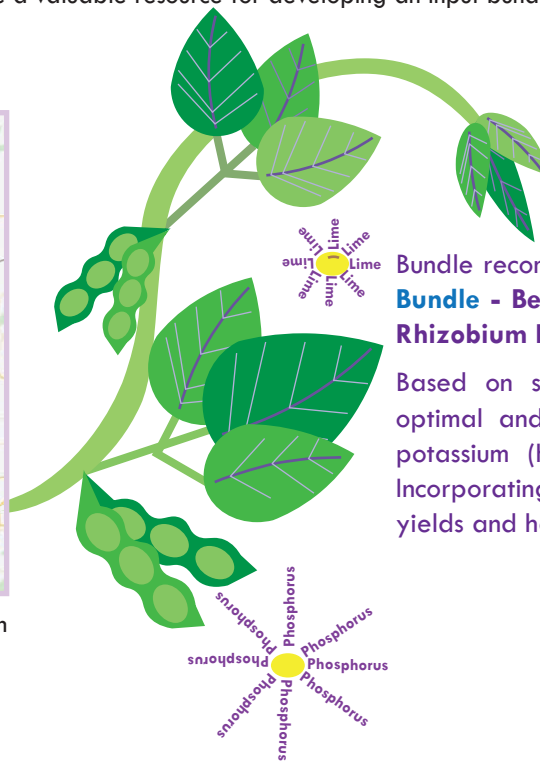


In partnership with the Soybean Innovation Lab (SIL), Horizon Farming Limited conducted a SMART (Soybean Management with Appropriate Research and Technology) Farm input omission trial at Lisungwi, Malawi (**Figure 1; Table 1**). This trial provides information on which inputs are best suited to maximize soybean yield and are a valuable resource for developing an input bundle approach to soybean production.



**Figure 1:** Horizon Farming Limited trial location for 2019-2020 season



### Summary

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

Based on soil fertility results, the Lisungwi site has optimal and very high levels of phosphorus (P) and potassium (K), respectively, and slightly acidic soils. Incorporating Inoculum and Lime significantly increased yields and had the highest 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 “Kafue” from IITA 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 at 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
Malawi	Lisungwi	12/27/2019	04/30/2020	-14.217	33.7	1156m

**Table 1:** Site information for the Horizon Farming Limited omission trial, including planting and harvest date.

	Phosphorus	Potassium	Inoculum	Lime	Seed
Product	Triple Super Phosphate	Muriate of Potash	Hi-Stick	Calciprill	Kafue
Source	-	-	BASF	OMYA	IITA
Concentration	P2O5-46%	K2O-60%	-	CaO-36%	-
Application 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:** Field plots at the Lisungwi SMART Farm omission trial

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
October	31.6	19.7	113
November	30.9	20.9	285.7
December	28.5	20.2	223.3
January	26.6	19.4	319.9
February	27.3	19.4	178.8
March	27.7	18.4	48.9
April	28.6	17.7	9.6

**Table 4:** Monthly averages for maximum and minimum temperatures and the total monthly rainfall for 2019-2020 season at the Lisungwi site.

Seasonal temperature and precipitation information for the field sites are displayed in **Table 4**. Temperatures peaked in October reaching 31.6°C. A minimum temperature of 17.7°C was observed in April. Between the months of October and April, the total observed rainfall was 1179.2mm.

Soil properties for Lisungwi are shown in **Table 5** with descriptions of the nutrient ratings indicated in **Figure 3**. The field site had a sandy clay texture with very high to low fertility. The soil has a pH of 6.0, so additional liming to raise the pH closer to the optimal level of 6.5 would benefit nutrient uptake. Phosphorus and Potassium levels are shown to be Optimum and Very High, respectively.

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

Test	Method	Units	Lisungwi	Rating
Soil pH	1:1 - Water pH	-	6	-
Phosphorus (P)	Mehlich 3	ppm	39	Optimum
Potassium (K)	Mehlich 3	ppm	273	Very High
Calcium (Ca)	Mehlich 3	ppm	1592	Medium
Magnesium (Mg)	Mehlich 3	ppm	267	Very High
Sulfur (S)	Mehlich 3	ppm	15	Medium
Boron (B)	Mehlich 3	ppm	0.2	Low
Copper (Cu)	Mehlich 3	ppm	3.4	Optimum
Iron (Fe)	Mehlich 3	ppm	41	Low
Manganese (Mn)	Mehlich 3	ppm	84	Medium
Zinc (Zn)	Mehlich 3	ppm	6.5	Optimum
Sodium (Na)	Mehlich 3	ppm	36	Very Low
Organic Matter	Loss On Ignition	%	4.8	Medium

**Table 5:** Soil fertility results for the Lisungwi site 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.

Trait	Unit	Measurement Metrics
Yield	tons/hectare	Plants harvested and threshed, seed winnowed and weighed at 13% moisture
Stand Count	count	Sum of plants in Row 2 and 3
Days to Flowering	days	Days after planting when the first flower is observed
Nodule Count	count	number of Rhizobium nodules on roots
Nodule Viability	%	Percentage of counted nodes that are active and viable
100 Seed Weight	grams	Random sets of 100 seeds selected and weighed
Seed Moisture	%	Percent moisture at harvest

**Table 6:** Data metrics for the 2019-2020 SMART Farm omission trial

Treatment	Rank	Yield	V2 Stand	R1	Nodule	Nodule	R8 Stand	100 seed	Seed
	Yield	Yield	Count	Flowering	Count	viability	Count	Weight	Moisture
		ton/ha	count	days	count	%	count	g	%
L+P+K	1	2.22	80	46	22	59	80	22.3	11
L+I	2	2.01	85	46	32	68	85	21.3	11
L+K	3	1.95	119	46	15	62	119	21.8	11
P+K	4	1.90	105	46	20	64	105	20.8	11
L+P	5	1.84	92	46	8	47	92	20.3	11
L+I+P+K	6	1.66	116	45	41	74	116	22.0	12
L+I+K	7	1.56	75	46	18	60	75	21.5	11
I+P+K (**)	8	1.47	127	46	37	74	127	20.3	11
I	9	1.46	112	46	18	66	112	22.0	11
P	10	1.42	118	46	7	41	118	19.5	10
K (***)	11	1.34	148	46	14	55	148	20.5	10
I+K (.)	12	1.30	82	46	26	76	82	21.5	11
I+P (***)	13	1.06	69	45	34	65	67	21.5	11
L (**)	14	1.00	76	45	18	67	66	20.0	10
No Input	15	0.86	82	45	27	62	77	21.3	11
L+I+P	16	0.78	70	46	34	58	70	19.9	12
AVG		1.49	97	46	23	62	96	21.0	11
LSD		0.58	22.2	2.3	24.4	0.2	23.2	3.2	1.3
CV%		37.0	27.7	3.3	77.7	27.3	29.2	10.0	8.5

**Table 7:** Averages, Least Significant Differences (LSD) at an alpha of 0.05, and Coefficient of Variations (CV%) for Yield, Stand Count, R1 Flowering, Nodule Count and Viability, R8 Stand Count, 100 Seed Weight, and Seed Moisture for the 2019-2020 omission trials at Lisungwi, 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.

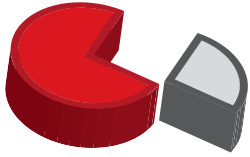
An Analysis of Variance (ANOVA) was conducted in R using the package “car” to test the main treatment effects, 2-way, 3-way, and 4-way treatment interactions in the omission trial. The Shapiro's Wilek and Brown-Forsythe test were employed to confirm residual normality and homogeneity of variance respectively. **Based on the ANOVA, the main-effect of lime was shown to significantly (P < 0.05) increase soybean grain yields by an overall 21%.** There was a significant interaction between I\*P\*K showing I+P did not significantly increase yields compared to the certified seed control, but the addition of I, P, or either input along with K did significantly increase yields. **The recommended bundle (L+I) significantly increased yields by 134% compared to Certified Seed only.**

The same significant interaction (I\*P\*K) and main effect of lime can be observed for V2 and R8 stand counts. Lime application increased stand by 18% which may be the reason we are seeing this significant increase in yield due to lime application. For the interaction, both V2 and R8 stand counts, the highest counts were observed when K was applied alone or all three inputs were applied together. It should be noted this trial experienced a drought period at the beginning of the season, which resulted in lower germination rates and therefore yields for this trial.

Mean yields ranged from 0.78 tons/ha (L+I+P) to 2.22 tons/ha (L+P+K). Stand count ranged from 69 (I+P) to 148 (K) plants and 66 (L) to 148 (K) plants at V2 and R8 developmental stages respectively. R1 flowering ranged from 45 to 46 days. Nodule counts ranged from 7 (P) to 41 (L+I+P+K) nodules per plant and 41% (P) to 76% (I+K) viability. Mean values for 100-Seed Weight ranged from 20g to 22g and Seed Moisture ranged from 10-12%.

**For further information on the 2019-2020 trials at Lisungwi with Horizon Farming Limited, contact the trial operator Andrew Goodman at [kanyantandrew@gmail.com](mailto:kanyantandrew@gmail.com)**

### Red Bundle



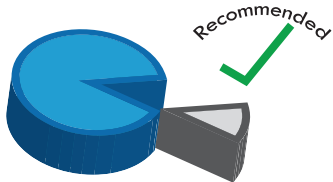
Best Management Practices  
Certified Seed  
-1x return on additional input costs compared to farmer practices  
**Marginal Ratio: 0.7**

### Yellow Bundle



Best Management Practices  
Certified Seed  
Rhizobium Inoculum  
16x return on additional input costs compared to Red Bundle  
**Marginal Ratio: 2.8\*\***

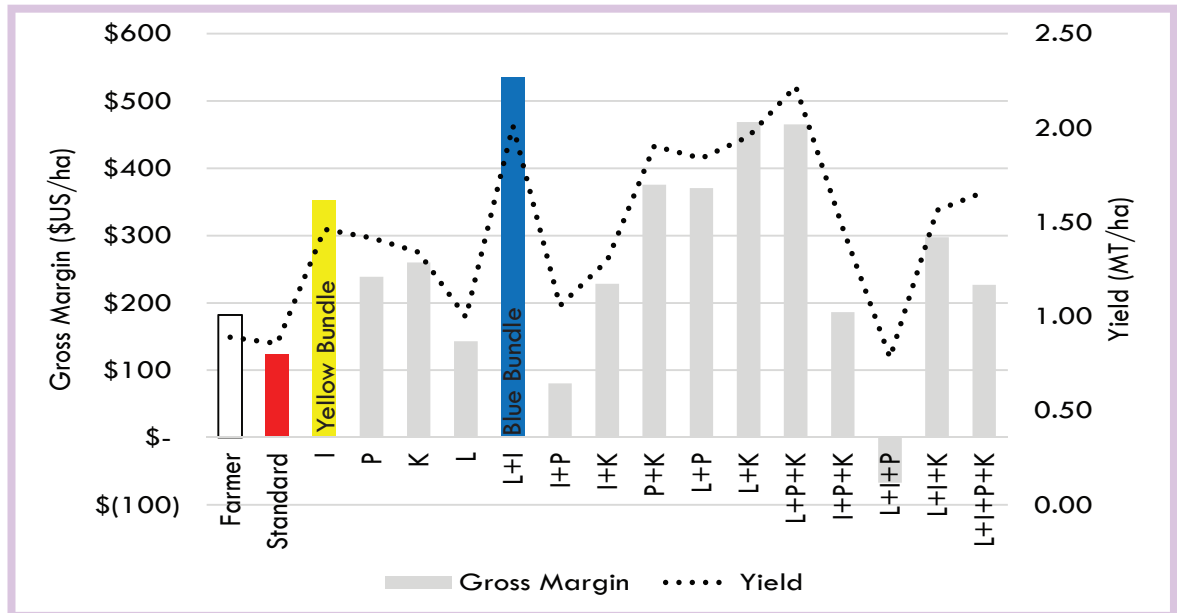
### Blue Bundle



Best Management Practices  
Certified Seed  
Rhizobium Inoculum  
Lime  
8x return on additional input costs compared to Red Bundle  
**Marginal Ratio: 4.3\*\***

\*\*Marginal Ratio compared to Red Bundle

Figure 4: 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 2019 SMART Farm omission trial has assessed the usage of these inputs and has assembled three input bundles for the Lisungwi 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 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. Under these conditions it is estimated that a typical farmer will generate a gross margin of \$182 USD and a yield of 0.89MT 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). For the Lisungwi site, the Red Bundle in Lisungwi would have cost the farmer \$57 USD per hectare and therefore not recommended for this site.

The **Yellow Bundle** includes the use of rhizobium inoculum along with the usage of certified soybean seeds and the adoption of best management practices in the Red Bundle. The Yellow Bundle generated an average gross margin of \$353 USD, a marginal ratio increase of 2.8 compared to the Red Bundle, and yielded 1.46MT per hectare. This produces an 16x return on rhizobium inoculum costs and provides an implicit wage of \$2.04 USD for every \$1.00 USD of labor spent (a 104% increase in wages compared to the typical farmer).

The **Blue Bundle** includes the use of rhizobium inoculum and lime along with the usage of certified soybean seeds and the adoption of best management practices in the Red Bundle. The blue bundle generated an average gross margin of \$535 USD, a marginal ratio increase of 4.3 compared to the Red Bundle, and yielded 2.01MT per hectare. This produces an 8x return on inoculum and lime costs and provides an implicit wage of \$3.09 USD for every \$1.00 USD of labor spent (a 209% increase in wages compared to the typical farmer). **The Blue Bundle generated the highest gross margin of all treatments for the Lisungwi site.**