USING IMPROVED VARIETIES AND FERTILITY TO INCREASE YIELD OF COMMON BEANS GROWN BY SMALL-LANDHOLDER FARMERS IN UGANDA

Gerald Sebuwufu[1], Robert Mazur[1], Michael Ugen[2] and MarkWestgate[1] *

[1]Iowa State University, Department of Agronomy, 2104 Agronomy Hall, Ames, IA 50011-1050

[2]National Crops Resources Research Institute, Namulonge, P.O. Box 7084, Kampala, Uganda.

Summary

Productivity of common bean (*Phaseolus vulgaris* L.) in Uganda is less than 30% of the yield of improved varieties grown on research stations (FAO, 2013). This yield gap has been attributed mainly to low soil fertility and susceptibility of local varieties saved by farmers to pests and disease. We evaluated the impact of improved varieties and improved soil fertility on bean yields on small-landholder farms in three agro-ecological zones in Uganda. Bean yields without fertilization averaged 523 kg/ha. In some cases, improved varieties produced up to 54% more yield than the local farmer-saved variety. Enhancing soil fertility with cattle manure (10 t/ha), P (60 kg/ha), or manure (5 t/ha) + P (30 kg/ha) increased average yields to 631 kg/ha, 615 kg/ha, and 659 kg/ha, respectively. Intensive application of P up to 180 kg/ha for three consecutive seasons, however, did not increase bean yields significantly.

Conclusions

- Although bean yields remained well below potential, there was a yield advantage of growing improved varieties, particularly K131, and adding locally-sourced manure on small-landholder farms.
- Soils in Kamuli District have an extremely high capacity to bind phosphorous. It is unlikely small landholders can afford to overcome this limitation using conventional fertilizer approaches.
- The combination of improved genetics and fertility intensification alone will not eliminate the yield gap between on-farm and potential bean yields in Uganda.

Results

On-Farm Variety x Fertility Trials

Across 60 trials, the four common bean varieties we tested on small-holder farms in Kamuli District yielded 460 to 588 kg/ha, on average. This was well below the potential observed in Research Station trials (Table 1). Soil tests revealed farm soils in the District were extremely low in N and P, and high in Ca^{++} and Mg^{++} (Table 2). Without supplemental fertilizer, however, the improved variety K131 yielded up to 40% more than the farmer selected variety Kanyebwa (Table 3). Addition of fertilizer as manure, phosphorous (P_2O_5), or manure + phosphorous often increased grain yields, but yield levels remained well below potential.

TABLE 1: Characteristics of six common beans varieties grown in Uganda. Information compiled from the NASECO Seed Company, Kampala, and the National Crops Resources Research Institute, Namulonge, Uganda.

Variety [Local name]	General Agronomic Characteristics	
K131 [Kazibwe]	Altitude: 1000-1800m Maturity: 90 days Seed rate: 50-60 kg/ha Expected yield: 2 – 2.5 ton/ha Growth habit: Trailing (Type II) Released in 1994	Small light brown mottled seed Good taste, good yield Resistant to bean common mosaic virus (BCMV), bean rust (BR), Angular Leaf Spot (ALS), Common Bacterial Blight (CBB), and Anthracnose. Susceptible to root rot • Performs relatively well under extreme environments Less marketable
K132 [Nambale Omuwanvu]	Altitude: 1000-1800m Maturity: 80 days Seed rate: 90-100 kg/ha Expected yield: 1.5 – 1.8 ton/ha Growth habit: Erect (Type I) Released in 1994	Large red mottled seed Resistant to BR Susceptible to anthracnose, ALS, CBB and root rot Popularly grown in most parts of Uganda Highly marketable
NABE 4 [Nambale Omumpi /VEDCO]	Altitude: 1000-1800m Maturity: 80-85 days Seed rate: 90-100 kg/ha Expected yield: 1.5-2.0 ton/ha Growth habit: Erect (Type I) Released in 1999	Large red mottled seed Resistant to major bean diseases Popularly grown in most parts of Uganda Susceptible to root rot, ALS, CBB and anthracnose Highly marketable
NABE 6 [Obweru]	Altitude: 1000-1800m Maturity: 90 days Seed rate: 50-60 kg/ha Expected yield: 1.5-2.5 ton/ha Growth habit: Trailing (Type II) Released in 1999	Small white seed Resistant to BR Susceptible to root rot, ALS, CBB and anthracnose Marketable, cooks fast but does not keep long after cooking
Farmers Seed [Kanyebwa/Kabonge]	Growth habit: Erect (Type I)	Brick red medium size seed, susceptible to many diseases, early maturing Good taste, cooks fast.

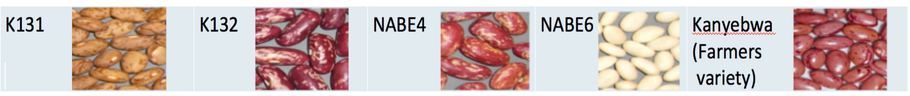

TABLE 2: Characteristics of soils sampled from trials sites in Bugulumbya, Butansi, Nakabango, Namulonge, and Mbarara, Uganda. The values are averages of samples taken at each location. * Critical valued according to Soil and Plant Analysis Laboratory – NARL Kawanda.

Location	pH	OM	N	P	Ca	Mg	K	Sand	Clay	Silt
		(%)	(%)	---------- (mg/kg) ----------				------- (%) -------		
On-farm trials										
Bugulumbya	6.5	3.5	0.2	1.8	2425	585	435	51.2	33.2	15.0
Butansi	6.4	2.8	0.2	1.9	2172	524	384	52.2	36.5	10.8
On-Station trials										
Nakabango	4.4	3.6	0.2	5.4	1882	406	344	63.3	21.6	15.2
Namulonge	4.8	2.8	0.2	8.3	1374	331	211	62.1	23.0	14.8
Mbarara	5.8	2.8	0.2	6.6	1134	222	399	64.3	16.3	19.3
Critical values*	5.2	3.0	0.2	5.0	350	100	150			

TABLE 3: Response of yield and yield components of three common bean varieties to phosphorus (60 kg/ha), manure (10T/ha) and phosphorus (30 kg/ha) + manure (5T/ha) fertilizer treatments. Data are the mean of 22 locations pooled for three seasons in 2010 and 2011. *Within each variety, fertility treatment means followed by the same later are not significantly different at p= 0.10.

Variety	Treatment	Yield (kg/ha)	100-seed wt (g)	Pods/plant	Seeds/pod	Plants/m^2
K131	Control	686.0	18.5	6.1	4.6	20.1
	Manure	806.7*	19.3*	7.1*	5.0	23.7*
	Manure + P_2O_5	675.9	20.7*	6.9*	5.1	22.9*
	P_2O_5	706.4	19.1*	6.8*	4.9	22.5*
NABE 4	Control	512.9	41.2	4.3	3.1	16.0
	Manure	634.8*	41.7	4.1	3.1	20.2*
	Manure + P_2O_5	636.7*	42.9	4.7	3.3	17.2
	P_2O_5	618.5*	41.7	4.2	3.2	16.0
KANYEBWA	Control	492.8	35.7	4.1	3.1	15.0
	Manure	524.3	34.7	4.3	3.1	14.6
	Manure + P_2O_5	664.5*	37.1	4.6*	3.3	18.1*
	P_2O_5	518.9	35.2	4.7*	3.2	15.3

This project was supported by a grant from

PULSE CRSP Dry Grain Pulses Collaborative Research Support Program — MICHIGAN STATE UNIVERSITY

Results

On-Station Phosphorous Intensification Trials

Limited yield response to P application despite very low soil P levels suggested applied P was not available to the plants. Estimates of P fixing capacity confirmed most of the applied P was fixed to the soil (Table 4). Attempts to overcome this limitation by intensive application of up to 180 kg/ha P_2O_5 for three consecutive seasons, however, did not increase bean yields significantly at any of the NaCRRi Research Station trials (Table 5).

TABLE 4: Estimate of phosphorus fixing capacity by soils at the Nakabango, Namulonge, and Mbarara trial sites. Calculations were based on available P (Bray 1) and clay % of soils sampled at the beginning of the experiment. The parameter (r1/R) estimates phosphorus fixation in the soil based on a model developed by Morel et al. (1998). At r1/R values less than 0.2, most applied phosphorus is fixed. At r1/R greater than 0.4, some of the applied P increases soil available P.

Soil P-fixing capacity (r1/R)			
Location	**Mean**	**Min**	**Max**
Nakabango	-0.095	-0.219	0.322
Namulonge	-0.006	-0.226	0.376
Mbarara	-0.058	-0.093	-0.058

TABLE 5: Impact of intensive phosphorus fertilization on the yield of two common bean varieties grown on NaCCRI Research Station in three agro-ecological zones in Uganda. *Within each variety, fertility treatment means followed by the same later are not significantly different at p= 0.10.

		Yield (kg/ha)			
Location/Variety	P_2O_5 (kg/ha)	2011A	2011B	2012A	Mean
NAKABANGO	0	1020	804	799	874
Kanyebwa	60	827	642	1081	850
	120	967	739	1164	957
	180	1133	724	1172	1010
NAKABANGO	0	1047	1049	626	907 bc
NABE 4	60	947	1054	649	883 c
	120	1133	1391	1133	1219 a
	180	1207	1244	1139	1197 ab
NAMULONGE	0	667	180	671	506
Kanyebwa	60	633	176	723	511
	120	542	168	533	421
	180	575	184	665	475
NAMULONGE	0	688	161	567	472
NABE 4	60	817	162	575	518
	120	510	145	437	364
	180	700	188	696	528
MBARARA	0	650	749		700
Kanyebwa	60	617	819		718
	120	475	1017		746
	180	725	751		738
MBARARA	0	592	1113		853
NABE 4	60	642	1097		870
	120	717	952		835
	180	537	877		707

Methods

On-Farm Variety x Fertility Trials

Three on-farm experiments were conducted in Butansi and Bugulumbya sub-counties located in Kamuli District (00°55' 33°06'E) Uganda. These involved three farmer groups from each sub-county actively involved in the establishment, execution, and evaluation of the trials. In the first experiment conducted in Seasons A (March to June) and B (September to December) of 2009 and Season A of 2010, farmers tested the performance of four improved varieties released by NaCRRI (K131, K132, NABE4 and NABE6) and a local variety, Kanyebwa, without soil amendments (Table 1). The second set of trials tested the response of the same varieties to 10 ton/ha application of cattle manure just prior to planting. Group 1 included K131, NABE4 and Kanyebwa; Group 2 included K132, NABE6 and Kanyebwa. Plot size was 5m x 5m arranged in a randomized complete block design with two replicates. A third trial evaluated the response of K131, NABE4, and Kanyebwa (selected by farmer cooperators) to cattle manure, phosphorus, and a combination of manure and phosphorous. The fertilizer treatments were 60 kg/ha phosphorus, 10 tons/ha manure, and 30 kg/ha phosphorus + 5 tons/ha manure. The phosphorus source was triple super phosphate (46% P_2O_5). Plot size was 3m x 3m arranged in randomized complete block design with two replicates. The experiment was conducted during Seasons A and B in 2010 and Season A in 2011.

On-Station Phosphorous Intensification Trials

This experiment was carried at three NaCRRI Research Stations representing three agro ecological zones where beans are commonly grown. Nakabango Variety Testing Center in East-Central Uganda (1178 masl, 1000 to 1350 mm rain/yr); Namulonge Research Station in Central Uganda (1155 masl,1200 to 1450 mm rain/yr); and Mbarara Zonal Agricultural Research Institute in Southwestern Uganda (1430 masl, 915 to 1020 mm rain/yr). Soils at all locations were acidic ferralsols with average pH below optimum for dry bean yields, moderate organic matter content, and low in nitrogen, phosphorus and potassium (Table 2). Bean varieties were Kanyebwa and NABE4 (Table 1) planted at 20 plants/m^2. Plot size was 5 x 5 m. Triple super phosphate (TSP- 46% P_20_5) was applied at rates of 0, 60, 120 and 180 kg P/ha. Urea nitrogen (46% N) was added at a rate of 25 kg N/ ha according to NaCRRI recommendations. Seeds were inoculated with Rhizobia TALL 899 strain (Makerere University, 4 x 10^6 rhizobia/g). Bean plots were rotated with maize variety 'Longe 5' grown with similar levels of P and N fertility. The same plot locations were used repeatedly providing a total of 0, 180, 360, or 540 kg P/ha over three successive seasons. At each site, the factorial treatment combinations were arrayed in a randomized complete block design (RCBD) with three replicates.