Miracle seeds: Biased expectations, complementary input use, and the dynamics of smallholder technology adoption

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Introduction I

- Observations
  - Agricultural technology adoption remains below optimum.
  - Learning about new technologies is difficult.
  - Some farmers try a new technology, then switch back to old technology. (Pattern of dis-adoption)
- Miracle seeds hypothesis
  - Farmers have biased expectations about technologies.
  - Farmers do not use enough complementary inputs or practices.
  - Farmers mis-attribute disappointing outcomes to technology. (Learning failure)
  - Farmers dis-adopt in subsequent seasons.

Introduction II

- Method
  - Field experiment with 3,500 Ugandan maize farmers.
  - Informational video intervention emphasizing that improved varieties benefit from complementary inputs and practices.
- Results
  - Treated farmers learn.
  - Treated farmers are less likely to adopt improved varieties.
  - Treated farmers are not more likely to use complementary inputs or practices.
  - Treated farmers have more realistic maize yield expectations.
- Explanation
  - A simple model of technology choice with biased expectations.

Literature

- Economics of agricultural technology adoption (e.g., Suri and Udry, 2022)
- Technology adoption dynamics across multiple agricultural seasons (e.g., Moser and Barrett, 2006; Ainembabazi and Mugisha, 2014; Chen, Hu, and Myers, 2022)
- Learning about new agricultural technologies (e.g., Foster and Rosenzweig, 1995; Conley and Udry, 2010; Lybbert and Bell, 2010; Hanna, Mullainathan, and Schwartzstein, 2014)
- Incorrect expectations about future returns (e.g., Nguyen, 2008; Jensen, 2010)
- Informational video interventions (e.g., Ferrara, Chong, and Duryea, 2012; Van Campenhout, Spielman, and Lecoutere, 2021; Riley, 2022; Abate et al., 2023)

Intervention

- Control video about best practices in maize cultivation:

  "I dug a 4-inch deep hole and added 1 water bottle cap of DAP."

- Treatment video: control video + information that improved varieties do not substitute for inputs or practices, but benefit from complementary investments:

  "I dug a 4-inch deep hole and added 1 water bottle cap of DAP."

  +

  "Did you know that DAP is even more important when using improved varieties?"

Empirical strategy

- ANCOVA regression.
- Standard errors clustered at village level (level of randomization).
- Outcome family indices to account for multiple hypothesis testing (Anderson, 2008).
- Original form of sandwich estimator (Liang and Zeger, 1986).

Data

- Balanced baseline sample of 3,470 maize farmers in April 2021.
- Follow-up sample of 3,407 maize farmers in January-February 2022.

Figure: Busoga region in Uganda

Descriptive statistics and orthogonality tests

	Mean	Difference T–C
Farmer's age in years	48.62	-0.247
	(13.38)	(0.561)
Farmer is male	0.777	0.022
	(0.421)	(0.022)
Number of household members	8.69	0.118
	(3.98)	(0.171)
Land for crop production in acres	3.35	0.172
	(4.32)	(0.180)
Used improved maize seed last season	0.492	-0.012
	(0.500)	(0.022)
Bought improved maize seed from agro-input shop	0.325	-0.009
	(0.468)	(0.021)
Rating of maize seed quality (1=poor to 5=excellent)	3.38	0.083^{+}
	(1.03)	(0.050)
Used organic manure	0.074	-0.009
	(0.262)	(0.011)
Land productivity in kg/acre	499.52	44.08
	(771.17)	(31.48)
Sold maize	0.513	0.023
	(0.500)	(0.025)

Note: Column 1 reports baseline means with standard deviations below; column 2 shows treatment - control mean differences and standard errors below, clustered at the village level; **, *, and + indicate significance at the 1, 5, and 10% levels; N = 3,470.

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## [1] "/Users/carolinemiehe/Desktop/from_now_on/prof/GitHub_rep
## [1] "/Users/carolinemiehe/Desktop/from_now_on/prof/GitHub_rep
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Results

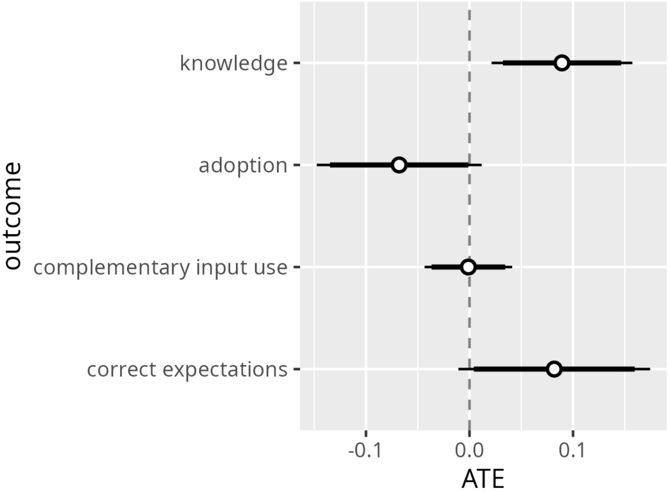

Figure: Average treatment effects

Model of technology choice with biased expectations I

In line with Suri (2011), farmers *i* compare the expected profits of Varieties H and L to maximize them in *t+1*:

$$E\left(\pi^{H}_{it+1}\right) = E\left(p_{t+1} Y^{H}_{it+1}\right) - b_t s_{it} - \sum w_t X^{H}_{it}$$

$$E\left(\pi^{L}_{it+1}\right) = E\left(p_{t+1} Y^{L}_{it+1}\right) - \sum w_t X^{L}_{it}$$

$E\left(p_{t+1}\right)$	Expected output price (for Varieties H and L)
$E\left(Y_{it+1}\right)$	Expected yield
s_{it}	Seed of Variety H
b_t	Cost of planting plot with Variety H seed (Variety L seed is free)
X_{it}	Complementary inputs and practices
w_t	Corresponding factor prices

Model of technology choice with biased expectations II

Farmers adopt Variety H if they expect it to be more profitable than L:

$$E\left(\pi_{it+1}^{H}\right) > E\left(\pi_{it+1}^{L}\right)$$

$$\left(E\left(Y_{it+1}^{H}\right) - \sum \frac{w_t}{E(p_{t+1})} X_{it}^{H}\right) - \left(E\left(Y_{it+1}^{L}\right) - \sum \frac{w_t}{E(p_{t+1})} X_{it}^{L}\right) > \frac{b_t}{E(p_{t+1})} s_{it}^{*}$$

Hence, adoption depends on yields, as functions of inputs:

$$Y_{it+1}^{L} = Y_{it}\left(X_{it}^{L}\right)$$

$$Y_{it+1}^{H} = A_i\left(X_{it}^{H} > X_{it}^{L}\right) + Y_{it}\left(X_{it}^{L}\right)$$

A_i is the adoption premium, which only materializes if the farmer uses more complementary inputs and practices than with Variety L.

Model of technology choice with biased expectations III

Heterogeneity in farmers' beliefs about the Y^H_{it+1} and X_{it} relationship:

Realistic farmers

- Believe that inputs are necessary to realize the adoption premium.
- Adopt if expected adoption premium exceeds seed costs + necessary inputs: $E\left(p_{t+1}A_i\left(X^H_{it} > X^L_{it}\right)\right) > \sum w_t X^H_{it} - \sum w_t X^L_{it} + b_t s_{it}$.
- Information will have no effect.

Optimistic farmers

- Believe that the adoption premium is always present, independent of inputs (i.e., believe in miracle seeds).
- Adopt if (misspecified) expected adoption premium exceeds seed costs: $E\left(p_{t+1}A_i\right) > \left(b_t s_{it}\right)$.
- Information will increase knowledge, decrease adoption (increase cost of obtaining premium), align expectations with reality, not affect input use.

Model of technology choice with biased expectations IV

Pessimistic farmers

- Believe that there is no adoption premium (e.g., due to negative experience).
- Do not adopt.
- Information will increase adoption, knowledge, and input use, will not affect expectations.

Overall net results

- Depend on the representation of each farmer type, as the intervention affects each type differently.
- Hence, we estimate treatment effects on subsamples of farmers.

Subgroup analysis I

1. Entire sample
2. Remove realistic farmers, as we expect no treatment effects for them. ➙ Keep only farmers with Anderson (2008) index of baseline complementary inputs and practices below average.
3. Identify optimistic farmers who believe in miracle seeds and overestimate returns to improved varieties. ➙ Keep only farmers with Anderson (2008) index of baseline complementary inputs and practices below average and in the top third of the baseline expected maize yield distribution.

Subgroup analysis II

Model's predictions for subgroups

	All	Without realistists	Only optimists
Knowledge index	↑	stronger ↑	even stronger ↑
Adoption index	ambivalent	ambivalent	↓
Inputs & practices index	↑	stronger ↑	no effect
Harvest met expectations	↑	stronger ↑	even stronger ↑

Results for subgroups

	Mean	All	Without realistists	Only optimists
Knowledge index	-0.024	0.089*	0.077^{+}	0.164*
	(0.635)	(0.035)	(0.041)	(0.073)
Adoption index	0.009	-0.068^{+}	-0.085^{+}	-0.248**
	(0.942)	(0.041)	(0.050)	(0.095)
Inputs & practices index	0.008	-0.001	-0.006	0.033
	(0.400)	(0.022)	(0.026)	(0.051)
Harvest met expectations	0.138	0.029^{+}	0.018	0.048
	(0.345)	(0.017)	(0.020)	(0.036)
Observations		3256	1615	361

Note: Column 1 reports post-intervention control group means (for knowledge and expectations) or baseline means (for adoption and input & practices) with standard deviations below; **, *, and + indicate significance at the 1, 5, and 10% levels; standard errors are clustered at the village level.

Conclusion

- Many farmers view "miracle seeds" as profitable under a misspecified production function, but not when complementary inputs and practices are considered.
- Bayesian learning via sequential adoption fails when technologies, inputs, and practices interact strongly.
- Public and private actors should not promote single "miracle seeds", but context-specific packages of technologies, inputs, and practices, and inform farmers of their interdependence.

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Impact on knowledge

	Mean	All	Without realistists	Only optimists
Farmer knows inputs and practices are important	0.357	0.049^{+}	0.029	0.048
when using an improved variety	(0.479)	(0.025)	(0.030)	(0.055)
Farmer knows weeding is important	0.790	0.024	0.016	0.013
when using an improved variety	(0.407)	(0.022)	(0.027)	(0.047)
Farmer knows applying fertilizer is important	0.379	0.053*	0.066*	0.180**
when using an improved variety	(0.485)	(0.023)	(0.027)	(0.053)
Knowledge index	-0.024	0.089*	0.077^{+}	0.164*
	(0.635)	(0.035)	(0.041)	(0.073)
Observations†		3256	1615	361

Note: Column 1 reports baseline means with standard deviations below; columns 2-4 report differences between treatment and control post-intervention; **, *, and + indicate significance at the 1, 5, and 10% levels; standard errors are clustered at the village level; †Numbers of observations in the index regression; individual outcome regressions have more observations.

Impact on adoption

	Mean	All	Without realistists	Only optimists
Farmer planted seed of an improved variety	0.435	-0.042*	-0.058*	-0.134**
	(0.496)	(0.021)	(0.026)	(0.051)
Farmer planted seed from agro-input shop	0.328	-0.022	-0.022	-0.099*
	(0.469)	(0.020)	(0.025)	(0.046)
Farmer planted seed that was recycled	0.569	0.032	0.035	0.122*
	(0.495)	(0.021)	(0.026)	(0.048)
Adoption index	0.009	-0.068^{+}	-0.085^{+}	-0.248**
	(0.942)	(0.041)	(0.050)	(0.095)
Observations†		2941	1449	336

Note: Column 1 reports baseline means with standard deviations below; columns 2-4 report differences between treatment and control post-intervention; **, *, and + indicate significance at the 1, 5, and 10% levels; standard errors are clustered at the village level; †Numbers of observations in the index regression; individual outcome regressions have more observations.

Impact on inputs and practices

	Mean	All	Without realistists	Only optimists
Row-planting	0.243	-0.070*	-0.107**	-0.095^{+}
	(0.429)	(0.027)	(0.032)	(0.056)
Reduced seed rate	0.237	0.009	0.012	-0.070
	(0.425)	(0.019)	(0.025)	(0.052)
Organic fertilizer use	0.075	-0.013	-0.006	0.024
	(0.263)	(0.017)	(0.022)	(0.043)
DAP/NPK use	0.251	-0.029	-0.026	-0.016
	(0.434)	(0.019)	(0.023)	(0.052)
Urea use	0.076	0.002	-0.008	0.034
	(0.265)	(0.015)	(0.017)	(0.032)
Weeding frequency	2.56	-0.021	-0.058^{+}	-0.008
	(0.650)	(0.027)	(0.035)	(0.069)
Pesticide etc. use	0.412	0.003	-0.009	-0.010
	(0.492)	(0.023)	(0.026)	(0.056)
Re-sowing	0.482	0.013	0.031	0.023
	(0.500)	(0.022)	(0.028)	(0.051)
Early planting	0.008	-0.001	-0.006	0.033
	(0.400)	(0.022)	(0.026)	(0.051)
Inputs and practices index	0.008	-0.001	-0.006	0.033
	(0.400)	(0.022)	(0.026)	(0.051)
Observations†		2970	1547	349

Note: Column 1 reports baseline means with standard deviations below; columns 2-4 report differences between treatment and control post-intervention; **, *, and + indicate significance at the 1, 5, and 10% levels; standard errors are clustered at the village level; †Numbers of observations in the index regression; individual outcome regressions have more observations.

Impact on expectations

	Mean	All	Without realistists	Only optimists
Harvest met expectations	0.138	0.029^{+}	0.018	0.048
	(0.345)	(0.017)	(0.020)	(0.036)
Observations		3185	1572	347

Note: Column 1 reports post-intervention control group means with standard deviations below; columns 2-4 report differences between treatment and control post-intervention; **, *, and + indicate significance at the 1, 5, and 10% levels; standard errors are clustered at the village level.