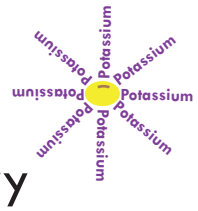
FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

SMART Farm Trials
Results from Uganda: Cottfield 2020

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 Group trial location for 2020 season



Summary

Bundle recommendation for the Bulangira field site: Yellow Bundle- Best Management Practices, Certified Seed, and Rhizobia Inoculant.

Rhizobia inoculant did not signficantly increase yields compared to the no input control, but had the highest gross margins of $465/ha.

The input omission trial is composed of 8 treatment combinations (**Table 2**) of phosphorus, lime, and inoculum (Table 3). Each set of 8 treatments were randomized and replicated 4 times. The soybean variety "Maksoy 6N" was planted in 5 meter by 2.4 meter plots with a seed spacing of 5 cm. Each plot contained 4 rows with a spacing of 60 cm. Seeds were treated with MAK-Bio-N-FIXER inoculum 1 hour prior to planting. Agricultural lime was applid one week prior to planting using the broadcast method. 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.

Treatment	L	I	P	S
1				+
2			+	+
3		+		+
4		+	+	+
5	+			+
6	+		+	+
7	+	+		+
8	+	+	+	+

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

Country	Location	Planting Date	Harvest Date	Latitude	Longitude	Elevation
Uganda	Bulangira	27/6/2020	18/10/2020	1°07'51.8"N	33°52'43.6"E	1131m

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

	Phosphorus	Inoculum	Lime	Seed
Product	Triple Super Phosphate	Mak-Bio-N-FIXER	Aglime	Maksoy 6N
Source	-	Makerere CAES	Makerere CAES	Makerere CAES
Concentration	P2O5-46%	-	CaO-37%	-
Application Rate	75kg ai/ha	400g/100kg	1500kg/ha	400000 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.

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Figure 2: Field plots at the Bulangira SMART Farm Omission Trial

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
May	30.3	18.8	111.1
June	29.5	18.6	79.9
July	28.8	17.9	111.0
August	29.3	18.1	174.6
September	30.1	18.0	132.7
October	30.2	18.6	246.1

Table 4: Monthly averages for maximum and minimum temperatures and the total monthly rainfall for 2020 season at the Bulangira site.

Seasonal temperature and precipitation information for the field sites are displayed in **Table 4**. Temperatures peaked in May reaching 30.3°C. Minimum temperatures of 17.9°C were observed in July. Between the months of May and October the total observed rainfall was 855.4 mm.

Soil property analyses were completed by Makerere CAES and displayed in **Table 5**. Soils at this location were a sandy clay loam soil texture. All nutrients analyzed were at sufficent levels for soybean production except phosphorus.

Data collection metrics for the input omission trial are described in **Table 6**. Stand counts were measured at the V2 and R8 growth stages. Plant heights were measured at R1 and R8 growth stages. Nodule count, weight, and viability were measured as R3. Measurements for yield, seed count, and 100 seed weight were measure post-harvest.

Test	Method	Units		Rating
Soil pH	1:1 - Water pH	-	6.5	Sufficent
Phosphorus (P)	Mehlich 3	mg/kg	2.43	Insufficient
Potassium (K)	Mehlich 3	cmoles/kg	1.04	Sufficent
Calcium (Ca)	Mehlich 3	cmoles/kg	7.44	Sufficent
Magnesium (Mg)	Mehlich 3	cmoles/kg	1.54	Sufficent
Sodium (Na)	Mehlich 3	cmoles/kg	0.27	
Organic Matter	Loss On Ignition	%	2.18	Low

Table 5: Soil fertility results for the Bulangira site generated from Makerere CAES. Available phosphorus is displayed in parts-per-million (mg/kg) and all other nutrients are displayed at cmoles/kg.

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 2020 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 Mositure
		tonnes/ha	plants/plot	days	cm/plant	nodules /plant	g/plant	%	plants/plot	cm	g	%
L (***)	1	2.13	190	48	57	9	0.2	78	171	101	15.2	3.0
L+P (***)	2	2.10	191	48	64	8	0.4	98	177	107	14.4	2.8
L+P+I	3	2.03	185	47	66	4	0.1	100	171	107	16.0	4.0
L+I (**)	4	2.02	175	48	60	8	0.3	94	167	107	15.3	3.0
P+I	5	2.00	192	47	59	6	0.1	78	174	103	15.3	4.2
I	6	1.95	187	47	61	5	0.1	71	167	97	14.1	4.4
P (.)	7	1.88	191	47	56	9	0.1	63	170	98	14.7	4.2
No Input	8	1.83	191	48	59	4	0	70	182	98	14.8	4.7
AVG		1.99	187.4	47.4	60.1	6.4	0.2	81.5	172.4	102.3	15.0	3.8
LSD		0.03	11.4	0.6	6.1	-	-	-	20.7	6.2	0.6	0.5
CV%		5.02	5.2	1.1	8.0	32.2	71.5	17.2	7.6	6.8	4.3	20.0

Table 7: Averages, Least Significant Differences (LSD) at an alpha of 0.05, and Coefficient of Variations (CV%) for yield, stand count, R1 flowering and height, nodule count, weight, and viability, R8 stand count, R8 plant height, 100 Seed Weight, and seed moisture for the 2020 omission trials at Bulangira, Uganda. In the treatment column: I-Inoculum, P-Phosphorus, L-Lime. 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 JMP 15.0 using the Fit Model platform 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, lime (L) had a significant main effect on yield, and phosphorus (P) main effect had a nearly signficant effect (P = 0.06). There were significant interactions between L and phosphorus (P) and L and Inoculum (I). For the LxP interaction, L and L+P treatments had significantly higher yields compared to P, which has significantly higher yields than no input control. For the LxI interaction, L+I had significantly higher yields than any other treatment, but all treatments were significantly higher than the no input control.

There were significant main effects and interactions for V2 stand count, R8 plant heights, and 100-seed weights, and seed moisture. There was a significant main effect for inoculum at V2 where application of I increased stand count. For R8 plant heights, the addition of all three inputs significantly increased plant height compared to other treatments. There were significant interactions for all three inputs for 100-seed weight. Treatments I+P, L, L+P, and L+I were all significantly higher than the no input controls. No statistical analyses were performed on nodule count, weight, or viability since values displayed are from only one replicate.

Mean yields ranged from 1.83(no input) to 2.13 (L) tonnes/ha. Stand counts ranged from 175 (L+I) and 167 (L+I, I) to 192 (P+I) and 182 (no input) plants/plot for V2 and R8, respectively. Plant heights ranged from 56 (P) and 97 (I) to 66 (L+P+I) and 107 (L+P, L+I, L+P+I) cm at R1 and R8, respectively. Nodule count ranged from 4 (L+P+I, no input) to 9 (L, P) nodules/plant, nodule weight ranged from less than 0.1 (no input) to .4 (L+P) grams/plant, and viability 63% (P) to 100% (L+P+I).

It was surprising to see lime have the greatest impact on yields since soils had a pH of 6.5., as well that phosphorus did not have a greater effect on yields since soils are deficient in P. Applying L and P together did signficantly increase yields compared to P application alone. This may be due to P being quickly tied up in the soils and the micro-environmental produced by the higher lime applicaiton allowing some P to be more available. Over all treatments, yields were considerably low; however, they are still higher than what has previously been shown for Maksoy 6N at this location.

For further information on the 2020 trial in Bulangira with Cottfield Group, contact the trial operator Pavel Kuzmenko, at p.kuzmenko@cottfield.com

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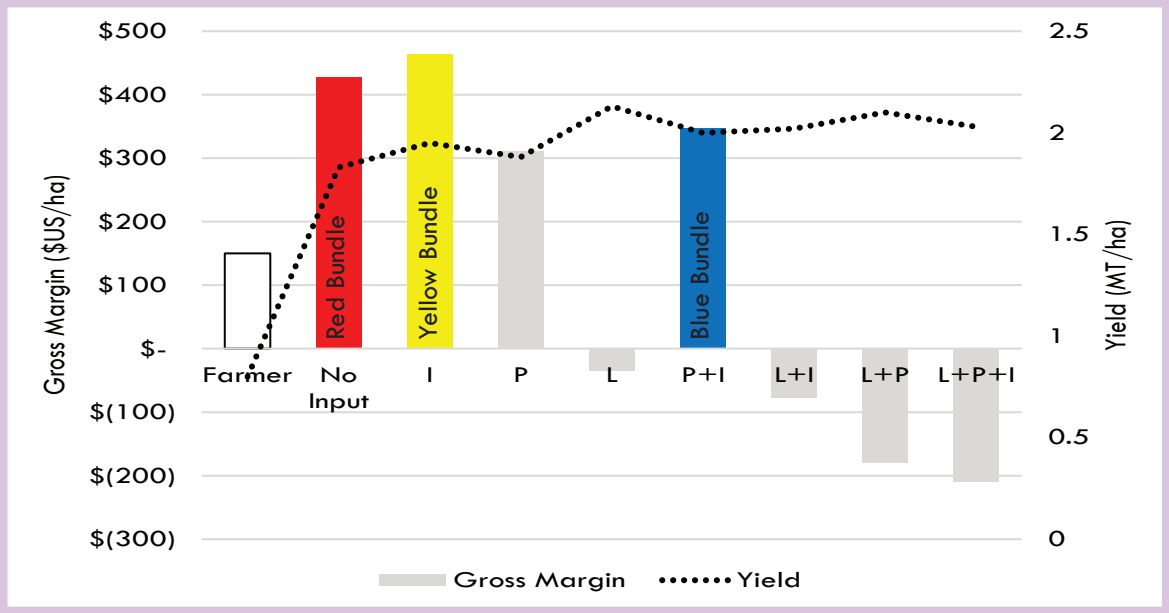
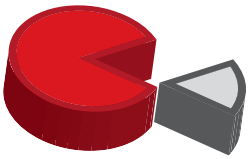


Figure 4: Treatment yields (line graph) and gross margins (bar graph)

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, and phosphorus 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 2020 SMART Farm omission trial has assessed the usage of these inputs and has assembled three input bundles 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 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 $150 USD and a yield of 0.8 MT per hectare laboring between 60 and 70 workdays in a season. This generates an implicit wage of $1.16 USD for every $1.00 USD of labor spent.

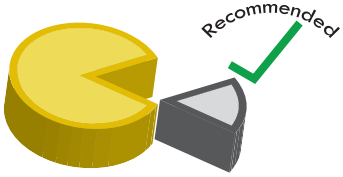
Red Bundle



Best Management Practices
Certified Seed
3x return on additional input costs compared to farmer practices
Marginal Ratio: 2.86*

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 Bulangira generated an average gross margin of $429 USD, a marginal ratio increase of 2.86 compared to typical farming practices, and yielded 1.83 MT per hectare. This produces a 3x return on seed costs and provides an implicit wage of $3.32 USD for every $1.00 USD of labor spent (a 232% increase in wages compared to the typical farmer).

Yellow Bundle



Best Management Practices
Certified Seed
Rhizobia Inoculant
0x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.08**

The **Yellow Bundle** represents a step up from the Red Bundle with the inclusion of rhizobia inoculant. The Yellow Bundle generated an average gross margin of $465 USD, a marginal ratio increase of 1.08 compared to the Red Bundle, and yielded 1.95 MT per hectare. This produces a 0x return on lime costs and provides an implicit wage of $3.60 USD for every $1.00 USD of labor spent (a 260% increase in wages compared to the typical farmer). **Based on these observations, the Yellow Bundle is recommended for the Bulangira location.**

The **Blue Bundle** includes the use of rhizobia inoculant along with phosphorus fertilizer, certified soybean seed and the adoption of best management practices. The blue bundle generated an average gross margin of $347 USD, a marginal ratio increase of 0.81 compared to the Red Bundle, and yielded 2.00 MT per hectare. This produces an 0x return on rhizobia inoculant and phosphorus costs and provides an implicit wage of $2.69 USD for every $1.00 USD of labor spent (a 169% increase in wages compared to the typical farmer).

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