

3. RESEARCH HIGHLIGHTS

Output 1: Biophysical and socioeconomic processes understood, principles, concepts and methods developed for protecting and improving the health and fertility of soils

Genetic diversity of indigenous rhizobia nodulating six promiscuous soybean varieties in three sites in coastal Kenya

Soybean is an exotic crop introduced in Kenya early this century. Promiscuous (TGx) varieties which nodulate with indigenous rhizobia have only recently been introduced. Genetic diversity of the indigenous rhizobia nodulating TGx soybean varieties has not been reported in Kenya. Research was carried out to determine genetic diversity and phylogeny of indigenous rhizobia strains nodulating six introduced promiscuous soybean varieties grown in three sites differing in agroecological zones and soil chemical characteristics in Coastal Kenya which had no known recorded history of soybean cultivation and rhizobial inoculation. Genetic diversity was assayed using the Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (PCR-RFLP) of the 16S-23S rDNA intergenic spacer region and 16S rDNA gene sequencing. PCR-Restriction Fragment Length Polymorphism (PCR-RFLP) analysis of the 16S-23S rDNA intergenic spacer region directly applied on 46 nodules using two enzymes (Msp I and Hae III) distinguished 8 and 9 genetic profiles respectively. The most predominant IGS groups were group A, B, C, D and E which constituted 41.3%, 17.4%, 10.9%, 10.9% and 10.9% respectively while IGS group F, G and H constituted less than 7% of all the analyzed nodules from the three sites. Some IGS groups were specific to sites and varieties. Phylogenetic analysis of the 16S rDNA gene sequences showed that all strains belong to the genus *Bradyrhizobium*. *Bradyrhizobium japonicum* and *Bradyrhizobium elkanii* related strains were the most predominant and accounted for 41.7% and 33.3% respectively while *Bradyrhizobium species*. and *Bradyrhizobium yuanmingense* accounted for 16.7% and 8.3% respectively of all strains identified. The diversity identified in *Bradyrhizobium* populations from the three sites represent a valuable genetic resource that has potential utility for the selection of more competitive and effective strains to improve biological nitrogen fixation and thus increase soybean yields at low cost.

Effect of farmer management strategies on spatial variability of soil fertility, crop nutrient uptake and maize fertilizer requirement in contrasting agro-ecological zones in Zimbabwe

Soil fertility variability within and across farms poses a major challenge for increasing crop productivity in smallholder farming systems. A study was carried out to assess the effect of farmers' resource management strategies on soil fertility variability and plant nutrient uptake on smallholder farms in Gokwe South (~650 mm yr⁻¹) and Murewa (~850 mm yr⁻¹) Districts of Zimbabwe. Farmers were grouped into: resource-endowed (RG 1), intermediate (RG 2) and resource-constrained (RG 3). In Murewa, wealthy farmers applied large amounts of manure (>10 t ha⁻¹ yr⁻¹) on fields closest to homesteads (homefields) and none to fields further away (outfields) and this created gradients of decreasing soil fertility with increasing distance from the homesteads. Soil available P most concentrated on homefields (8-13 mg kg⁻¹) of wealthy farms and to 2-6 mg kg⁻¹ on outfields and all fields on poor farms. At both sites, maize grain yields in farmers' fields were largest on the homefields on the wealthy farms (2.7–5.0 t ha⁻¹), but poor across all fields on the poor farms (0.3–1.9 t ha⁻¹). Maize responded significantly to addition of N

and P on homefields in Murewa and all fields in Gokwe, but responded poorly on degraded outfields in Murewa due to deficiencies Ca and Zn. Consideration of key factors driving soil fertility variability including soil type, farmer management practices and agro-ecology is required when developing fertilizer recommendations.

Output 2: Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes

Integrated management of striga and stem borer and soil fertility in Western Kenya.

To address *Striga hermonthica* (Delile) Benth., stemborers, and declining soil fertility constraints in Western Kenya, promising integrated crop management technologies were evaluated. Technologies evaluated consisted of the traditional maize–bean intercrop push-pull intercrop, *Crotalaria*–maize rotation, and soybean–maize rotation. Within each of these systems, imazapyr-coated herbicide-resistant maize (IR-maize) and fertilizer were super-imposed as sub-plot factors. The push-pull system was observed to significantly reduce *Striga* emergence and stemborer damage from the second season onwards. IR-maize reduced and delayed *Striga* emergence from the first cropping season. After five cropping seasons, the *Striga* seed bank was significantly higher in the maize-bean intercrop system than in the push-pull system under both maize varieties while the rotational systems had intermediate values not different from the day zero values. Under IR-maize, the *Striga* seed bank was significantly lower than under local maize for all cropping systems. In the short term, IR-maize integrated in a push-pull system is the most promising options to reduce *Striga* while the rotational systems may need a longer timeframe to reduce the *Striga* seedbank.

Scientific evaluation of smallholder land use knowledge in central Kenya:

Complimentarily between and integration of local and scientific knowledge are critical for sustainable and low-input agricultural production system in sub-Saharan Africa. This study determined smallholder farmers' land use management practices and indicators of farm-level agricultural land quality in Chuka and Gachoka divisions in Kenya. Face-to-face interviews and field examinations were used to collect data on cropping practices and soil quality indicators. Farmers characterized their fields into high and low fertility plots, after which soils were geo-referenced and sampled at surface depth (0–20 cm) for subsequent physical and chemical analyses. Results show that farmers' indicators of productive and non-productive plots included crop yields and performance and weed species on agricultural land. Soils that were characterized as fertile or productive by farmers also had significantly higher chemical characteristics (pH, total organic carbon, exchangeable cations and available nitrogen) than the fields that were characterized as low fertility. Results from factor analysis indicate that four main factors (connected with farmers' soil assessment indicators and main soil processes that influenced soil quality) explained 76% of the total variation in soil quality in the study area. Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilized spatial heterogeneity and temporal variability in soil quality status within their farms to maintain and enhance agricultural productivity.

Integrating scientific and farmers' evaluation of soil quality indicators in Central Kenya:

A study was conducted to determine farmers' perceptions of soil quality and common soil management practices that influenced soil fertility within farmers' fields in Kenya. Soils were characterized by smallholders. Thereafter, they were sampled at 0–20

cm depth for subsequent physical and chemical analyses. Indicators for distinguishing productive and non-productive fields included crop yield and performance, soil colour and soil texture. There were significant differences among soil fertility categories, using parametric techniques (ANOVA) for key soil properties ($p < 0.005$), implying that there was a qualitative difference in the soils that were characterized as different by farmers. Fertile soils had significantly higher pH, total organic carbon, exchangeable cations and available-N. Factor analysis on 15 soil properties identified 4 main factors that explained 68% of the total variance in soil quality. The four Varimax-rotated factors were designated as contrasts that described soil quality status on farmers' fields. The first factor grouped calcium, magnesium and soil pH, while the second component comprised available nitrogen, organic carbon and total nitrogen. The third factor included plant nutrients mainly extractable phosphorus and available nitrogen, while the fourth factor comprised soil physical properties (macroaggregates, microaggregates, silt, and clay). Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilized spatial heterogeneity and temporal variability in soil quality status within their farms as a resource to maintain or enhance agricultural productivity.

Output 3: Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils

Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils. Recognizing the benefits of networking, AfNet has continued to promote strategic linkages with several partners across the research and development continuum. AfNet teamed up with ICRISAT and the CPWF Theme 2 to organize several training workshops. Most of the research activities undertaken in the different benchmark sites have been through a strong collaboration with researchers from national agricultural research organizations, CG centres and challenge programmes. Joint research, proposal writing and training initiatives have also been promoted through collaboration with advanced research organizations (JIRCAS, JORDFORSK, ISRIC, ETC.), local and foreign universities (Wageningen University, Hohenheim university, Kiels University, Kassel University and Witzenhausen/Göttingen, Kenyatta, Moi, Nairobi and Egerton Universities in Kenya, National University of Rwanda among others) as well as national agricultural research systems. AfNet has also continued to strengthen linkages with IFS for research support towards upcoming African scientists. AfNet has also strengthened linkages with regional agricultural bodies and networks as strategy of benefiting from synergies of networking.

In its effort to build capacity of researchers in the region, AfNet organized three training workshops on thematic areas of importance. These training courses were Decision Support Systems for Agrotechnology Transfer (DSSAT), Soil and Water Assessment Tool (SWAT) and Baseline Data Analysis. These training courses have improved the 'T-shaped' skills of the scientists making them able to address the complex issues affecting resource allocation and natural resource management at farm level.

Output 4: improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems

Balanced Nutrient Management System Technologies in the Northern Guinea Savanna of Nigeria: Validation and Perspective

Based on experimental evidence that combining mineral fertilizers with organic matter may address poor soil fertility status and result in added benefits, farmer-managed demonstration trials were initiated in 9 villages in the northern Guinea savanna (NGS) of northern Nigeria. The trials had four treatments: (i) a farmers control in which the farmer grows maize according to his usual practice, (ii) the maize technology being promoted by the NGO Sasakawa-Global2000 (SG2000), involving hybrid seeds, proper plant density and fertilizer application practice, and fertilizer application rates that are relatively high for the region (136 kg N, 20 kg P, and 37 kg K ha⁻¹), (iii) the Balanced Nutrient Management Systems (BNMS) manure technology that follows the SG2000 package for maize, except that part of the fertilizer quantity is replaced by animal manure; and (iv) a soybean-maize rotation, again with reduced fertilizer rate to the maize. Results from the full 2-year cycle indicated that the improved systems out-yielded the farmers' control treatment by about 1000 kg ha⁻¹. Maize after soybean gave yields similar to those obtained with the combined application of fertilizer and manure (BNMS-manure) to maize but slightly higher than the fertilizer-only practice (SG2000). There was large variability in the quantities of manure and fertilizers applied and maize yields obtained among farmers. Over the 2-year cycle, the improved soybean/maize rotation system was economically superior and dominated all the other systems because of its lowest variable costs and highest gross margins. At the end of the season, using an overall satisfaction score based on eight criteria, 94% of the farmers were satisfied with the soybean-maize rotation, 83% with the BNMS-manure treatment, and 29% with the SG2000 treatment. Farmers indicated manure availability as the main constraint for the BNMS-manure system; therefore, further research should focus on closed systems with crop-livestock integration in order to increase the manure availability within the farm. As many farmers were enthusiastic about the soybean-maize rotation treatment, SG2000 in partnership with the Agricultural Development Projects (ADPs) have started promoting this system alongside the SG2000 maize package to farmers in northern Nigeria

Ex-ante evaluation of the impact of a structural change in fertilizer procurement method in sub-Saharan Africa: In June 2006, the African Heads of State made a declaration to support increase in use of fertilizers in the farming systems of sub-Saharan Africa from the present average, about 8 kg ha⁻¹, to about 50 kg ha⁻¹. One route to attain this goal is to engender regional joint fertilizer procurement to reduce farm gate price and increase fertilizer demand and use. A review of fertilizer use in Africa has shown that structural changes in fertilizer procurement can reduce farm gate price by 11-18%. Using an average of these figures (15%), this study compares the effect of structural changes in fertilizer market (reducing farm gate price by 15%) on total fertilizer demand, total farm income, and additional farm income with the base situation (using FAO data) under three own fertilizer price elasticity of demand scenarios (low: -0.38; medium: -1.43; and high: -2.24) for 11 sub-Saharan Africa countries. Data were analyzed using Microsoft Excel. Result shows that compared with the base level, structural change in fertilizer procurement arrangement (reducing farm gate price by 15%) led to 6% additional farm income (US\$125 million) under low elasticity; 22% (US\$472 million) under medium elasticity; and 34% (US\$730 million) under high elasticity. Switching from one scenario

to another indicates the potential to further increase farm income from 20% to 32%. The paper concludes with the support for structural interventions that reduce farm gate price of fertilizers and other inputs. Such interventions increase farmer productivity, total production, and total farm income and lead to improved livelihoods

Output 5: Sustainable land management for social profitability developed, with special emphasis on reversing land degradation

Soil Quality Indicators

All the countries participating in the BGBD project are to adopt a similar approach to investigate meaningful indicators. These indicators will result from multivariate analyses (factorial analyses) of the complete data (including data on soil biodiversity and on soil chemical, physical or morphological characteristics) set from each country or benchmark site separately. The indicator will be an indicator of soil biological quality. The resulting indicator(s) will be used for monitoring the demonstration and experimental plots, by which these indicators will at the same time be tested. Indicators of BGBD will result from the same analysis by considering BGBD as a component of the overall soil biological quality. Indicator species then can be found by looking at correlation between occurrence of particular species and the soil biological quality indicator values (and components of it, like BGBD).

Conservation and Sustainable Management of Below-Ground Biodiversity

Soil macrofauna collections were carried out in the Centre-West Ivory Coast. Altogether, 13 earthworm species were recorded, of which four belonged to the family Eudrilidae and nine to the family Acanthodrilidae. From the species collected, two, *Dichogaster* (*Dichogaster*) *eburnea* sp. nov. and *Dichogaster* (*Dichogaster*) *mamillata* sp. nov., proved to be new to science. To accommodate the enigmatic eudrilid earthworm species *Scolecillus compositus* Omodeo, 1958, a new genus, *Lavellea* gen. nov., is proposed.