SMART Farm Trials

Results from Malawi: JTI 2020

In partnership with the Soybean Innovation Lab (SIL), Japan Tobacco International (JTI) conducted SMART (Soybean Management with Appropriate Research and Technology) Farm input omission trials at a single location in Kanengo, Malawi (Figure 1, Table 1).

Figure1: JTI trial location for 2020 season

Summary

Bundle recommendation for the Kanengo field site: **Blue Bundle- Best Management Practices, Certified Seed, Rhizobium Inoculum, Phosphorus Fertilizer.**

Based on soil fertility results, the Kanengo site is deficient in phosphorus.

Late July planting of the 2020 irrigated trials resulted in soybean pod maturity coinciding with the Summer planting rains in December. This delayed grain drying, and delayed harvest. Planting in late May will avoid this in future trials.

The input omission trials at both locations were composed of 16 treatment combinations (Table 2) of phosphorus, potassium, lime, and inoculant (Table 3). Each set of 16 treatments were randomized and replicated 4 times. The soybean variety "Serenade" was planted in 5 meter by 3 meter plots with a seed spacing of 5cm. Each plot contained 4 rows with a spacing of 75 cm. Seeds were treated with Hi-Stick rhizobia inoculant 1 hour prior to planting. Calciprill lime was applied in the seed-furrow at planting. Approximately 21 days after germination at the V2 or V3 developmental stage, single super phosphate and muriate of potash were applied to treated plots as a side-dress 5 centimeters from the furrow, and 5 centimeters deep. The field site was watered using drip-irrigation throughout the season.

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
Malawi	Kanengo	07/02/2020	1/04/2021	-13.90492	33.802682	1121m

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

	Phosphorus	Potassium	Inoculum	Lime	Seed
Product	Single Super Phosphate	Muriate of Potash	Hi Stick	Calciprill	Serenade
Source	-	-	BASF	OMYA	Seed Co.
Concentration	P2O5-13%	K2O-60%	-	CaO-36%	-
Appication Rate	75kg ai/ha	75kg ai/ha	400g/100kg	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: Kanengo field location. The top-left image shows drip- irrigation set-up (Photo taken July 3, 2020). The top-right image depicts healthy, but delayed soybean growth at 64 days after planting (photo taken September 12, 2020). The bottom-left image shows delayed soybean maturity at 151 days after planting (Photo taken November 30, 2020).

Test	Method	Units	Kanengo
Soil pH	1:1 - Water pH	-	6.8
Phosphorus (P)	Mehlich 3	ppm	16
Potassium (K)	Mehlich 3	ppm	524
Calcium (Ca)	Mehlich 3	ppm	2279
Magnesium (Mg)	Mehlich 3	ppm	300
Sulfur (S)	Mehlich 3	ppm	9
Boron (B)	Mehlich 3	ppm	0.45
Copper (Cu)	Mehlich 3	ppm	1.68
Iron (Fe)	Mehlich 3	ppm	64
Manganese (Mn)	Mehlich 3	ppm	129
Zinc (Zn)	Mehlich 3	ppm	3.03
Sodium (Na)	Mehlich 3	ppm	13
Organic Matter	Loss On Ignition	%	5.13

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

Soil properties for the Kanengo site are shown in Table 5. The field site had a sandy clay texture with good fertility. The soil has a pH of 6.8. 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. Soil phosphorus levels are shown to be below our 30 mg/kg threshold for sufficient soybean production and would benefit from in-field fertilizer application.

Month	Min Temperature (°C)	Max Temperature (°C)	Rainfall (mm)
June	13.1	23.8	3.0
July	12.0	22.9	2.4
August	13.9	26.6	0.0
September	16.3	28.5	0.0
October	19.3	30.6	10.8
November	21.0	32.7	26.5
December	19.8	29.0	152.7
January	19.2	28.1	319.0

Table 4: Monthly averages for maximum and minimum temperatures and the total monthly rainfall for 2020 season at the Kanengo site. This does not include water applied through irrigation.

Seasonal temperature and precipitation information for the field site is displayed in **Table 4**. Temperatures peaked in October reaching 30.6°C with a minimum temperature of 12.0°C occurring in July. Between the months of June 2020 and January 2021 the total observed rainfall was 514.4mm. Supplemental irrigation was applied each day as approximated in **Table 6**. During this trial soybean maturity was delayed from the expected 90-120 days after planting to 186 days. Two potential reasons for this delay are the shift in photoperiod and reduced temperatures due to planting during the winter season. Irrigated 2020 winter season trials were planted in July, which resulted in soybean pod maturity coinciding with the 2020-2021 summer season planting rains in December. This delayed grain drying, and delayed harvest. Ensuring irrigated winter season trials are planted in late May will avoid this situation in future trials.

Growth Stage	Days after planting	Millimeters of water per day
Germination and Seedling	1-20	2.5
Vegetative growth (V2 up to flowering)	20-30	5
Bloom (R1-R2)	30-40	5
Early pod development (R3)	50-60	5
Pod-elongation (R4)	65-75	6
Seed development and fill (R5-R6)	75-105	7
Pod color change (R7)	102-116	5
Maturity (R8)*	113-130	1
Estimated seasonal irrigation	455-500mm	

Table 6: Approximate rates of irrigation. *Once plants reach full maturity (R8), irrigation ends.

Data collection metrics for the input omission trial are described in **Table 7**. 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	days	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 7: Data metrics for the 2020 SMART Farm omission trials.

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	nodules	g	%	count	cm	g	%
I+P+K	1	4.01	238	74	56	21	0.9	12	236	92	20.6	10.1
L+I+P	2	3.95	238	74	57	27	0.8	19	235	96	20.9	10.3
P+K	3	3.92	238	74	51	1	0	0	234	84	15.4	9.9
I+P	4	3.89	238	74	57	18	2.7	9	235	93	21.8	9.2
L+K	5	3.80	239	74	51	1	0.1	0	238	77	21.6	9.7
L+I+P+K	6	3.73	239	74	58	26	0.4	11	235	91	21.0	9.6
L+I	7	3.70	239	74	52	26	0.7	13	237	84	20.6	9.6
I+K	8	3.65	239	74	55	19	0.6	10	234	88	19.5	9.9
P (.)	9	3.63	240	74	50	1	0	0	234	82	20.4	9.7
K	10	3.63	238	74	49	2	0.1	1	234	80	21.6	9.5
L+P	11	3.60	238	74	50	1	0	0	234	81	19.0	9.8
I	12	3.54	239	74	52	22	1.9	12	236	86	13.8	9.7
L	13	3.43	238	74	50	2	0	1	235	76	21.0	9.7
L+I+K	14	3.42	238	74	52	27	0.6	16	231	89	21.3	10.1
L+P+K	15	3.24	240	74	50	1	0	0	228	81	19.1	9.5
No Input	16	3.21	239	74	48	1	0	1	238	78	20.4	9.5
AVG		3.65	238.5	74.0	52.4	12.2	0.6	6.6	234.6	85.0	19.9	9.7
LSD		0.66	2.7	0.0	4.6	6.9	1.9	7.8	7.0	7.9	5.3	0.6
CV%		12.75	0.7	0.0	8.1	99.7	255.8	123.6	2.1	9.0	19.8	4.8

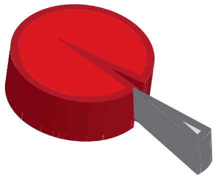
Table 8: Averages, Least Significant Differences (LSD) at an alpha of 0.05, and Coefficient of Variations (CV%) for Yield, Stand Count, R1 Flowering, Height, Nodule Count, Nodule Weight, 100 Seed Weight, and Seed Moisture for the 2020 omission trials at Kanengo, Malawi. In the treatment column: I-Inoculum, 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-effect of phosphorus, while not statistically significant (P-value 0.09), is linked to increased soybean grain yields.**

Mean yields ranged from 3.21 tons/ha (No Input) to 4.01 tons/ha (I+P+K). Stand count ranged from 238 to 240 and 228 to 238 at V2 and R8 developmental stages, respectively. R1 flowering occurred across treatments at 74 days after planting. For reference, R1 flowering occurred at 46 days after planting during the 2019-2020 summer season at Kanengo. For plant height, all treatments lay between 48 and 58cm, and 76 and 96cm at R1 flowering and R8 developmental stages, respectively. Mean values for 100-seed weight ranged from 15.4g (P+K) to 21.6g (L+K). Nodule count and nodule weight showed a strong treatment effect in connection to inoculum usage. Treatments containing inoculum produced 18-27 nodules with weights ranging from 0.40g to 2.27g. Treatments without inoculum produced 1-2 nodules with weights ranging from 0.00g to 0.10g. Nodule viability was low across treatments, but inoculum addition increased the number of active nodules. Nodule viability for treatments with inoculum ranged from 9-19%, and treatments without inoculum had nodule viabilities ranging from 0-1%. 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.

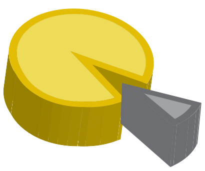
For further information on the 2020 trials at Kanengo with JTI, contact the trial operator Ipyana Mwalwanda, at Ipyana.Mwalwanda@jti.com

Red Bundle



Best Management Practices
Certified Seed
20x return on input costs compared to farmer practice
Marginal Ratio: 5.8*

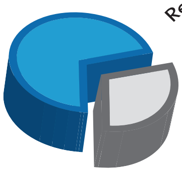
Yellow Bundle



Best Management Practices
Certified Seed
Inoculum
8x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.1**

Blue Bundle

Recommended



Best Management Practices
Certified Seed
Phosphorus
Inoculum
1x return on additional input costs compared to Red Bundle
Marginal Ratio: 1.1**

*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.

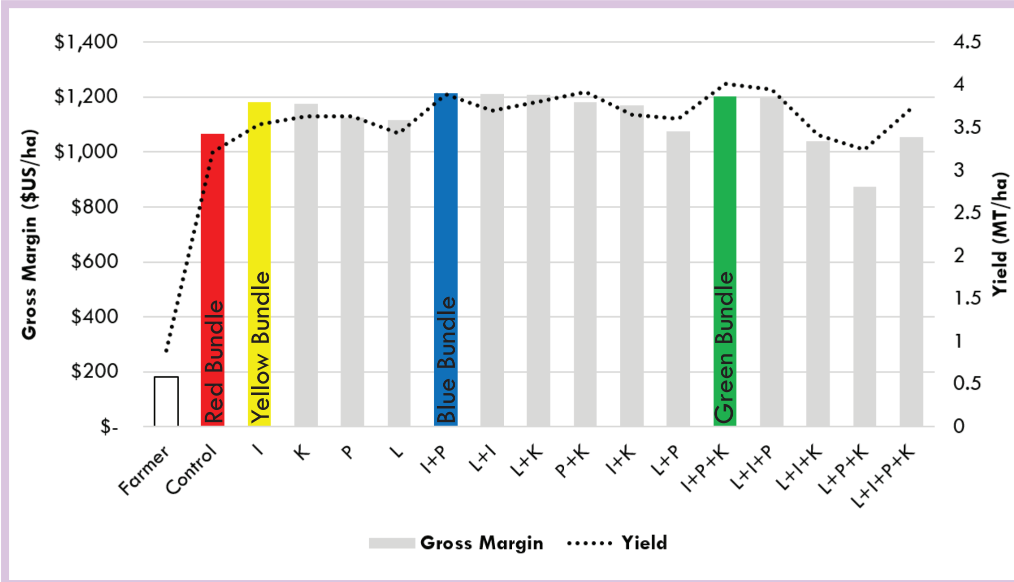


Figure 3: Treatment yields (line graph) and gross margins (bar graph).

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 2020 SMART Farm omission trial has assessed the usage of these inputs and has assembled three input bundles for the Kanengo 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 Malawi. 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 Kanengo generated an average gross margin of $1,068 USD, a marginal ratio increase of 5.8 compared to typical farming practices, and yielded 3.21MT per hectare. This produces a 20x return on seed costs and provides an implicit wage of $6.17 USD for every $1.00 USD of labor spent (a 517% increase in wages compared to the typical farmer).

A step up from the Red Bundle with the inclusion of inoculum, the **Yellow Bundle** generated an average gross margin of $1,183 USD, a marginal ratio increase of 1.1 compared to the Red Bundle, and yielded 3.54MT per hectare. This produces a 8x return on inoculum costs and provides an implicit wage of $6.84 USD for every $1.00 USD of labor spent (a 584% increase in wages compared to the typical farmer).

The Blue Bundle is recommended for the Kanengo site. The **Blue Bundle**, including inoculum and phosphorus generated yields of 3.89MT per hectare and a gross margin of $1,215 USD, the highest among observed treatments. Based on the trial ANOVA and soil fertility analysis, the addition of phosphorus fertilizer likely contributed to this increase in yield. This produces a 1x return on inoculum and phosphorus costs and provides an implicit wage of $7.02 USD for every $1.00 USD of labor spent (a 602% increase in wages compared to the typical farmer).

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)