Research Application Summary

Improving biological nitrogen fixation (BNF) by groundnuts grown in acid soils through amendment with calcitic and dolomitic limestones

Ogega, J.[1], Onyango, D.A.[2], Otinga, A.N.[1], Okalebo, J.R.[3], Pypers, P.[4], Okello, D.K.[5], Merckx, R.[6], Othieno, C.[3] & Were, B.A.[2]
[1] Department of Soil Science, Moi University, Chepkoilel Campus, P. O. Box 1125-30100, Eldoret, Kenya
[2] Department of Biological Sciences, Moi University, Chepkoilel Campus, P. O. Box 1125-30100, Eldoret, Kenya
[3] Soil Fertility and Plant Nutrition, Moi University, P. O. Box 3900-30100, Eldoret, Kenya
[4] Tropical Soil Biology and Fertility, P. O. Box 30677, Nairobi, Kenya
[5] National Semi-Arid Resources Research Institute/NARO, P.O. Soroti, Uganda
[6] Division Soil and Water Management, Department Earth and Environmental Sciences, Kasteelpark Arenberg 20 bus 2459, 3001 Leuven, Belgium
Corresponding author: wbeatrice@hotmail.com

Abstract

Groundnut (*Arachis hypogeal* L.) is an oil crop legume capable of symbiotic nitrogen fixation. Soil acidity is a major limitation to symbiotic nitrogen fixation. Acid soils are widespread in Western Kenya and Eastern Uganda where groundnut is an important crop. This study seeks to isolate and characterize indigenous rhizobia capable of nodulating groundnut from the region and establish the best soil conditions under which their N-fixing efficiency is enhanced. The native strains will be compared to commercial rhizobium inoculants specific to groundnuts for their effectiveness. The project is envisaged to increase groundnut yields (to 2-3 t ha^{-1}) in the depleted acidic soils of western Kenya and eastern Uganda through the use of BNF technology.

Key words: Acid soils, *Arachis hypogea* L., BNF, indigenous strains, symbiotic rhizobia

Résumé

L'arachide (*Arachis hypogeal* L.) est une plante légumineuse riche en huile capable de fixer l'azote symbiotique. L'acidité du sol est une limitation importante à la fixation de l'azote symbiotique. Les sols acides sont répandus au Kenya occidental et en Ouganda oriental où l'arachide est une culture importante. Cette étude cherche à isoler et caractériser le rhizobium indigène capable de noduler l'arachide de la région et à établir les meilleurs conditions du sol dans lesquelles leur efficacité de fixation de N est améliorée. Les contraintes indigènes seront comparées aux inoculants commerciaux de rhizobiums spécifiques aux arachides pour leur efficacité. Le projet est envisagé pour augmenter des rendements d'arachide (à 2-3 t ha^{-1}) dans les sols acides épuisés du Kenya occidental et de l'Ouganda oriental par l'utilisation de la technologie de BNF.

Mots clés: Sols acides, *Arachis hypogea* L., BNF, contraintes indigènes, rhizobium symbiotique

Background

Groundnuts (*Arachis hypogeal* L.) grow in slightly acidic soils with pH of about 6.0-6.5 but the range of 5.5-7.0 is acceptable. Although groundnuts are popularly grown for family income and as a source of dietary protein, their yields are low with a continual decline in the recent past. In western Kenya, yields as low as 200-400 kg ha^{-1} have been reported (Nekesa *et al.*, 1999). The low yield is attributed to soil degradation through deforestation, soil fertility depletion, soil erosion and water scarcity. Soil fertility depletion is the biggest constraint to sustained crop productivity across smallholder farms in this region (Sanchez *et al.*, 1997; Woomer, *et al*., 1997). In Kenya, nitrogen (N) and phosphorus (P) nutrients are widely deficient with N deficiencies occuring in 48% of the croplands, largely accounting for the low per capita food production. Use of fertilizer N to replenish soil is the most logical way to counterbalance its depletion in this region. However, due to the spiraling costs of fertilizers in the recent past, poor efficiency of utilization of fertilizer N and the increasing awareness of the environmental costs of N lost from fertilizers (Bohlool *et al*., 1992), this option remains a challenge. A feasible alternative to fertilizer N is to employ biological nitrogen fixation (BNF) technologies. This study will focus on assessing and utilizing the BNF potential of groundnut in ameliorating soil N deficiencies to achieve better yields in an agricultural system where it is already an important crop.

Literature Summary

The use of BNF to alleviate soil nutrient depletion and increase crop yields is a system that can achieve stable and sustainable crop yields in the long term (Mugwe *et al*., 2007). The BNF process involves enzymatic conversion of inert atmospheric dinitrogen gas (N_2) to nitrogen-containing organic compounds that become available to all forms of life through the nitrogen cycle (Brady and Weil, 2002). Higher plants in association of the nitrogen-fixing bacteria supply the energy from photosynthesis to facilitate the conversion.

Giller *et al*. (1997) established the effectiveness of legumes in improving soil fertility in many areas. Nodulation is used as an indicator of a legume's ability to fix N from the atmosphere.

Nodulation of legumes is, however, affected by site characteristics such as nutrient deficiencies, soil acidity and presence of native rhizobia capable of nodulating the legumes (Dommergues, 1995).

Nitrogen fixation is hindered in acidic soils as most rhizobia are sensitive to acidity. Mugwe *et al.* (2007) attributed low nodulation to soil acidity, low soil P and lack of adequate indigenous rhizobia in Chuka, Eastern Kenya. Such conditions would not only lead to low yields of legumes but also deny the soil of adequate N that would otherwise have been derived from the system. In cases of low abundance of native rhizobia in a soil, inoculation with effective and persistent rhizobia strains can be explored. This has various advantages including non-repeated application of N fertilizers and higher pod yield due to increased nodulation (Sanginga *et al.,* 1994). Giller (2001) reported N fixation rates of 1 to 2 kg N ha^{-1} day^{-1} in a growing season by most tropical legumes. Therefore, by exploring BNF, the systems optimize economic returns to farmers while minimizing the environmental concerns associated with high N use (Bundy and Andraski, 2005).

Study Description

The experiment will be two phase, viz; greenhouse/laboratory experiments and field experiments. In the greenhouse, groundnuts will be grown in pots up to nodulation to enable isolation of symbiotic rhizobia. The isolates will be characterized using growth attributes, biochemical tests and PCR amplification of the 16s-23s rDNA spacer region (Navarro *et al*., 1992; Ponsonnet and Nesme, 1994) to understand the diversity of the native strains.

Field experiments will be carried out at four sites in Western Kenya and Eastern Uganda, viz; Bungoma East and Siaya district in Kenya and Mbale and Bukedea districts in Eastern Uganda. One student will work with a sole monocrop of groundnuts while the other student will work with a groundnut/ maize intercrop using the Managing Beneficial Interactions in Legume Intercops (MBILI) technology (Tungani *et al*., 2002). The field set up will comprise treatments with and without inoculants of the superior rhizobial strains obtained from the greenhouse experiment. Biomass cover in the two cropping systems will be measured. N_2 fixed by the inoculated and non inoculated groundnuts will be assessed by the natural ^{15}N abundance method.

Research Application

The project will contribute to increased groundnut yield in the depleted acidic soils of Western Kenya and Eastern Uganda. An economic analysis of groundnut production in the study sites will be carried out to assess the gains made through the use of rhizobia inoculants. Through this study, the BNF potential of groundnuts will be established and in this way its contribution to soil N fertility determined.

Acknowledgement

The authors are grateful to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for financing this study.

References

Bohlool, B.B., Laddha, J.K., Garrity, D.P. and George, T. 1992. Biological Nitrogen Fixation for sustainableagriculture: A perspective. *Plant and Soil* 141:1-11.

Brady, N.C. and Weil, R.R. 2002. Elements of the nature and properties of soils. 2nd ed.. Pearson Education, inc. Upper saddle River, New Jersey 07458.

Bundy, G.L. and Andraski, W.T. 2005. Recovery of fertilizer nitrogen in crop residues and cover crops in an irrigated sandy soil. *Soil Sci. Am. J.* 69:640-648.

Dommergues, Y. R. 1995. Nitrogen fixation by trees in relation to soil nitrogen economy. *Fertilizer Research* 42:215-223.

Giller, K.E., Cadish, G., Ehaliotis, E., Adams, E., Sakala, W.D. and Mafangoya, P.L. 1997. Building up soil nitrogen capital in sub-Saharan Africa. In: Sanchez, P. A. (Ed.). Replenishing soil fertility in Africa. Special publication of the American Society of Agronomy, Madison, WI, USA.

Giller, K.E. 2001. Nitrogen fixation in tropical cropping systems. 2nd edn, CAB International, Wallingford, UK., ISBN-10:0851986714.

Mugwe,J., Mugendi, D., Odee, D. and Otieno, J. 2007. Evaluation of the potential of using nitrogen fixing legumes in smallholder farms of Meru South District, Kenya. In: Bationo, A., Waswa, B., Kihara, J. and Kimetu, J. (Eds.). Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities. Springer NL. pp. 947-953.

Navarro,E., Simonet, P., Normand, P. and Bardin, R.1992. Characterisation of natural population of nitrobacter spp using PCR-RELP analysis of ribosomal intergenic spacer. *Arch Microbial* 157:107-115.

Ponsonnet, C. and Nesme, X. 1994. Identification of agrobacterium strains by PCR-RELP analysis of pTi and chromosomal regions. *Arch Microbial* 161:300-309.

Sanchez, P., Shepherd, K., Soule, M., Place, F.M., Buresh, R. and Izac, A.M.N. 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh, R.J. and Sanchez, P.A. (Eds.). Replenishing Soil Fertility in Africa. ASA, CSSA, SSSA, Madison, WI. pp. 1–46.

Sanginga, N., Mulongoy, K. and Ojeifo, A.A. 1994. Persistence and recovery of induced rhizobium ten years after inoculation on *Lueceana lucocephala* grown on an Alfisol in Southwestern Nigeria. *Plant Soil* 159:199-204.

Tungani, J.O., Mukhwana, E.J. and Woomer, P.L. 2002. MBILI is Number 1: A Handbook for Innovative maize-legume Intercropping. SACRED Africa. 20 pp.

Woomer,P.L., Okalebo, J.R. and Sanchez, P.A.1997. Phosphorus replenishment in western Kenya from field experiment to an operational strategy. *African Crop Science Conference Proceedings* 3:559-570.