Dr. Zingore and Mr. Wafula (M.Sc. student) assessing a soybean fertilizer response trial in western Kenya.

Soil Fertility Management for Soybean Intensification in Western Kenya

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Soybean yields in smallholder farming systems in sub-Saharan Africa (SSA) are severely constrained by poor soil fertility and a lack of nutrient management recommendations that are suited for the highly variable growing conditions within the region. Most smallholders practice continuous cropping with little or no nutrient inputs, which leads to severe nutrient depletion and soil acidification (Sanchez, 2002). Apart from widespread limitations of N and P across the highly weathered soils in SSA, deficiency of other essential nutrients, low organic matter, and soil acidity also contribute to low crop yields (Kihara et al., 2017).

Fertilizer recommendations for soybean in Kenya have been largely focused on P. However, there is a growing realization that integrated nutrient management practices that provide a balanced application of fertilizer, manure, and lime are essential to sustaining higher yields.

Study Description

On-farm experiments were conducted to investigate the effects of balanced fertilizer use in combination with manure and lime on soybean yield and biological nitrogen fixation (BNF) potential. The experiments were carried out for two seasons at two sites representative of low and moderate soil fertility conditions in Kenya. The first site at Masaba had an infertile, sandy clay loam soil (Cambisol) and much low-

Large soybean yield gaps on smallholder farms in Kenya are associated with multiple soil constraints, including nutrient depletion, low organic matter, and soil acidity. Integrated nutrient management practices are necessary to increase productivity, particularly on degraded course-textured soils.

KEYWORDS:
integrated soil fertility management; yield potential; smallholders; biological nitrogen fixation.

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; Mo = molybdenum; Zn = zinc; C = carbon.

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Table 1. Soil characteristics of the two experimental sites in Western Kenya.

Sites	pH	C, %	N, %	K, $cmol_c/kg$	P, mg/kg	Ca, $cmol_c/kg$	Mg, $cmol_c/kg$	Zn, mg/kg	Particle size distribution, % Sand	Silt	Clay
Masaba	5.2	1.2	0.13	1.38	5.7	0.55	0.64	1.5	58	15	27
Nyabeda	5.7	2.4	0.22	1.11	5.0	0.59	2.42	8.5	12	20	68

er organic C and available Zn compared to the moderately fertile, clay soil (Ferralsol) in Nyabeda (**Table 1**). Available soil P was very low at both sites and was below the critical value of 15 mg/kg (Nziguheba et al., 2002).

The experiment was laid out in a randomized complete block design with three replications. The treatments included: 1) Control - without inoculant and fertilizer; 2) Inoculation alone; 3) N+P+K; 4) P+K; 5) N+P; 6) N+K; 7) N+P+K+S+Ca+Mg+Zn+Mo (Complete Fertilizer) and 8) Complete Fertilizer+Cattle Manure+Lime.

Fertilizer application rates required to achieve the attainable yields for the study area were: 30 kg P/ha, 60 kg K/ha, 23 kg S/ha, 20 kg Ca/ha, 5 kg Mg/ha, 3 kg Zn/ha, and 3 kg Mo/ha. Starter N was applied at a rate of 20 kg/ha. Manure was applied at 10 t/ha and dolomitic lime at 5 t/ha. All fertilizer, manure, and lime treatments were incorporated to 20-cm soil depth at the time of planting. All the treatments, except the control, were planted with soybean inoculated with *Bradyrhizobium japonicum* (USDA-110 strain). The locations of trial plots were changed after the first season to avoid varying soil fertility conditions. Fields with similar soil conditions were selected for the second season.

Soybean Nodulation and Yield

At both sites, the nodule dry weight was the lowest for inoculated treatments without P, which suggested that P was the most limiting nutrient and its absence significantly impaired BNF (**Table 2**). The highest values for soybean nodule dry weight were achieved with the Complete Fertilizer+Manure+Lime treatment. Integrated nutrient management had its strongest influence on BNF potential at the poorer soil site at Masaba.

Table 2. Average dry weight of nodules in soybean plants grown on-farm in Masaba and Nyabeda for the two cropping seasons.

Treatment	Masaba	Nyabeda
	-------- mg/plant --------	
Control	0.0 a	0.0 a
Inoculation alone	34.0 a	51.0 bc
NK	25.2 a	38.4 ab
PK	89.3 b	97.4 cd
NP	91.0 b	123.3 d
NPK	132.3 c	107.2 d
NPKSCaMgZnMo (Complete)	86.9 b	88.3 cd
Complete+Manure+Lime	182.8 d	107.3 d
LSD (p = 0.05)	37.5	47.9

Values in the same column followed by the same letter are not significantly different at p = 0.05.

Masaba – Low Yield Potential

Soybean yield for the control treatment at the coarser-textured Masaba site was very low in both seasons compared to more fertile Nyabeda site (**Table 3**). Neither inoculation alone nor application of N+K increased soybean yield at Masaba compared to the control in both seasons. The application of P significantly increased yield in most treatments, but the combination of P with other primary, secondary, and micronutrient fertilizers proved inadequate to achieve maximum attainable yields at each site. The addition of manure and lime along with fertilizers increased soybean yield by >150% in the first season and 68% in the second season. Despite these yield gains, they were less than 50% of the maximum yields obtained in Nyabeda.

Table 3. Average grain yield of soybean grown on-farm in Masaba and Nyabeda for the two cropping seasons.

Treatment	Season 1 Masaba (t/ha)	Season 1 Nyabeda (t/ha)
Control	0.04 a	1.36 a
Inoculation alone	0.06 ab	2.02 b
NK	0.04 a	1.95 b
PK	0.22 c	2.14 b
NP	0.42 d	2.47 c
NPK	0.16 bc	2.03 b
NPKSCaMgZnMo (Complete)	0.39 d	2.33 bc
Complete+Manure+Lime	1.40 e	3.15 d
LSD (p = 0.05)	0.10	0.30
Season 2		
Control	0.85 a	1.34 a
Inoculation alone	1.11 ab	2.08 b
NK	1.40 abc	2.35 bc
PK	1.61 bc	2.46 c
NP	1.39 abc	3.04 d
NPK	1.86 c	2.44 c
NPKCaMgZnMo (Complete)	1.80 c	2.82 d
Complete+Manure+Lime	2.24 d	3.99 e
LSD (p = 0.05)	0.60	0.33

Values in the same column followed by the same letter are not significantly different at p = 0.05.

Nyabeda – Moderate Yield Potential

In Nyabeda, control plots showed relatively high yields (>1 t/ha) if compared to Masaba (**Table 3**). Inoculation alone increased grain yield over the control across seasons. Similar to Masaba, significantly lower grain yields were recorded in the NK treatment compared to the NPK, NP, and PK treatments. Adding manure and lime along with fertilizers increased yields by 35 to 42%. The highest soybean yields for both sites and years were associated with application of macronutrients, secondary nutrients, micronutrients, manure, and lime.

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Analysis of the yield responses showed that P and manure+lime application had the strongest effects on soybean yield in the first season for both sites (**Table 3**). Application of secondary and micronutrients consistently increased yields by at least 0.2 t/ha in the first season. During the second season, yield responses to P decreased at the moderately fertile Nyabeda site, while they increased at Masaba. Manure and lime application led to the overall largest yield responses (>1 t/ha) in both sites.

TAKE IT TO THE FIELD

Phosphorus application was responsible for significant yield increases at both sites, but the integration of fertilizers with lime and manure is essential to maximizing grain yield potential. Higher yield responses should be expected on clay soils with less severe fertility restrictions.

Conclusions

Adverse soil conditions in Western Kenya can be overcome with integrated nutrient management. The practice has been demonstrated to have a great impact on soybean yields, which provides an opportunity for profitable intensification among smallholders. **BC**

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