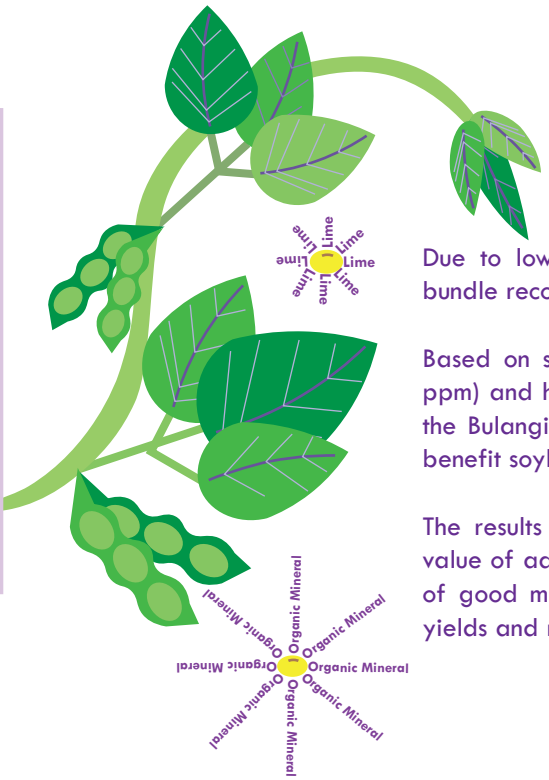
SMART Farm Trials
Results from Uganda: Cottfield 2021

In partnership with the Soybean Innovation Lab (SIL), Cottfield Group conducted a SMART (Soybean Management with Appropriate Research and Technology) Farm input omission trial at a single location in Bulangira, Uganda (**Figure 1**, **Table 1**). 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.

Figure 1: Cottfield trial location for the 2021 season.

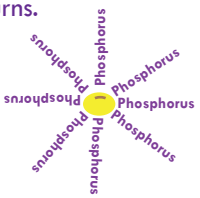


Summary

Due to low recorded yields across all treatments, a bundle recommendation could not be made.

Based on soil analysis, the severe salinity (Na= 147 ppm) and high iron levels (Fe= 290 ppm) observed in the Bulangira site require soil amendments that would benefit soybean growth and inputs availability.

The results from the Bulangira field site highlight the value of adequate soybean stands and the importance of good management practices for maintaining good yields and reasonable economic returns.



Trial Takeaways

During the 2021 planting season a reduced plant stand count and delayed plant development resulted in decreased yield at Bulangira. Potential causes for the yield reduction include challenges with the Maksoy 6N soybean variety itself, adverse soil conditions (high levels of Na), and heavy rainfall observed before the plant's establishment. For future trials, Cottfield could explore the use of calcium in a soluble form, such as gypsum, to reduce the impact of exchangeable sodium in the soil. If possible, selection of another location with historic agricultural use may also improve soybean performance.

In most SMART Farm trials, the Red Bundle marks a large improvement (2x yield gains) over typical farming practices. The use of certified seed and good management practices can make the difference between a poor field and a profitable one. However, the Red Bundle at Bulangira did not perform well once the yield was affected by the reduction of plant population and plant development. With this in mind, some management practices can be recommended to increase soybean production at Bulangira, namely:

Test seed germination: On average 180 plants were observed at V2 stand count (for the middle two rows), 10% below what would be considered a perfect stand (200 plants). Testing seed germination prior to planting can help arm growers with a more realistic view of seed viability. Increased planting rates can then be used to ensure a robust stand count. Using high quality certified seeds and testing seed germination before planting can go a long way toward improving in-season yields for Cottfield.

Plant on ridges: It was observed that several weeks of heavy rainfall at the beginning of the growing season resulted in waterlogging, which could have contributed to the 10% reduction in plant population from V2 to R8 stage. Planting on ridges supports water drainage between the rows and can help protect the Bulangira site against flood damage.

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Country	Location	Planting Date	Harvest Date	Latitude	Longitude	Elevation
Uganda	Bulangira	4/17/2021	8/9/2021	1.1280404	33.8876154	1131m

Table 1: Site information for the Cottfield omission trial, including planting and harvest date. Dates are written as month/day/year.

Treatment	L	I	P	OM	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, OM: organic mineral fertilizer, S=seeds.

The input omission trial was composed of 16 treatment combinations (**Table 2**) of lime, inoculum, phosphorus, organic fertilizer (**Table 3**). Each set of 16 treatments were randomized and replicated 4 times. The soybean variety "Maksoy 6N" was planted in 5 meters by 2.8-meter plots with a seed spacing of 5cm. Each plot contained 4 rows with a spacing of 60 cm. Seeds were treated with Rizoliq rhizobia inoculant 1 hour before planting. Aglime was applied as a broadcast lime treatment before planting. Organic mineral fertilizer Fertiplus was applied as broadcast and incorporated into the topsoil approximately one week before planting. Approximately 21 days after germination at the V2 or V3 developmental stage, triple super phosphate was applied to treated plots as a side-dress 5 centimeters from the furrow and 5 centimeters deep.

	Lime	Inoculum	Phosphorus	Organic Fertilizer	Seed
Product	Aglime	Rizoliq	Triple Super Phosphate	Fertiplus	Maksoy 6N
Source	Makerere CAES	Rizobacter	-	-	Makerere CAES
Concentration	CaO-37%	-	P2O5-46%	4-3-3	-
Application Rate	1,500kg/ha	2ml/1kg	75kg ai/ha	1,500kg/ha	400,000 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: Field plots at the Bulangira SMART Farm omission trial. The left image shows soybean plants 55 days after planting (photo taken June 11, 2021). The right image shows soybean growth at 105 days after planting (photo taken July 31, 2021).

Month	Min Temperature (°C)	Max Temperature (°C)	Rainfall (mm)
April	20.3	29.1	251.9
May	20.3	28.2	149.7
June	19.5	28.8	51.0
July	19.4	27.5	60.7
August	18.9	28.5	254.9
September	19.7	28.1	273.2

Table 4: Monthly averages for minimum and maximum temperatures and the total monthly rainfall for the 2021 winter season at the Bulangira site.

Test	Method	Units	Bulangira
Soil pH	1:1 - Water pH	-	7.9
Phosphorus (P)	Mehlich 3	ppm	101
Potassium (K)	Mehlich 3	ppm	230
Calcium (Ca)	Mehlich 3	ppm	887
Magnesium (Mg)	Mehlich 3	ppm	123
Sulfur (S)	Mehlich 3	ppm	54
Boron (B)	Mehlich 3	ppm	0.31
Copper (Cu)	Mehlich 3	ppm	1.04
Iron (Fe)	Mehlich 3	ppm	290
Manganese (Mn)	Mehlich 3	ppm	38
Zinc (Zn)	Mehlich 3	ppm	19.59
Sodium (Na)	Mehlich 3	ppm	147
Organic Matter	Loss On Ignition	%	1.89

Table 5: Soil fertility results for the Bulangira site generated from Brookside Laboratories. Soil nutrient amounts are displayed in parts-per-million (mg/kg).

Seasonal temperature and precipitation information for the field site is displayed in **Table 4**. Temperatures peaked in April reaching 29.1°C with a minimum temperature of 18.9°C occurring in August. Between April and September 2021, the total observed rainfall was 1041.4mm.

Soil properties for the Bulangira site are shown in **Table 5**. The soil has a pH of 7.9. Optimal soil pH for soybean ranges from 6.5-7.0, so no additional liming would be recommended for this site. Potassium levels are well above the threshold (110mg/kg) for sufficient soybean production, and no potassium amendments are required. Similarly, soil phosphorus levels are well above the threshold (30mg/kg) for sufficient soybean production, and no phosphorus amendments are required.

The Bulangira site has high iron levels (high level above 7.6 ppm) and salinity soil (high level above 120 ppm). High levels of sodium reduce plant growth and water infiltration in the soil. And it can also destroy soil structure and productivity at high levels.

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 R1 and R8 developmental stages. Measurements for nodule count, weight, and viability were measured at the R3 developmental stage. Measurements for yield, seed count, and 100 seed weight were measured post-harvest.

Trait	Unit	Measurement Metrics
Yield	tonnes/hectare	Plants harvested and threshed, seed winnowed and weighed at 13% moisture
Stand Count	plants/plot	Sum of plants in row 2 and 3
R1 Flowering	days	Days until mid-flowering
Plant Height	centimeters	Distance from soil to the shoot apical meristem on main stem
Nodule Count	nodules/plant	Number of rhizobium nodules on roots collected at R3-pod filling stage
Nodule Weight	grams/plant	Mass of rhizobium nodules on roots collected at R3-pod filling stage
Nodule Viability	%	Percent of viable nodules on roots collected at R3-pod filling stage
100 Seed Weight	grams	Random sets of 100 seeds selected and weighed
Seed Moisture	%	Percent moisture at harvest

Table 6: Data metrics for the 2021 SMART Farm omission trial.

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 Moisture
		ton/ha	count	days	cm	nodules	g	%	count	cm	g	%
L+I+OM (.)	1	1.02	172	47	40	20	2.87	100	162	70	17	3.9
I+OM	2	1.01	172	47	40	25	2.72	100	161	73	19	4.0
OM (*)	3	0.99	190	47	38	13	2.52	100	148	74	18	4.0
L+I (**)	4	0.93	162	47	39	27	2.91	99	159	69	18	4.2
I (***)	5	0.93	171	47	43	20	2.08	99	146	78	17	4.0
P (***)	6	0.91	171	47	40	14	2.86	98	155	70	18	4.2
I+P (***)	7	0.89	174	47	39	18	1.81	100	156	74	17	4.0
L+P (***)	8	0.88	191	47	36	18	1.81	100	177	70	18	4.3
L+P+OM (***)	9	0.88	200	47	41	11	1.77	99	185	68	17	4.1
L+I+P+OM (***)	10	0.86	191	47	41	13	1.07	100	176	66	18	4.1
L+I+P (***)	11	0.86	175	47	34	19	1.34	99	161	61	18	3.8
I+P+OM (***)	12	0.78	186	47	43	19	1.31	100	150	73	19	4.2
L+OM (*)	13	0.78	183	47	36	18	1.36	99	167	70	18	3.9
No Input	14	0.77	174	47	33	11	1.64	99	154	68	18	4.3
L	15	0.75	191	47	41	15	1.45	100	181	70	17	4.1
P+OM (***)	16	0.71	189	47	40	9	1.09	99	167	67	18	4.3
AVG		0.87	180.55	46.86	38.92	17.00	1.91	0.99	162.80	69.95	17.75	4.07
LSD		0.04	31.49	0.51	0.51	8.96	2.16	0.02	32.63	13.55	0.69	0.29
CV%		10.93	12.16	0.75	13.58	42.85	77.11	1.11	14.21	13.13	4.18	5.44

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, nodule viability, 100 seed weight, and seed moisture for the 2021 omission trials at Bulangira, Uganda. In the treatment column: I-inoculum, L-lime, P-phosphorus, and OM- organic mineral fertilizer. P-values for each treatment main-effect or interaction are represented as follows: (.)<0.1, (*)<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 (**Table 7**). The Shapiro's Wilk and Brown-Forsythe tests were employed to confirm residual normality and homogeneity of the variance respectively. **Based on the ANOVA, 3 out of 4 main effects were significant, inoculum, (P-value 2.228e-15), phosphorus (P-value 7.642e-10), organic mineral fertilizer (P-value 0.048). The 2-way interactions between lime and inoculum (P-value 0.0076), lime and organic mineral fertilizer (P-value 0.0276) and the 3-way interactions among lime, inoculum, and organic mineral fertilizer (P-value 0.0561) were significant and generated a slight increase in soybean grain yields. While lime by itself did not have a significant yield increase, in combination with I, OM, and I+OM the pH buffering qualities of lime did have a significant positive impact. Conversely, the 2-way interactions between inoculum and phosphorus (P-value 4.620e-15), phosphorus and organic mineral fertilizer (P-value 2.2e-16), lime and phosphorus (P-value 1.332e-09), and the 3-way interactions among inoculum, phosphorus, and organic mineral fertilizer (P-value 0.0006), lime, inoculum, and phosphorus (P-value 3.126e-08), lime, phosphorus, and organic mineral fertilizer (2.223e-12) and the 4-way interactions among lime, inoculum, phosphorus and organic mineral fertilizer (P-value 1.209e-06) generated a slight decrease in soybean grain yields.**

Mean yields ranged from 0.71 tons/ha (P+OM) to 1.02 tons/ha (L+I+OM). Stand count ranged from 162 (L+I) to 200 (L+P+OM) and 146 (I) to 185 (L+P+OM) at V2 and R8 developmental stages, respectively. R1 flowering occurred across treatments at 47 days after planting. For plant height, all treatments lay between 33cm (no input) and 43cm (I and I+P+OM), and 61cm (L+I+P) and 78cm (I) at R1 flowering and R8 developmental stages, respectively. Mean values for 100-seed weight ranged from 17g to 19g.

It was observed that several weeks of heavy rainfall (**Table 4**) at the beginning of the growing season resulted in waterlogging, which could have contributed to the reduction in plant population and plant height. Besides that, the high sodium levels observed in the soil analysis (Table 5) could also have reduced plant growth. For the 2020 season, the variety Maksoy 6N presented an average plant height of 60cm at R1 and 102cm at R8, a reduction of 30% in plant height compared to the 2021 season. The yield had an average reduction of 58% compared to the 2020 season.

Nodule count, nodule weight, and nodule viability did not show a strong treatment effect in connection to inoculum usage. Nodule counts ranged from 9 (P+OM) to 27 (L+I) nodules with nodule weights ranging from 1.07g (L+I+P+OM) to 2.91g (L+I). Nodule viability ranged from 98-100%.

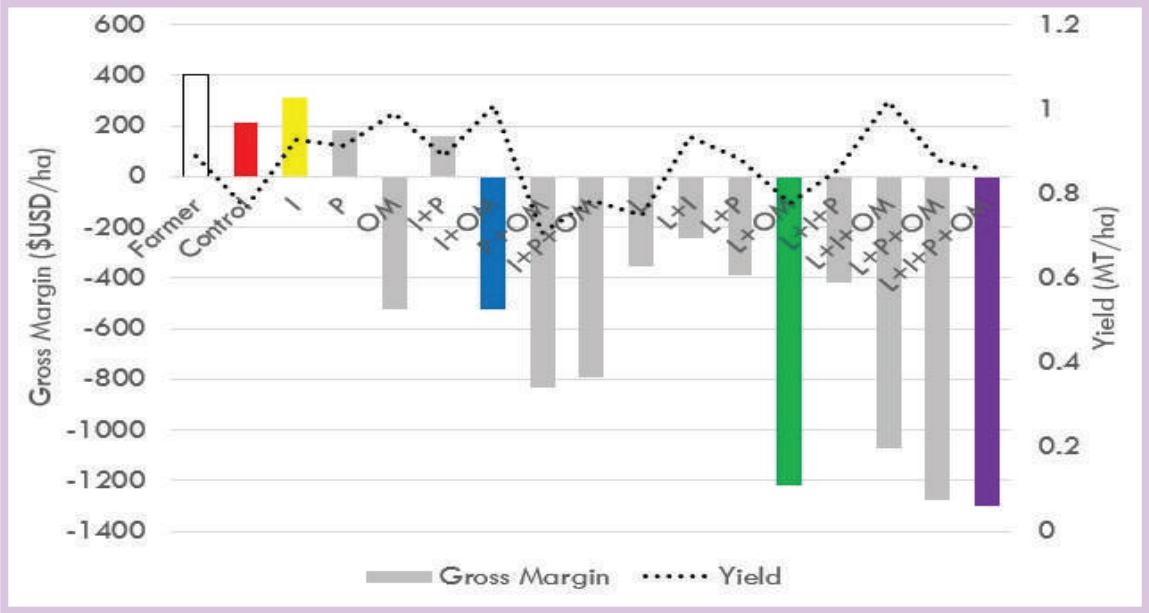

Figure 3: Treatment yields (line graph) and gross margins (bar graph).

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 2021 SMART Farm omission trial has assessed the usage of lime, inoculum, phosphorus, and organic mineral fertilizer for the Bulangira 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 3**. 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 USD 150 and a yield of 0.80 MT per hectare laboring between 60 and 70 workdays in a season. This generates an implicit wage of USD 1.16 for every USD 1.00 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).

Due to the low yield obtained at the Bulangira site, economic returns cannot be accurately represented across input treatments.

[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.

For further information on the 2021 trial in Bulangira with Cottfield Group, contact the trial operator Pavel Kuzmenko, at p.kuzmenko@cottfield.com

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 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, including labor, minus the Revenue generated from grain 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	$111.00	1
Rhizobium Inoculum	$10.00	2
Phosphurus Fertilizer	$124.50	3
Organic Mineral Fertilizer	$885.00	4
Lime	$555.00	5
Labor Costs		
Labor (land preparation, planting, weeding, harvest, bagging)	$173.01	6
Soybean Selling Price		
Item	$USD/Kg of Seed	
Grain Price	$0.65 ($650.00/MT)	7

Source

1) Internal SIL communications. (2021).

2) Internal SIL communications. (2021).

3) Internal SIL communications. (2021).

4) Internal SIL communications. (2021).

5) Internal SIL communications. (2021).

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 (2021).