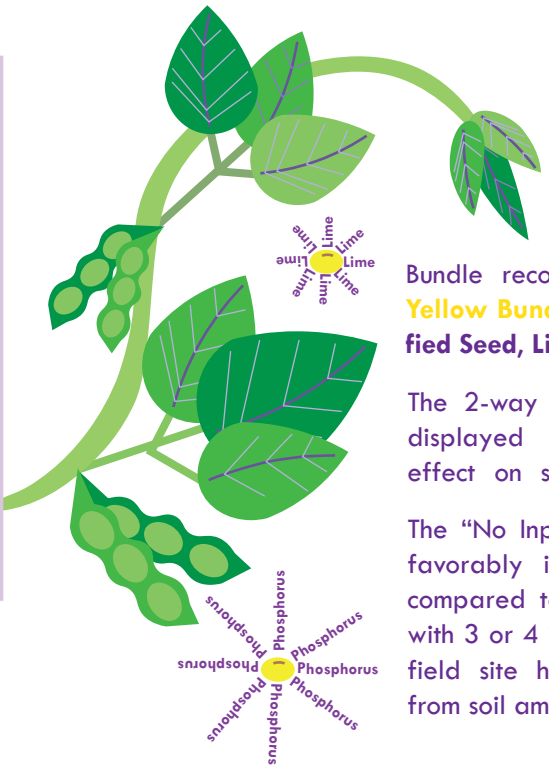
SMART Farm Trials
Results from Ethiopia: EIAR 2019

In partnership with the Soybean Innovation Lab (SIL), the Ethiopian Institute of Agricultural Research (EIAR) conducted SMART (Soybean Management with Appropriate Research and Technology) Farm input omission trials at a single location in Dimtu, Ethiopia (**Figure 1**, **Table 1**).

Figure 1: EIAR trial location near Dimtu for 2019 season



Summary

Bundle recommendation for the Dimtu field site: Yellow Bundle- **Best Management Practices, Certified Seed, Lime.**

The 2-way interaction between Lime and Inoculum displayed a small but significant negative effect on soybean grain yields.

The "No Input" treatment performed favorably in terms of grain yield compared to treatment combinations with 3 or 4 inputs, suggesting that the field site had previously benefited from soil amendments.

The input omission trial is composed of 16 treatment combinations (**Table 2**) of phosphorus, potassium, lime, and inoculum (**Table 3**). Each set of 16 treatments were randomized and replicated 3 times. The soybean variety "Clark-63k" was planted in 3 meter by 2.4 meter plots with a seed spacing of 5cm. Each plot contained 4 rows with a spacing of 60cm. Seeds were treated with Nodumax inoculum 1 hour prior to planting. Agricultural lime was applied and incorporated into the soil manually. Lime application coincided with planting. Approximately 21 days after germination at the V2 or V3 developmental stage, Triple Super Phosphate and Muriate of Potash were applied to treated plots as a side-dress 5 centimeters from the furrow, and 5 centimeters deep.

Treatment	L	I	P	K	S
1					+
2		+			+
3			+		+
4				+	+
5		+	+		+
6		+		+	+
7			+	+	+
8		+	+	+	+
9	+				+
10	+	+			+
11	+		+		+
12	+			+	+
13	+	+	+		+
14	+	+		+	+
15	+		+	+	+
16	+	+	+	+	+

Table 2: Treatment combinations for the omission trial. L=Lime, I=Inoculum, P=Phosphorus, K=Potassium, S=Seeds.

Country	Location	Planting Date	Harvest Date	Latitude	Longitude	Elevation
Ethiopia	Dimtu	7/18/2019	12/15/2019*	7.852389	37.236917	1750m

Table 1: Site information for the EIAR omission trial, including planting and harvest date. *Approximate harvest date.

	Phosphorus	Potassium	Inoculum	Lime	Seed
Product	Triple Super Phosphate	Muriate of Potash	NoduMax	Bulk lime CaCO3	Clark-63k
Source	-	-	IITA	-	EIAR
Concentrat	P2O5-46%	K2O-60%	-	-	-
Appication	43 kg ai/ha	56 kg ai/ha	1000g/100kg	1500kg/ha	320000 seed/ha

Table 3: The product names, sources, concentrations and application rates of inputs used for the omission trial. kg ai/ha – Kilograms of active ingredient per hectare.

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
May	29.9	16.9	163.9
June	25.3	15.7	296
July	23.5	14.6	208.3
August	21.2	13.2	136.1
September	22.3	13.5	168.6
October	23.4	12.9	189.8
November	23.7	14.2	117.8

Table 4: Monthly averages for maximum and minimum temperatures and the total monthly rainfall for the 2019 season at the Dimtu site

Seasonal temperature and precipitation information for the field sites are displayed in **Table 4**. Temperatures peaked in May reaching 29.9°C. Minimum temperatures of 12.9°C were observed in October. Between the months of May and November the total observed rainfall was 1280.5mm. Soil properties analysis was not completed for the 2019 Dimtu location.

Data collection metrics for the input omission trial are described in **Table 5**. Stand count, pod count, branch count and plant height were measured at the R8 developmental stage. Measurements for yield, seed count, and 100 seed weight were measure post-harvest.

Treatment	Rank Yield	Yield	R8 Stand Count	Pod Count	Seeds Count	R8 Height	Branch Count	100 seed Weight
		ton/ha	days	count	count	cm	count	g
L	1	3.02	114	20	32	51	3	12.5
I+K	2	3.02	112	25	45	50	4	11.4
L+K	3	2.82	92	26	45	44	2	12.4
L+P+K	4	2.75	109	24	45	50	4	11.1
L+P	5	2.68	95	27	47	52	4	12.0
P+K	6	2.65	132	25	44	50	4	10.6
I+P	7	2.61	96	25	47	52	3	11.7
L+I (*)	8	2.49	100	21	39	49	3	12.6
No Input	9	2.47	109	26	47	53	3	12.1
K	10	2.42	97	21	42	46	3	12.4
I	11	2.34	95	23	45	47	4	11.4
I+P+K	12	2.23	93	22	39	48	3	13.3
L+I+P+K	13	2.21	90	21	35	47	3	13.0
L+I+P	14	2.17	94	23	43	48	3	13.1
L+I+K	15	2.17	96	24	46	45	3	12.6
P	16	1.94	94	27	49	54	4	12.1
AVG		2.50	101.2	23.7	43.2	49.0	3.3	12.1
LSD (0.05)		0.70	27.0	6.7	15.1	6.7	12.9	1.7
CV%		20.35	18.9	18.7	22.9	9.7	19.1	10.0

Table 6: Averages, Least Significant Differences (LSD), and Coefficient of Variations (CV%) for Yield, Stand Count, Height, Pod Count, Seed Count, Branch Count, and 100 Seed Weight for the 2019 omission trials at Dimtu, Ethiopia. In the treatment column: I-Inoculum, P-Phosphorus, K-Potassium, L-Lime. P-values for each treatment main-effect or interaction are represented as follows: (.)<0.10, (*)<0.05, (**)<0.01, (***)<0.001

An Analysis of Variance (ANOVA) was conducted in R using the package "car" to test the main treatment effects, 2-way, 3-way, and 4-way treatment interactions in the omission trial. The Shapiro's Wikle and Brown-Forsythe test were employed to confirm residual normality and homogeneity of variance respectively.

Based on the ANOVA, none of the single treatment effects of Lime, Phosphorus, Potassium, or Inoculum were statistically significant. The 2-way interaction between Lime and Inoculum displayed a small but significant (P-value 0.014) negative effect on soybean grain yields. Increasing the number of replicates from 3 to 4 in future trials will assist in increasing the power of the trial to better determine treatment significance.

Trait	Unit	Measurement Metrics
Stand Count	Count	Sum of plants in Row 2 and 3
Plant Height	Centimeter	Distance from soil to the Shoot Apical Meristem on main stem
Pod Count	Count	Average number of pods per plant
Seed Count	Count	Average number of seeds per plant
Branch Count	Count	Average number of branches per plant
Yield	Ton/Hectare	Plants harvested and threshed, seed winnowed and weighed at 13% moisture
100 seed weight	Gram	Random sets of 100 seeds selected and weighed

Table 5: Data metrics for the 2019 SMART Farm omission trial

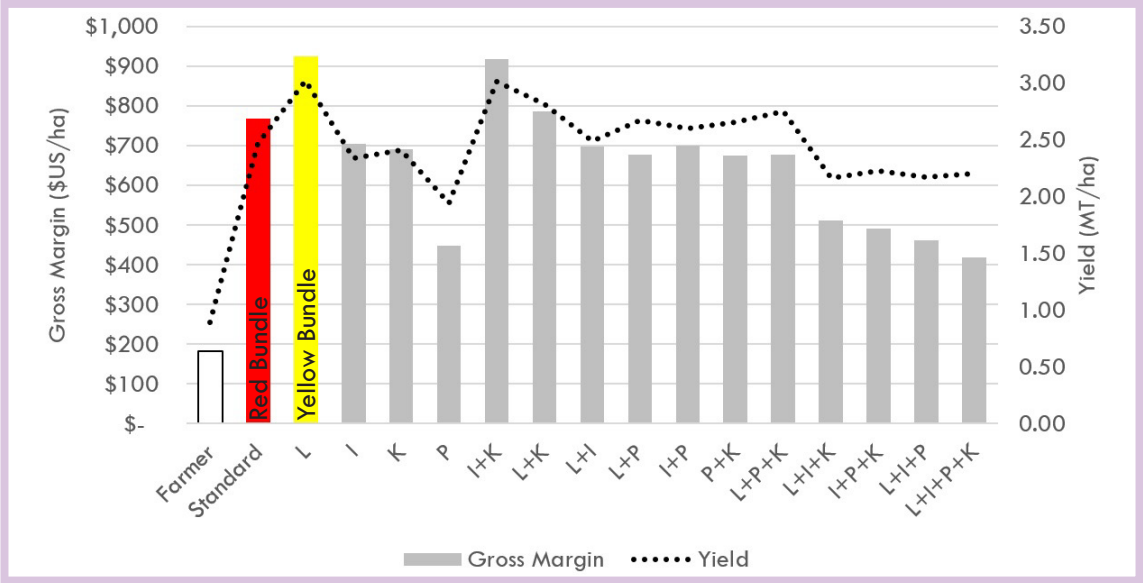


Figure 2: Treatment yields (line graph) and gross margins (bar graph) for the Dimtu field site.

Mean yields ranged from 1.94 tons/ha (P) to 3.02 tons/ha (L) (**Table 6**). In general, it is expected that treatments with more inputs will generate higher yields. Therefore, it is notable that the "No Input" control containing only certified seeds generated higher yields on average than 7 of the other treatment combinations. This is especially true given that 4 out of 7 of these treatment combinations contained 3 or more inputs. One possible explanation is that the trial was conducted on land that has previously benefited from soil amendments, and that the inputs added during the omission trial did not greatly shift in-season soil fertility. This highlights the importance of soil testing prior to planting to help determine a field's fertility levels, and the potential benefit of adding inputs.

Stand count ranged from 90 (L+I+P+K) to 132 (P+K) at the R8 developmental stage. Plant height at the R8 developmental stage ranged from 44cm (L+K) to 54cm (P). Mean values for pod count per plant from 20 pods (L) to 27 pods (P, L+P). Mean values for number of seeds per plant ranged from 32 (L) to 49 (P). 100-Seed Weight ranged from 10.6g (P+K) to 13.3g (I+P+K). This trial provides information on which inputs are best suited to maximize soybean yield and are a valuable resource for developing an input bundle approach to soybean production.

Agricultural inputs such as lime, inoculum, phosphorus and potassium contribute to increases in soybean yield. However, the combination of specific field conditions and a farmer's limited cash funds may make using all four inputs either unnecessary or financially impractical. The 2019 SMART Farm omission trial has assessed the usage of these inputs and has assembled three input bundles for the Dimtu field site. To balance the financial risk of applying new inputs, SIL recommends a stepwise investment in new technology. This prioritizes the maximum financial returns on the minimum input costs, and allows initial successes to feed into additional future inputs.

The gross margins[1] and yield averages are displayed in **Figure 2**. The "Farmer" treatment represents typical soybean farming practices in Ethiopia. It is assumed that saved seed is used with no additional inputs, and that labor costs are absorbed by the household[2]. Under these conditions it is estimated that a typical farmer will generate a gross margin of $182 USD and a yield of 0.82 MT per hectare laboring between 60 and 70 workdays in a season. This generates an implicit wage of $1.05 USD for every $1.00 USD of labor spent.

SMART Farm Trials
Results from Ethiopia: EIAR 2019

Red Bundle

Best Management Practices
Certified Seed

13x return on input costs compared to farmer practice
Marginal Ratio: 4.2*

Yellow Bundle

Best Management Practices
Certified Seed
Lime

2x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.2**

The Red Bundle is the Standard growing package. This includes the usage of certified soybean seeds and the adoption of best management practices (early planting, planting in rows, increased seed population, and timely weeding). The Red bundle in Dimtu generated an average gross margin of $769 USD, a marginal ratio increase of 4.2 compared to typical farming practices, and yielded 2.47MT per hectare. This produces a 13x return on seed costs and provides an implicit wage of $4.44 USD for every $1.00 USD of labor spent (a 344% increase in wages compared to the typical farmer).

The Yellow Bundle represents a step up from the Red Bundle with the inclusion of lime. Despite producing the highest yields observed at Dimtu, the addition of lime did not statistically increase soybean yields. Without seasonal soil tests the initial field soil pH, and by extension the site's need for lime amendments, could not be determined. However, acidic soils are a common issue for Ethiopian agriculture and the addition of lime at a rate of 1.5 tons per hectare is predicted to have a positive impact on yield. The Yellow Bundle generated an average gross margin of $918.00 USD, a marginal ratio increase of 1.2 compared to the Red Bundle, and yielded 3.02MT per hectare. This produces a 2x return on lime costs and provides an implicit wage of $5.30 USD for every $1.00 USD of labor spent (a 430% increase in wages compared to the typical farmer).

*Marginal Ratio compared to farmer practices
**Marginal Ratio compared to Red Bundle

[1]gross margin=revenue – variable costs

[2]Van Vugt, D., Franke, A. C., & Giller, K. E. (2017). Participatory research to close the soybean yield gap on smallholder farms in Malawi. Experimental Agriculture, 53(3), 396-415.

SMART Farm Trials
Appendix for Economic Costs, Definitions, and Assumptions

Economic Assumptions

- For the typical African farmer it is assumed that soybean seeds are saved from one year to the next, and that no additional inputs are purchased.
- A season of labor is estimated to be 60-70 workdays (472-560 hours) from land preparation to harvest. It is assumed that for a given household any necessary field labor will be conducted by members of that household.
- Fixed costs such leasing costs for land, property tax, insurance, managerial overhead, or transportation costs are not included in the variable cost estimates. It is assumed that these costs are consistent across treatments.
- It is assumed that the labor involved in applying different input treatments is equal.
- It is assumed that local African soybean prices are linked to and stabilized by world-wide soybean prices.

Definitions

Gross Margin: For the SMART Farm reports SIL defines the Gross Margin as the Variable Costs of soybean production minus the Revenue generated from seed sales.

Marginal Ratio: is the quotient between two gross margin values.

Return on Input Costs: The return on input costs compares how much was spent on inputs to how much additional monetary value that input provides.

Values for Economic Analysis

Item	$ USD/ Hectare	Source
Input Costs		
Certified Soybean Seed	$44.40	1
Rhizobium Inoculum	$14.13	2
Phosphorus Fertilizer	$109.00	3
Potassium Fertilizer	$58.14	4
Lime	$65.53	5
Labor Costs		
Labor (Land preparation, planting, weeding, harvest, bagging)	$173.01	6
Soybean Selling Price		
Item	$USD/ Kg of Seed	Source
Seed Price	$0.40 ($400.00/MT)	7

Source

1) Internal SIL communications, Analysis of the Soya Bean Value Chain in Zambia's Eastern Province (2012), Soybean Value Chain-AECOM International Development (2011), IAPRI-soybean value chain and market analysis -Zambia (2014), Profitability and technical efficiency of soybean production in northern Nigeria (2017), Income and Cost Budgets for summer crops in South Africa- (2018-2019), SOYBEAN Production Guide In Uganda (2015)

2) Internal SIL communications, IAPRI-soybean value chain and market analysis -Zambia (2014), N2F-Production and use of Rhizobial inoculants in Africa (2011)

3) Internal SIL communications, Income and Cost Budgets for summer crops in South Africa- (2018-2019), South African Fertilizer Market Analysis Report (2018), Agricultural Prices, USDA, National Agricultural Statistics Service (2020), Spatial variation in fertilizer prices in Sub-Saharan Africa (2020)

4) Internal SIL communications, Income and Cost Budgets for summer crops in South Africa- (2018-2019), South African Fertilizer Market Analysis Report (2018), Agricultural Prices, USDA, National Agricultural Statistics Service (2020), Spatial variation in fertilizer prices in Sub-Saharan Africa (2020)

5) Internal SIL communications, 5) H Pistorius & KIE aglime price list (2017), http://www.kalkor.co.za/site/content/id/price-list (2020), https://-farmbizafrica.com (2020), Local development of affordable lime in southern Africa (1997), Managing Soil Acidity with Lime 2015 Trial Report (2016), FarmLime: Low-cost lime for small-scale farming (2005).

6) Internal SIL communications, Soybean Costs of Production-(2019), Soybean Value Chain-AECOM International Development (2011), IAPRI-soybean value chain and market analysis -Zambia (2014), Profitability and technical efficiency of soybean production in northern Nigeria (2017), Soybean Production Guide In Uganda (2015)

7) Internal SIL communications, www.selinawamucii.com (2020), soybean prices (2019), Zambia National Farmers Union, USDA Market News