SOYBEAN RESEARCH & DEVELOPMENT IN UGANDA

A case of paradigm shift in an African University (2002-2015)

Makerere University

Phinehas Tukamuhabwa and Herbert Oloka

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MAAIF VODP

Cover:

Front: A Ugandan farmer displays recently harvested quality soybean
Back: A research Technician examines the soybean plants at MUARIK

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Foreword

I am very pleased to write a foreword for this very inspiring report sharing 13 years of soybean research at Makerere University. The result of this research has led to rapid increase in the number of industries involved in processing soybean in Uganda and neighbouring countries. Traditionally, the kinds of results presented here have been dominated by research Institutes as opposed to the academia. The current development prospects and challenges demand that students be directly exposed to the application of science in their day to day experience for enhanced skills acquisition and self actualization later in life. Through this approach, the centre for Soybean Improvement and Development has provided a Plant Breeding Laboratory for Practical Plant Breeding and Seed Technology within the University environment, paving way for easy access to hands-on practice during training. I want to thank the soybean research team for the innovations brought in the University system. This publication is meant to provide highlights of the contribution of rust resistant soybean varieties to the agricultural sector in Uganda. It contains forward-looking research results based on current research findings and forecasts made by the centre for Soybean Improvement and Development.

Soybean was first introduced in Uganda way back in 1908. Its production was emphasized during the Second World War to combat malnutrition and feed soldiers with a highly nutritious food. Like most new crops soybean was not readily accepted by the local people on allegations that it depletes soil fertility, cannot be cooked like commonly known legumes, has beany flavor and lacked readily available market.

The soybean crop was also not given consistent recognition by national agricultural research system and suffered decline due to a major outbreak of soybean rust in 1996. Makerere University in collaborating with NARO and Vegetable Oil Development project of MAAIF undertook research to control soybean rust disease and to promote soybean seed dissemination of locally developed improved varieties. It is now very gratifying to note that through efforts of the centre for Soybean Improvement and Development, the soybean rust pandemic was brought under control, through breeding of superior varieties and dissemination of the varieties to the farming communities. The fact that over 93% of these varieties are grown in Uganda is clear manifestation that the centre has impacted the target end users with improved technologies.

On behalf of the College of Agricultural and Environmental Sciences, I greatly appreciate the efforts by the authors, soybean research teams during the past 13 years, and all partners who contributed to the research and development activities highlighted in this report.

Wishing you good reading as **"We Build for the Future".**

Prof. Bernard Bashaasha
Principal
College of Agricultural and Environmental Sciences (CAES)

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The authors appreciate the research team at the centre for Soybean Improvement and Development the donors especially Vegetable Oil Development Project (VODP), Alliance for Green Revolution in Africa (AGRA) and the Reginal Universities Forum for Capacity Building in Agriculture (RUFORUM). We thank the other partners including National Agricultural Research Organisation (NARO), National Crops Resources Research Institute (NaCRRI), NGOs, Private Companies and CBOs for their enormous contribution in facilitating the research process and seed dissemination. Finally we thank Consortium for enhancing Univeristy Responsiveness to Agribusiness Development (CURAD) for providing funds to publish this report.

CONTENTS

QUICK FACTS

- Originates from East Asia
- Economically the most important legume in the world
- Naturally rich and cheapest source of protein and oil
- Erect, branching plant with oblong leaves
- Thrives in warm, fertile, well drained, sand loams
- Determinate and indeterminate growth habits
- Capable of biological nitrogen fixation
- Produces about 80 pods with 2-4 seeds
- Matures in 90-120 days in the tropics
- Pods are harvested when dry and threshed by hand

Overview

Early soybean research in Uganda started in the 1930s and resulted in the release of the varieties Kabanyolo 1, Kabanyolo 2 and Congo 72. These varieties served communities in Uganda up to the 1990s when Nam 1, Nam 2 and Namsoy 3 were released and commercialized. However, the severe soybean rust epidemic seen from 1996 rendered these varieties obsolete because they all succumbed to the disease.

Soybean research and breeding activities were conducted by the centre for Soybean Improvement and Development in all major soybean growing areas of Uganda using a participatory approach. Research was executed in research institutes, technology verification centers, and farmers fields all over the country. The main objectives were to to develop soybean varieties that are: 1) high yielding with medium maturity of less than 120 days, 2) resistant to diseases and pest with focus on soybean rust disease and groundnut leaf miners, 3) resistant to lodging and pod shattering, 4) promiscuous in the formation of active nodules with local rhizobia, 5) rich in protein and oil contents, 6) having high pod clearance, and 7) having general end-user acceptance in terms of seed appearance and other traits. When soybean rust empidemic hit Uganda in 1996, two strategies (short and long-term) were adopted to mitigate the effects of the soybean rust epidemic. The short-term strategy involved introduction and testing of germplasm, while long-term comprised of making crosses between resistant and elite susceptible soybean lines, which resulted in the release of six new varieties that included Namsoy 4M, Maksoy 1N, Maksoy 2N, Maksoy 3N, Maksoy 4N and Maksoy 5N.

However, private seed companies were not keen on production of certified soybean seed due to its nature of reproduction. Self fertilization nature of soybean makes it possible for farmers to successfully reproduce seed every season, a trait that does not favour profit making in seed business. Therefore, a holistic seed system was adopted to ensure farmer access to the new soybean varieties. The reseacrh team worked with community based organizations (CBOs), non-governmental organizations (NGOs) and other stakeholders in the soybean value chain.

CBOs and NGOs were instrumental and accounted for 50% of nationwide dissemination of foundation seed to different stakeholders for further multiplication. Maksoy 1N is the most widely adopted variety by farmers, while Maksoy 3N has the largest quantities of foundation seed disseminated by the program.

As a result, national soybean area soon increased from 144,000 to 155,000 hectares between 2004 and 2009, with annual production increasing from 158,000 to 181,000 tonnes respectively.

Recent impact studies showed that the new varieties were the most planted and accounted for 93% of the soybean varieties grown by Ugandan farmers. Currently, contribution of soybean to smallholder household incomes is estimated at 1,185,600 UGX per hectare per season (Tukamuhabwa and Obua, 2015). The processing capacity for soybean increased from 300 to 600 MT per day between 2004 and 2011, while export value of soybean increased by 288% (Ssengendo *et al*., 2010).

Available range of varieties, government investment in soybean research, and increased private sector investment along the soybean value chain were identified as major strengths for the growth of the soybean subsector in Uganda. However, strengthening policies that favour industrial or medium scale enterprises in soybean processing should enhance further national soybean production. Additional support to other components such as mass education and promotion of utilisation of soybean products at household level are equally important.

Soybean (*Glycine max* (L.) *Merrill*) is the world's most important legume crop because of its high protein (40%) and oil (20%) content. In fact, soybean produces the highest amount of protein per unit land area among all crops.

Soybean originated from East Asia, and was first domesticated in China in the second century BC (Xu et al., 2002). Japan, China, and Taiwan have showed the earliest known dishes made from soybean, including tofu, the soybean curd, and tempeh, a fermented product.

Soybean is ranked the number one most important oil crop in the world, providing the cheapest source of protein for both human and livestock diets. The protein content of soybean is the highest among legume crops, averaging 40% on dry matter basis. Soybean protein is balanced with all the essential amino acids, while the seed also contains significant amounts of minerals (notably Fe, Zn, Ca, Mg).

Due to its nutritional superiority, soybean flour is the only substitute to animal and fish protein. For this reason, soybean based foods are highly recommended for children under 5 years, expectant mothers and HIV patients. Soybean oil is 85% unsaturated, comprising linoleic acid (omega-3 fatty acid) and oleic acid which are kown to reduce the risk of heart disease by lowering serum cholesterol by about 33%.

Plate 1: Soybean plants after germination

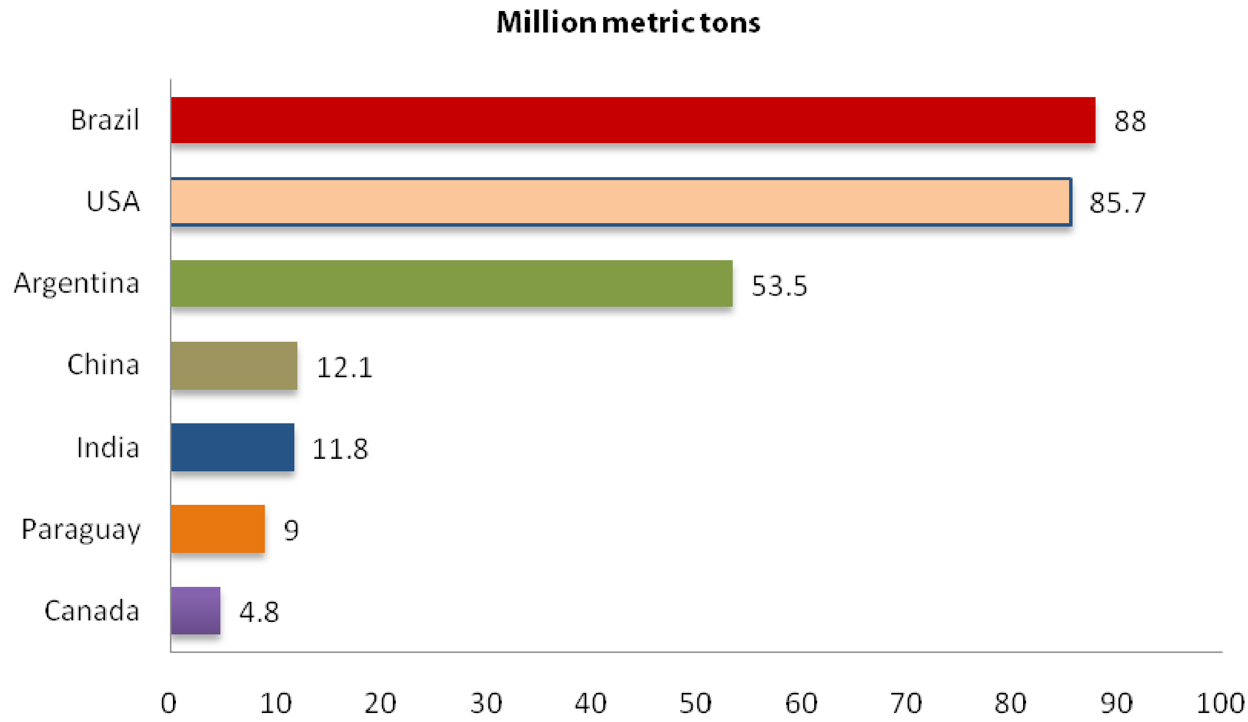


Figure 1: Leading global producers of soybean 2013/2014

Besides soybean also contains isoflavones which increase artery and heart health. Impact studies have also shown that regular soy food consumption can reduce the risk of rectal cancer by 80%, mammary tumor by 40% and breast cancer by 50%. Daily consumption of 25 grammes of soy protein a day was recommended as a means to reduce the risk of heart disease by the US Food and Drug Administration in 1999. Countries whose diets are based on soybean such as China, Japan and Korea are known to have long life expectancy and experience minimum cases of cancers.

Production of soybean stands at 264 million MT worldwide, with United States of America (USA), Brazil, and Argentina being the largest producers, where the crop is of strategic national importance (Figure 1). In Africa, Nigeria, South Africa and Uganda are the largest producers, with annual volumes estimated at 1.5 million metric tonnes. Soybean producation in East and Central Africa is presented in figure 2.

The United States of America (USA), Brazil, Argentina, and a host of other countries have promoted the cultivation of soybean in the past century as a rich protein and oil source to support the feed and food sectors.

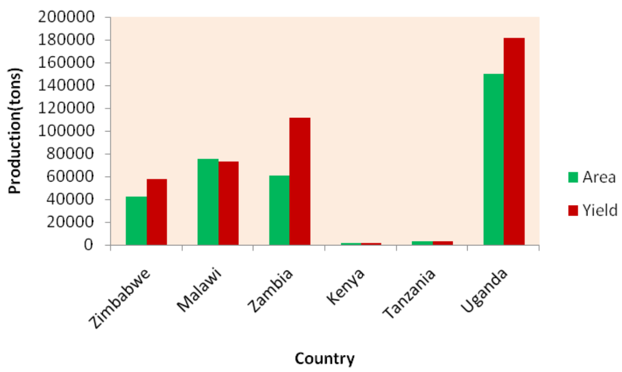


Figure 2: Soybean production in eastern and central Africa.

A miracle crop indeed, soybean (Glycine max (L) has many uses to mankind, ranging from human food, livestock feed to industrial products. According to the American Soybean Association, there are 27 whole bean products, 53 soy oil products and 48 products from soybean flour/meal

Soybean is internationally used in a variety of foods as snacks or as main dishes in various preparations. Japan, China, and Taiwan have shown some of the earliest known dishes and preparations made from soybean such as soy milk, soy sauce, natto, tofu the famous soybean curd, and tempeh the fermented product (Table 1).

In the western world, cultivation of soybean was promoted in the past century to support the feed and food sectors as a rich protein and oil source. Soybean preparations are mostly included as ingredients in different food products, often inadvertently serving as a fortifier, providing high quality protein and cholesterol-free oil.

Livestock feed is often prepared from fat-free soybean, which has higher protein content compared to the whole grain. However, in Uganda, the crop is used mainly in making food formula for infants and in the livestock sector for making animal feeds. Despite the various forms in which soybean could be used, the country has not yet fully exploited most of the major uses of soybean. Inclusion of soybean products into common diets would significantly benefit the human nutrition sector.

Table 1: World wide uses of soybean

Industrial	Edible uses	Livestock
Adhesives	Baby food	Fish meal
Engine oils	Cooking oil	Calf milk replacers
Alternative fuels	Bakery products	Bee food
Lubricants	Breakfast cereal	Poultry feeds
Agricultural adjuvants	Beverage powder	Soybean meal
Analytical reagents	Margarine	Cattle feeds
Crayons	Soy milk	Dairy feeds
Candles	Tofu	Pig feeds
Biodiesel	Miso-shiru	
Paint	Tempeh	
Ink	Natto	
Hydraulic fluids	Soy sauce	
Electrical insulation	Mayonnaise	
Pesticides	Soy flour	
Resins	Roast snack	
Plastics	Sake	
Soaps and detergents		

Soybean in Uganda

Soybean is believed to have been introduced into Uganda between 1918 and 1945, an era marked by the first and second world wars, to combat protein malnutrition among soldiers of the King's African Rifles (KAR) and kwashiorkor among children and in interest of crop diversification.

Owing to the high nutritious status of soybean, the colonial government made deliberate attempts during the 1940s and 50s to encourage local production of soybean in order to combat protein malnutrition among soldiers of the King's African Rifles (KAR) and kwashiorkor among children and in interest of crop diversification. Despite efforts to promote use of soybean in improvement of human nutrition, soybean production continued declining since only few varieties were available to farmers. This was apparently aggravated by the seldom use of soybean in local diets and reduced enthusiasm among potential growers who opted for competing crops namely coffee and cotton that produced greater returns.

Its important to note that systematic soybean research only begun in the late 1930s. This resulted in the release of three varieties (Kabanyolo 1, Kabanyolo 2 and Congo 72) that pioneered large scale production of soybean in the 1940s. Between 1970-1980, average annual soybean production was less than 50,000 tonnes produced from 5,600 hectares (Tukamuhabwa, 2001). However, in the later years, soybean production has undergone.

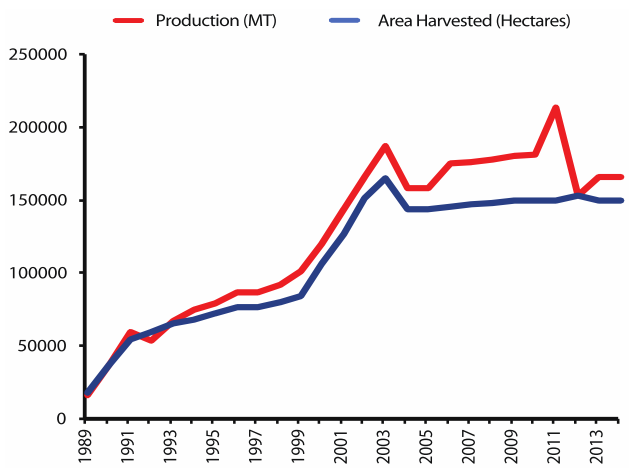


Figure 3: Trend in soybean production in Uganda 1989-2014

Some fundamental changes in acreage planted due to renewed interest by the Ministry of Agriculture, which resulted in the introduction and development of additional varieties for farmers. In addition, farmers were motivated by the renewed interest and support from the oilseed sector and livestock feed sector. Between 2004 and 2010, production increased from 158,000 to 180,000 MT (Fig 3). This significant boost in production made Uganda the third leading producer of soybean in Africa after Nigeria and South Africa.

Nevertheless, as soybean is widely adopted for improvement of human and livestock diets, significantly higher production volumes are required to meet the potential need of the country to mitigate malnutrition caused by Fe, protein, Zn and fat deficiencies in local diets.

Soybean products in Uganda

The products named below are made by over 30 different food processing firms. The major soybean products in Uganda are soybean meal, soybean oil and several soybean based food products summarized below: Energy booster (soya, maize and pumpkin seeds), baby soya enkejje (soya, maize, enkejje), baby soya chocolate (maize, soya, carrots, sugar, chocolate, milk solids, vitamins, and minerals), baby soya with banana, baby soya with oats, nutri pumpkin porridge (Pumpkin flour, corn flour, soya flour), super soya rice, soy millet, cookies (wheat, soya), queen cakes (wheat, soya), soya milk, soya cup plain, soya cup spiced (vanilla, ginger, cinnamon), soya meat, spicy beef flour soya mince, brown butter, baby porridge (maize, mushroom, soya, carrots), tasty soya protein pieces (soya, maize, spices). soya and rice flour soya rice (oats, rice grains, selected soya beans) and others.

Production of good quality soybean requires the crop to be free of pests and diseases. Pests and diseases reduce yield, so should be controlled with recommended agrochemicals once observed in the field. However, use of verieties that are resistant to pests and diseases is the most cost effective and recommended control measure.

Soybean suffers from several pests and diseases that occur over a wide range of conditions and plant growth stages. Common biotic constraints to soybean production include pests like groundnut leaf miners(webworms), bean leaf beetles, green clover worms and stink bugs, and diseases like soybean rust, bacterial pustule, root rots, mosaic virus, frog eye leaf spot, red leaf blotch, downy mildew, and nematodes among others (Table 2).

Amongst these, soybean rust is the most economically significant constraint. It is very important for growers and extension agents to have an enhanced capacity to detect and identify soybean diseases especially in scenarios where symptoms of several diseases co-exist in the same field.

Moreover, accurate identification of pathogen species is very difficult if the infected plants are already dead. When this happens it is advisable to submit samples to a credible plant pathology laboratory. the most important biotic constraints in Uganda are presented in plate 2.

Table 2: Major diseases of soybean

Disease	Causal agent	Relative importance	
		Uganda	World
Soybean rust	*Phakopsora pachyrhizi* Sydow	Very important	Very high
Frog eye leaf spot	*Cercospora sojina*	Moderate	Moderate
Bacterial pustule	*Xanthomonas axonopodis* pv. *glycines*	Moderate	High
Bacterial blight	*Pseudomonas syringae* pv. *glycinea*	Moderate	Moderate
Fusarium root rot	*Fusarium solani*	Minor	Moderate
Downy mildew	*Peronospora manshurica*	Minor	Moderate
Red leaf blotch	*Pyrenochaeta glycines*	Important	Moderate
Soybean cyst nematode	*Heterodera glycines*	Minor	High
Soybean Mosaic	*Soybean Mosaic Virus*	Moderate	Moderate
Phytophthora rot	*Phytophthora sojae*	Minor	High
Purple stain	*Cercospora kikuchii*	Important	High

Pests

Beetle damage

Green cloverworm

Green stink bug and pod damage

Groundnut leaf miners

Diseases

Soybean rust

Red leaf blotch

Bacterial pustule

Soybean mosaic virus

Plate 2: Biotic constraints to soybean production in Uganda

Soyabean rust caused by fungus *Phakospora pachyrizi* Sydow is the most limiting factor to soybean production in Uganda and the tropical world at large. Its entry and rapid establishment in sub-Saharan Africa (SSA) has caused major yield losses.

Symptoms of soybean rust include small-water soaked lesions on underside of leaves, blister-like uredia with a central pore with extruding uredinospores on the abaxial (lower) side of the leaf (Plate 3). Lesions gradually increase in size and later turn from gray to tan, reddish-brown or dark brown and assume a polygonal shape restricted by leaf veins.

The impact of soybean rust is linked to the high specialization and the significant genetic variation that exists in the population of this obligate pathogen, which reduces the effectiveness of specific resistance genes deployed against the pathogen.

The disease is believed to have originated from Asia thus the name Asian soybean rust (ASR). However, it was first reported in 1996 at Namulonge (Tukamuhabwa and Dashiell, 1999) in central Uganda, where it caused up to 100% yield loss. Further, severe soybean rust outbreaks that occurred between 2004 and 2005 discouraged many potential farmers from cultivating the crop until rust resistant cultivars were released. (Plate 5)

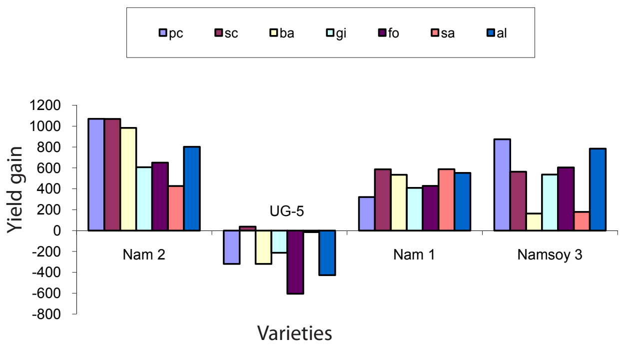
Plate 3: Soybean rust disease on lower side of leaves

Soybean rust has been the greatest soybean disease burden in Uganda and the tropical world at large. Fungicides have been proven to be effective in controlling soybean rust, however, the additional costs of purchasing and application of fungicides have made chemical control impracticable among many farmers in Uganda.

Under resource limited farming systems, use of plant host resistance is the only sustainable approach to managing soybean rust. Yet, sustainable resistance is difficult to obtain at present, due to the high degree of genetic variability of the pathogen, that causes resistance to break down in a short period after new resistant varieties have been released.

Chemical control of soybean rust

The soybean research team screened seven fungicides against soybean rust disease in Uganda and scored yield loss of up to 52.6%. Interestingly, the resistant control UG 5 showed significant reduction in yield when sprayed with the fungicide, suggesting that it uneconomical to spray resistant varieties (Figure 4).



pc = Punch C; sc = Score; ba = Bayco, gi = Gibben; fo = Folicur; sa = Saprol; and al = Alto 100

Figure 4: Yield benefits from fungicide use.

Plate 4: Examining a diseased soybean plant in field trials at Namulange

Plate 5: Wonder soya a variety susptible to soybean rust growing next to Maksoy 4N (resistant) at Namulonge, 2015B.

The general objective of soybean research and development activities in Uganda has been to develop locally adapted resistant varieties and to disseminate to farmers.

Soybean Breeding Objectives

Specifically, the centre for Soybean Impovement and Development focuses on developing soybean varieties that are 1) high yielding with medium maturity of less than 120 days, 2) resistant to diseases and pest with focus on soybean rust disease and groundnut leaf miners, 3) resistant to lodging and pod shattering, 4) promiscuous in the formation of active nodules with local rhizobia, 5) rich in protein and oil contents, 6) having high pod clearance, and 7) general end-user acceptance in terms of seed appearance and other traits.

Achieving all the above has necessitated collaboration with various stakeholders that include Local Government (LG), Non-governmental Organizations (NGOs), seed companies, soybean processing firms, National Agricultural Advisory Services (NAADS), Vegetable Oil Development Project (VODP), Alliance for Green Revolution in Africa (AGRA) and the Regional Universities Forum (RUFORUM).

Breeding for resistance to rust disease

A number of diseases have contributed to the slow growth of the soybean sector in Uganda, however, soybean rust has been the most economically significant. At the onset of the soybean rust epidemic in 1996, all existing local and commercial cultivars showed susceptibility. The fungus spread rapidly to all soybean growing areas in Uganda. For this reason, the quest for rust resistant varieties has been the prime focus of research in the country in the last 15 years.

Early advanced breeding efforts conducted between 1997 and 2004 deployed short and long-term strategies that resulted in the identification of locally adapted resistant varieties. The short-term strategy involved the importation and screening of over 200 accessions from the Asian Vegetable Research and Development Centre (AVRDC) and International Institute of Tropical Agriculture (IITA), South Africa, USA and Zimbabwe (Tables 3 and 4). Meanwhile, the long-term strategy comprised of the hybridization program, which involved resistant germplasm and elite adapted varieties.

The tested materials showed different levels of soybean rust resistance, with the accessions GC 00138-29 from AVRD Cand TGX 1035 10E from IITA showing considerable resistance to the disease (Table 4). However, GC 00138-29 suffered from pod shattering and susceptibility to bacterial pustule *(Xanthomonas campestris pv. glycines)*.

Similarly, resistance in TGX 1035 10E was not uniform hence was subjected to mass selection in order to constitute a variety that was early maturing and resistant to soybean rust disease. As a long-term strategy, crosses of GC 00138-299 × Nam 2, GC 00138-299 × Duiker and TGX 1035 10E × Duiker (Plate 6) were made resulting in progenies which underwent development along the complete cultivar value chain.

In 2004 the varieties Namsoy 4M and Maksoy 1N were released following extensive on-station testing and consultation with farmers. In as much as Maksoy 1N and Namsoy 4M provided the needed relief to farmers, the yield potential of Maksoy 1N was low compared to earlier cultivars Nam 1 and Nam 2. In addition, Namsoy 4M was mildly susceptible to pod shattering, during intense heat since it was a direct progeny from the shattering-susceptible GC 00138-29. More than 1000 breeding lines were obtained from other crosses between rust susceptible and rust resistant lines to produce better varieties for farmers as well as diversify the genetic base of resistance as the rust pathogen is known to challenge single resistance genes against it, due to its high degree of genetic variability.

Table 3: Root germplasm used in breeding for resistance to soybean rust disease

Genotype	Source	Traits of interest	Negative traits
TGX 1835-10E	IITA, Nigeria	Resistance to rust, pod shattering, early maturity	Short pod clearance
GC 00138-29	AVRDC	Rust resistance	High levels of pod shattering
Duiker	Zimbabwe	Excellent seed quality	Rust susceptibility
Nam 2	Uganda	High yield potential	Rust susceptibility
UG 5	Uganda	Rust resistance	Susceptible to bacterial pustule and pod shattering
Nam 1	Uganda	High yield potential	Rust susceptibility

Plate 6: Making soybean crosses at a screen house at MUARIK

Plate 7: AGRA officials visiting program activities at MUARIK

Table 4: Performance of resistance germplasm from AVRDC

Plot	Accession number	Rust scores*			
		R1	R3	R6	Mean
1	G 00073	3	3	3.5	3.2
2	G 02020	1	2	3	2
3	G00033	2	2.5	2.5	2.5
4	UG 5 (Local resistant line)	2	2	3	2.3
5	GC 86048-429-3	2	3	3.5	2.8
6	GC 84058-21-4	1	1	2	1.3
7	GC 86049-35-2-1-1-8-1 N	2	2.5	2.5	2.3
8	GC 84051-32-1	2	2.5	2.5	2.3
9	GC 84040-21	2	2.5	3	2.5
10	GC 86045-23-2	2	3	3	2.7
11	GC 8586	2	2.5	3	2.5
12	G 58	3	3	3	3
13	G 10429	2	2.5	2.5	2.3
14	G 7955	1	2	3	2
15	GC 84040-27-1	2	2.5	3	2.5
16	AGS 183	2	3	3	2.6
17	GC 00138-29	1	1	1.5	1.2
18	GC 60020-8-7-7-18	1	2	2.5	1.8

*Scores: 1 = no lesion; 2 = few lesions (5%); 3 = medium lesions (25%); 4 = heavy lesion (>50%)

R1=Beginning of Bloom, R3= Beginning of podding, R6=Full pod filling

Consequently, new varieties namely Maksoy 2N and Maksoy 3N were released in 2008 and 2010 respectively. Meanwhile, soybean acreage steadily increased from 144,000 to 155,000 hectares, while the annual production increased from 158,000 to 181,000 MT between 2004 and 2009 (UBOS, 2010).

An annual growth rate of 2.4% indicates that soybean production has been growing at twice the rate of change in acreage, reflecting the increased national soybean productivity (UBOS, 2011). This can be attributed to the improved varieties accompanied by better management practices that were recommended by the program.

Breeding for pest resistance

The green stink bug *Nezara viridula*, has been a major pest to soybean production in the country. The pest damages developing pods and significantly affects seed yield.

The effects of the stink bug are usually seasonal although the pest is constantly present in many soybean growing areas. In the country, direct efforts to breed for resistance to the stink bug have not been made. Further research needs to be conducted to quantify the effects of the pest as well as devise management strategies.

Groundnut, leaf miners (web worms) are now a major challenge to soybean farmers in Uganda. These pests are also seasonal and incidences have tended to be higher during the second rains of the year in Uganda. Management options have mainly been through the application of insecticides. None of the current released varieties is resisitanat to groundnut leaf miners.

Recent screening work has identified 4 genotypes with substantial resistance to the pest which is most severe in Eastern Uganda, during second growing season.

Breeding for drought tolerance

Drought is undoubtedly a serious production constraint for smallholder farmers in most developing countries who grow soybean under rainfed farming systems. In Uganda, yield variations between seasons and locations have been to a great extent affected by the amount of moisture available to the plant. Figure 5 shows the effect of drought on yield results obtained from testing sites which were not irrigated in comparison to Mubuku Irrigation Scheme in Kasese, western Uganda, which is always under irrigation. Breeding for drought tolerance is traditionally difficult to achieve since soybean is heavily moisture dependent for optimal growth and yield. Hence drought effect in the other locations was inadvertently noted by comparing the Mubuku Irrigation Scheme results whose mosture is always adquate. Observations over the past 10 years suggested that second growing season is better for soybean production in Uganda (Figure 6) which may suggest better rainfall distribution for soybean growth in second season. However, ongoing climatic changes and cyclic whether patterns such as the El Niño phenomenon can greatly affect rain fed agriculture, both positively and negatively regardless of traditional cropping seasons in Uganda.

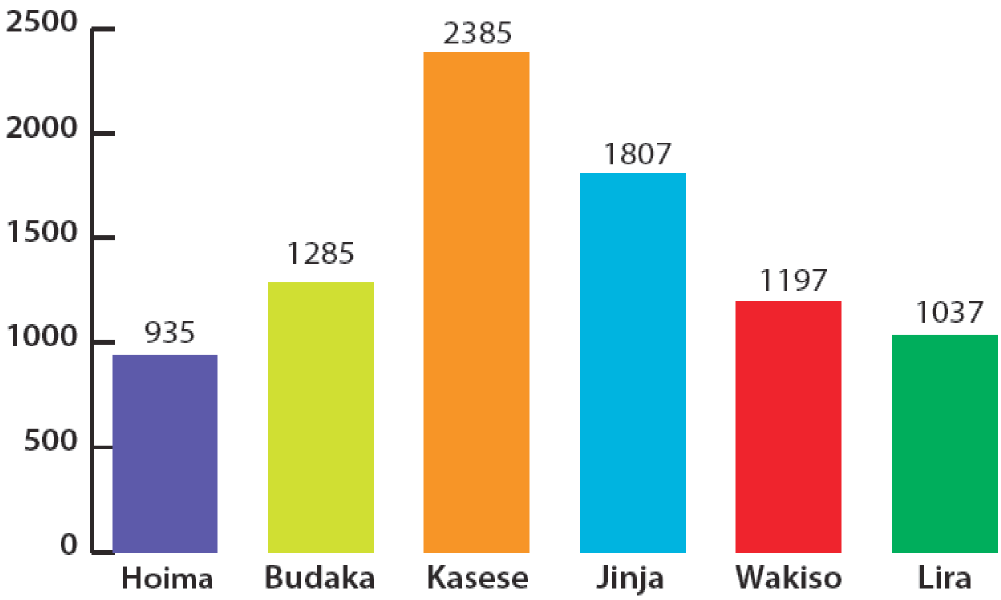


Figure 5: Mean yield data (Kg/ha) at six national soybean evaluation locations

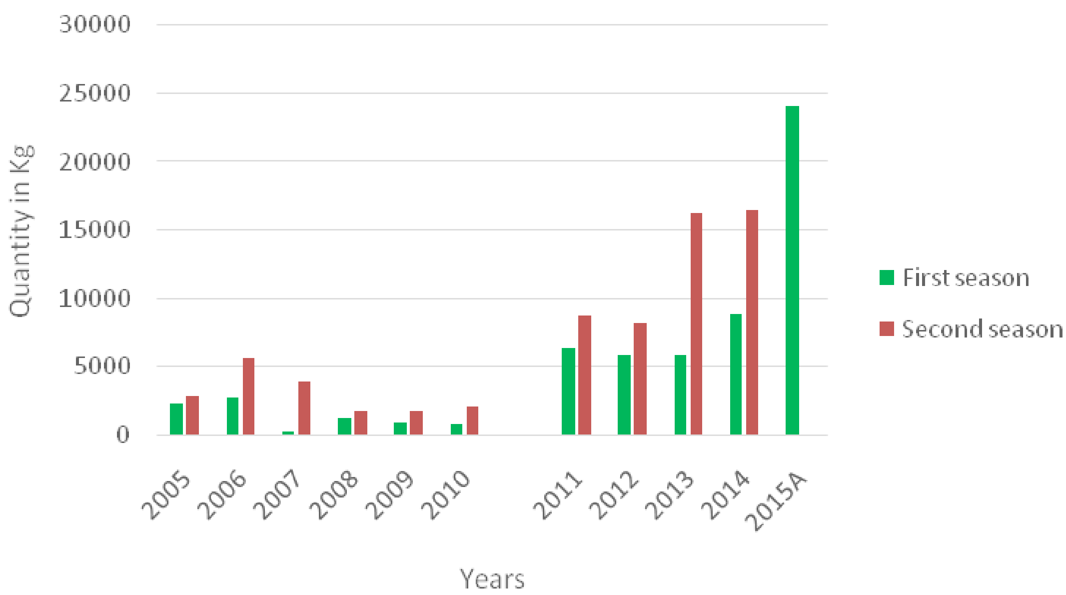


Figure 6. Foundation seed production in Kg from 2005 to 2014

New selections were subsequently tested in preliminary yield trials at Namulonge and later at various research stations in advanced yield trials and farmers' fields where they displayed considerable resistance to ASR and gave acceptable yields under ASR pressure.

Breeding Strategy

On-station trials were conducted at the National Crops Resources Research Institute (NaCRRI) at Namulonge in Wakiso, Nakabango Variety Trial Center (NVTC) in Jinja, Bulindi Zonal Agricultural Research and Development Institute (BuZARDI) in Hoima, Ngetta Zonal Agricultural Research and Development Institute (NgeZARDI) in Lira, and District Agricultural Training and Information Centre (DATIC) at Iki-Iki in Budaka.

On-farm trials were conducted at more than 14 districts in all soybean-growing areas of the country (Figure 7). But fewer elite lines (less than 5) were considered for trials in farmers' fields. Whereas soybean rust was a major breeding objective for these trials, farmers' major concerns were yields of the test materials that indeed varied by farmer location (Figures 8 , 9 and Plate 9).

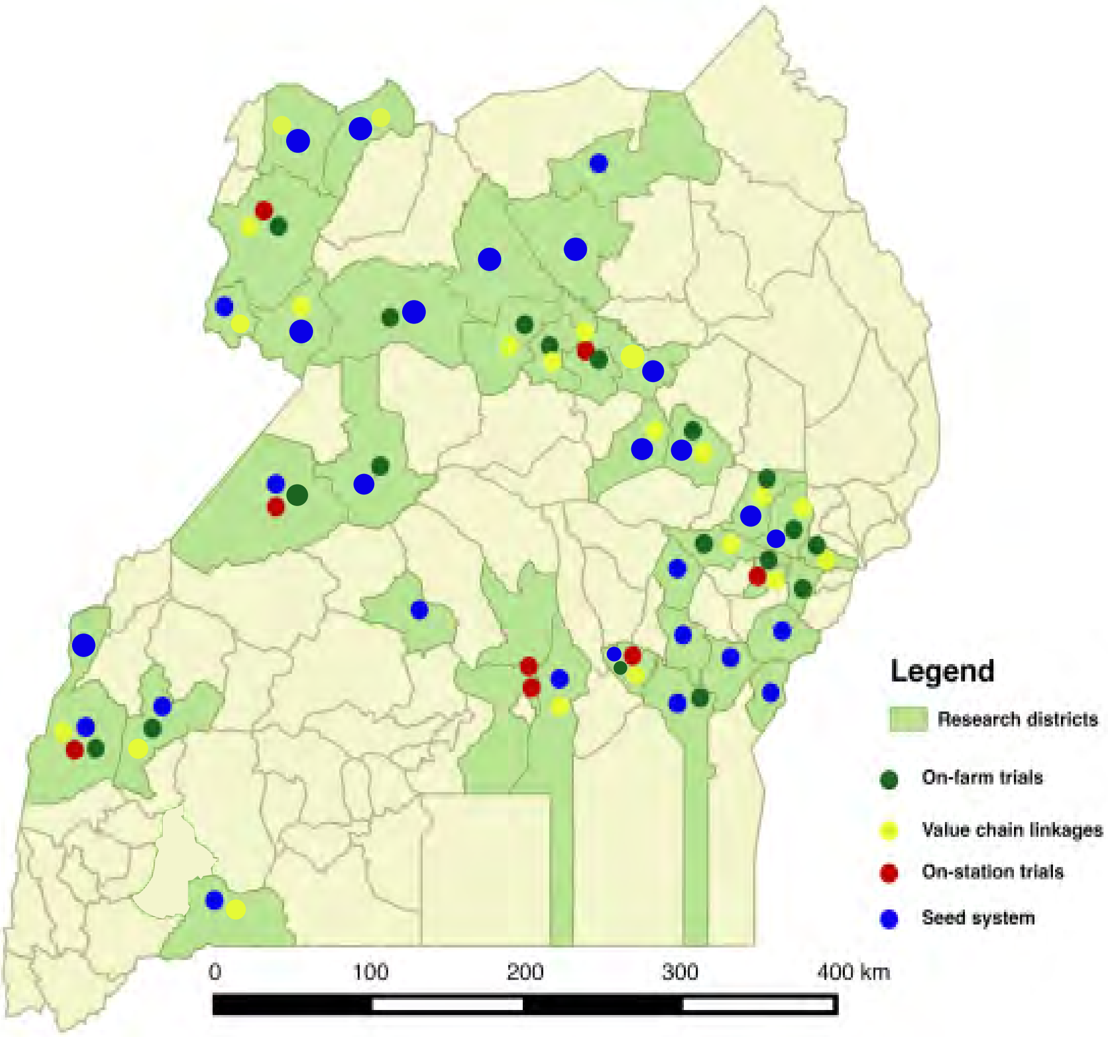


Figure 7: Map of Uganda illustrating areas of direct contact with soybean research activities

Plate 8: Mr. Paul Kabayi, Senior Soybean Technician, examining soybean variety trial at Nakabango Technology Verification Centre

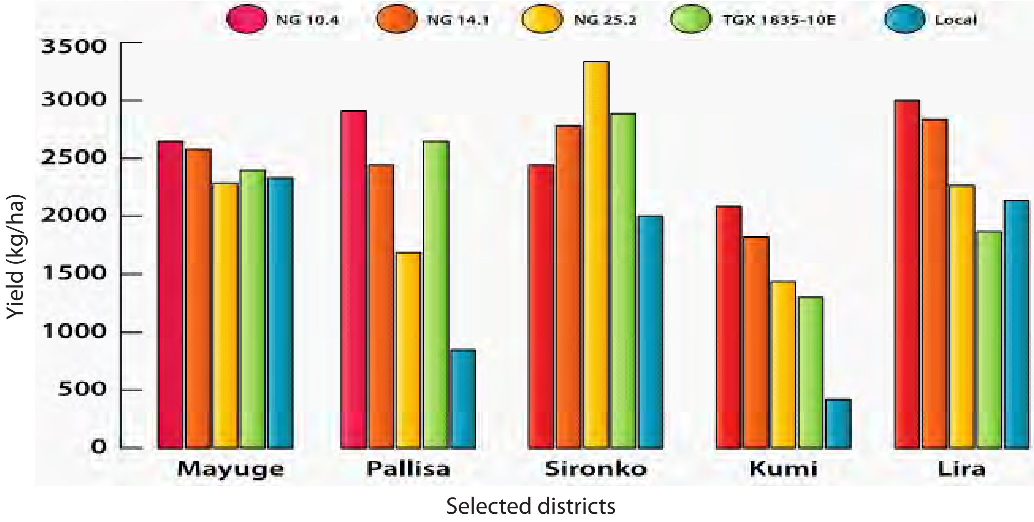


Figure 8: On-farm yield of elite breeding matrials in selected districts during National Soybean Evalutions, 2003

The Variety development efforts were supported by various development partners and the Government of Uganda (GoU) in particular, the Vegetable Oil Development Project (VODP) of the Ministry of Agriculture Animal Industries and Fisheries (MAAIF) has been very instrumental in providing direct financial support to the soybean rust resistance breeding efforts. Other major donors were Alliance for a green revolution in Africa (AGRA) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

After passing variety release tests for distinctness, uniformity and stability (DUS), the first elite lines resistance to ASR were formally released in 2004 as Namsoy 4M (NG 10.4) and Maksoy 1N (TGX 1835-10E). The probability of farmers accepting these genotypes are demonstrated in Figure 7 and 8.

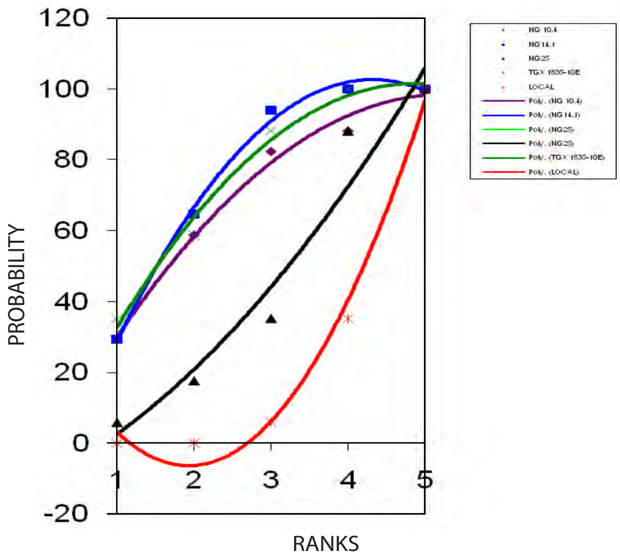


Figure 9: Farmer prefrence of soybean genotypes on a 1-5 scale (1=least prefered, 5=highly prefered) in 2004.

Plate 9: A farmer and her family with Oloka Hebert (extreme right) and the extension worker (in hat) in an on-farm field trial in Hoima district

Two new soybean varieties were released in 2004, namely Namsoy 4M derived from GC 00138-299 . Nam 2 and Maksoy 1N, a selection from TGX 1035 10E. Additional varieties; Maksoy 2N and Maksoy 3N were released in 2008 and 2010 respectively.

Disease scores in some of the breeding lines and elite genotypes developed by the centre are presented in Table 5 and Appendix 3.

In 2013, two other varieties Maksoy 4N (BSPS 48A-27) and Maksoy 5N (NG 14.1-24) were released. Maksoy 4N is a line developed from Duiker x GC 00138-29 progenies while Maksoy 5N is derived from a cross of Nam 2 x GC 00138-299 (Table 7). The description of these varieties is presented in Appendix 2. Yield and other agrononic traits of some of the elite lines are presented in Appendices 4, 5, 6, 7 and 8.

Table 5: Mean rust sore of 15 soybean lines at four locations in 2005B, 2006Aand 2006B seasons

Genotype	Mean rust score at R6 (0-9 scale)									
	2005B			2006A			2006B			
	[1]Nam	Naka	Bul	Nam	Naka	Bul	Nam	Naka	Nget	Bul
MNG 1.37	1.8	3	0.8	1.1	0.5	0	4	8.3	7.8	8.3
MNG 1.38	1.9	3	0.8	0	0.3	0.8	3.3	8.8	8.3	7.6
MNG 1.41	1.5	3	0.8	1.5	0.5	0.5	1.8	6.8	7	6.4
MNG 1.60	1.3	3.3	1.4	0.5	0.5	0.3	1	6.3	6.5	6.3
MNG 1.63	1.8	3	0.8	1.4	0	0.3	0.8	6.3	7.4	7.1
MNG 2.12	1.5	3	1	0	0.3	0.3	2.9	7.5	7.1	7.9
MNG 2.13	2	3.3	1	2	0.3	0.5	5.8	6.8	7.3	6.6
MNG 2.15	1.8	3	0.8	0	0.3	0.5	2.8	7.8	7	7.8
MNG 5.17	1.8	3	0.8	0	0.3	0.3	1.4	6.8	7.3	8.5
MNG 7.13	2	3.8	1	0	0.3	0.3	0	7.9	8.3	9
MNG 8.10	2.1	4.6	1.4	0.5	4.8	0	5.3	7.8	6.4	7.6
MNG 8.25	1.9	3	1.3	0.8	0.6	0.5	1.1	7.4	6.8	8.1
MNG 4.11	1.4	3	1	0	0.5	0	0.8	5.5	5.4	8.3
NAM 1	3	7.9	2	5.4	5.8	0.3	7.4	8.8	7.8	8
MAKSOY 1N	1	3	1	0.8	0.9	1.8	1.5	5.8	6.6	6.4
Mean	1.8	3.5	1	0.9	1	0.5	2.6	7.2	7.1	7.6
F-prob	**	**	*	**	**	*	**	**	**	**

[1]Nam = Namulonge, Naka = Nakabango, Bul = Bulindi, Nget = Ngetta. *, ** significant at 5% and 1% respectively.

Germplasm conservation is a core component of any breeding programme given that plants require variation in the gene pool for any selections to be made. Hence countries should develop their own genetic conservation programmes.

National systems should be established where national collections of key germplasm can be maintained for all crops in the country. In the past 12 years, research collaboration between Makerere University and National Crop Resources Research Institute (NaCRRI) has helped maintain eight varieties, and more than 400 germplasm materials, and more than 1000 breeding lines.

Conservation has been mainly through field banks and short-term storage in seed genebank with regular regeneration. Materials in storage were received from the AVRDC, USA, IITA – Nigeria, Zimbabwe, and farmers' fields in Uganda. The accessions under conservation also includes vegetable soybean.

Descriptors for these accessions have been recorded and whenever necessary, specific accessions are used in crossing experiments. Whereas many of these accessions are not locally adapted, they contain important traits such as soybean rust resistance (Rpp1, Rpp2, Rpp3, Rpp4, UG-5, TGX-1835-10E) that have been crucial in breeding programmes in the country.

A lot of effort is still needed to improve germplasm conservation infrastructure. A seed bank was established at Makerere University Agricultural Research Institute Kabanyolo (MUARIK) in the 1960s but considerable efforts and resources should be committed to utilise this facility.

Maintenance and operational resources have to be provided in a manner that will be sustainable such as solar powered storage facilities. Irrigation facilities should also be established at field locations where regeneration activities will be conducted to avoid crop failure. The major commercial cultivars and previous cultivars are also being maintained at Namulonge through seasonal regeneration to ensure availability of breeder seed. Ten released varieties are being maintained (Table 7).

Table 6: Some of soybean germplasm being conserved at MUARIK 2014B

Genotypes	Number
AVRDC	49
USA Germplasm	17
Vegetable soybeans	3
Uganda parents	15
Zimbabwe parents	6
NGDT 8.11 series	24
BSPS 48A series	25
NG 14.1 series	20
NGDT series	44
N II× GC progenies	35
BSPS SPS 48A	34
S-lines	16
Maphosa (F4)	40
Kiryowa	28
Bulindi BLP series	159
F3 Progenies	7
F4 Progenies	24
F5 Progenies	6
BSPS 48A single row selection	14

Development of a germplasm database for researchers

A database has been developed by the centre for Soybean Improvement and Development for management of various soybean research information to ensure proper storage, retrievals and sharing information among scientists to facilitate germplasm use and exchange. It is a relational database of linked primary and secondary tables developed using Microsoft Access Program. The primary tables have fixed fields for variables and draw a lot of the information from the different secondary tables which are designed to have continuous gap fillings.

Key data fields in the database include; different types of germplasm (released varieties, introductions, elite stock, breeding lines and landraces). For each germplasm category, information provided includes sources and origin, pedigree, qualitative information like seed colour and size, plant architecture and plant vigor, as well as quantitative information including different yield parameters. Other variables are adaptations of the germplasm to different locations and resistance to major constraints such as pests, diseases and drought.

The plans for further improvement and accessibility of the database include gap fillings with the available information. The database will also need to be integrated with a website so that it can be accessed online by many users. However, the rights to full and limited access to this information by different users is under review. There is need also to test the ease of use of the database by the end-users.

Table 7: Released soybean varieties 1990-2013

Cultivar	Pedigree	Released	Current use status
Maksoy 5N	Nam 2 x GC 00138-299	2013	Commercial
Maksoy 4N	Duiker x GC 00138-29	2013	Commercial
Maksoy 3N	GC 00138-29 x Duiker	2010	Commercial
Maksoy 2N	Maksoy 1N x Duiker	2008	Commercial, tolerant to ASR
Maksoy 1N	TGX 1835-10E	2004	Commercial
Namsoy 4M	Nam2 x GC00 139-29	2004	Commercial
Namsoy 3	Kabanyolo 1 x Nam 1	1995	Parental line
Nam 2	TGM 79	1992	Parental line
Nam 1	ICAL 131	1990	Parental line
Kabanyolo 1	Mutant of Clark 63	-	Parental line

The soybean research and development team has in the past 12 years supported various seed dissemination activities to avail new rust resistant varieties to farmers.

The details of some of the channels used to disseaminate improved seed are represented in appendix 2. In a drive to promote soybean production in Uganda, the centre has trained selected farmers' groups in Mukono, Wakiso, Kole, Kamwenge and Luwero districts in the production of quality seed. Seed multiplication of varieties Maksoy 1N, Namsoy 4M, Maksoy 2N and Maksoy 3N, Maksoy 4N and Maksoy 5N have been carried out every season since time of their respective release. Table 8 is a summary of the Breeder and Foundation seed that has been disseminated via several seed channels to the communities.

Experience has also shown that the informal seed system is important in Uganda, which heavily relies on farmer-to-farmer seed distribution season after season. For this reason, the research team has involved the interested farmers' groups in the multiplication and dissemination of the newly released soybean varieties. Farmers were targeted in their special interest groups and trained how to produce viable soybean seed. They were supplied with these new varieties and each one of them was continuously inspected by researchers through out the season. It is assumed that if well conducted, this multiplication would lead to the trickling down of the new soybean seed varieties to most remote of farmers through the traditional farmer to farmer seed distribution. It is also assumed that some farmers will eventually specialise in soybean seed multiplication as a commercial activity becoming suppliers to the surrounding farming communities.

The research team has worked in a number of areas through various stakeholders to ensure supply of the new varieties in the informal seed system (Fig 4 and Appendix 9). The reseacrh team worked with community based organizations (CBOs), non-governmental organizations (NGOs) and other stakeholders in the soybean value chain. CBOs and NGOs were instrumental and accounted for 53% of nationwide dissemination of foundation seed to different stakeholders for further multiplication.

The centre has produced over 190 tones of soybean foundation seed in the last 10 years for the different varities (table 8). Figure 10 illustrats the life cycle and trend of the different varieties produced by the centre through the years. Varieties Maksoy 3N and Maksoy 2N have been demaded most accounting for 46% and 26% of the breeders and foundation seed disseminated respectively. Maksoy 4N and Maksoy 5N were least disseminated because they are the most recent releases and require further promotional activities as illustrated in Figure 11.

Plate 11: Soybean field at NaCRRI - Namulonge

Table 8: Total seed dissemination through various channels over 10 years.

Seed dissemination Channel	Year and season							Total	%
	2004-2008	2009-2010A	2010B-2011B	2012	2013	2014	2015A		
Government bodies	11,050	30	300	-	7975	10,120	6,060	**35,535**	19
Seed companies	2,300	500	7,000	2462	360	4,631	2,950	**20,203**	11
Private companies	3,000	880	4,370	6250	-	12	12,400	**26,912**	14
NGOs/CBOs	900	68,000	12,150	2700	741	4614	755	**96,529**	50
Others	1,120	390	1,050	200	7,410	5068	1980	**15,539**	7
Total	**18,370**	**69,800**	**2,4870**	**11,612**	**18,511**	**24,445**	**24,145**	**191,718**	100

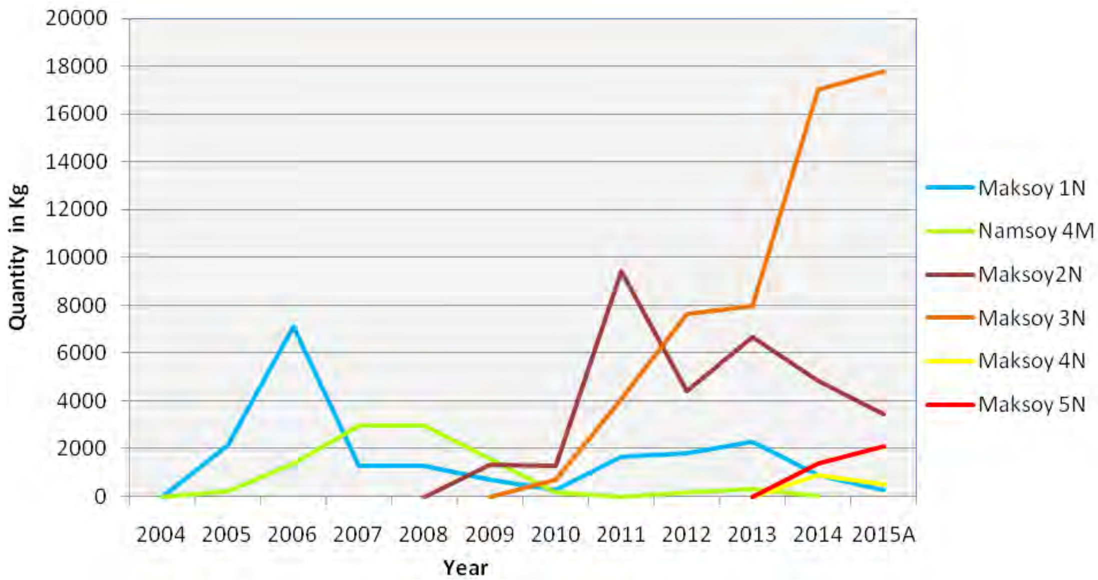


Figure 10: Life cycle of varieties and trends of foundation seed producation of the different soybean varieties in 10 years.

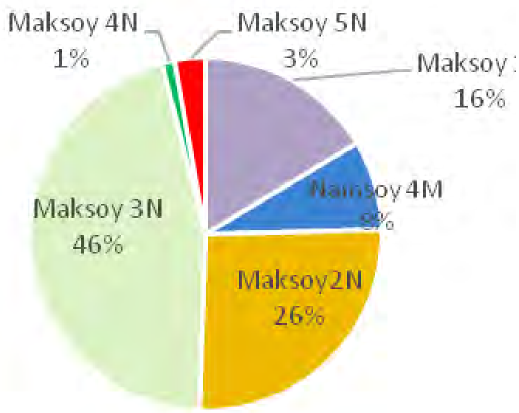


Figure 11: Demand of the different soybean varieties disseminated in 10 years.

Plate 12: AGRA officals with the research team discuss research strategies at MUARIK.

Soybean research and development work in Uganda over the past 12 years has supported various capacity building activities to avail students, farmers and scientists with knowledge and understanding of the crop.

The centre for soybean improvement and development at MUARIK has acted as a springboard to train and equip students with hands-on practical skills. In total, 10 graduate students successfully completed their degrees and are currently contributing to national and regional development work in breeding and seed systems. The research of current and past students attached to the program are summarised in Appendix 1. A list of related publications are presented before the appendices. Efforts to scale up capacity on soybean production have been acheived through training of stakeholders from Zonal Agricultural research and Development Institutes (ZARDI), NGOs, seed companies and farmers.

Besides, In collaboration with World Vision, the programme has undertaken a number of trainings in the Districts of Kiboga, Oyam, Kasese and Soroti in order to enhance farmers' soybean production techniques and prospects of local markets for soybeans and identification of products that can be obtained from soybean grain for home use. During such workshops, the participants were also presented with information on soybean cost benefit analysis and a list of potential buyers whom the farmers could contact after bulking at one location, preferably a group store.

In addition, the programme also conducted training of trainers workshops for staff from VEDCO and AFARD, with a focus on seed production. It should be noted that most of the training activities are carried out on the farm and farmers, homes during monitoring and evaluation activities.

Plate 13: Farmer consultation meeting in West Nile Region.

Plate 14: Field training for plant breeding students

Plate 15: Scientists from Kenya and Ethiopia on a soybean breeding familiarization visit at MUARIK

Impact of soybean breeding activities in Uganda

Makerere University has developed and released six soybean varieties that are superior, high yielding (2000-3500 kg/ha), and adapted to most agro-ecological zones in Uganda.

The Centre for Soybean Breeding and Development has multiplied and disseminated over 190 tonnes of foundation seed to provide basic requirements for seed companies producing certified seed, including other private companies and NGOs. According to the survey by Obaa and Tukamuhabwa (2015), over 93% of soybean varieties grown in Uganda were developed by Makerere University in collaboration with NARO (Figure 10). These developments triggered enormous interest among farmers to grow soybean as a major cash crop because of the readily available market. The different companies involved in processing soybean offer competition for the commodity resulting in better prices for the farmer.

Plate 16: A farmer tending his soybean crop in Kamwenge

For instance, soybean price increased from 600 UGX per kilo in 2008 to 1000 UGX per kilo in 2011 (SNV, 2011). About 90% of farmers in northern Uganda observed that the demand for soybean is increasing. Further, Ssengedo *et al.* (2010) observed that soybean contributed US$ 1,163,000 in 2009 up from US$ 300,000 in 2006 in terms of export earnings which is equivalent to an increase of 288%. Tukamuhambwa and Obua (2015) estimated the returns from soybean to reach 1,185,600 UGX per hectare per season. However, a wide range of soybean varieties, government investment in soybean research and increasing investments in soybean value chain are major strengths for the soybean subsector in Uganda.

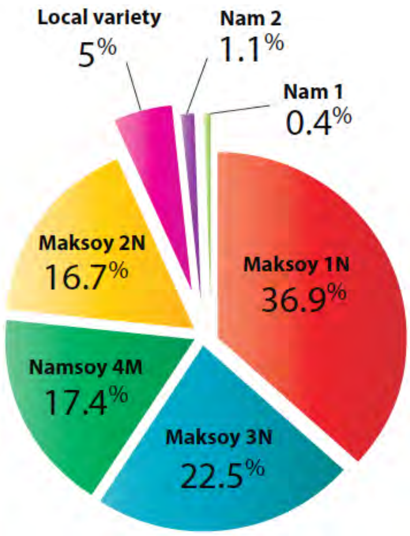


Figure 12: Farmer awareness of soybean varieties in Uganda, 2015

Processing Capacity

The processing capacity for soybean increased from 300 tons in 2009 (Anon, 2010) to over 600 tons in 2011 (SNV, 2011). This dramatic increase was due to the increased private sector investment in the vegetable oil production sector. Particularly, installation of Mt Meru Oil Mill with processing capacity of 300 MT per day, Mukwano with 250 MT per day, Guru Nana Oil Mill with 15 MT per day, Nile Agro in Jinja with 150 MT per day and Seba Foods in Tororo with an installed capacity of 15 MT per day, which manufactures soy pieces, and unimix for human consumption.

In addition, several processing plants have been established in the last 5 years due to the availability of improved soybean varieties available in Uganda for their outgrowers program. These include the East African Basic Foods Ltd, Maganjo Grain Millers, Sesaco Ltd, Ugachick, Kayebe Sauce Packers and Soy Products International Limited in northern Uganda and several oulets. Formula Feeds and others accounts for over 300 MT per day (Kawuki, 2004). These are relatively heavy investments that were developed upon the assurance offered by the high yielding soybean varieties.

Opportunities for national economy

While soybean is a major crop in industrialised countries such as USA, Argentina, Brazil, and China, in Uganda, the crop has not been given adequate priority in the past despite its potential in enhancing both nutrition and incomes of the Uganda people. Being a tropical country with largely suitable soils, Uganda can produce competitive quantities of soybean to meet the increasing demand for the grain as both human food and livestock feed. At the current production estimate of 180,000 MT, and a retail value of USD 0.5 per kilogram of grain, soybean production is worth over USD 90 million to the country's economy.

Soybean is globally an important crop. It is ranked the sixth most important crop in the word. As an oil crop, soybean has a significant amount of oil and as a grain legume, soybean has the highest amount of dietary protein. Therefore, Uganda cannot manage to ignore the crop and efforts should be made to promote the crop as much as possible.

The economies of Argentina and Brazil are greatly supported by soybean. In Argentina, soybean and soy products contributed nearly a third (a USD 20 billion value) of the country's USD 72 billion export value. This was achieved only the past twelve years when the government of Argentina made deliberate decisions to promote the crop as a food, industrial and export commodity (Schnepf *el at*., 2001, Ridley D. and Devadoss S., 2015).

Soybean, being an easy crop to cultivate, can be expanded to larger areas with intensification of production systems that could yield up to one million MT, a figure that would guarantee the economy over half a billion dollars' worth of production, without considering the value chain for soybean in the economy. Farmers in eastern, northern and western Uganda have shown enthusiasm to grow soybean, mostly as a cash crop, with the major buyers being Kenya, and food and feed processors in the country. Improving agronomic practices, including the use of nutrient amendments and the use of improved disease resistant cultivars will greatly enhance soybean production in the country.

Way Forward

The soybean industry in Uganda could benefit from strengthening of policies that favour industrial or medium scale enterprises that would enhance value addition to the country's produce. The value chain of soybean, once developed, can be a major contributor to the national economy. Policies alone will not grow the sector. Additional support to other components such as mass education, development of high yielding varieties, improved agronomic practices, promotion of soybean consumption among rural and urban vulnerable populations, marketing systems, and processing facilities, will be needed in the country. Such efforts have been made but additional resources and technical support is still needed to make the crop a premium commodity in the Ugandan agricultural landscape.

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Appendices

Appendix 1: List of academic studies implemented

Name	Country	Level	Subject	Year
Angele' Ibanda	DR. Congo	PHD	Inheritance of resistance to groudnut leaf miners in soybean	On going
Mercy Ulemu Msiska	Malawi	PhD	Genetics of resistance to bruchids in soybean	On going
Hailay Mehari Gebremedhn	Ethiopia	PhD	Mapping resistance genes to soybean rust(Phakopsora pachyrhizi) in local germplasm	On going
Eric Agoyi Etchikinto	Benin	PhD	Screening soybean genotypes for symbiotic promiscuous association with bradyrhizobium spp.	On going
Tonny Obua	Uganda	PhD	Genetic improvement of soybean oil quality and yield in Uganda	On going
Mercy Namara	Uganda	MSc	Resistance of soybean germplasm to the groundnut leaf miner (Aproaerema modicella) in Uganda	2015
Albert Tsindi	Zimbabwe	MSc	Evaluation of exotic vegetable soybean (edamame) germplasm in uganda	2015
Godfrey Ssendege	Uganda	MSc	Soybean genetic diversity and resistance to soybean rust disease	2015
Tonny Obua	Uganda	MSc	Soy bean rust diversity and adaptation of elite soy bean lines to the Ugandan environment	2013
Maphosa Mcebisi	Zimbabwe	PhD	Enhancing genetic resistance to soybean rust disease	2013
Asiimwe Moses	Uganda	MSc	Evaluation of new soybean varieties for market traits and adaptation in	2012
Oloka Herbert	Uganda	MSc	Tolerance to soybean rust (phakopsora pachyrhizi) and stability of elite soybean genotypes in Uganda	2008
Buyinza Musa	Uganda	MSc	On-farm seed quality, production and profitability of rust resistance soybean varieties in eastern Uganda	2008
Kiryowa Moses	Uganda	MSc	Inheritance of resistance to soybean rust	2007
Robert Kawuki	Uganda	MSc	Soybean germplasm reaction to rust in Uganda, associated yield loss, and rust control using fungicides	2003

Appendix 2

Description of six Soybean Varieties Developed at Makerere University						
Character	Variety					
	Maksoy 1N	Namsoy 4M	Maksoy 2N	Maksoy 3N	Maksoy 4N	Maksoy 5N
1) Pedigree	TGX 1035-10E	NG 10.1	MNG8.10	BSPS 48A	BSPS48A-27	NG14.1--24
2) Hypocotyl anthocyanin coloration	Dark	Mild	None	None	None	Present
3) Days to flowering	43	45	50	50	48	45
4) Growth habit	Det	Det	Det	Det	Det	Det
5) Days to physiological maturity	90	100	105	102	103	96
6) Reaction to soybean rust	Res	Res	Tol	V Tol	Res	Res
7) Pubescence colour	Grey	Brown	Grey	Brown	Light brown	Brown
8) Pod colour	Cream	Dark brown	Dark	Brown	Light brown	Brown
9) Pod clearance (cm)	7.4	14	12	10	20	14
10) Pod shattering	Very Res	Moderate Res	Res	Res	Res	Res
11) Leaf colour	Dark green	Dark green	Pale green	Dar green	Pale green	Pale green
12) Plant height at physiological maturity (cm)	52	89	90	90	88	87
13) Leaf shape	Rhom	Rhom	Rhom	Rhom	Rhom	Pointed-Rhom
14) Leaflet size	Large	Medium	Medium	Medium	Large	Large
15) Flower colour	Light purple	Light purple	Purple	Purple	Purple	Purple
16) Seed size	Medium	Large	Large	Large	Large	Large
17) Seed shape	Ovoid	Ovoid	Round	Round	Ovoid	Round
18) Seed coat colour	Cream	Cream	Cream	Cream	Cream	Cream
19) Helium colour	Light Brown	Black	Cream	Light brown	Grey	Dark brown
20) Number of seeds/ pod	3	3	3	3	3	3
21) 100 seed weight (gms)	15	17	17	17	19	19
22) Protein content (%)	41	43	38	36	38	38
23) Oil Content (%)	17	19	18	23	21	19

Det=Determinate, Res=Resistant, Tol= Tolerance, VTOL=Very Tolerant, Mod=Moderate, Rhom= Rhomboid

Appendix 3: Mean seed yield (kg ha^{-1}) of soybean lines at six locations during 2008A

	Mean yield (kg ha^{-1})						
Line	**Bulindi**	**Iki-Iki**	**Kasese**	**Nakabango**	**Namulonge**	**Ngetta**	**Mean**
BSPS 17(b)	630	1204	2926	2037	1111	1056	1494
BSPS 34	907	1074	2685	1667	1333	574	1373
BSPS 42	778	1167	2167	1537	926	815	1231
BSPS 43	778	1222	2500	2037	1278	991	1468
BSPS 48(a)	1352	1185	2815	2519	1259	1444	1762
BSPS 85	778	1296	2093	1778	1333	926	1367
Duiker	944	1296	2426	1630	1019	1463	1463
DxT (PYT 06A) 2.14	1111	1315	2426	1778	1259	1019	1485
DxT(PYT 06A) 4.22	981	1333	2759	1593	1130	1037	1472
DxT (PYT 06A) 7.1	963	1296	2185	1796	741	1407	1398
DxT (PYT 06A) 8.11	1481	1407	2278	2019	1222	1120	1588
DxT (PYT 06A) 8.12	1093	1444	2796	1815	1352	1111	1602
DxT (PYT 06A) 8.3	704	1398	2370	1778	1296	852	1400
DxT BLP (SRB) 12.4	833	1481	2130	1870	1056	1046	1403
DxT BLP (SRB)4.21	741	1259	2796	2204	1389	1315	1617
DxT progeny 1.3	722	1111	1815	1611	1259	1222	1290
DxT progeny 4.17-4	870	1093	2111	1556	1093	1324	1341
DxT progeny 4.7	1074	1463	2519	1519	1389	1037	1500
DxT SPS 1.19	870	1426	2241	1852	1333	852	1429
Maksoy 1N	833	1241	1796	1870	1111	1148	1333
Nam 1	1037	1074	2074	1333	1111	1111	1290
Nam II x GC (BLP) 11.3	1278	1389	2574	1796	1389	889	1552
Nam II x GC (BLP) 20.2	667	1278	2352	1704	1278	889	1361
NGDT 8.10-10	1019	1130	2333	1907	1481	852	1454
Mean	935	1274	2382	1800	1215	1063	1445
LSD5%	NS	NS	662.5	500.8	305.3	370.0	511.6
%CV	37.5	17.3	16.9	16.9	15.3	21.2	22.0
F-prob	0.327	0.478	0.046	0.022	0.004	0.001	<0.001

Appendix 4: Lodging and disease scores, days to flowering and maturity and yield of 23 AVRDC lines grown at Namulonge in 1998

Genotype	RLB*	LDG	BP	VIR	RST	DF	DM	Yield
GC84040-27-1	2.0	1.0	3.3	1.0	3.3	47.0	104	2094
AGS 183	2.5	1.0	3.3	1.0	3.5	38.0	92	1276
GC86048-427-3	2.3	1.0	2.0	1.5	3.5	40.0	90	1356
GC60020-8-7-7-18	3.5	1.0	1.0	1.0	2.3	41.0	93	998
GC00138-29	4.3	1.0	1.5	1.5	2.0	48.0	98	1969
GC84058-21-4	4.0	1.0	1.0	2.0	1.5	39	97	2107
GC86049-35-2-1-1-8-IN	2.8	1.5	1.8	1.5	3.3	43	101	1775
GC84051-32-1	2.3	1.0	2.8	1.0	4.3	43	94	1969
GC84040-7-1	3.8	1.0	3.3	1.0	4.3	42	95	1331
SS86045-23-2	3.8	1.0	3.8	1.8	3.8	40	89	693
G58	4.0	1.0	3.5	1.8	3.0	31	82	693
G8586	2.8	1.5	3.0	1.0	4.0	48	104	1359
UG5 (control)	3.0	1.0	2.8	1.0	2.0	46	96	2029
G10427	2.8	1.0	1.5	1.5	3.5	43	95	1220
G7955	2.0	1.0	1.0	1.0	3.3	47	107	2283
G73	2.5	1.0	2.0	1.5	4.0	43	94	1874
G33	4.3	1.0	2.0	1.5	3.5	36	92	915
G2020	3.0	1.0	3.3	1.0	2.5	45	96	1742
P1200451	3.0	1.0	4.8	1.0	2.5	31	109	305
P1200465	4.0	1.0	4.8	1.0	3.0	31	88	527
P1200492	2.8	1.0	3.5	1.0	3.3	33	90	360
P1459023	2.5	1.0	2.5	1.0	5.0	46	95	1442
P1230970	3.0	2.0	2.8	1.5	4.3	41	99	2552
Mean	**3.1**	**1.1**	**2.6**	**1.3**	**3.3**	**40.9**	**95.6**	**1428.9**
LSD (5%)	**1.3**	**NS**	**1.4**	**1.0**	**0.7**	**3.8**	**4.0**	**664.8**
% CV	**20.7**	**35.9**	**24.7**	**38.6**	**10.3**	**4.5**	**2.0**	**22.4**

*RLB - red leaf blotch, LDG - lodging, BP - bacterial pustule, VIR - Viruses, RST - rust, DF - days to flowering, DM - days to maturity, NS - not significant at 0.05

Appendix 5A: Seed yield (kg/ha) of six genotypes tested on farmers' field in different districts

Season	District	Variety					
		MNG 1.63	MNG 2.12	MNG 2.15	MNG 7.13	MNG 8.10	Farmer seed
2005A	Apac	4167	2292	1958	1875	2083	1667
	Mayuge	667	625	1083	1000	1083	1250
	Lira	2604	3125	3542	3125	3542	3750
	Hoima	2083	2500	2292	2708	3125	1667
2005B	Apac	1006	1879	1765	1200	2155	1800
	Mayuge	1088	1900	1980	1897	1509	1050
	Lira	599	400	340	460	850	580
	Hoima	780	834	790	600	880	230
2006A	Apac	1796	1997	1565	1440	1800	1500
	Lira	1657	2300	1967	1700	2493	1020
	Hoima	1112	1584	1110	1409	1603	857
Mean		1595	1767	1672	1583	1920	1397

Appendix 5B: Mean yield of genotypes across four seasons (2005A, 2005B, 2006A and 2006B)

	Mean yield (kg ha^{-1})				
Genotype	Bulindi	Nakabango	Namulonge	Ngetta	Genotype mean
MNG 1.37	1084	1831	1866	1217	1500
MNG 1.38	889	1827	1738	1000	1364
MNG 1.41	1035	1728	1785	1010	1389
MNG 1.60	1001	1702	1635	1032	1343
MNG 1.63	942	1740	1814	1101	1399
MNG 2.12	1043	1714	1860	1126	1436
MNG 2.13	896	2038	2062	1154	1537
MNG 2.15	966	1663	1892	1120	1410
MNG 4.11	808	1734	1727	1037	1326
MNG 5.17	922	1703	1892	1014	1382
MNG 7.13	1040	1755	1723	1006	1381
MNG 8.10	1033	1907	1869	1135	1486
MNG 8.25	775	1782	1642	929	1282
Maksoy 1N	822	1560	1582	932	1224
Nam 1	796	1535	1367	1069	1192
Location Mean	937	1748	1764	1059	1377
$LSD_{p=0.05}$	178.6	NS[a]	191.6	153.2	117.1
F-prob	0.002	0.317	<0.001	0.008	<0.001

Appendix 6: Seed yield of 24 Soybean lines tested at six locations in season 2009B in Advanced Yield Trial

GENOTYPE	Grain yield (Kg/Ha)					
Variety	**Bulindi**	**Iki-Iki**	**Nakabango**	**Namulonge**	**Ngeta**	**MEAN**
BSPS48A	2037	1019	2760	2074	611	**1700**
DXTPROGENIES4.7	1426	1037	2648	2278	500	**1578**
BSPS43	1444	1018	2463	2407	315	**1530**
DXTPYT06A8.3	1630	926	2537	2000	556	**1530**
NGDT8.10-10	1222	1574	2500	1739	389	**1485**
DXTSPS4.19	1352	1073	2500	2000	315	**1448**
DXTPYT06A8.12	1481	1056	2593	1741	259	**1426**
DXTPROGENIES1.3	1296	1185	2148	2204	278	**1422**
DXTPYT06A7.10	1741	815	2185	1981	370	**1419**
BSPS85	1371	1093	2259	1833	519	**1415**
DXTBLP(SRB)12.4	1555	889	2408	1778	444	**1415**
DXTBLP(SRB)4.21	1518	889	2333	1889	425	**1411**
DXTPROGENIES4.17-4	1370	685	2518	2148	315	**1407**
NAMIIXGCBLP11.3	1148	1037	2555	1815	444	**1400**
BSPS34	1092	908	2167	2148	518	**1367**
DXTPYT06A8.11	1389	815	2204	2056	370	**1367**
DXTPYT06A4.22	1333	907	2000	1981	204	**1285**
DUIKER	1185	1204	1537	2019	444	**1278**
MAKSOY1N	1148	630	2315	1759	463	**1263**
BSPS17B	1389	667	2426	1463	333	**1256**
BSPS42	1222	926	2166	1519	426	**1252**
DXTPYT06A2.14	1518	852	1778	1574	352	**1215**
NAMIIXGCBLP20.2	1241	759	2074	1778	222	**1215**
NAM1	1112	797	1741	1370	352	**1074**
Mean	**1384**	**948**	**2284**	**1898**	**393**	**1381**
s.e.d 178; l.s.d 351; %cv 21.89						

Appendix 7: Seed yield of 24 Soybean lines tested at six locations in 2011A, 2012A, 2012B and 2013A seasons

Genotypes	Iki	Kab	Mub	Nak	Nam	Nge	Mean	Vs Maksoy 1N	Vs Maksoy 3N
DXT SPS 16.6-2	608	967	401	1347	1325	1042	948	-35	-336
BSPS 24.2A-3	733	1,230	605	1812	1326	1062	1,128	240	-61
BSPS 27A	593	809	632	1200	973	726	822	-65	-366
BSPS 42	774	991	554	1554	1231	1035	1023	67	-234
BSPS 48A-27	807	1,191	921	1803	1399	1623	1291	387	86
NIIGC 4.1-2	886	991	1,033	1602	1338	1418	1,211	279	-22
NG14.1-6B	995	988	765	1706	1468	1311	1205	301	0
NG 14.1-24	993	962	934	1718	1430	1511	1258	319	18
NGDT 2.15-4	621	1,103	696	1400	1177	1107	1017	73	-228
NGDT 2.15-10	708	932	704	1495	1238	1215	1049	102	-199
NGDT 8.11	777	899	546	1305	1192	1039	960	-27	-328
NGDT BLP 12.4	623	787	607	1383	1391	1212	1000	44	-257
Maksoy 1N	649	739	665	1346	1243	1125	961	0	-301
Maksoy 3N	966	1,017	929	1847	1310	1313	1230	301	0
Mean	757	980	675	1578	1292	1221	1084		
LSD (5%)	134.5	112.8	119.0	88.31	106.7	133.1			
% CV	44.97	30.84	63.55	14.37	26.69	32.65			
F-Prob	0.033	0.001	<.001	<.001	0.059	<.001			

Iki = Iki-Iki, Kab = Kananyolo, Mub =Mubuku, Nak= Nakabango, Nam= Namulonge, Nge= Ngeeta

Appendix 8: Phenological and seed traits of 24 genotypes tested in ATY 2010

Genotype	Days to flower	Days to Maturity	Crude protein %	Crude fat %
BSPS48A	42	94	36	23
DXTPROGENIES4.7	47	97	40	15
BSPS43	46	97	39	19
DXTPYT06A8.3	45	92	35	17
NGDT8.10-10	47	97	38	14
DXTSPS4.19	45	96	40	16
DXTPYT06A8.12	47	93	41	13
DXTPROGENIES1.3	45	91	34	18
DXTPYT06A7.10	41	88	36	17
BSPS85	43	94	38	15
DXTBLP(SRB)12.4	44	91	39	23
DXTBLP(SRB) 4.21	42	92	37	21
DXTPROGENIES4.17-4	43	88	41	17
NAMIIXGCBLP11.3	51	100	39	15
BSPS34	46	98	40	14
DXTPYT06A8.11	44	91	38	19
DXTPYT06A4.22	46	96	36	12
DUIKER	42	91	37	20
MAKSOY1N	43	85	41	17
BSPS17B	45	96	34	21
BSPS42	44	90	37	18
DXTPYT06A2.14	49	95	39	18
NAMIIXGCBLP20.2	43	92	34	21
NAM1	45	97	39	18
Mean	**45**	**93**	**38**	**18**

Appendix 9: Major soybean seed dissemination channels along the value chain

Major seed channels used to disseminate seed along the value chain		
Category	**Name of Organization**	**Location of soybean operations**
NGO	World Vision	National
CBO	Mayuge Farmers Association	Eastern Uganda
Government Project	Vegetable Oil development Project	National
Government service	NAADS	National
Private seed company	Victoria seeds	National
Private seed company	East African Seed Co	National
Private seed company	Equator seeds	National
Private seed company	Vedco	National
Private seed company	Mak Seeds Ltd	National
Private seed company	Pearl Seeds	National
Private seed company	Naseco Seeds Co	National
Private seed company	FICA	National
Private seed company	Masindi seed company	national
Private company	Mt Meru Oil Mills	Nothern Uganda
Private company	Mukwano group	Nothern Uganda
Private company	Formula Feeds	National
Private company	Aliwol Enterprises, Kitgum	Kitgum
Private company	Soybean Products International	National
Private company	Omer Farming Company Limited	Nothern Uganda
NGO	Uganda Seed Traders Association	National
CBO	Canmiidiro group	Lira
CBO	Par Pir Itino	Lira
CBO	Cam Kwok Kin	Lira
CBO	Yele ICOM Can Atur	Lira
CBO	Adyeda women's guild	Apac
CBO	Zirobwe Agali-awamu Agribusines Enterprise (ZABTA)	Luwero
Local government	District Agriculture office	Kaberamido, Apac Kaliro, Lira, Gulu, Soroti, Sironko, Mbale, Palisa, Kumi,
NGO	Africa 2000	Tororo
NGO	Pakanyi United Young Farmers Enterprise (PUYFE)	Masindi
NGO	Juna Magara	Kamwenge
NGO	Bala women and youth farmers' association	Apac
NGO	Pallisa progressive farmers association	Pallisa
NGO	Oilseed Producers and ProcessorsAssociation	Lira

NGO	Lira concerned parents association	Lira
NGO	Care international	Lira
NGO	International Rescue Committee	Nothern Uganda
NGO	Agency For Accelerated Regional Development (AFARD),	West Nile
NGO	Millennium villages,	Isingiro district
NGO	Rugendabara Cooperative Society	Kasese
CBO	Karo one twins group	Isingiro
NGO	Federation of Association of Uganda exporters	National
NGO	CIAT	Eastern
NGO	IITA	Kiboga
NGO	N2 Africa	Northern
NGO	ISSD	National
NGO	One Acre Fund	Eastern Uganda
NGO	Ug Soybean Intiative	National
CBO	Mirembe Farmers Group	Central
CBO	Awak Farmers Group	Northern region
NGO	Integrated Seed Sector Development Project	National
Private company	Intaz (U) Ltd	Central
NARO	Ngetta ZARD and Abi ZARDI	Lira and Arua
NGO	Farm Solutions Africa	Central
NGO	ISU-UP	Central
NGO	Akalo Farmers Group	Aleptong

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