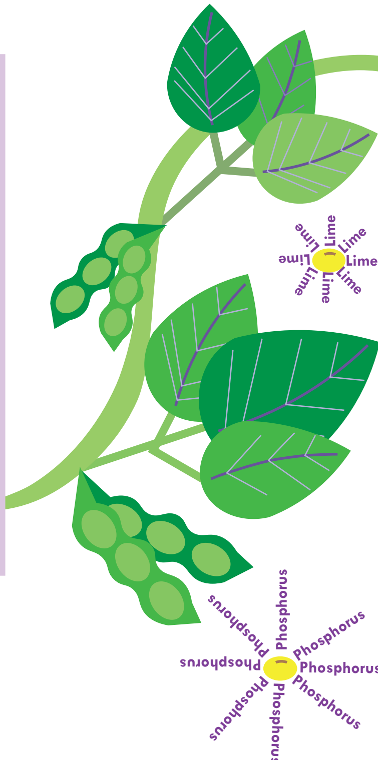
SMART Farm Trials

Results from Mozambique: IITA 2019-2020

In partnership with the Soybean Innovation Lab (SIL), the International Institute of Tropical Agriculture (IITA) conducted SMART (Soybean Management with Appropriate Research and Technology) Farm input omission trials at two locations in Angonia (Tete) and Gurue (Namarripe) Mozambique (Table 1).

Figure 1: IITA trial locations for 2019 - 2020 season



Summary

Bundle recommendation for the Gurue field site: Blue Bundle- **Best Management Practices, Certified Seed, Lime and Inoculum.**

For the Angonia field site, the Yellow Bundle (Phosphorus), Green Bundle (Lime, Phosphorus, and Potassium), and Purple Bundle (Lime, Inoculum, Phosphorus, and Potassium) all generated similar gross margins.

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 4 times. The soybean variety "Safari" from SeedCo was planted in 3 meter by 5 meter plots with a seed spacing of 5cm. Each plot contained 4 rows with a spacing of 75cm. Seeds were treated with Hi-Stick Inoculum 1 hour prior to planting. Calciprill Lime was applied in-furrow coinciding 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
Mozambique	Gurue (Namarripe)	1/8/2020	4/21/2020	-15.35	36.7888	766 m
Mozambique	Angonia (Tete)	1/7/2020	4/28/2020	-14.748	34.3665	1206m

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

	Phosphorus	Potassium	Inoculum	Lime	Seed
Product	Triple Super Phosphate	Muriate of Potash	Nodumax	Calciprill	Safari
Source	-	-	IITA	OMYA	SeedCo
Concentration	P2O5-46%	K2O-60%	-	CaO-52%	-
Appication Rate	75kg ai/ha	75kg ai/ha	100g/10kg	300kg/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.


Figure 2: -Images from Gurue field location.

Month	Max Temperature (°C)		Min Temperature (°C)		Rainfall (mm)	
	Gurue	Angonia	Gurue	Angonia	Gurue	Angonia
October	31.7	31.3	20.0	18.9	87.5	45.6
November	31.5	30.5	21.2	20.0	203.2	189.4
December	29.9	28.3	21.0	19.5	126.5	136.8
January	27.7	26.2	20.5	18.7	329.2	302.9
February	29.2	27.2	21.2	18.9	113.8	129.1
March	28.8	27.4	19.9	17.8	15.9	9.8
April	28.7	28.2	19.0	17.0	12.8	8.1

Table 4: Monthly averages for maximum and minimum temperatures and the total monthly rainfall for the 2019-2020 season at the Gurue and Angonia sites

Test	Method	Units	Gurue	Rating	Angonia	Rating
Soil pH	1:1 - Water pH	-	5.5	-	5.8	-
Phosphorus (P)	Mehlich 3	ppm	122	Very High	1	Very Low
Potassium (K)	Mehlich 3	ppm	128	Medium	71	Low
Calcium (Ca)	Mehlich 3	ppm	1136	Medium	1367	Medium
Magnesium (Mg)	Mehlich 3	ppm	187	Medium	393	Very High
Sulfur (S)	Mehlich 3	ppm	8	Low	4	Very Low
Boron (B)	Mehlich 3	ppm	0.2	Low	0.1	Very Low
Copper (Cu)	Mehlich 3	ppm	0.4	Low	0.9	Medium
Iron (Fe)	Mehlich 3	ppm	169	Optimium	116	Optimum
Manganese (Mn)	Mehlich 3	ppm	40	Medium	46	Medium
Zinc (Zn)	Mehlich 3	ppm	0.8	Low	1.4	Low
Sodium (Na)	Mehlich 3	ppm	31	Very Low	12	Very Low
Organic Matter	Loss On Ignition	%	4	Medium	5.1	Optimum

Table 5: Soil fertility results for the Gurue and Angonia sites generated from Waypoint Analytics. Soil nutrient amounts are displayed in parts-per-million (mg/kg). The nutrient rating provides a general description of nutrient presence in the tested soil and is ordered as follows: very low, low, medium, optimum, very high.

Rating	Very Low	Low	Medium	Optimum	Very High
Probability of Crop Response	~100%	~75%	50%	0-25%	0-10%

Figure 3: Descriptions of the "Rating" column in Table 5. Indicates the probability that additional nutrient amendments will positively impact crop performance.

Seasonal temperature and precipitation information for the field sites are displayed in **Table 4**. Temperatures peaked in October for both Gurue and Angonia reaching 31.7°C and 31.3°C respectively. Minimum temperatures of 19.0°C and 17.0°C were observed in April for Gurue and Angonia respectively. Between the months of October and April the total observed rainfall was 888.9mm in Gurue and 821.7mm in Angonia.

Soil properties for Gurue and Angonia are shown in **Table 5** with descriptions of the nutrient ratings indicated in **Figure 3.** The Gurue site had a sand clay loam texture with medium fertility. Not enough soil was provided from the Angonia site to determine soil texture. Gurue and Angonia had soil pHs of 5.5 and 5.8 respectively, both of which would benfit from additional liming to raise the pH closer to the optimal level of 6.5. The Gurue site had very high levels of Phosphorus and medium levels of Potassium. The Angonia site had low levels of both Phosphorus and Potassium, and would benefit from in-field fertilizer application.

Data collection metrics for the input omission trial are described in **Table 6**. Stand count was measured at V2 and R8 developmental stages. Plant Height was measured at R1and R8 developmental stages. Measurements for Nodule Count, Weight, and Viability were measured at the R3 developmental stage.

Trait	Unit	Measurement Metrics
Stand Count	count	Sum of plants in Row 2 and 3
Days to Flowering	day	Days after planting when the first flower is observed
Plant Height	centimeter	Distance from soil to the Shoot Apical Meristem on main stem
Nodule Count	count	Number of Rhizobium nodules on roots collected at R3-pod filling stage
Nodule Weight	gram	Mass of Rhizobium nodules on roots collected at R3-pod filling stage
Nodule Viability	%	Percentage of counted nodules that are active and viable
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 6: Data metrics for the 2019-2020 SMART Farm omission trial

Gurue Trial Results

Treatment	Rank Yield	Yield	V2 Stand Count	R1 Flowering	R1 Height	Nodule Count	Nodule Weight	Nodule Viability	R8 Stand Count	R8 Height	100 seed Weight	Seed Mositure
		ton/ha	count	days	cm	count	g	%	count	cm	g	%
L+I+P+K	1	2.80	303	33	68	64	0.69	76	155	75	15.6	13.4
L+I	2	2.57	301	33	67	53	0.55	73	171	85	16.2	13.3
L+P	3	2.55	254	33	65	50	0.41	58	133	78	16.3	13.5
I+P	4	2.46	314	33	69	56	0.55	74	139	82	16.0	13.6
L+I+P	5	2.44	305	33	67	58	0.62	75	150	73	15.7	13.6
L+I+K	6	2.40	318	33	71	57	0.63	70	133	78	15.3	13.3
I+P+K (*)	7	2.38	231	33	62	76	0.71	77	122	75	15.1	13.2
I (**)	8	2.32	263	33	68	50	0.49	71	124	79	16.0	13.5
L+K	9	2.26	278	33	64	57	0.50	55	110	71	15.4	13.5
I+K	10	2.25	269	33	65	55	0.60	74	134	78	15.8	15.9
L+P+K	11	2.22	290	33	66	52	0.43	60	142	74	15.2	13.3
P (.)	12	2.21	244	34	64	52	0.41	56	123	75	15.3	13.6
K	13	2.20	236	34	60	53	0.34	56	120	75	16.0	13.4
P+K	14	2.16	234	33	60	53	0.43	58	124	75	15.5	12.9
L (*)	15	2.15	263	33	66	48	0.36	55	138	69	15.3	12.8
No Input	16	1.99	245	33	63	32	0.23	51	121	75	15.6	13.5
AVG		2.34	271.7	33.2	65.2	54.0	0.50	0.6	133.6	76.0	15.6	13.5
LSD		0.42	75.7	0.6	6.7	13.5	0.13	0.1	30.6	10.7	1.5	1.9
CV%		13.80	20.2	1.2	7.8	22.1	30.84	15.1	18.0	9.9	6.2	9.8

Table 7: Averages, Least Significant Differences (LSD) at an alpha of 0.05, and Coefficient of Variations (CV%) for Yield, Stand Count, R1 Flowering, Height, Nodule Count, Nodule Weight, 100 Seed Weight, and Seed Moisture for the 2019-2020 omission trials at Gurue, Mozambique. 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, the main-effects of Lime (P-value 0.02) and Inoculum (P-value 0.002) were shown to significantly increase soybean grain yields.** The 3-way interaction between Inoculum, Phosphorus, and Potassium showed a small positive effect on soybean yield (P-value 0.04) among the three inputs.

Mean yields ranged from 1.99 tons/ha (No Input) to 2.80 tons/ha (L+I+P+K) . Stand count ranged from 231 to 305 and 110 to 171 at V2 and R8 developmental stages respectively. Notably, for stand count measured at the V2 developmental stage, all 4 rows were counted instead of the two middle rows. R1 flowering ranged from 33 to 34 days. For plant height, all treatments lay between 60 and 71cm, and 69 and 85cm at R1 flowering and R8 developmental stages respectively. Mean values for 100-Seed Weight ranged from 15.1g (I+P+K) to 16.3g (L+P).

Nodule Count, Nodule Weight, and Nodule Viability show a treatment effect in connection to Inoculum usage. Treatments containing Inoculum produced 50-76 nodules with weights ranging from 0.49g to 0.71g. Treatments without Inoculum produced 32-57 nodules with weights ranging from 0.23g to 0.50g. In treatments containing Inoculum nodules displayed an average viability of 74%. Treatments without Inoculum had an average nodule viability of 56%. 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.

For further information on the 2019-2020 trials at Gurue with IITA, contact the trial operator, Steve Boahen at S.Boahen@cgiar.org.

Angonia Trial Results

Treatment	Rank Yield	Yield	V2 Stand Count	R1 Flowering	R1 Height	Nodule Count	Nodule Weight	Nodule Viability	R8 Stand Count	100 seed Weight	Seed Mositure
		ton/ha	count	days	cm	count	g	%	count	g	%
L+I+P+K (**)	1	1.98	215	36	70	17	0.36	80	116	11.9	13.3
L+P+K (**)	2	1.97	211	36	69	19	0.34	78	149	12.1	12.6
P (***)	3	1.71	199	36	71	15	0.28	55	127	11.5	12.4
L+I+P (*)	4	1.60	195	36	72	17	0.35	80	110	11.9	12.1
I	5	1.49	230	36	72	22	0.34	75	123	11.4	13.1
I+P	6	1.43	234	36	72	18	0.36	78	112	11.7	12.8
K	7	1.42	218	36	69	18	0.26	53	99	11.8	12.1
L+P (***)	8	1.36	207	36	70	13	0.21	57	114	11.9	12.1
L	9	1.30	209	36	69	10	0.14	52	118	11.9	11.6
I+P+K	10	1.24	220	36	71	14	0.26	77	114	11.9	12.8
P+K	11	1.20	219	36	72	13	0.22	59	119	12.1	12.0
L+K	12	1.20	222	36	70	13	0.19	52	107	12.0	11.8
I+K (***)	13	1.17	229	36	71	15	0.27	74	103	12.1	12.6
L+I+K	14	1.16	222	36	69	16	0.33	75	106	12.1	13.2
No Input	15	1.13	214	36	61	20	0.18	41	143	11.1	11.4
L+I	16	0.96	185	36	70	12	0.26	72	119	11.9	12.3
AVG		1.40	214.3	36.0	69.9	15.7	0.3	0.7	117.4	11.8	12.4
LSD		0.29	46.8	0.0	1.6	7.4	0.1	0.1	23.6	0.4	0.9
CV%		23.80	14.0	0.0	3.8	34.2	37.3	19.9	16.2	3.2	6.1

Table 8: Averages, Least Significant Differences (LSD) at an alpha of 0.05, and Coefficient of Variations (CV%) for Yield, Stand Count, R1 Flowering, Height, Nodule Count, Nodule Weight, 100 Seed Weight, and Seed Moisture for the 2019-2020 omission trials at Angonia, Mozambique. 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 on the Angonia site data (**Table 8**) in a similar manner to the Gurue site (**Table 7**). **Based on the ANOVA, the main effect of Phosphorus was shown to significantly (P-value 2.84x10-6) increase yield.** The 2-way interaction between Lime and Phosphorus (P-value 0.0002) and Lime and Potassium (P-value 0.0004) both significantly contribute to increased yield. The 3-way interactions of Lime, Inoculum, and Phosphorus (P-value 0.041), and Lime, Phosphorus and Potassium (P-value 0.002) both significantly contribute to increased yield. The 4-way interaction among Lime, Inoculum, Phosphorus, and Potassium showed a significant positive effect on soybean yield (P-value 0.004).

Based on the soil analysis for Angonia (Table 5), the positive impact of Phosphorus amendments, and the various combinations of Phosphorus, Potassium, and Lime correspond with the low fertility values for those soil nutrients for P and K and acidic soils.

Mean yields ranged from 0.96 tons/ha (L+I) to 1.98 tons/ha (L+I+P+K). Stand count ranged from 185 to 234 and 99 to 149 at V2 and R8 developmental stages respectively. Notably, for stand count measured at the V2 developmental stage, all 4 rows were counted instead of the two middle rows. R1 flowering occurred on average 36 days after planting for all treatments. For plant height, all treatments lay between 61 and 77cm at the R1 developmental stage. Mean values for 100-Seed Weight ranged from 11.1g (No Input) to 12.1g (L+P, K).

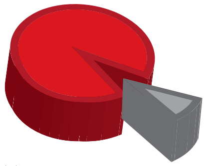
Nodule Weight, and Nodule Viability show a treatment effect in connection to Inoculum usage, but Nodule Count did not exhibit an Inoculum treatment effect. Treatments containing Inoculum produced 12-22 nodules with weights ranging from 0.26g to 0.36g. Treatments without Inoculum produced 10-20 nodules with weights ranging from 0.14g to 0.34g. In treatments containing Inoculum nodules displayed an average viability of 76%. Treatments without Inoculum had an average nodule viability of 56%. 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.

For further information on the 2019-2020 trials at Angonia with IITA, contact the trial operator, Steve Boahen at S.Boahen@cgiar.org.

SMART Farm Trials

Results from Mozambique: IITA 2019-2020

Red Bundle



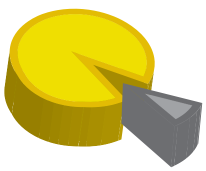
Best Management Practices

Certified Seed

9x return on input costs compared to farmer practice

Marginal Ratio: 3.1*

Yellow Bundle



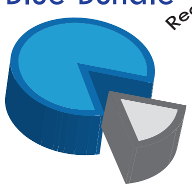
Best Management Practices
Certified Seed
Inoculum

8x return on additional input costs compared to Red Bundle

Marginal Ratio: 1.2**

Blue Bundle

Recommended



Best Management Practices
Certified Seed
Inoculum
Lime

3x return on additional input costs compared to Red Bundle

Marginal Ratio: 1.3**

*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.

Gurue Trial Results

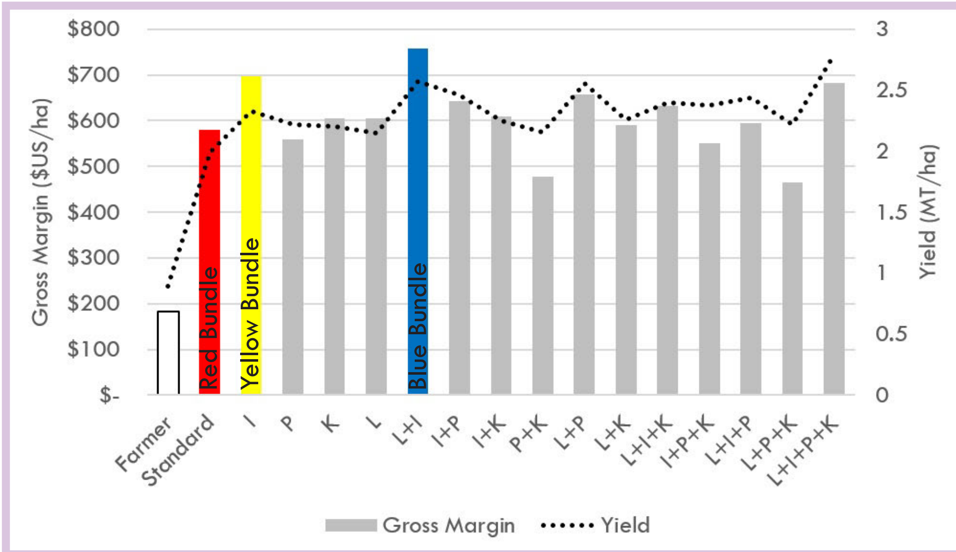


Figure 4: Treatment yields (line graph) and gross margins (bar graph) for the Gurue field site.

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 2019-2020 SMART Farm omission trial has assessed the usage of these inputs and has assembled three input bundles for the Gurue 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 4**. The "Farmer" treatment represents typical soybean farming practices in Southern Africa. 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 0.82MT per hectare laboring between 60 and 70 work days in a season. This generates an implicit wage of $1.05 USD for every $1.00 USD of labor spent.

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 Gurue generated an average gross margin of $580 USD, a marginal ratio increase of 3.1 compared to typical farming practices, and yielded 1.99MT per hectare. This produces a 9x return on seed costs and provides an implicit wage of $3.35 USD for every $1.00 USD of labor spent (a 235% increase in wages compared to the typical farmer).

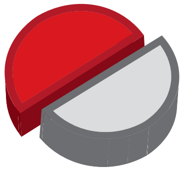
The Yellow Bundle, including certified seed and Inoculum, generated an average gross margin of $697 USD, a marginal ratio increase of 1.2 compared to the Red Bundle, and yielded 2.32MT per hectare. This produces a 8x return on Inoculum costs and provides an implicit wage of $4.03 USD for every $1.00 USD of labor spent (a 303% increase in wages compared to the typical farmer).

The Blue Bundle, including Lime and Inoculum, generated the highest yields and gross margins at 2.56MT per hectare and $759 USD respectively. This produces a 3x return on Lime and Inoculum costs and provides an implicit wage of $4.38 USD for every $1.00 USD of labor spent (a 338% increase in wages compared to the typical farmer). Based on the trial ANOVA, the main effects of Inoculum and Lime significantly contributed to increasing yields at the Gurue site. The significant effect of Lime amendments aligns with the acidic soils (pH 5.5) displayed in **Table 5**.

SMART Farm Trials

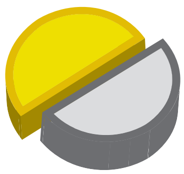
Results from Mozambique: IITA 2019-2020

Red Bundle



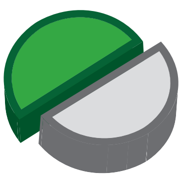
Best Management Practices
Certified Seed
1x return on input costs compared to farmer practice
Marginal Ratio: 1.2*

Yellow Bundle



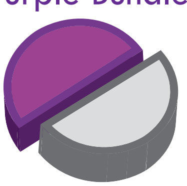
Best Management Practices
Certified Seed
Phosphorus
1x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.5**

Green Bundle



Best Management Practices
Certified Seed
Phosphorus
Potassium
Lime
1x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.5**

Purple Bundle



Best Management Practices
Certified Seed
Phosphorus
Potassium
Inoculum
Lime
1x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.5**

Angonia Trial Results

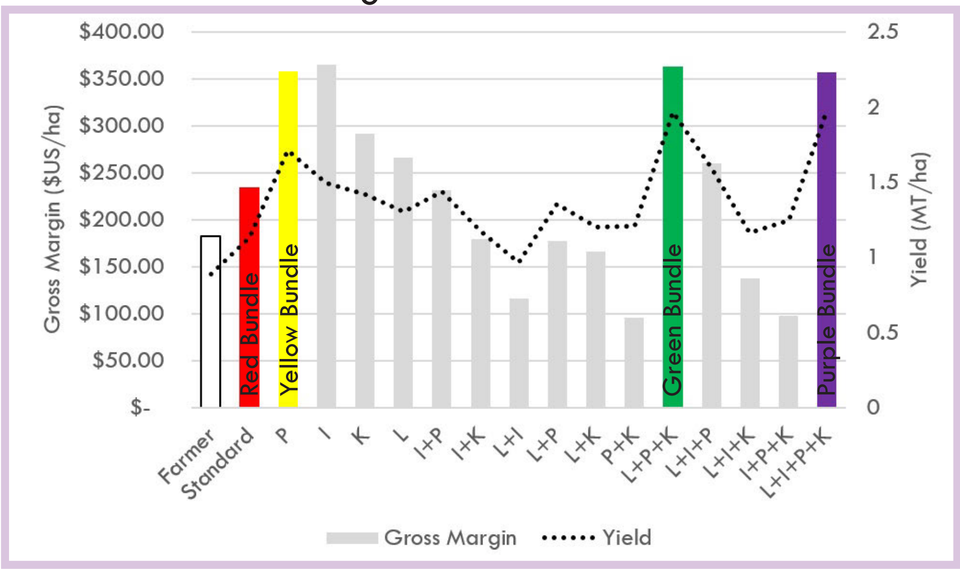


Figure 5: Treatment yields (line graph) and gross margins (bar graph) for the Angonia field site.

The economic analysis in **Figure 5**, is identical to the analysis in **Figure 4**. As with the Gurue site, 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 Angonia generated an average gross margin of $235 USD, a marginal ratio increase of 1.2 compared to typical farming practices, and yielded 1.13 per hectare. This produces a 1x return on seed costs and provides an implicit wage of $1.36 USD for every $1.00 USD of labor spent (a 36% increase in wages compared to the typical farmer). Notably, reduced rainfall at the Angonia site in early February and March (coinciding with pod-elongation and pod-filling) delayed plant development and may contribute to reduced yields at the Angonia site compared to the Gurue site.

In terms of gross margin, the Yellow Bundle (Phosphorus), Green Bundle (Lime, Phosphorus, and Potassium), and Purple Bundle (Lime, Inoculum, Phosphorus, and Potassium) all generate similar values: $357 USD, $363 USD, and $356 USD respectively. For a farmer with the goal of using as few inputs as possible, the Yellow Bundle (1.71 MT per hectare) is the most attractive choice as Phosphorus fertilizer is the only input applied. The Yellow Bundle produces a 1x return on Phosphorus and provides an implicit wage of $2.07 USD for every $1.00 USD of labor spent (a 107% increase in wages compared to the typical farmer). It should be noted that the Inoculum only treatment does have a slightly larger gross margin ($365 USD) compared to the Phosphorus only treatment. However, due to the highly significant ANOVA values for Phosphorus, the non-significant values for Inoculum, and the nutrient poor soils for the Angonia trial site displayed in **Table 5**, selecting Phosphorus as the Yellow Bundle candidate was a better supported choice.

If maximizing yield is more important for a farmer, then the Green Bundle (1.97MT per hectare), or the Purple Bundle (1.98MT per hectare) is a better choice. The Green Bundle produces a 1x return on Lime, Phosphorus, and Potassium and provides an implicit wage of $2.10 USD for every $1.00 USD of labor spent (a 110% increase in wages compared to the typical farmer). Similarly, the Purple Bundle produces a 1x return on Lime, Inoculum, Phosphorus, and Potassium and provides an implicit wage of $2.06 USD for every $1.00 USD of labor spent (a 106% increase in wages compared to the typical farmer).

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

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

Economic Assumptions

- For the typical Southern 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 as 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: 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	$37.25	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

*Costs and prices are average values aggregated from multiple sources

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, Income and Cost Budgets for summer crops in South Africa- (2018-2019)

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 (2020), USDA Market News (2020)