farming Experince	22.2	16.7	21.9	17.1
Avg. Size of Total Cultivated Land (Hectares)	8.2	5.2	7.2	5.2
Avg. Size of Maize Cultivated Land (Hectares)	4.0	2.6	2.9	2.6
Avg. PPI® Index Score (Range: 0-100)	52.4	61.0	58.1	61.5

Farmers identified the highest level of education they had obtained; results are reported in Figure 3. Slightly more than one-third of farmers reported attaining tertiary education. College graduates are involved in farming more than ever before due to a scarcity of white collar jobs in Nigeria. About one-third of farmers have obtained secondary education. A higher percentage of women had tertiary education than men. A lower percentage of women had secondary education as their highest education attainment than men. Observations from Bauchi and Kaduna States are included in Figure 3.

Figure 3. Highest Level of Education Attained, n=901

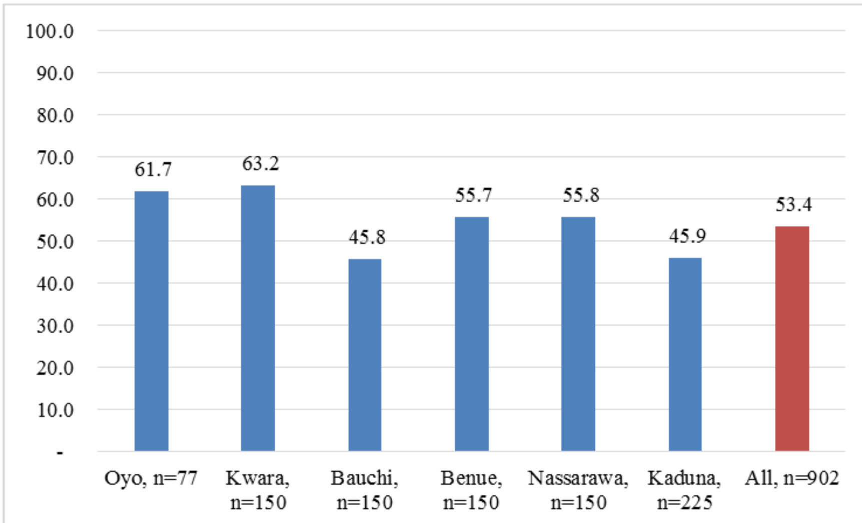


Progress Out of Poverty Index (PPI®)

The average scores on the PPI® for each state are shown in Figure 4. As shown in Appendix C, higher scores on the index correspond to lower likelihoods of living in poverty (Schreiner, 2015a). Farmers in the southwestern states of Oyo and Kwara had the highest average score on this index. Farmers in the northern states of Bauchi and Kaduna had the lowest average PPI® scores.

The average farmer from Kwara scores 63.2 on the PPI®. This farmer has approximately a 26.5% chance of having per capita household consumption below US$2.00/day in 2005 Purchasing Power Parity (PPP) dollars. By virtue of scoring 45.9 on the PPI®, the average farmer from Kaduna State has a 56.7% chance of having per capita household consumption below US$2.00/day (Appendix C).

Figure 4. Average PPI® Index Score (Range: 0-100)



Farmers were asked specific questions about their household as part of the PPI®. These results are reported in Table 3 where differences across states can be observed. The weight each question carries in the cumulative PPI® calculation is given in the "Max Points Possible" column. (For full details of the questions asked and scoring methodology, see Appendix B.) The column totals for each state in Table 3 match the data presented in Figure 4.

The household living conditions that were the leading drivers of differences in cumulative PPI® between states are highlighted in the yellow rows. Average scores in Bauchi and Kaduna States were substantially lower than the other four states on Question 1 because the average household was larger in Bauchi and Kaduna States (see Figure 5). The largest difference in mean scores between Kwara and Bauchi States was on Question 4, which measured the sophistication of a household's toilet facility. The other variables with notable differences across state drives include the quality of households' cooking equipment, whether households owned a television, and the type of vehicle a household owned for transportation.

It is also interesting to note the areas were differences between states were negligible. These areas include the number of rooms in the house a family occupied, the roofing material of the house, the number of mattresses owned, and the number of mobile phones owned.

Table 3. Mean Farmer Score on PPI® Index Questions by State

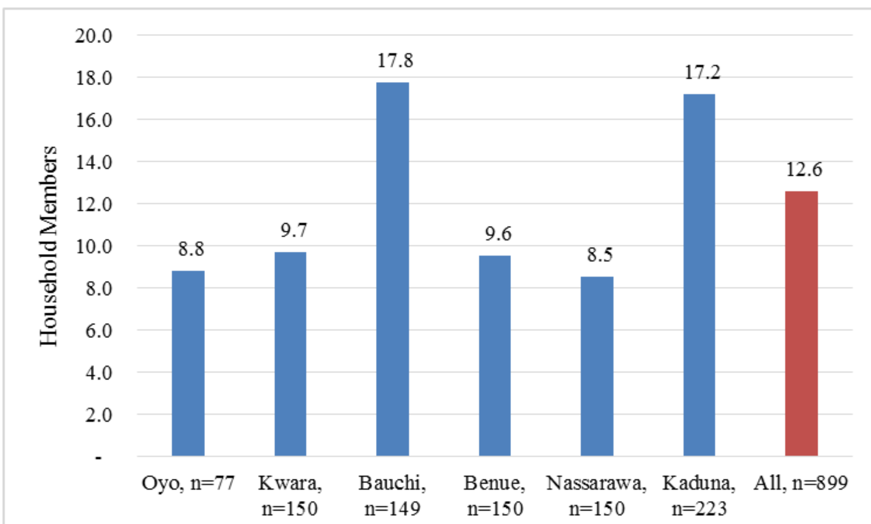
Question	Type of Question	Max Points Possible	Kwara, n=150	Oyo, n=77	Nassarawa, n=150	Benue, n=150	Kaduna, n=225	Bauchi, n=150
#1	Number of Members in Household	32	6.7	8.6	9.2	6.9	3.5	2.9
#2	Number of Rooms in House	7	6.0	5.6	6.4	6.3	6.7	6.6
#3	Roofing Material of House	4	4.0	4.0	3.9	4.0	3.9	3.7
#4	Toilet Facilities	15	11.1	9.7	8.3	8.4	6.4	5.5
#5	Cooking Equipment	3	2.5	2.4	1.0	1.2	0.5	0.7
#6	Number of Mattresses Owned	10	9.6	9.1	9.5	9.8	9.7	9.6
#7	Television Ownership	8	7.8	7.6	6.3	6.8	4.3	5.5
#8	Number of Mobile Phones Owned	7	6.7	6.6	5.8	6.1	5.8	5.8
#9	Type of Vehicle Owned	11	6.1	5.2	3.3	3.3	3.5	3.4
#10	Farming Practice Sophistication	3	2.6	2.8	2.1	2.9	1.6	2.0
Total		100	63.2	61.7	55.8	55.7	45.9	45.8

Note: The unit of measure for all questions is points, not tangible objects such as persons, rooms, mattresses, etc.

<u>Demographics by State</u>

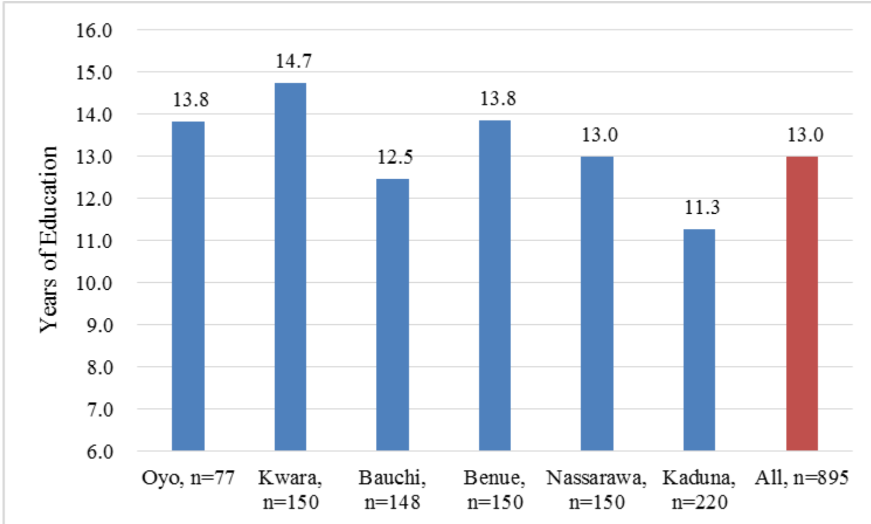
The average household size of each state is reported in Figure 5. Farmers in Bauchi and Kaduna States had the largest households on average. It is interesting to note that these are the same states where farmers have the lowest average scores on the PPI® Index.

Figure 5. Average Household Size



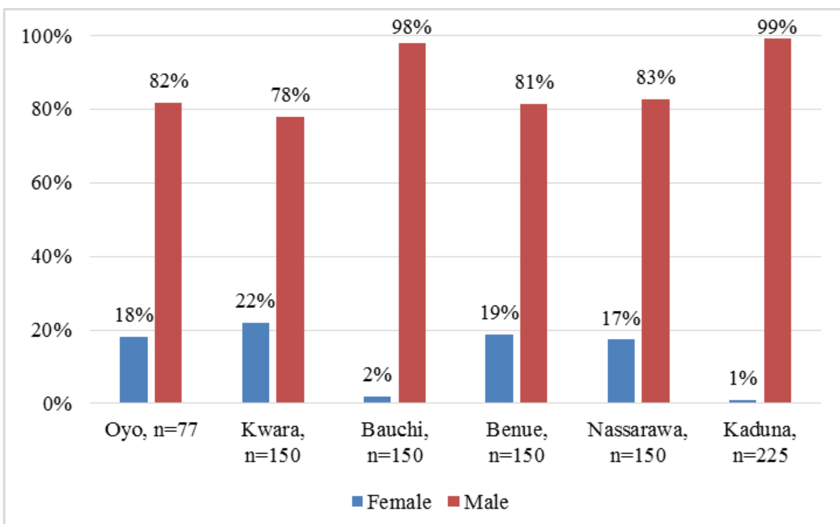
Farmers were asked to identify the highest number of years of education obtained by a member of their household. The mean responses to this question are shown in Figure 6. Households in Bauchi and Kaduna States were the least educated on average. Again, it should be observed that the two states where farmers had the lowest average PPI® scores had less educated farmers.

Figure 6. Average Highest Years of Education Attained by Household Member



The distributions of male to female farmers within each state are shown in Figure 7. As demonstrated by the blue bars, female representation was far lower in Bauchi and Kaduna States than in other states.

Figure 7. Gender Distribution by State

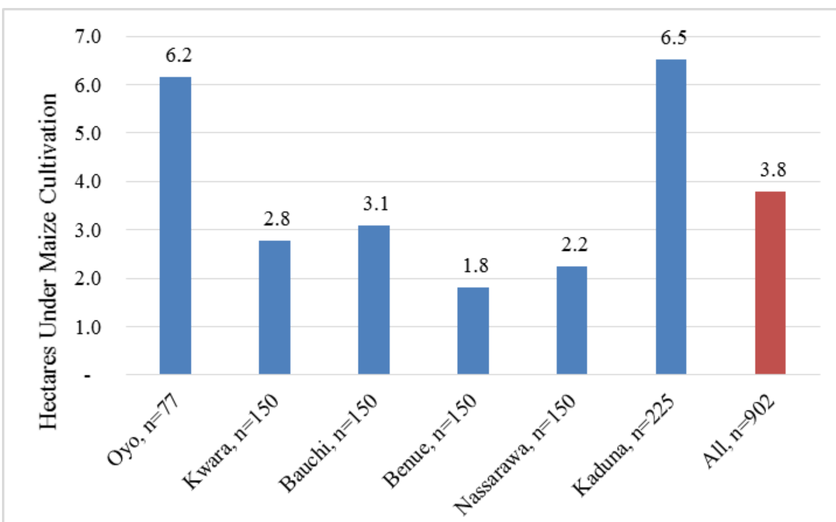


Farmers were also asked to indicate the amount of hectares they had under maize cultivation. The average answers for each state are reported in Figure 8. The average farm size was the largest in Oyo and Kaduna States. As discussed with Figure 2, regions of Oyo and Kaduna States renowned for maize production were intentionally targeted by researchers. This targeting may contribute to higher average farm sized in these states. It is noteworthy that Oyo and Kaduna States were so similar in this statistics given the differences between the two states in Figures 4-7. Household expenditures in Oyo State were relatively high while household expenditures in Kaduna State were relatively low (Figure 4). The average household size was substantially smaller in Oyo State than in Kaduna States (Figure 5). The average years of education in Oyo State was relatively high, while the average years in Kaduna State was the lowest of any state (Figure 6). Women represented 18% of farmers in Oyo State but only 1% in Kaduna State (Figure 7). Again, sampled farmers in Kaduna State primarily lived in the northern part of the state. If southern Kaduna State had been more heavily sampled, education levels and female representation would likely be higher.

It is curious that the average size of maize cultivated land in Oyo State was more than double the amount in Kwara. The statistics in Figures 4-7 for Oyo and Kwara were consistently very similar. Likewise, average size of maize cultivated land was twice as high in Kaduna State as in Bauchi State. The data for Kaduna and Bauchi States was highly comparable in Figures 4-7.

Average farm size was lowest in Benue. It is interesting to compare this finding with a result from an analogous survey given to poultry farmers and feed millers concurrently with this survey. That survey was administered in the same six states as this maize farmer survey. The other survey found that the prevalence of "small scale" enterprises was substantially higher in Benue than in any other states. Taken together, results from this farmer survey and that agribusiness survey suggest that both farming and agribusiness enterprises were smaller in size in Benue than in the other five states.

Figure 8. Average Size of Maize Cultivated Land

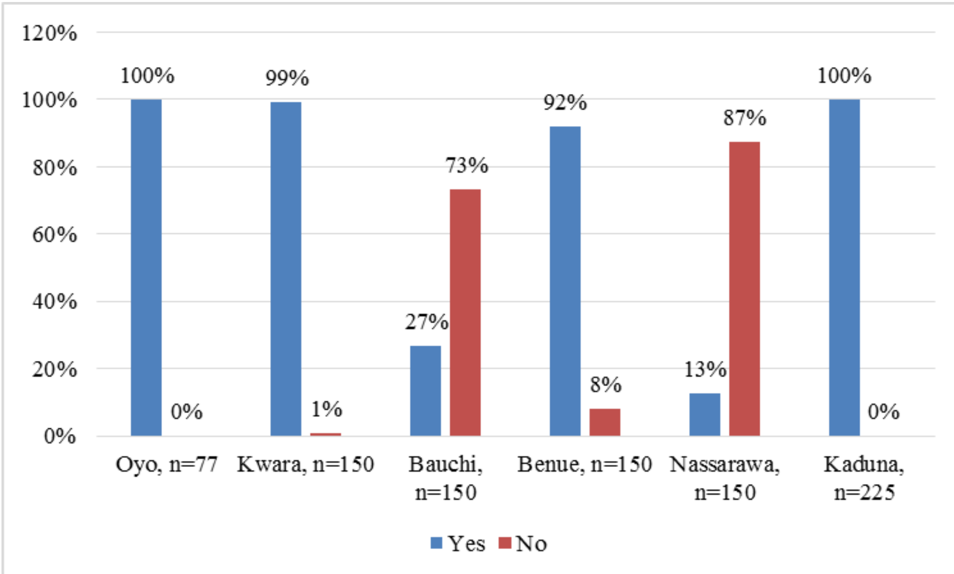


Aflatoxin Awareness and Perceptions

The percentages of farmers in each state who had heard of aflatoxin are shown by the blue bars in Figure 9. In total, 648 farmers had heard of aflatoxin. The level of awareness was substantially lower in Bauchi and Nassarawa States than in other states. The statistics in Figure 9 are consistent with the data in Figures 1 and 2. Aflatoxin awareness was over 90% in the four states in which the majority of farmers have heard of Aflasafe or use Aflasafe: Oyo, Kwara, Benue, and Kaduna.

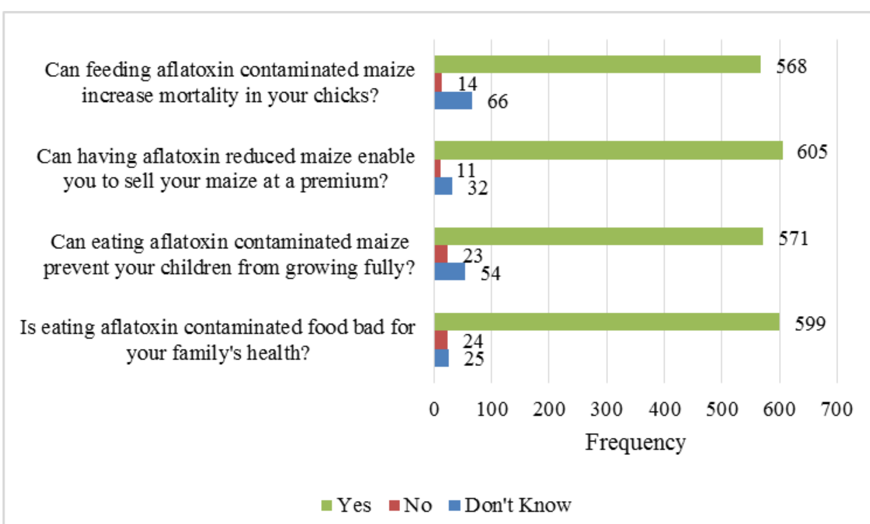
The large difference in the level of aflatoxin awareness between Bauchi and Kaduna States is most likely due to the fact that as of October 2015, the AgResults Nigeria Aflasafe pilot project was operating in Kaduna State but not in Bauchi State (AgResults Initiative, 2015).

Figure 9. Have You Heard of Aflatoxin?



Farmers that had heard of aflatoxin were asked four questions about the impacts they believed aflatoxin has on human health, poultry health, and maize pricing. These questions and farmers' responses are recorded in Figure 10. As show by the green bars, 571 farmers (88% of 648) recognized that aflatoxin inhibits child growth, and 599 farmers (92% of 648) believed aflatoxin was bad for their family's health. About the same number of farmers believed aflatoxin increases mortality in chicks as believed aflatoxin inhibits growth in human children. Six hundred five farmers (93% of 648) claimed that they could sell aflatoxin reduced maize at a price premium.

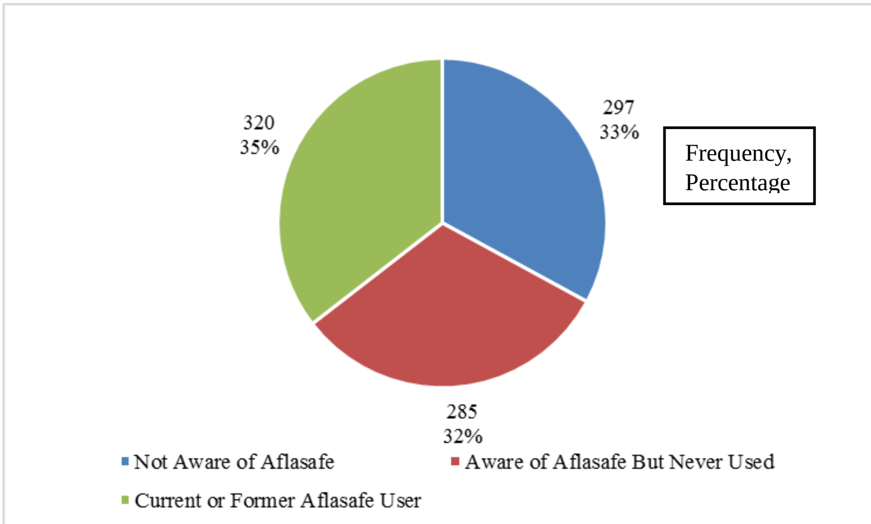
Figure 10. Aflatoxin Perceptions, n=648



Aflasafe Experience

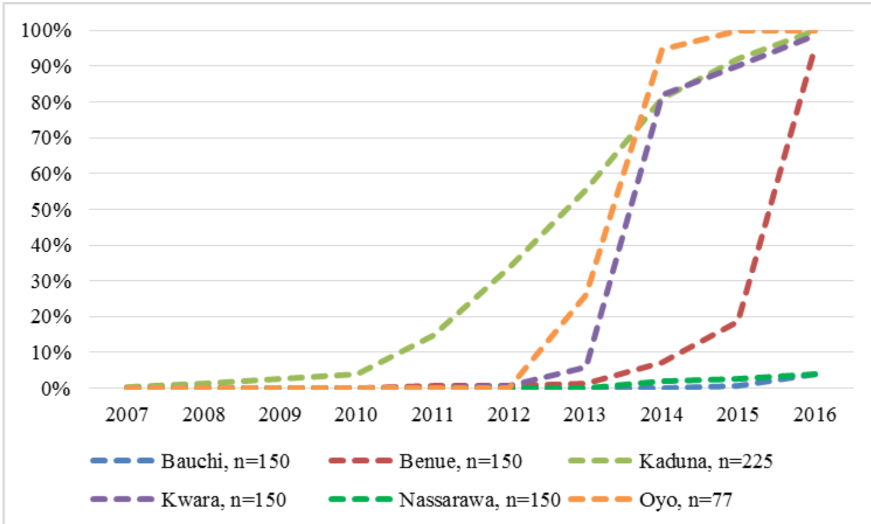
Farmers were classified into three groups based on their experience with Aflasafe. These groups were approximately equal in size, as demonstrated in Figure 11. The numbers presented in Figure 11 match the numbers from the discussion of Figure 1.

Figure 11. Experience with Aflasafe



Farmers who had heard of Aflasafe were asked to identify the year they learned about the product. Results are plotted in Figure 12. Nearly all respondents in Benue, Kaduna, Kwara, and Oyo States had heard of Aflasafe by 2016. Awareness of Aflasafe in Kaduna State increased gradually from 2010 to 2016. There was a substantial increase in awareness levels in Kwara and Oyo States in 2014. Similarly, there was a large increase in the awareness level in Benue in 2016. As expected, only 4% of farmers in both Bauchi and Nassarawa States had heard of Aflasafe in 2016.

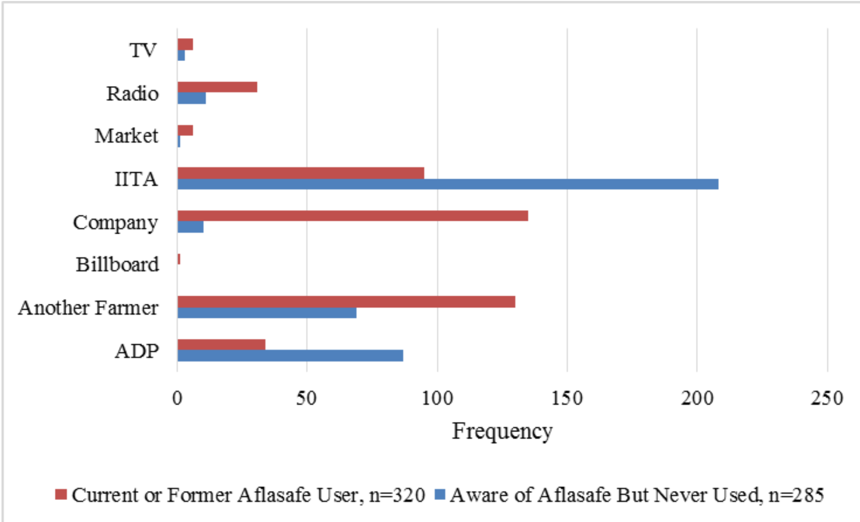
Figure 12. Percentage of Respondents Who Heard of Aflasafe By Year



Farmers who had heard of Aflasafe were also asked about their source of information. Farmers' answers are shown in Figure 13; responses are separated between those farmers who have used Aflasafe (red bars) and those farmers who have not used Aflasafe (blue bars). As shown by the red bars, the most frequently identified source of information by Aflasafe users was companies with which they do business. This fact highlights the important role that implementers, as agricultural input suppliers, play in promoting adoption of Aflasafe by farmers. The "Company" category includes implementers enrolled in the AgResults Nigeria Aflasafe pilot project and who had received information and knowledge from IITA.

The second-longest red bar is in the "Another Farmer" category. Farmer-to-farmer networking appeared to be an important means of disseminating information about Aflasafe. IITA (as the primary channel of information to farmers), ADP, and radio were other sources of information frequently cited by the Aflasafe user group. Non-users of Aflasafe (blue bars) frequently cited IITA and ADP as sources of information. This may reflect efforts by IITA and ADP to educate farmers about Aflasafe in areas where implementers are not active yet and where Aflasafe is not yet commercially available.

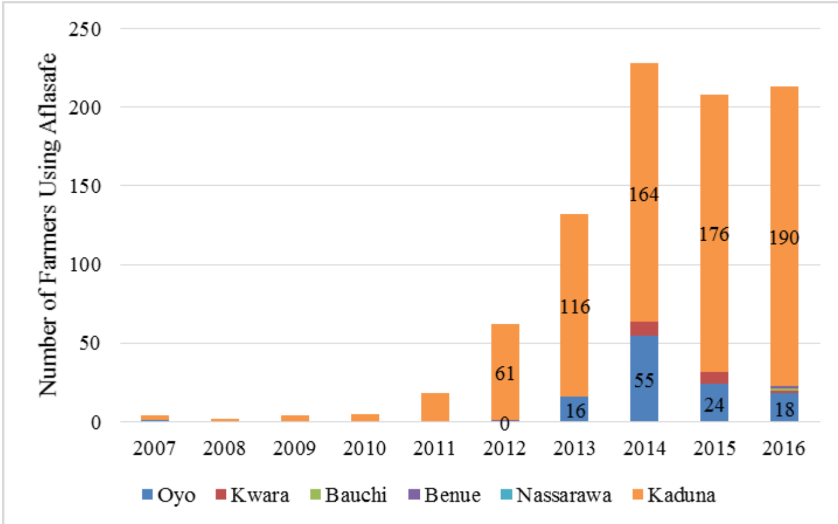
Figure 13. Where have you heard of Aflasafe?



Farmers with experience using Aflasafe (n=320) were asked which years they used Aflasafe. The numbers of farmers from each state who reported using Aflasafe each year are reported in Figure 14. The low number of farmers claiming to use Aflasafe before 2010 or 2011 may be reflect a few long-time Aflasafe users not recalling their precise start date. When interpreting Figure 14, readers should recall that 225 farmers were surveyed in Kaduna State and only 77 farmers were surveyed in Oyo State.

The number of Aflasafe users was trending in opposite directions in Kaduna and Oyo States from 2014-2016. In Kaduna State (orange section of bars), the number of Aflasafe users increased every year from 2011 to 2016. In Oyo State (blue section of bars), the number of Aflasafe users increased in 2013 and 2014, but declined in 2015 and 2016. The number of users declined in both Oyo and Kwara States in 2015 and 2016 as well. The declining usage in Oyo State is believed to the result of two factors. First, an insufficient quantity of Aflasafe was available in the area for farmers to purchase in 2015 and 2016. Second, Aflasafe vendors in that area generally have not kept their promises to purchase aflatoxin-safe maize from farmers that adopt Aflasafe. The trend that farmers in southwestern Nigeria were not persisting in using Aflasafe is further explored in the "Aflasafe Usage Attrition" subsection.

Figure 14. Number of Aflasafe Users by Year



Aflasafe Purchase Patterns

Under the current arrangements in the AgResults Nigeria Aflasafe pilot project, IITA manufactures Aflasafe at its campus in Ibadan, Nigeria. Implementers purchase the Aflasafe from IITA. Implementers then have discretion for deciding how to market Aflasafe to farmers (Akande Adebowale, Manager of the AgResults Nigeria Aflasafe pilot project, personal communication, Oct 2016). This means that implementers decide how much to charge farmers and whether to sell Aflasafe as a stand-alone product or bundled with other maize inputs. Farmers were asked whether they purchased Aflasafe bundled or not; results are reported in Table 4.

Table 4. Pricing and Bundling of Aflasafe

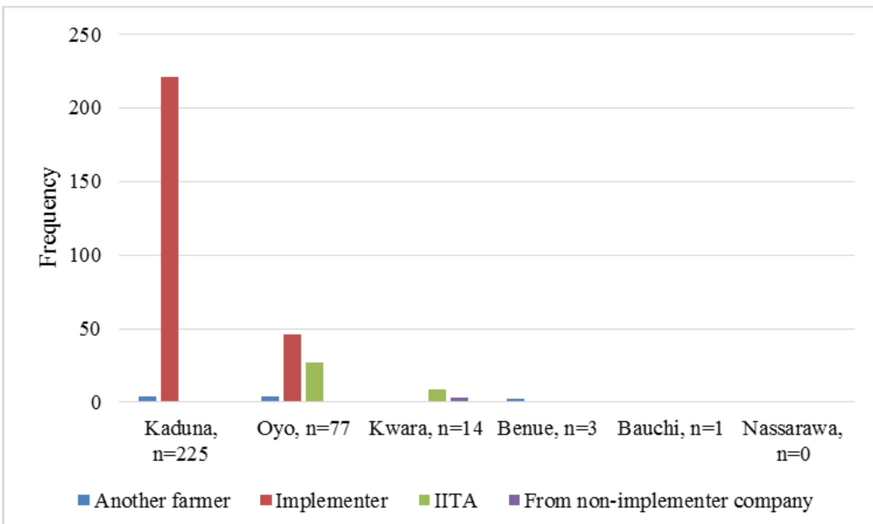
State	# of Farmers with Experience Using Aflasafe	# of Farmers who Purchased Aflasafe Bundled	Mean Price (Per 10kg)*
Kaduna	225	140	₦ 3,501
Oyo	77	10	₦ 2,924
Kwara	14	2	₦ 3,217
Benue	3	2	₦ 3,400
Bauchi	1	1	₦ 3,000
Nassarawa	0	0	
Total	320	155	

*Kwara mean excludes 8 farmers who did not report a price or paid 0₦ for Aflasafe from IITA.
Benue mean exlcudes one farmer who did not report a price.

As per Figures 1 and 2, the clear majority of Aflasafe users in this sample were located in Kaduna or Oyo States. The average price is Kaduna State was ₦ 578 per 10 kg higher than the average price in Oyo State. It should be noted that the highest average price was in the state where the number of Aflasafe users was increasing (Kaduna State). The market for aflatoxin-safe maize appeared to be stronger in Kaduna State than in Oyo State. Also, a substantially higher percentage of farmers in Kaduna State purchased Aflasafe bundled with other maize inputs (140/225 = 62%) than in Oyo State (10/77 = 13%).

The entities providing Aflasafe to farmers in each state are shown in Figure 15. In Kaduna State, over 98% of farmers received Aflasafe from an implementer. IITA was a substantial provider of Aflasafe to farmers in Oyo State but not in Kaduna State. If farmers were working with an implementer, they were asked to identify the implementer. All the farmers in Kaduna State receiving Aflasafe from an implementer are working with the same company. In Oyo State, all but one of the farmers receiving Aflasafe from an implementer were working with a single company as well.

Figure 15. Provider of Aflasafe to Farmer



It is interesting to note the lack of variation in prices farmers are paying for Aflasafe. Price histograms for Kaduna and Oyo States are provided in Figures 16 and 17 respectively. Almost all the farmers in Kaduna State paid exactly ₦ 3,500 for 10 kg of Aflasafe, and almost all the farmers in Oyo State paid ₦ 3,000. In Oyo State, farmers receiving Aflasafe from the implementer paid an average price of ₦ 2,979, and farmer who receiving Aflasafe from IITA paid an average price of ₦ 2,874. The small difference between these prices suggests that different Aflasafe providers were charging similar prices to farmers. Furthermore, the lack of variation overall shows that farmers who purchase Aflasafe bundled with other maize inputs are paying essentially the same price as farmers who purchase Aflasafe unbundled.

Figure 16. Price Farmers Report Paying for Aflasafe in Kaduna State, n=225

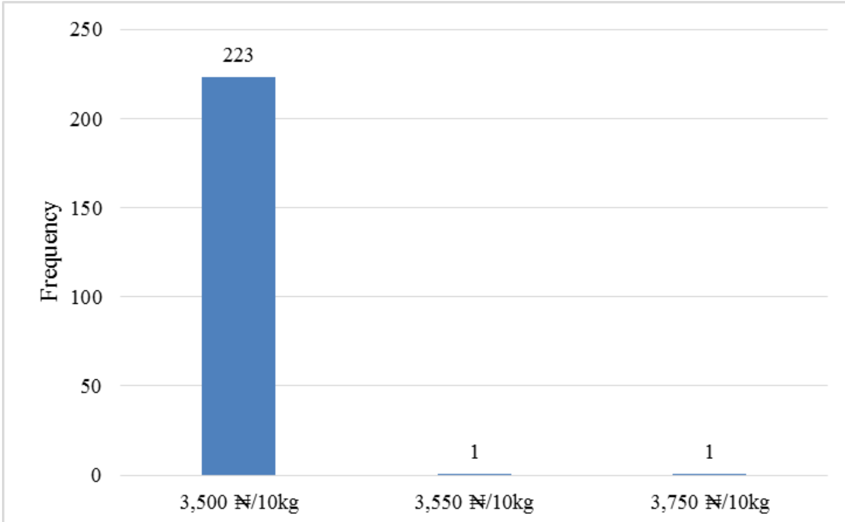
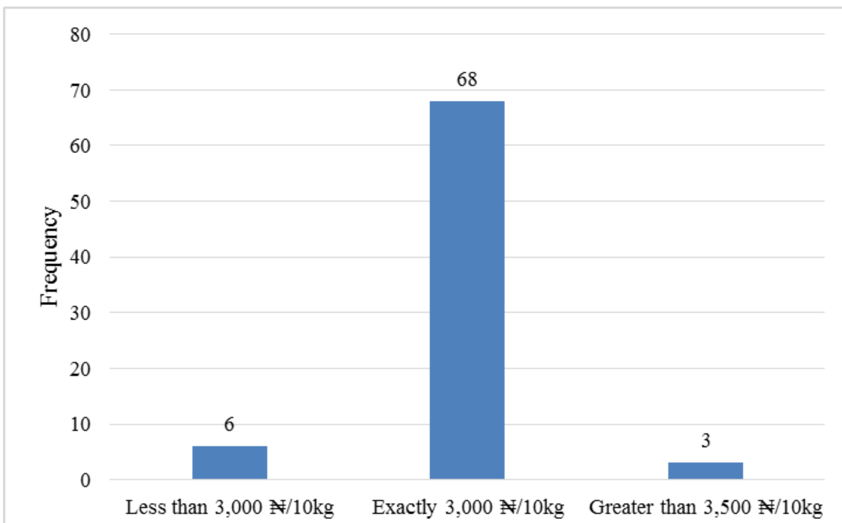
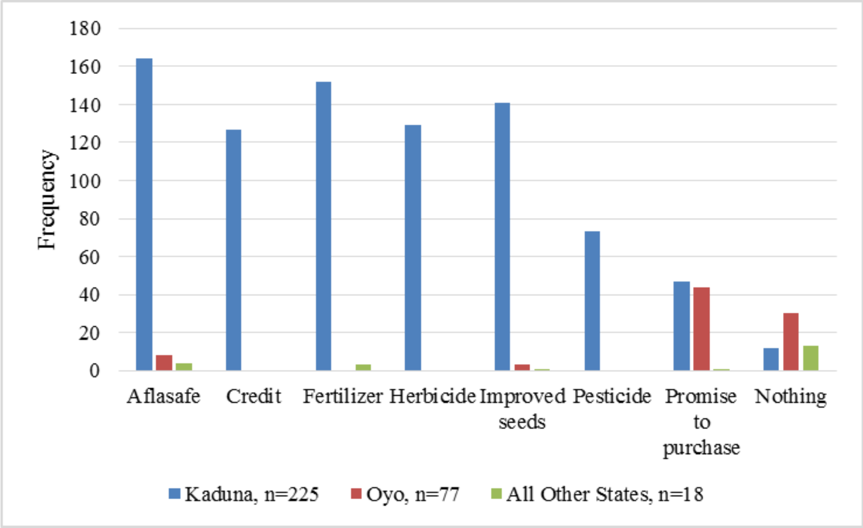


Figure 17. Price Farmers Report Paying for Aflasafe in Oyo State, n=77



Farmers were presented with a list of inputs and asked to choose which inputs they always receive from their implementer. Responses are summarized in Figure 18. The blue bars, representing Kaduna State, are substantially higher than the red bars, representing Oyo State, for Aflasafe, credit, fertilizer, herbicides, improved seeds, and pesticides. Implementers in Oyo State were less organized and less consistent in doing business with a farmer year-after-year than implementers in Kaduna State. Implementers in Oyo State often operated in an area for a brief period, say a year, and then moved to a new area. In all states, implementers often promised to purchase a farmer's aflatoxin-safe maize at the time they sell the farmer Aflasafe. However, implementers in Oyo State often failed to fulfill that promise.

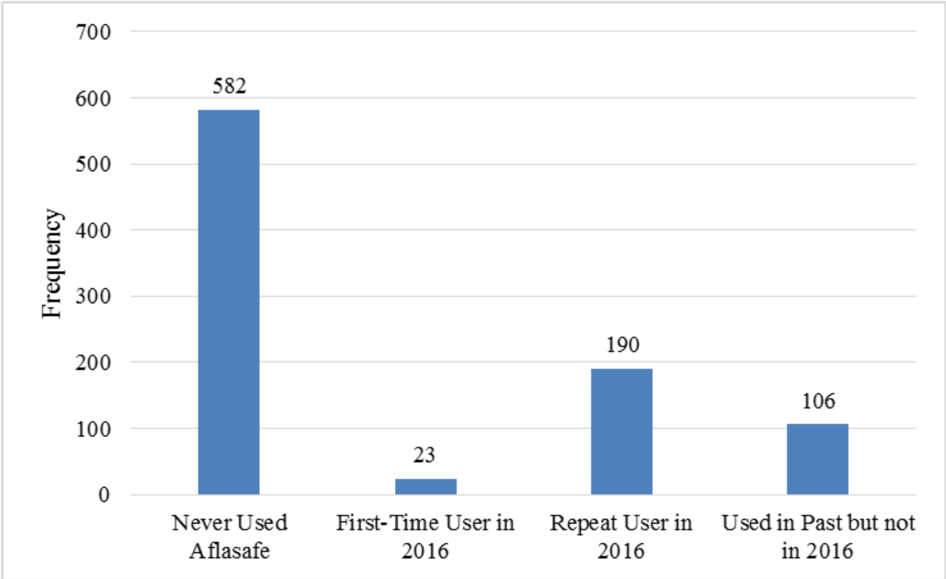
Figure 18. What do you always receive from your Implementer?



Aflasafe Usage Attrition

As per Figure 14, the number of farmers using Aflasafe was declining in some states. Two hundred ninety six farmers used Aflasafe prior to 2016. As shown by the "Repeat User" column in Figure 19, 190 of the 296 farmers (64%) were still using Aflasafe in 2016. The other 106 farmers stopped using Aflasafe, meaning the attrition rate is 36%.

Figure 19. Past Usage of Aflasafe, n=901



Further analysis of the data was conducted to examine whether there was a correlation between attrition rates for Aflasafe (no longer using the product) and perceptions of the health impacts of Aflatoxin. Results are presented in Figures 20 and 21. The two groupings in Figure 20 represent whether the farmer perceived eating aflatoxin-contaminated food was bad for their family or not.

The red bars illustrate the attrition rates among Aflasafe users, while the blue bars represente those who continued to use Aflasafe. The hypothesis that perceptions about the health impacts of Aflatoxin have a substantial impact on attribution rates among Aflasafe users is not supported. The difference between the red columns is minimal.

The results presented in Figure 21 parallel Figure 20 but the question was about the farmers' perception of contaminated feed. A similarly small difference is observed in Figure 21, where the grouping is based on perception of the impact of aflatoxin consumption on chick health.

Figure 20. Farmer Attrition Rates of Aflasafe Usage by Perception of Whether Eating Aflatoxin Contaminated Food is Bad for a Farmer's Family, n=296

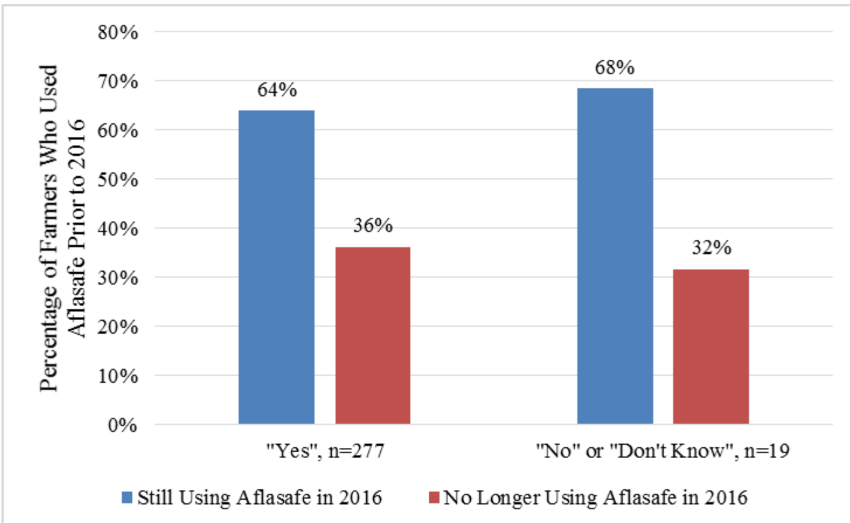
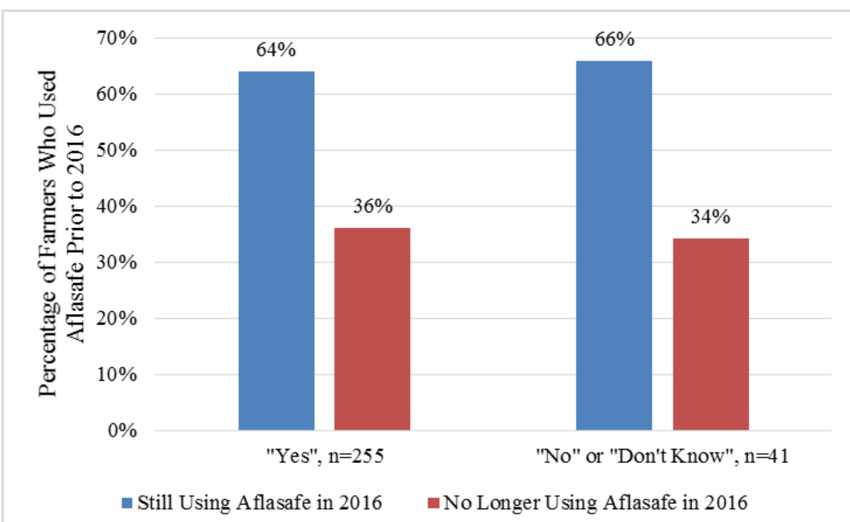
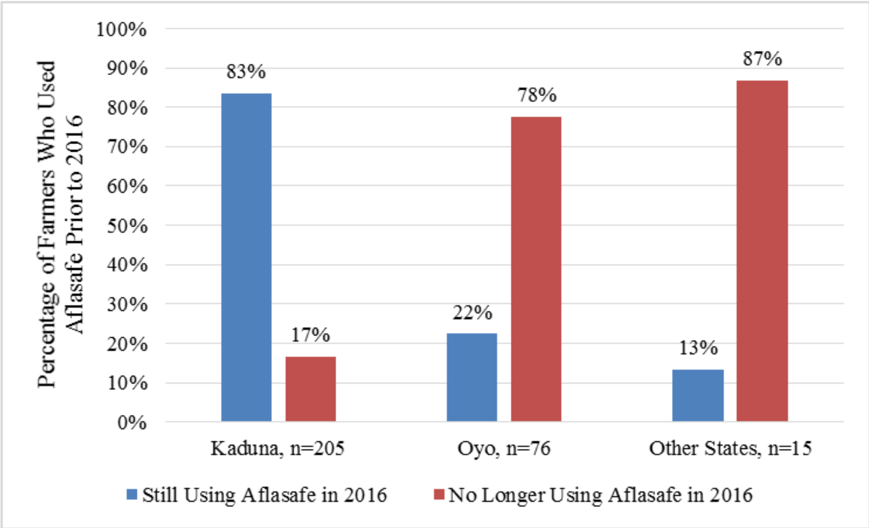


Figure 21. Farmer Attrition Rates of Aflasafe Usage by Perception of Whether Aflatoxin Contaminated Feed Increases Chick Mortality, n=296



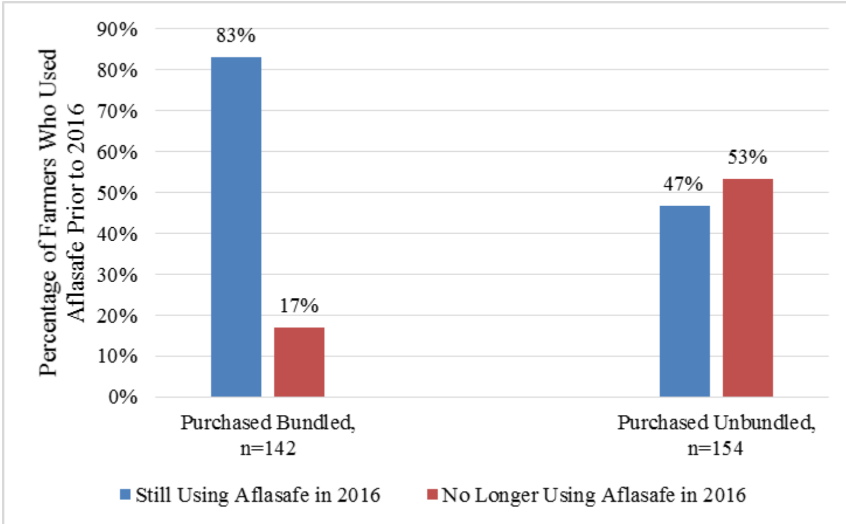
Attrition rates for states are shown by the red bars in Figure 22. While only 17% of previous Aflasafe users in Kaduna State had stopped using it in 2016, over three-quarters of previous users in Oyo State had stopped using Aflasafe. This finding was consistent with the observation from Figure 14 that the number of Aflasafe users increased in Kaduna State in 2016 but fell in Oyo State.

Figure 22. Farmer Attrition Rates of Aflasafe Usage by State, n=296



Attrition rates, based on whether a farmer purchased Aflasafe bundled with other inputs, are shown by the red bars in Figure 23. Farmers who purchased Aflasafe bundled had a substantially lower attrition rate (17%) than farmers who do not purchase Aflasafe bundled (53%). Products that come bundled with Aflasafe may include improved seed, fertilizer, herbicides, or other inputs listed in Figure 18. During the 2014 growing season, farms working with implementer enrolled in the AgResults Nigeria Aflasafe pilot project "yielded more than 70% the normal yield of 1.5 tons per hectare due to use of improved seeds, fertilizers, and crop management practices" (AgResults Initiative, 2017). It is important to note that the improved inputs and management practices, not the Aflasafe, are credited with improving farmer yields. Aflasafe is believed not to increase or decrease maize yields. The results in Figure 23 may suggest that the increased yield is necessary for making Aflasafe a profitable investment.

Figure 23. Farmer Attrition Rates of Aflasafe Usage by Bundling of Purchase, n=296



Conclusion

Surveys were administered to farmers in six Nigerian states: Bauchi, Benue, Kaduna, Kwara, Nassarawa, and Oyo. Household sizes were largest in the northern states of Bauchi and Kaduna. Women represented a substantially lower proportion of farmers in those states compared to others. Average score on the PPI®, a proxy for measure of household consumption levels, were highest in the southwest (Oyo and Kwara States) and lowest in the north (Bauchi and Kaduna States). The average size of maize cultivated land was higher in Kaduna State than in any other state; this may be the result of sampling Kaduna State farmers in regions proficient in maize production.

Knowledge about aflatoxin and Aflasafe seemed to be following the rollout across states of the AgResults Nigeria Aflasafe pilot project. At least 88% of farmers who head heard of aflatoxin claimed to recognize the negative health impacts of aflatoxin consumption on human and animal health. Implementers (who are also input suppliers) and other farmers were the most frequently cited sources of information about Aflasafe by farmers with experience using Aflasafe. Therefore, private sector players seemed to be critically important means of disseminating information about Aflasafe.

It is concerning that fewer farmers were using Aflasafe in 2016 than in 2014. Knowledge of the negative health consequences of aflatoxin consumption, as reported by the survey respondents, did not seem to influence a farmer's decision about continuing to use Aflasafe. There appeared to be substantial geographic variation in the level of farmer attrition in using Aflasafe. Only 17% of Kaduna State farmers had stopped using Aflasafe in 2016 but 78% of Oyo State farmers had quit. This difference may largely be attributable to difference in implementer business models between the two states. Implementers had stronger, more committed relationships with farmers in Kaduna State than in Oyo State. There was an insufficient number distribution outlets for farmers to purchase Aflasafe in Oyo State.

Farmers who purchase Aflasafe bundled with other inputs appeared more likely to persist in using the product. Aflasafe has no effect on maize yields, so it may be complimented well by other inputs that increase yields. A marketing opportunity for AgResults could potentially be to increase the frequency with which Aflasafe is bundled with other inputs.

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Appendix A: Farmer Survey Questions (excluding choice experiment)

A. SOCIO-ECONOMICS CHARACTERISTICS OF FARMER

1. Are you male or female? (0=female 1=male)
2. What is your telephone numbers (if any) ______________________
3. What is your age*?(put 999 if farmer refuse to give real age)*________________
4. What is your household size (those living with the farmers)_______________
5. How many in your household are less than 15 years old ____________?
6. How many in your household are more than 60 years old ___________?
7. Do you have any formal education? *(0=No 1=Yes)*
8. What is the highest level of education attained? 1. Primary, 2. Secondary, 3. Tertiary, 4. Adult education, 5. Arabic, 6. Other(Specify)___________
9. What is the highest years of education attained by a member of your household? ____
10. Marital status ________ (1=Single, 2=Married, 3=Divorced/Separated, 4=Widowed/Widower)
11. Years of farming experience_________________
12. What is the size of your total cultivated farm land area in ha?________
13. What is the size of your total maize farm land area in ha? *(All fragment pieces combined)*

B. INFORMATION AWARENESS & COMMUNICATION

14. Have you heard about aflatoxin? (0=No 1=Yes)

If yes, answer questions in the table below

Variable	**1=Yes, 2=No, 3= Don't know**
Can eating aflatoxin contaminated maize bad for your family's health?	
Can eating aflatoxin contaminated maize prevent your children from growing fully?	
Can having aflatoxin reduced maize enable you to sell your maize at a premium?	
Can feeding aflatoxin contaminated maize increase mortality in your chicks?	

15. Have you heard about Aflasafe? (0=No 1=Yes)
16. When did you first hear about Aflasafe? ______________ (enter year)
17. Where did you hear about it? (check all that apply)1. TV, 2. Ratio, 3. Another farmer, 4. Billboard, 5. IITA, 6. ADP, 7. Other __________
18. Have you ever use Aflasafe? 0=No, 1=Yes_
19. If yes, where did you get it from?_ 1. Implementer, 2. From non-implementer company, 3. IITA 4.Another farmer, Other(specify):_____
20. If an implementer or company, give the name of the implementer or company:_________________
21. How much did you pay for Aflasafe? ________ (for 10 kg.)
22. Did you buy Aflasafe on its own or bundled with other products? _________
23. If it was bundled, would you be willing to purchase it on its own? (0=No;1=Yes)
24. Which years in the table below did you use Aflasafe?

Variable	**Used Aflasafe**	**Did not use Aflasafe**
Before 2007,		
2008,		
2009,		
2010,		
2011		
2012		
2013		
2014		
2015		
2016		

25. What do you always receive from your implementer?______ (check all that apply)

1. Fertilizer, 2. Pesticide, 3. Herbicide, 4. Improved seeds, 5. Credit, 6. Aflasafe, 7. Promise to purchase

PPI® Assets

ITEMS	G04:No/Code
1. How many members does the household have? 1 = Ten or more, 2 = Eight or nine, 3 = Seven, 4= Six, 5= Five, 6 = Four, 7 = Three, 6 = Two, 8 = One or two.	
2. How many separate rooms do the members of the household occupy (do not count bathrooms, toilets, storerooms, or garage)? 1= One, 2= Two, 3= Three, 4=Four, 5=Five or more	
3. The roof of the main dwelling is predominantly made of what material? 1= Grass, claytiles, asbestos or plastic sheets or others; 2 = Concrete, Zinc, or iron sheets	
4 What kind of toilet facility does the household use? 1 = None, bush,pail/bucket, or other; 2= Uncovered pit latrine, or V.I.P. latrine; 3= Covered pit latrine, or toilet on water; 4= Flush to septic tank or flush to sewage.	
5. Does the household own a gas cooker, stove (electric, gas, table, or kerosene). or microwave? (1 = Yes, 0 = No)	
6. How many mattress does the household own? 1= None, 2= One, 3= Two, 4= Three or more	
7. Does the household own a TV set? (1 = Yes, 0 = No)	
8. How many mobile phones does the household own? 1= None, 2= One, 3= Two, 4= Three or more	
9. Does the household own a motorbike or a car or other vehicle? 1= No, 2= Only motorbike. 3= Car(regardless of motorbike)	
10. Does any member of this household pratice any agricultural activity such as crop, livestock, or fish farming, or own a land that is not cultivated? If so, does the household own any sprayers, wheelbarrow or sickles? 1= Farms or has uncultivated land, but no sprayers, wheelbarrows or sickles. 2= Farms or has uncultivated land, and has sprayers, wheelbarrows or sickles. 3= Does not farm nor has uncultivated land.	

Appendix B: Simple Poverty Scorecard™ for PPI®

"Important: A PPI score **must** be converted into a poverty likelihood using the PPI Look-up Table" in Appendix C. (Schreiner, 2015b, p. 1).

Indicators	Responses	Score
1. How many members does the household have?	A. Ten or more	0
	B. Eight or nine	5
	C. Seven	10
	D. Six	11
	E. Five	17
	F. Four	19
	G. Three	25
	H. One or two	32
2. How many separate rooms do the members of the household occupy (do not count bathrooms, toilets, storerooms, or garage)?	A. One	0
	B. Two	4
	C. Three	5
	D. Four	6
	C. Five or more	7
3. The roof of the main dwelling is predominantly made of what material?	A. Grass, clay tiles, asbestos or plastic sheets, or others	0
	B. Concrete, zinc, or iron sheets	4
4. What kind of toilet facility does the household use?	A. None, bush, pail/bucket, or other	0
	B. Uncovered pit latrine, or V.I.P. latrine	3
	C. Covered pit latrine, or toilet on water	6
	D. Flush to septic tank, or flush to sewage	15
5. Does the household own a gas cooker, stove (electric, gas table, or kerosene), or microwave?	A. No	0
	B. Yes	3
6. How many mattresses does the household own?	A. None	0
	B. One	6
	C. Two	8
	D. Three or more	10
7. Does the household own a TV set?	A. No	0
	B. Yes	8
8. How many mobile phones does the household own?	A. None	0
	B. One	2
	C. Two	5
	D. Three or more	7
9. Does the household own a motorbike or a car or other vehicle?	A. No	0
	B. Only motorbike	3
	C. Car (regardless of motorbike)	11
10. Does any member of this household practice any agricultural activity such as crop, livestock, or fish farming, or own land that is not cultivated? If so, does the household sprayers, wheelbarrows, or sickles?	A. Farms or has uncultivated land, but no sprayers, wheelbarrows, or sickles	0
	B. Farms or has uncultivated land, and has own any sprayers, wheelbarrows, or sickles	3
	C. Does not farm nor has uncultivated land	3
	Total Score:	

For transparency, the authors disclose that this table was lifted directly from the Nigeria PPI® 2012 Scorecard and Look-up Table PDF documents (Schreiner, 2015b, p. 1). It should not be misconstrued as an original product of the authors of this paper. "This PPI was created in July 2015 using Nigeria's 2012/13 General Household Panel Survey by Mark Schreiner of Microfinance Risk Management L.L.C. For more information, please visit www.progressoutofpoverty.org" (Schreiner, 2015b, p. 1).

Appendix C: PPI® Look-Up Table

"The following look-up tables are used to convert PPI scores to poverty likelihoods: International 2005 PPP" (Schreiner, 2015b, p. 4).

PPI Score	$1.25/day 2005 PPP	$2.00/day 2005 PPP	$2.50/day 2005 PPP	$4.00/day 2005 PPP	$5.00/day 2005 PPP
0 - 4	100.0	100.0	100.0	100.0	100.0
5 - 9	100.0	100.0	100.0	100.0	100.0
10 - 14	81.0	98.5	100.0	100.0	100.0
15 - 19	77.7	98.5	100.0	100.0	100.0
20 - 24	74.1	96.1	97.5	99.7	99.8
25 - 29	63.1	92.9	96.4	99.6	99.8
30 - 34	48.8	85.0	92.5	99.2	99.8
35 - 39	35.8	76.6	87.5	98.5	99.2
40 - 44	25.8	62.4	78.5	96.5	98.3
45 - 49	16.8	56.7	75.5	95.3	98.1
50 - 54	11.1	43.5	63.0	90.2	96.6
55 - 59	4.6	32.5	49.2	84.3	91.6
60 - 64	2.9	26.5	44.9	82.3	87.7
65 - 69	2.5	14.3	32.1	70.0	83.2
70 - 74	2.5	9.5	19.1	55.3	73.6
75 - 79	0.0	2.7	7.1	43.2	59.9
80 - 84	0.0	0.0	3.5	22.5	43.1
85 - 89	0.0	0.0	0.0	11.7	26.9
90 - 94	0.0	0.0	0.0	1.5	19.0
95 - 100	0.0	0.0	0.0	0.0	13.4

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