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Do improved drying and storage practices reduce aflatoxin contamination in stored maize? Experimental evidence from smallholders in southern Senegal

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IMPORTANT TO RECOGNIZE THAT FOOD "QUALITY" CAN BE OBSERVABLE OR UNOBSERVABLE

- Example: Aflatoxin is a big problem in maize and other crops.
- Potent toxin produced by several species of fungi (notably *Aspergillus flavus*).
- Estimated 4.5 Billion people in developing world are exposed to aflatoxins (Williams et al. 2004).

Aspergillus

Observable aflatoxin in maize

Unobservable aflatoxin in maize
@ 51 ppb

Levels safe for human consumption

US standard is < 20 ppb

EU/Kenya standard is < 10 ppb for processing

- **Lemons market: quality not observable no available way to test. No incentive to grow, preserve, and sell quality.**
- **Could inhibit market participation (Hoffmann and Gatobu 2014).**

Prevention of aflatoxin contamination post-harvest

- Knowledge to increase awareness
- Proper drying
  - Off ground
  - Quickly
  - Until maize moisture content < 13.5%
- Proper storing
  - Airtight container

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Source: Ka, Doumbouya and Seck 2015

EVALUATING COST-EFFECTIVE INTERVENTIONS TO REDUCE AFLATOXINS IN STORED MAIZE IN SENEGAL

- HACCP Analysis revealed problem occurring from harvest to storage
- 26 of 88 maize samples (30%) taken randomly from post-harvest cobs or shelled corn contained aflatoxin >20 ppb (Woloshuk, et al. 2016)
- Many people drying maize on the ground (25%)
- Little awareness of aflatoxin (29%).

Photo 1. A practice the project seeks to improve – ground drying increases aflatoxin contamination. *Photo courtesy of Stacy Prieto*

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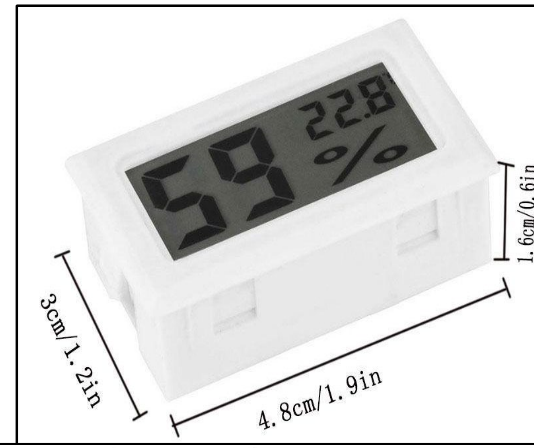
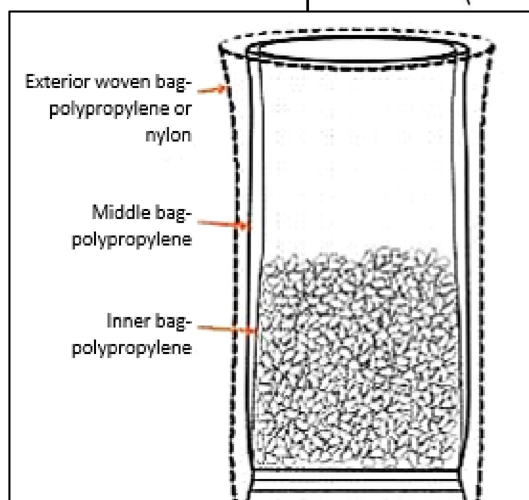
WHAT SHOULD FARMERS DO TO PREVENT AFLATOXIN CONTAMINATION?

Training on good post-harvest practices



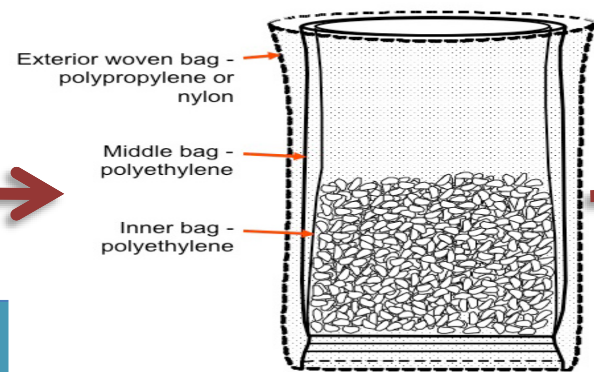
$2.00

$3.25 per 5 x 2 m



$2.22

Technology Intervention: Traditional. Vs Improved



Courtesy: Murdock et al., 2014

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Intervention

Use Cluster Randomized Control Trial (RCT) to see which combo of training/technologies is most efficient

Treatment Groups

	No. of Villages	No. of Households
1. Control	41	382
2. Receives training only	41	394
3. Receives training + hygrometer	42	398
4. Training + hygrometer + tarp	42	410
5. Training + hygrometer + tarp + PICS	43	409
Total	209	1,993

- 1,580 samples analyzed for aflatoxin using VICAM reader.
- Treatment at village level: Everyone in village invited, 10 HH per village given technologies and followed
- Training and intervention before harvest in October 2016
- Follow up in Feb 2017, May 2017 (+ April 2019 for long-term impacts; no results yet)

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CONTRIBUTION

- Adds to sparse literature with randomized intervention to potentially reduce aflatoxin in stored grain among smallholder farmers.
- Focus on major staple food crop (maize)
- Links drying and storage training and technology
- Cost-effectiveness analysis on interventions.

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Aflatoxin empirical model

$$A_{ij} = \beta_1 + \beta_2 Train_{ij} + \beta_3 Hygro_{ij} + \beta_4 Tarp_{ij} + \beta_5 PICS_{ij} + \tau T_{ij} + \boldsymbol{\delta}_k \boldsymbol{X}_{ijk} + \boldsymbol{\alpha}_m \boldsymbol{E}_{ijm} + \mu_{ij} \quad (2)$$

- A_{ij} is the aflatoxin level in ppb [0, 100] of the household's stored maize in April 2017
- *Train*, *Hygro*, *Tarp*, and *PICS* are binary variables equal to 1 if the household received the input of training, a hygrometer, a tarp, or a PICS bag, respectively
    - $\hat{\beta}_2$, $\hat{\beta}_3$, $\hat{\beta}_4$, and $\hat{\beta}_5$ estimate the marginal effect of receiving only information, a hygrometer, a tarp, or a PICS bag, respectively, on the household's aflatoxin levels.
- T_i is a binary variable that equals 1 if enumerators took two maize samples for testing
- $\boldsymbol{X}_{ik}$ is a vector of the covariates that were not balanced at baseline
- $\boldsymbol{E}_{im}$ is a vector of dummy variables denoting the extension agents, excluding agent 10
- μ_{ij} is the error term

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RESULTS

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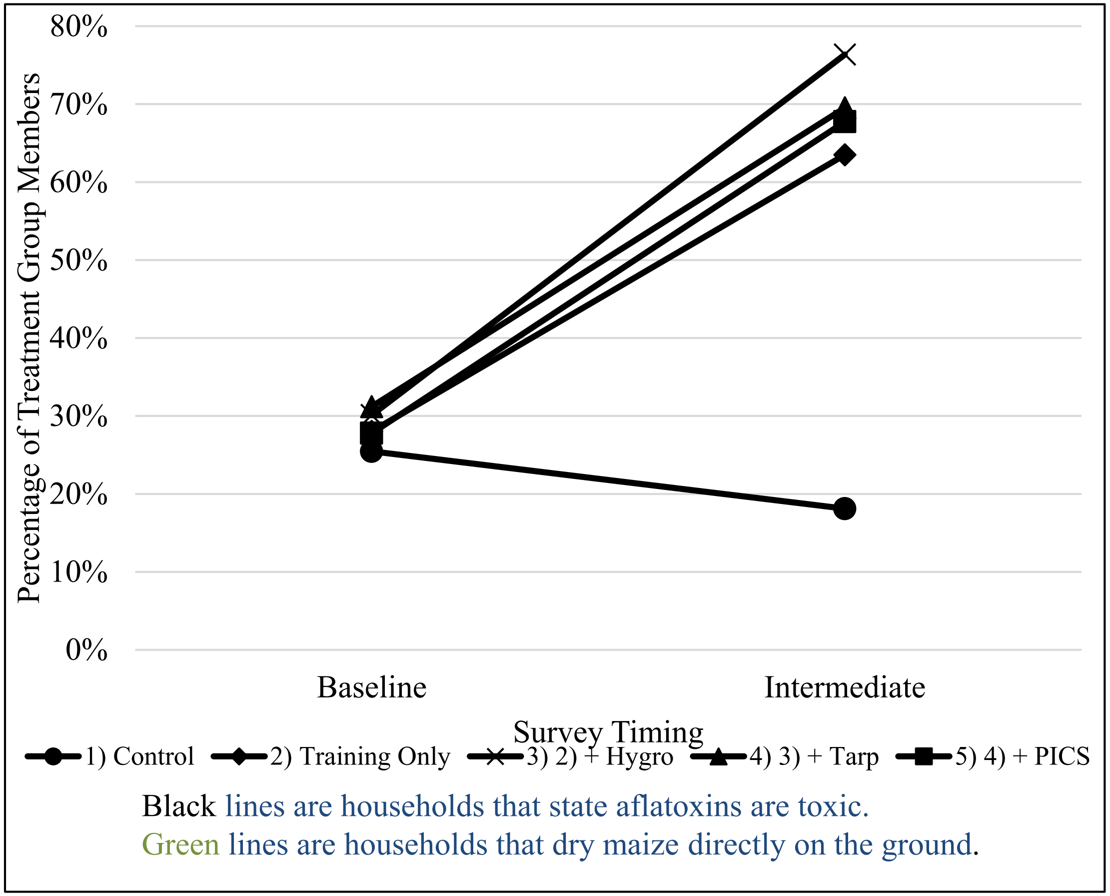
BEHAVIOR CHANGE FROM BASELINE TO INTERMEDIATE SURVEY BY TREATMENT GROUP

- For all treated groups, knowledge of aflatoxin toxicity (black lines) is upward sloping, whereas for the control group it is downward sloping.
  - 29% awareness at baseline



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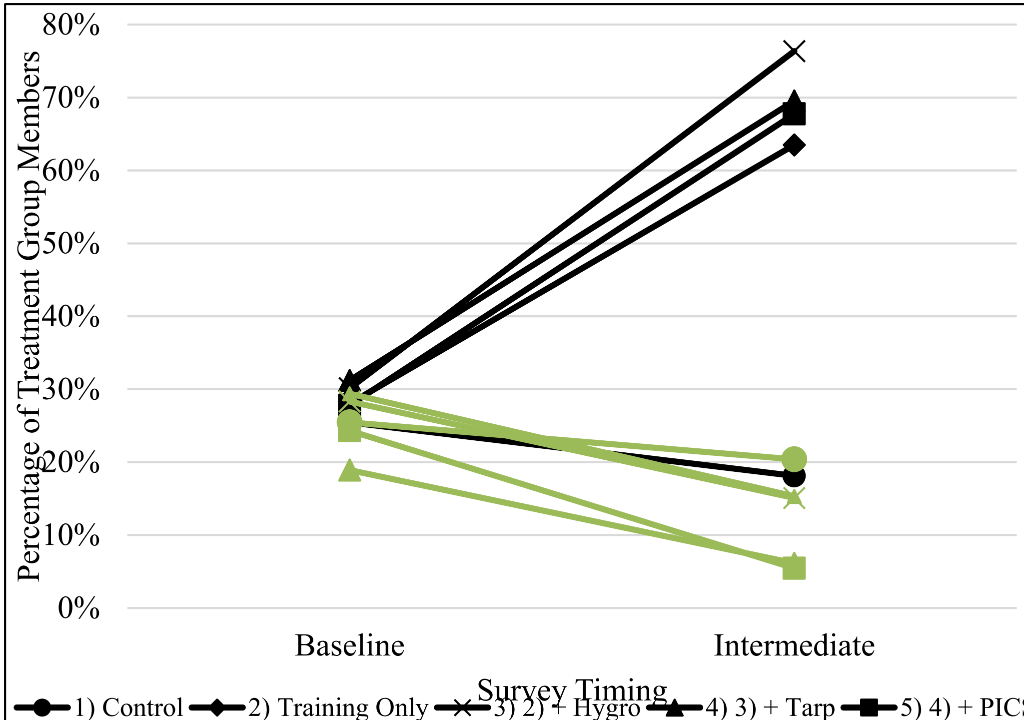
BEHAVIOR CHANGE FROM BASELINE TO INTERMEDIATE SURVEY BY TREATMENT GROUP

- For all treated groups, knowledge of aflatoxin toxicity (black lines) is upward sloping, whereas for the control group it is downward sloping.
  - 29% awareness at baseline
- All groups decreased ground drying (green lines), but this slope is the steepest for Group 5.
  - 25% ground dry at baseline



Black lines are households that state aflatoxins are toxic.
Green lines are households that dry maize directly on the ground.

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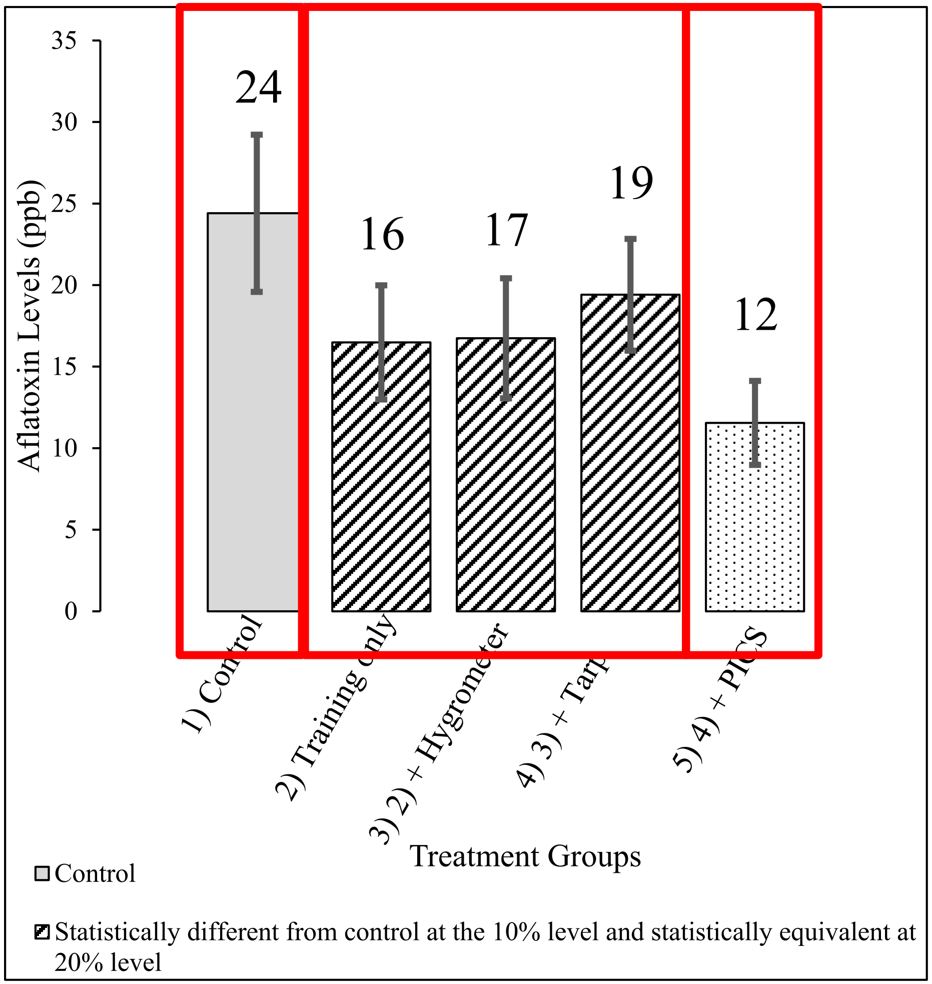
MEAN AFLATOXIN LEVELS BY TREATMENT GROUP



1. **Bad News**: Aflatoxins are a big problem in stored maize in our sample.
   - 28% of control above US legal limit of 20 ppb
   - 32% of control above Senegal/EU limit of 10 ppb
2. **Good News:** Training reduced mean aflatoxins levels by 30%.
3. Biggest impact was from combination of inputs including PICS bag.
   - 50% reduction in mean aflatoxins level
4. Hygrometer and tarps were not additively effective at lowering mean aflatoxins level
5. Adding PICS bag to treatment had largest marginal impact

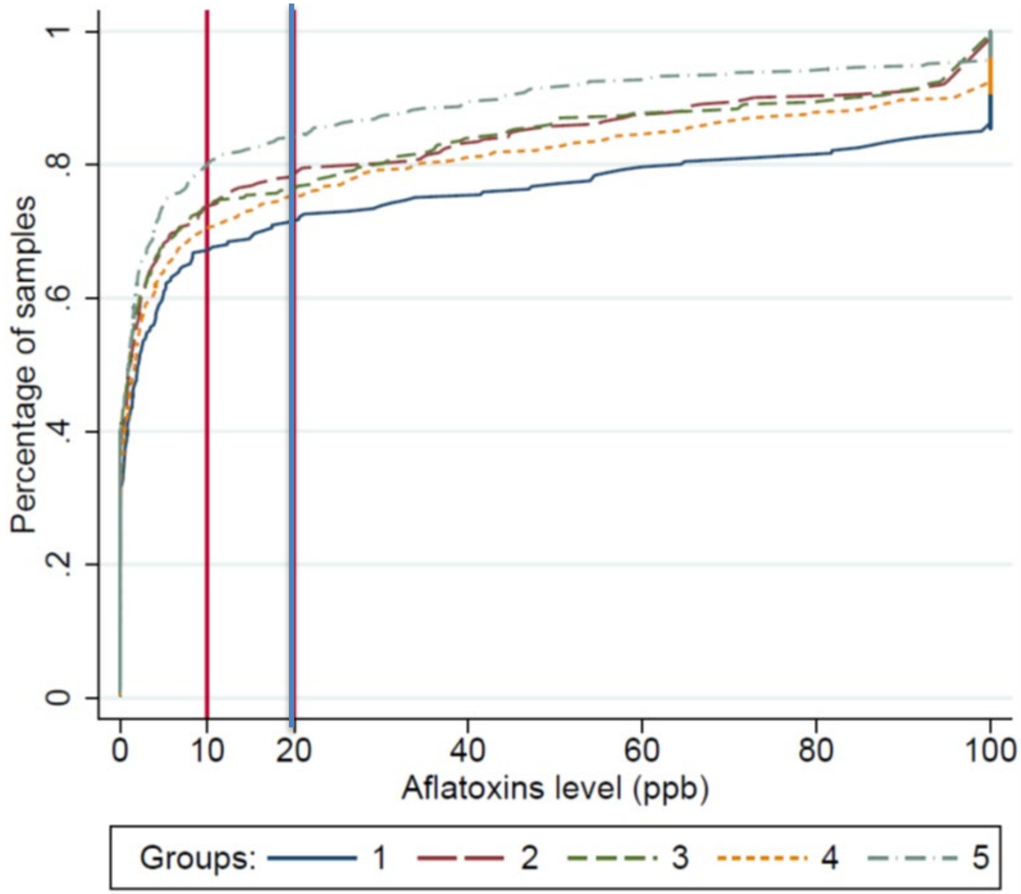
Impacts of interventions on aflatoxin levels (ppb) in stored maize

	OLS		Censored Regression Marginal Effects	
	(1)	(2)	(3)	(4)
Control group (Intercept) - $\hat{\beta}_1$	24.41***	25.60***	—	—
	(3.67)	(4.82)		
Training only - $\hat{\beta}_2$	-9.68**	-10.24**	-11.02***	-10.49***
	(4.65)	(4.33)	(2.68)	(2.74)
Hygrometer only - $\hat{\beta}_3$	1.39	1.40	0.71	1.00
	(3.38)	(3.35)	(2.30)	(2.34)
Tarp only - $\hat{\beta}_4$	1.63	2.49	2.72	3.16
	(3.69)	(3.53)	(2.19)	(2.22)
PICS bag only - $\hat{\beta}_5$	-7.67**	-7.78**	-6.86***	-6.90***
	(3.18)	(3.12)	(2.03)	(2.04)
Two samples taken from HH	—	-3.81	—	-1.44
		(3.05)		(2.09)
Baseline variables		YES		YES

Regression results support notion that the significant marginal impacts come from training and PICS bag.

CUMULATIVE DISTRIBUTION FUNCTIONS OF AFLATOXIN LEVELS BY TREATMENT GROUP

- Intervention seems to have lowered aflatoxin levels across the distribution.
- EU limit = 10 ppb
- US limit = 20 ppb



Numbers in parentheses after legend entries are mean aflatoxin levels. For the 134 samples measuring > 100 ppb, we use the value of 100 ppb.

Impact of interventions on probability of aflatoxin levels in stored maize being below the EU and US standards

	EU standard (≥ 10 ppb unsafe)		US standard (≥ 20 ppb unsafe)	
	(1)	(2)	(3)	(4)
Control group (Intercept) - $\hat{\beta}_1$	0.33***	0.35***	0.29***	0.31***
	(0.04)	(0.07)	(0.04)	(0.06)
Training only - $\hat{\beta}_2$	-0.10*	-0.08	-0.10*	-0.07
	(0.06)	(0.06)	(0.06)	(0.05)
Hygrometer only - $\hat{\beta}_3$	0.02	0.01	0.03	0.02
	(0.05)	(0.05)	(0.05)	(0.05)
Tarp only - $\hat{\beta}_4$	0.02	0.03	0.01	0.01
	(0.06)	(0.05)	(0.05)	(0.05)
PICS bag only - $\hat{\beta}_5$	-0.09*	-0.09**	-0.09**	-0.09**
	(0.05)	(0.05)	(0.04)	(0.04)
Two samples taken from HH	—	-0.03	—	-0.04
		(0.04)		(0.04)
Baseline variables		YES		YES

Regression results of pushing households to "safe" levels are consistent. Training and PICS have significant impacts

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Intervention Cost-effectiveness Estimates

- Training cost of $6,082 to reach 3,806 households in 168 villages.
- Trainings reduced aflatoxin levels by 9.68 ppb on average.
  - if we consider a training cost of $1.60/ household, then the marginal cost of using only trainings to lower aflatoxin levels is $1.60/ 9.68 ppb = $0.17/ ppb reduced / household.
- Cost per 50 kg PICS bag is $2.22
- Receiving only the PICS bag reduced aflatoxin levels by 7.67 ppb on average.
  - Cost of PICS bag only per ppb is $2.22/ 7.67 ppb = $0.29/ ppb reduced / household
- Combined cost would be ($2.22 + $1.60) / (7.67 ppb + 9.68 ppb) = $0.22/ ppb reduced/ household.
- So to move people from the control group avg. of 24.41 ppb in sample to 7.06 ppb

  24.41 - 7.67 – 9.68 ≈ $3.82 ≈ ($0.22* 17.35)
- Cost is for one year. If practices continue, then benefit/cost ratio will be much larger.

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Why did training and PICS bags work?

- Training
  - Low initial knowledge of aflatoxins
  - Trainers were trusted info sources (extension agents)
- PICS hermetic bags
  - Physical effectiveness known
    - Killing insects stops aflatoxin spread
  - Suggests links between drying and storage in farmers' mind

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Why did hygrometer and tarps not work?

- Tarps
  - Tarps are about not drying on the ground → Existing alternatives to tarps (roofs, concrete slabs)
- Hygrometers
  - Most people in sample grow maize for subsistence
  - Hygrometer has food safety value
  - Lower opportunity for hygrometer to yield large benefits through higher market power, certification, higher price

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CONCLUSIONS

- Training shown to be most cost-effective
  - background knowledge of aflatoxins was low.
  - we used trusted info sources (extension agents) as trainers.
  - ensured women attended training (35% women)
- PICS hermetic bags were effective
  - behavioral links between drying and storage.
  - should train on both together.
- Suggests that farmers take value-chain approach to post-harvest activities
  - development projects and policies should too.
- Role for government involvement to raise awareness and promote technologies.

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THANK YOU FOR YOUR TIME!

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