Research Application Summary

Productivity and phosphorus use efficiencies of soybean genotypes on fields of differing soil fertility in two agroecological zones of Uganda

Ssekamwa, J.[1], Ebanyat, P.[1] & Tukamuhabwa, P.[1]
[1]Department of Agricultural Production, School of Agricultural Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda
Corresponding author: ebanyat@agric.mak.ac.ug

Abstract

On- farm trials were conducted in the Northern moist farmlands (NMF) and South and Eastern Lake Kyoga basin (SELKB) agro-ecological zones of Uganda for two seasons of 2011 to determine the yield response of soybean genotypes to phosphorus and to identify genotypes that efficiently utilise P. The treatments include different P levels (0, 5, 10, and 20 kg ha^{-1}) with and without rhizobia. These were applied in four fields each of good, medium and poor fertility each season. Biomass yield and P enrichment of biomass at flowering, and grain yield and maturity were determined. Genotype grain yield responses were significantly (P<0.001) higher in the SELKB compared to NMF. Largest yield responses to P were from good fields in the NMF (28 to 229%) and medium fields in SELKB (7-113%). On the basis of the phosphorus efficiency ratios and biomass production, MAKSOY 1N and MNG 2:14 were identified as the most efficient P- utilising genotypes.

Key words: Lake Kyoga basin, phosphorus efficiency ratio; smallholder farming systems, soil fertility heterogeneity, soybean

Résumé

Les essais à la ferme ont été menés dans les terres agricoles humides du Nord (NMF) et dans les zones agro-écologiques de l'Ouganda au Sud et à l'Est du bassin du lac Kyoga (SELKB) pendant deux saisons de l'année 2011 afin de déterminer la réponsede rendement des génotypes de soja au phosphore et d'identifier des génotypes qui utilisent efficacement le Phosphore P. Les traitements comprennent des niveaux différents de P (0, 5, 10, et 20 kg ha- 1) avec et sans rhizobiums. Ceux-ci ont été appliqués dans quatre champs chacun d'une bonne, moyenne et faible fertilité à chaque saison. Le rendement en biomasse et l'enrichissement de P de la biomasse à la floraison, et la maturité et le rendement en grain ont été déterminés. Les réponses de rendement en grains des génotypesétaient significativement (P <0,001) élevées dans le SELKB par rapport aux NMF. Les plus grandes réponses de rendementauphosphore P provenaient de bons champs dans les NMF (28 à 229%) et de champs moyens dans le SELKB (7-113%). Sur la base des rapports d'efficacité du phosphore et de la production de biomasse, MAKSOY 1N et MNG 2:14 ont été identifiés comme étant les génotypes les plus efficaces utilisant le phosphore P.

Mots clés: bassin du lac Kyoga, rapports d'efficacité du phosphore, petites exploitations agricoles, hétérogénéité de la fertilité des sols

Background

Most agricultural soils in sub-Saharan Africa are deficient in phosphorus (P) yet this is one of the most essential nutrients for increased productivity of grain legumes such as soybean (Bationo *et al*., 2006). As soils do not readily supply P, addition of external P fertilisers is essential for maximising legume yields. Cognizant of the high costs of mineral fertilisers, production approaches that enhance resource use efficiency are needed. One important such approach is using cultivars that have high P utilisation efficiencies. The objectives of this study were to determine yield response of soybean genotypes to P application and to identify efficient and non efficient P- utilising soybean genotypes.

Literature Summary

Over five high yielding rust-resistant varieties of soybean have been released to farmers in Uganda during the last decennium and there are other potential genotypes for release (Tukamuhabwa *et al*., 2012) but efficiency in P utilisation is unknown. Soil fertility variability has been recognised as a key factor influencing fertiliser use efficiencies (Tittonell *et al*., 2010) and targeting P fertilisers with these varieties to fields of varying fertility can potentially contribute to increased productivity of the varieties and cropping systems.

Study Description

On-farm experiments were conducted in Southern and Eastern Lake Kyoga Basin (SELKB) and the Northern Moist Farmlands (NMF) agro-ecological zones where soybean is mostly produced in Uganda. Researcher-farmer managed experiments were established in a total of 48 farms during the first and second cropping seasons of 2011 on plots measuring 3 x 3 m^2. In each season, P was applied with and without rhizobium inoculation at levels of 0, 5, 10 and 20 kg P ha^{-1} as TSP on four new fields each of good, medium and poor fertility. Soybean varieties NAM1, MAKSOY 1N, MAKSOY 2N, MAKSOY 3N, MNG 2:14, NAMSOY 4M, NGDT 8:11 were planted at a spacing of 60cm x 5cm. Plant biomass and grain yield were determined at

Table 1a. Average grain yield (kg ha^{-1}) of soybean genotypes at different P levels without and with rhizobia by field type in the NMF over two seasons in 2011 (*n*= 22 fields).

Field type / genotype	P level (kg ha^{-1})				Rhizobia + P level (kg ha^{-1})				Mean trt	Apparent increase (%)
	0	5	10	20	0	5	10	20		
Good										
Maksoy 1N	799	1327	1101	1194	1349	876	1056	1230	1162	45
Maksoy 2N	710	1197	1374	991	739	1231	1321	1284	1162	64
Maksoy 3N	1027	960	1106	1540	1211	1301	1491	1611	1317	28
MNG 2:14	419	850	620	1032	549	1232	1023	1138	921	120
Nam 1	887	1542	904	1067	1318	1122	847	1128	1132	28
Namsoy 4M	602	961	876	1312	1393	1339	1473	1545	1271	111
NGT 8:11	467	1268	620	1327	1065	1807	2235	2424	1535	229
Medium										
Maksoy 1N	374	591	506	707	767	527	932	675	672	79
Maksoy 2N	784	746	715	603	626	840	889	827	749	-4
Maksoy 3N	518	583	396	303	435	623	590	612	506	-2
MNG 2:14	695	847	856	818	635	631	870	1008	809	17
Nam 1	738	863	641	833	513	738	580	1076	749	2
Namsoy 4M	709	584	489	840	719	694	771	833	704	-1
NGT 8:11	1346	726	885	824	1520	1408	1433	1727	1218	-10
Poor										
Maksoy 1N	436	551	567	511	495	490	470	456	506	16
Maksoy 2N	350	330	674	588	442	462	633	681	544	55
Maksoy 3N	284	404	365	529	481	384	564	543	467	65
MNG 2:14	330	447	417	435	470	442	531	540	469	42
Nam 1	491	499	612	406	544	546	552	604	537	9
Namsoy 4M	435	476	450	450	593	651	689	438	535	23
NGT 8:11	293	432	565	418	403	868	594	447	532	82

SED Field type = 318P<0.001
SED variety = 316P<0.001
SED Fertiliser= 320P<0.001
SED FTxVar = 113P<0.01

Mean trt is mean yield for fertilised treatments. Apparent yield response is the increase of grain yield due to fertilisation above the control for each variety and calculated as $\frac{Mean\ trt - Control}{Control} \times * 100$

flowering and maturity, respectively. Tissue P contents were measured and phosphorus efficiency ratio (PER), an index that can be used to differentiate genotypes into efficient and non efficient P-utilisers (Fargeria and Bilgair, 1997) calculated. Statistical analysis of data was performed using the Restricted Maximum Likelihood (REML) algorithm in Genstat Version 13.

Table 1b. Average grain yield (kg ha^{-1}) of soybean genotypes at different P levels without and with rhizobia by field type in the SELKB over two seasons in 2011 (*n*= 21 fields).

Field type / genotype	P level (kg ha^{-1})				Rhizobia + P level (kg ha^{-1})				Mean trt	Apparent increase (%)
	0	5	10	20	0	5	10	20		
Good										
Maksoy 1N	1184	1068	872	1179	1417	1356	680	1141	1102	-7
Maksoy 2N	901	1397	1168	658	1249	1290	1155	1576	1213	35
Maksoy 3N	1182	1606	783	990	828	1202	1051	1413	1125	-5
MNG 2:14	1048	1034	1031	1011	947	796	1710	994	1075	3
Nam 1	877	1640	1295	1606	1236	1702	1088	1359	1418	62
Namsoy 4M	1366	1569	1226	1010	1152	1196	1111	786	1150	-16
NGT 8:11	1193	1269	978	1328	977	1181	846	1072	1093	-8
Medium										
Maksoy 1N	688	1283	2261	1336	648	1881	1176	1649	1462	113
Maksoy 2N	1044	1088	1503	1488	981	1539	1808	1131	1363	31
Maksoy 3N	1052	1088	1199	955	1662	1383	1175	899	1194	14
MNG 2:14	940	1068	862	981	1057	1253	1175	933	1047	11
Nam 1	1028	979	1232	1063	984	1104	1060	1259	1097	7
Namsoy 4M	1112	1037	1905	1535	1063	1205	1468	936	1307	18
NGT 8:11	960	1353	954	1129	829	1064	867	1203	1057	10
Poor										
Maksoy 1N	380	641	688	530	574	855	606	525	631	66
Maksoy 2N	722	887	879	897	1153	842	987	890	934	29
Maksoy 3N	772	509	808	1005	665	626	853	790	751	-3
MNG 2:14	987	788	638	954	1014	950	1159	1230	962	-3
Nam 1	871	828	808	865	719	600	758	847	775	-11
Namsoy 4M	847	779	948	971	650	1266	897	762	896	6
NGT 8:11	874	1278	1157	698	850	846	901	609	906	4

SED Field type = 382P<0.001
SED variety = 381 Ns
SED fertiliser= 383NS

Mean trt is mean yield for fertilised treatments. Apparent yield response is the increase of grain yield due to fertilisation above the control for each variety and calculated as $\frac{Mean\ trt - Control}{Control} \times * 100$

Research Application

Genotype responses to P application significantly differed (*P*<0.001) between the agroecological zones over the two seasons. Genotype responses to P were therefore considered for within farm viability by agro-ecological zone. In the NMF (Table 1a), the largest genotype yield responses to P were on the good fields with apparent yield increases of 28 to 229%. The largest yield responses were obtained from the medium fertility fields. Best responses to P were from NAM 1(62%) on the good fields and MAKSOY 1N on both medium (113%) and poor (66%) fields.

Field type and genotype interaction was significant (*P*<0.01) and the best responsive genotypes were NGT 8:11 (229%), MAKSOY 1N (79%) and MAKSOY 3N (65%) on the good, medium and poor fields respectively. In the SELKB (Table 1b), grain yield response only significantly differed (*P*<0.001) for field types. Using PER and biomass production across the three field types amended with P fertilisers in both agroecological zones, the seven soybean genotypes were categorised into four categories on the basis of efficiency and responsiveness to P fertilisation (Fig. 1). i) efficient and responsive (ER)–genotypes MAKSOY 1N and MNG 2:14; ii) efficient and non-responsive (ENR)- genotypes NAMSOY4 and NAM; iii) non-efficient and responsive (NER)- MAKSOY 2N and MAKSOY 3N and (iv) the non-efficient and nonresponsive (NENR) - NGT 8:11. This implies that it would be best to apply P in the production of MAKSOY 1N and MNG 2:14 in both agro-ecological zones. More data are being collected to validate this preliminary categorisation.

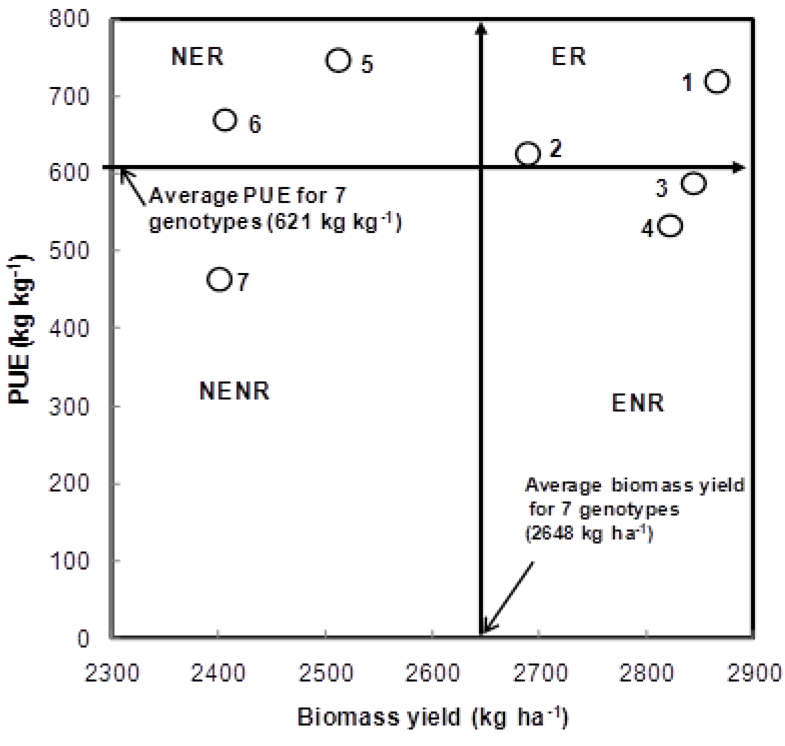

Figure 1. Phosphorus use efficiencies by soybean genotypes and biomass yield production across fields of differing fertility. ER= efficient and responsive; ENR= efficient and non responsive, NER= non efficient and responsive; NENR= non efficient and non responsive. Genotypes:1= MAKSOY 1N; 2= MNG 2:14; 3= NAMSOY 4M; 4=NAM 1; 5= MAKSOY 3N; 6= MAKSOY 2N; 7= NGDT 8:11. The data are averages for the three field types in two agro-ecological zones over two seasons.

Acknowledgement

This work is supported under the RUFORUM grant RU/2010/GRG22 to Makerere University. We thank the farmers for their collaboration.

References

Bationo, A., Hartemink, A., Lungu, O., Naimi, M., Okoth, P., Smaling, E. and Thiombiano, L. 2006. African Soils: Their Productivity and Profitability for Fertiliser Use. Background Paper for the Africa Fertiliser Summit. 9-13 June 2006 in Abuja, Nigeria.

Fageria, N.K. and Baligar, V.C. 1997. Phosphorous-use efficiency by corn genotypes. *Journal of Plant Nutrition* 20: 1267–1277.

Tukamuhabwa, P., Oloka, H.K., Sengooba, T. and Kabayi, P. 2012. Yield stability of rust resistant soybean lines at four mid-altitude tropical locations. *Euphytica* 183:1-10.

Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L.V., Coe, R. and Vanlauwe, B. 2010. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa–A typology of smallholder farms. *Agricultural Systems* 103:83-97.