Boosting soybean production for improved food security and incomes in Africa

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Overview

Despite growing productivity in many parts of the world, the average crop yields in sub-Saharan Africa (SSA) have stagnated at less than 30% of the regional potential. The low yields in this region have been attributed to many reasons; key among them being the poor soils aggravated by low fertilizer use, poorly developed agricultural advisory services and farmers in ability to access favorable input and outputs markets. Soybean production presents a great potential for improving livelihoods of these resource constrained farmers as it can grow well with limited fertilizers, fix N that can boost production of associated cereals and its market value and demands are high. This brief draws lessons from soybean research and development work in some parts of SSA to describe the challenges for improving soy bean production in Africa, existing opportunities and potential benefits of improved soybean production.

Introduction

Soybean (*Glycine max*) is one of the most valuable crops in the world, due to its multiple uses as a source of livestock and aquaculture feed, protein and oil for the human diet and biofuel. It is one of the tropical legume crops that have showed sustained growth in all the production parameters (cultivated area, yield and production) over the last 4 decades (Fig 1). Although it's global production has been on the rise, its estimated demand of about 300 million tons exceeds the current supply by over 40 million tons (FAOSTAT, 2010). With current yields estimated at less than 30% of actual potential and only about 7% of favorable land allocated to soybeans, SSA presents a great opportunity for closing this global demand-supply gap (Masuda and Goldsmith, 2009; Hartman et al., 2011). A number of recent studies have attributed low soybean yields in SSA to poor yielding varieties, limited application of fertilizers and limited utilization of rhizobia inoculants in soils with no history of soybean production (Woomer et al., 2012).

Besides producing valuable grain, soybean fixes between 44 and 300 kg N ha^{-1} which makes a significant N contribution to intercropped and rotated cereal crops. For example, Peoples and Craswell (1992) estimated the improvement of maize crop following soybean crop at between 0.5 and 3.5 tons ha^{-1} or 30-350% relative to maize-maize sequences.

Status of soybean work in Africa

Within the last decade, huge investments and research on soybean has been carried out in SSA. Between 2005 and 2008 through the support of Rockefeller Foundation, TSBF-CIAT introduced farmers to soybean agronomy, value addition and marketing in Eastern and Southern Africa. Through this program, over 20,000 ha of land in these regions were put under soybean and more than 10,000 poor households trained on soybean agronomy, utilization, health benefits, value addition and marketing (Chianu et al., 2007). Presently AGRA is funding over 10 projects implemented by the National Agricultural Research Institutes (NARS) in Eastern, Central Southern and Western Africa (SSA) with the aim of integrating soybean into the integrated soil fertility management programs and to boost its production and marketing and thus boost household food/nutrition security and incomes.

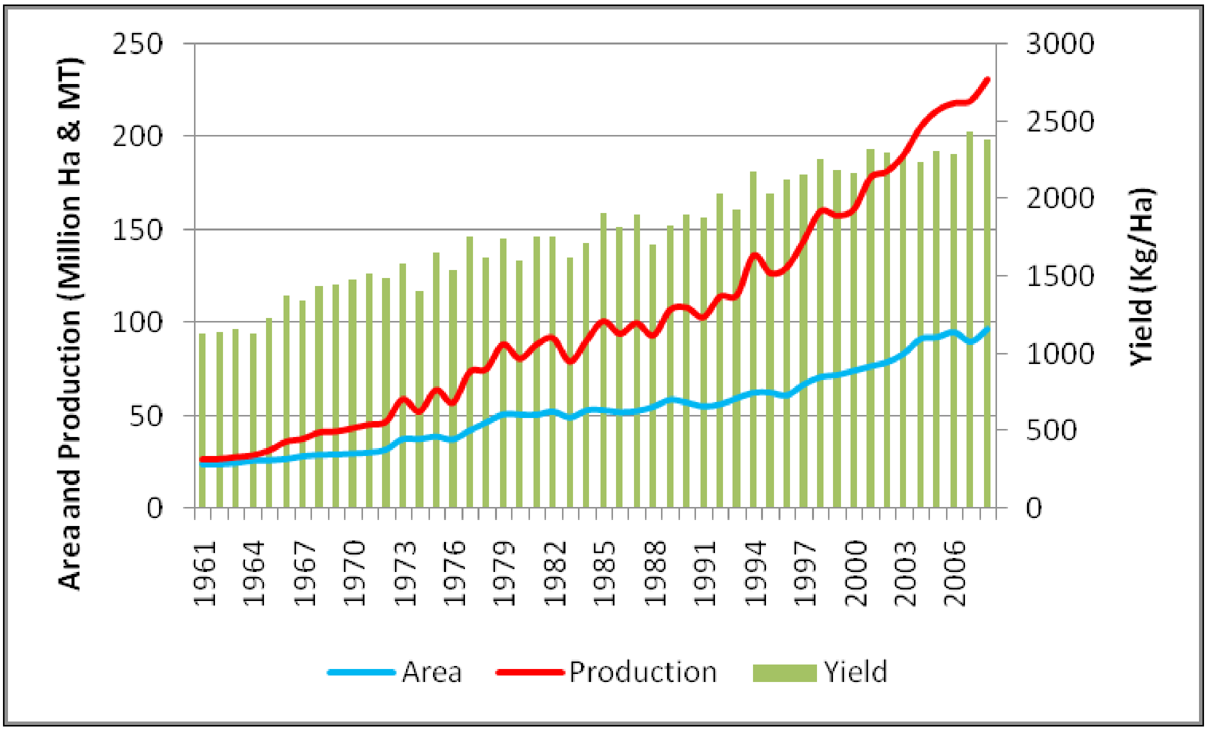

Fig 1: Soybean production world trends (Abate et al., 2011)

Funded for five years (2008-2012) by Bill & Melinda Gates Foundation and Howard G. Buffet Foundation, N2Africa is a large scale science research project focusing on putting nitrogen fixation to work for smallholder farmers through growing legume crops in Africa. The project brings together a team of scientists and graduate students from Wageningen University, CIAT, IITA, NARS, local universities, innoculant manufacturers and legume breeders and its mandate countries are the Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Zimbabwe, Ethiopia, Uganda, Tanzania, Liberia and Sierra Leone. The first phase of N2Africa among other things promoted and tested niches for targeting with soybeans and other N fixing legumes (see, Fig 2). The second phase which aims at scaling out the most promising varieties and agronomic methods developed during phase 1 to ensure large scale adoption of high producing varieties of soybean and other legumes.

Tropical Legumes-II is another joint initiative of three international agricultural research centres, i.e. ICRISAT (chickpea, groundnut and pigeonpea), IITA (cowpea & soybean), and CIAT (common bean) that aims to increase productivity and production of legumes and the income of poor farmers in SSA and SA by 15 percent, with improved varieties occupying 30 percent of the total area planted by some 57 million poor farmers in the coming 10 years. The project's strategy is to fast track testing and adoption of existing varieties and advanced breeding lines for use by famers; generate new farmer- and market-preferred varieties and hybrids with desirable traits (high yields, tolerance to moisture stress, and resistance to pests and diseases); and establish decentralized, pro-poor seed production and delivery systems.

Other institutions such as the International Plant Nutrition Institute (IPNI) have established an active soybean research program with the objective of improving soybean production and sustainability (economic, social, and environmental) through nutrient stewardship and responsible crop management. In collaboration with CGIAR centres and NARS, IPNI is testing the nutrient response of various legumes including soybeans within various trials in Eastern and Southern Africa. Furthermore, through recent support from AGRA, IPNI is spearheading the country level soil health consortia project cutting across 8 countries in SSA to improve access to ISFM technologies with soybean as one of key target crops. This initiative seeks to harmonize the existing knowledge on most applicable methods for optimizing production of various crops based on ISFM techniques across the Eastern and Southern Africa as a way of boosting the large scale adoption of production techniques where they work best.

Fig 2: Farmer training on growth of soybeans and N fixation in root nodules in Rwanda, 2012

Best management practices

The yields of soybean in most parts of Africa can increase from 0.5 to 2.5 tons ha^{-1} if the recommended steps are followed during their production. In most cases when soybean yields exceed 1.2 ton ha^{-1}, farmers are likely to make profits but at less than 0.7 tons/ha farmers may not be able to recoup the cost of production. As soybean market value is good, application of little fertilizer like 20 kg P ha^{-1}, starter nitrogen and innoculant is often profitable even with conservative yield increment of 0.5 tons ha^{-1}. Important measures for boosting soybean yields include; adoption of high yielding seed varieties, soil fertility management, pest/disease control, observing the most appropriate planting time. This section reviews existing knowledge on some of the best management practices for soybean.

Soil nutrient management

Even with the best yielding varieties, soils in SSA cannot support optimal soybean yields without soil fertility amendment. A range of studies have shown that soybeans will perform well in soils with pH of between 5.5 and 7.0 and that correction for soil pH could improve crop response to P and K by over 30%. Soybeans are more sensitive to high levels of soil acidity than most other field crops. The optimum pH for soybeans on sandy and clay-textured soils ranges from 5.8 to 6.2. Yields on mineral soils decrease as soil pH decreases below pH 5.5. For organic soils, optimum soybean yields can be achieved at pH 5.0 (IPNI, 1999).

Phosphorus fixation by Fe and Al oxides is greatest in acid soils, but it decreases as soils are limed. As low soil pH are the most common scenario, soil liming or other measures that increase pH like boosting soil organic matter are crucial for P fertilizer response for most of African soils. Inadequate supply of P decreases nitrogenase activity and ATP concentration in nodules decreasing the ability of plant to fix N and thus meet its N requirements. Recent studies have indicated that P is the most important element in soybean production. On average, soybean yields increase by over 60% as a function of P amendment/fertilization when soil P level is less than 5% and by between 20 and 60% when the P level is between 5 and 10% (Fig 3).

Potassium deficiency restricts grain development, which reduces the size and weight of beans, thus lowering yields. Most extremely sandy-textured soils do not have the capability to hold potassium against leaching and show little or no accumulation from long-term potash application. In such cases, annual K application is the best way to supply enough potassium to sustain good soybean production. Split applications of potash during the early growth stage on very sandy-textured soils could also reduce losses of K by leaching. Most of the potassium utilized by soybeans is taken up within 60–100 days after emergence (Tucker, 1997). Therefore, adequate potassium must be provided within the first 60 days of planting.

In the recent AGRA funded trials, soybean yields under farmer practice (un inoculated soybean seeds planted without fertilizer) averaged between 0.3 and 0.8 tons/ha across six countries in SSA (Fig 1). The main constraints were low soil P levels and lack of indigenous strains of rhizobia. By application of 20 kg P ha^{-1} soybean yields were boosted by between 70 and 120% in all the fields. Similarly in Zimbabwe, DR Congo and Mozambique, N2Africa demonstrated yield increase of between 0.3 and 0.7 tons/ha when soybeans were established with P fertilizers at a rate of 20 kg P ha^{-1} (Woomer et al, 2012).

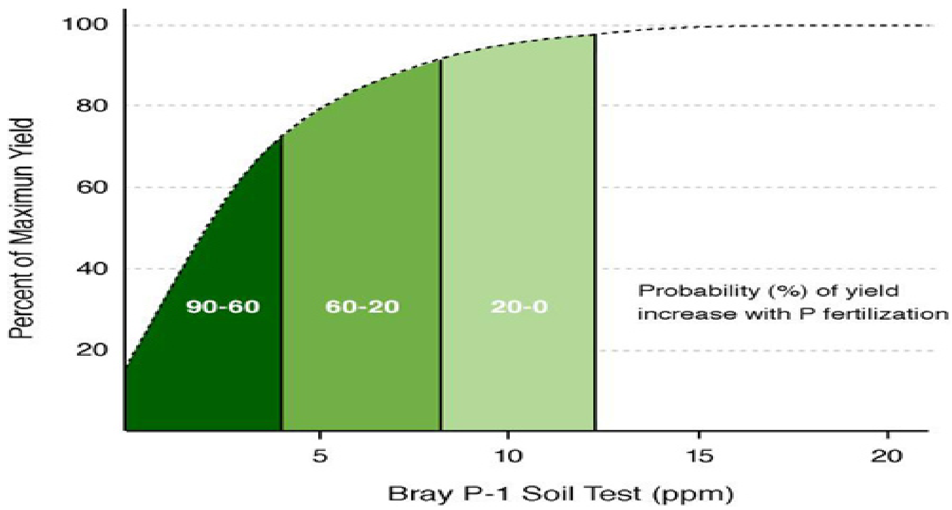

Fig 3: Soybean response to P application, on soils of different P levels (adapted from Nebraska guide 2006)

Planting time

Recently N2Africa demonstrated that in most of their mandate countries, farmers need to plant soybean at the beginning of the growing season in order to have a mature crop by the time the rains cease. The humid tropics covering most of Sierra Leone and Liberia presented a different scenario because they are characterized with more months of rainfall than all the other regions within the N2Africa mandate. Results from a planting date trial conducted in Sierra Leone in 2012 give good insights into the effect of planting time on soybean production, especially within the rainfed production systems in Africa. The results of these trials demonstrated that the long growing season does not mean that farmers have a long window to plant soyabean. In all three agro-ecological zones, the rain forest, the forest transition and the savannah, highest grain yields were achieved with planting before August (slightly before the start of rainy season). Planting in August or September gave an increased risk of drought stress towards the end of the growing period (November – December). Because of the photosensitivity of soybean, late planting led to early flowering and a long grain-filling period, which further reduced yields. Early planting however was associated with increased fungal attacks on grains before and after harvest, which were worsened by poor post-harvest drying conditions. This led to a poor grain quality from soybean planted in June. Given the trade-off between early planting providing high grain yields and late planting giving grains of a higher quality, the optimum planting period for soybean is likely to be around mid July.

The role of N fixation and inoculation on soybean yields

Nitrogen fixation influences soybean yields significantly. The nitrogen requirement of a soybean crop is estimated at 350 kg N ha^{-1} (Abendroth et al., 2006). With adequate supply of P, soybeans can fix up to 450 kg N ha^{-1}(Unkovich and Pate, 2000) making it possible for the crop to satisfy its nutritional requirements and leave some residual N for use by associated crops. The amount of fixed nitrogen which is ultimately used by soybean crop is a function of available N, with the plants utilizing available soil N prior to fixed N (Salvagiotti et al., 2009). Application of N to a soybean crop that is already fixing N may therefore not boost soybean yields. For fields with no history of soybean production, inoculation is required for optimal production. This is the case with most soils in SSA, as soybean is a relatively new crop in most parts of Africa. Within the AGRA trials we mentioned in the previous sections, for some sites, soybean seed was inoculated and planted with P at a rate of 20 kg P ha^{-1}. Owing to inoculation, soybean yields increased by between 0.4 and 1.0 tons ha^{-1} (or between 20 and 100%) (Fig 4). Although for some countries the yield increase attributable to inoculation was lower than that attributable to P, the net benefits associated with P + innoculum was higher in all the cases, because on a per hectare basis, the cost of inoculation is less than 30% of the cost of fertilization cost. On the basis of similar comparisons Schulz and Thelen (2008), determined that even, with an average increase of 0.09 Mg ha^{-1} the return from the application of inoculants could be profitable at the average innoculant costs of about US$ 10 ha^{-1}.

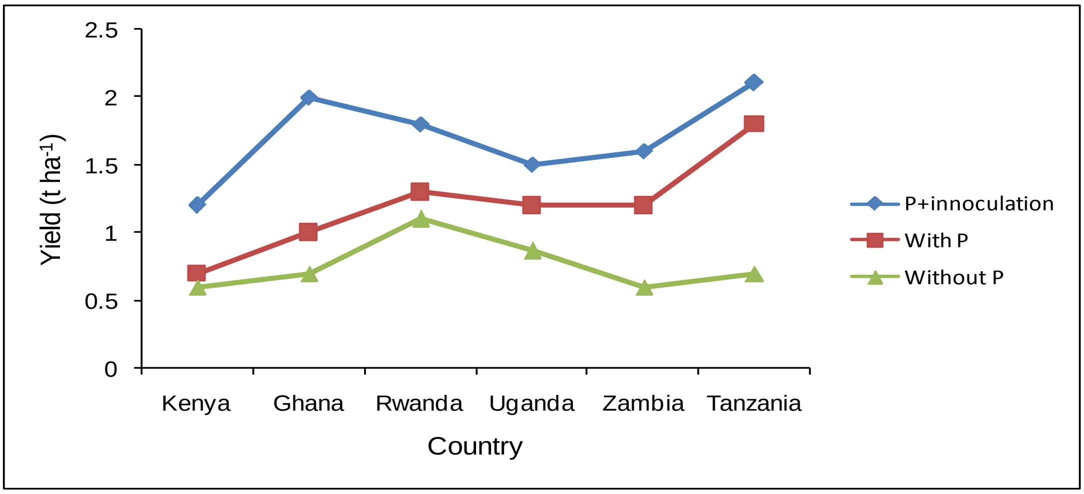

Fig 4: Soybean yield trend with and without P fertilization and inoculation for an average of three seasons for the period between 2010 and 2012 (adopted from AGRA database)

Economic potential of soybean production

Soybean import to the SSA region is estimated at nearly 112,000 MT valued at a little less than US$ 34 million (FAOSTAT, 2010). South Africa, Nigeria, and Kenya account for nearly 43%, 21%, and 18%, respectively, of the total import volume in this region. Ethiopia, Zambia, Zimbabwe, Botswana, Tanzania, and Gabon also import significant amounts of soybean each year. Soybean export in SSA is relatively small, well below 29,000 MT worth less than US$ 11 million each year (FAOSTAT, 2010, Abate et al., 2011). On average, it is estimated that the world annual demand of about 300 million tons exceeds the current supply by over 40 million tons (FAOSTAT, 2010). Additionally the market value of soybean of US$ 650 ton^{-1} is about two times higher than the value of a ton of common cereals (FAOSTAT 2010). This implies that a large market exist both regionally and internationally for whole and range of processed soybean products from Africa. Sanginga et al. (1995) estimated that by adopting soybean-maize cropping systems, household could boost their incomes by between 50 and 70% relative to continuous cereal cropping.

The net profits for soybeans under the best performing intervention (i.e. P + innoculum) for the favorable AGRA project sites (data presented in Fig 4) ranged between US$ 363 ha^{-1} and US$ 961 ha^{-1}. Similar ranges of profits for soybeans have been observed for other sites in SSA under the N2Africa project (Woomer et al., 2012). Analysis for AGRA project sites, further evaluated the potential impacts of scaling up soybean production with the best performing interventions in favorable areas. For each of the six project countries (Fig 4) the size of arable land with similar soil and rainfall characteristics were determined from agro-ecological/soil maps and labeled 'the potentially favorable areas'. If such inoculated-P fertilized soybeans are established on 50% of the potentially favorable land areas in these countries, the returns at a national level would be approximately US$ 670 million for Kenya, US$ 440 million for Ghana, US$ 50 million for Rwanda, US$ 320 million for Uganda, US$ 290 million for Zambia and US$ 1,400 million for Tanzania. Such returns especially when viewed from the perspective of these poor developing economies could provide great leverage to other important developmental sectors like education and health.

Challenges and opportunities for boosting soybean production in Africa

Production of soybean in Africa faces several challenges. These challenges include:

i. **Agricultural advisory services -** At present, the extension staff-farmer ratio in most African countries is lower than 1:1000 against the international recommendation of 1:400. For countries like Mozambique this ratio is lower than 1:10,000 (Abate et al., 2011). Furthermore, even the skills of most of the existing extension workers are outdated as a result of limited in service training. Being a new crop, soybean needs to be supported with good extension, for farmers to understand its agronomy, production and market potential. To optimize returns from soybeans there is therefore a need for enactment of policies to enhance training and participation of private sector and other players such as agro-dealer in providing extension services and support for post harvest handling and marketing. Greater knowledge penetration into rural areas could be achieved through innovative extension mechanisms such as the use of radio and mobile phones in dissemination of agronomic knowledge and market information.

ii. **Access to inputs -** As indicated in the previous sections, improved soybean production requires use of high quality seeds and fertilizers. Due to financial, institutional and infrastructural challenges, majority of smallholder farmers in SSA are unable to access quality sufficient inputs. For example, a recent survey showed that about 75% of farmers in Malawi, 80% of farmers in Mali and 86% farmers in Niger use recycled legume seeds (Ndjeunga et al., 2010). This has been attributed to many factors including the fact that seed production by parastatals does not meet the demand for grain legumes seed, partly because priority is given to seeds of cereals (Niels et al., 2012). Fertilizers on the other hand are often not locally available in sufficient quantities and are unaffordable to majority of the smallholder farmers.

iii. **Input financing -** Farm level fertilizer prices in Africa are among the highest in the world. For example, TSP costs about US$ 150 in Europe, US$ 800 in western Kenya and US$ 900 in Rwanda (AGRA, 2012). At these costs, majority of poor smallholder African farmers cannot afford fertilizer. To afford quality and sufficient seeds and fertilizers, these farmers have to be supported through innovative input financing mechanisms that links them to affordable input credit. The financing mechanisms that have worked recently in Africa include; the revolving fund, bank credit guarantees and farmer savings and credit co-operatives commonly referred to as SACCOS. Furthermore, government interventions through smart subsidies have proved effective in lowering prices and boosting adoption of fertilizers in countries such as Malawi.

iv. **Linking farmers to output markets** - As direct consumption of soybean among majority of producing households is less than 5% (Chianu et al., 2007), increased investment in soybean production can only be driven by availability of attractive markets for surplus. The demand and market value of soybean is high, but often farmers have no access to the existing profitable markets. As an indicator of the market potential available for exploitation; over 40% of soybean that is used by Kenyan companies with estimated capacity of 150,000 tons/year are imported from Brazil. This shortfall in supply that forces companies to import can be met by improved local production, enabling companies to save on cost of imports and farmers to benefit from increased revenue. Some of the strategies that could be employed for increasing soybe**a**n production and associated profits include development of appropriate price control policies, establishment of farmer groups for bulking produce, value addition and ensuring advance access to market information.

Conclusions

We conclude that there are opportunities for boosting soybean production in SSA to ensure enhanced food/nutrition security and household incomes. Improved production requires use of good quality seeds, fertilizers, inoculum and appropriate advisory services. Achieving high soybean yields in SSA will require supporting farmers by improving availability of inputs (fertilizer and seeds), input financing and access to remunerative output markets.

References

Abate T, Alene AD, Bergvinson D, Silim S, Orr A, Asfaw S. 2011. Tropical Legumes in Africa and South Asia: knowledge and opportunities. TL II Research Report No. 1, ICRISAT-Nairobi vi + 104 pages

Abendroth, L.J., R.W. Elmore, and R.B. Ferguson. 2006. Soybean inoculation. University of Nebraska-Lincoln Extension pub. G1621. University of Nebraska-Lincoln.

Bationo A, Hartemink , Lungu O, Naimi M, Okoth P, Smaling E and Thiombiano L (2006) African soils: The productivity and profitability of fertilizer use. Paper presented at Africa Fertilizer Summit, Abuja Nigeria

Chianu J, Vanlauwe B, Mahasi, JM, Katungi E, Akech C, Mairura FS, and Sanginga N (2008) Soybean situation and outlook analysis. The case of Kenya. TSBF-CIAT Project Report

FAOSTAT, (2010). Agriculture data, agricultural production. http://faostat. fao. org/site/567/, last accessed 23.11.2012.

Lucas, R and Knezek B (1972): Climatic and soil conditions promoting micronutrient deficiencies in plants. In: Micronutrients in Agriculture (Mortvedt J. J., Giordano P. M. and Lindsay W. L. editors). Soil Sci. Soc. America, Madison, p. 265-288

Masuda T and Goldsmith P (2009). World Soybean Production: Area Harvested, Yield, and Long-Term Projections. International Food and Agribusiness Management Review 12 (4): 145-164.

Ndjeunga J, Ibro A, Cisse Y, Ben Ahmed, Miko I, Moutari A, Abdoulaye A, Kodio O, Mohammed SG, Echekwu CA. 2010. Characterizing village economies in major groundnut producing countries in West Africa: cases of Mali, Niger and Nigeria. ICRISAT, 89 pp. www.icrisat.org/tropicallegumesII

Niels P. Louwaars & Walter Simon de Boef (2012) Integrated Seed Sector Development in Africa: A Conceptual Framework for Creating Coherence Between Practices, Programs, and Policies, Journal of Crop Improvement, 26:1, 39-59, DOI: 10.1080/15427528.2011.611277

Okalebo J, Othieno C, Nekesa A, Ndungu K and Kifuko M (2009) potential for agricultural lime on improved soil health and agricultural production in kenya. African crop science conference proceedings, vol. 9. pp. 339 – 341

Peoples M, and Craswell E (1992) Biological nitrogen fixation: investments, expectations and actual contributions to agriculture. Plant and Soil 141:13–39.

Salvagiotti F, Cassman K, Specht J, Waters T, Weiss A and Dobermann A (2008) Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. Field Crops Res. 108: 1-13

Schulz T and Thelen K (2008) Soybean seed inoculant and fungicidal seed treatment effects on soybean. Crop Science, 48: 1975-1983.

Tucker (1997) Higher Soybean Yields Still Possible. Southeast Farm Press 24(8): 31; March 19, 1997.

Unkovich, M.J., and J.S. Pate. (2000). An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes. Field Crop Res. 65:211-228.

Woomer, P.L., Baijukya, F. and Turner, A. (2012). Progress Towards Achieving the Vision of Success of N2Africa. www.N2Africa.org. 23 pp.