

A Review of Maize, Rice, Tomato and Banana Research in Tanzania

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Abstract

Crop improvement is critical for the sustainable production of crops that contribute to healthy diets, alleviation of hunger and poverty, and enhanced quality of life for people across diverse social economic strata around the world. The development and improvement of crops that can cope with the extreme biotic and abiotic stresses brought about by climate change is probably one of the most important steps that can be taken by any country to ensure a plentiful, healthy, and nutritious food supply for its population. This requires the use of all tools and technologies in the development of new and improved crop cultivars. Maize, rice, and vegetables (tomatoes and bananas) are important crops grown in Tanzania and production has steadily increased for the past 40 years. However, yield per unit area is generally very low, Maize averages 1.4 t/ha while the potential yield is 5 t/ha and rice averages 0.5-2 for upland ecologies and 4.5-6.0 t/ha for irrigated ecologies compared to the potential yield of 5t/ha and 10-11 t/ha respectively. Tomato production is higher than other vegetable crops in Tanzania, with a total annual production of 129,578 t, representing 51% of the total vegetable production. Average tomato yield is from 2.2 to 3.3 t/ha which is far below the world average of 27.5 t/ha. This stands in contrast to overall global production of maize, rice, and tomatoes which averaged 34, 21, and 43%, respectively, over the same time period, mainly through crop improvement programs and the use of new technologies. The innovative Agricultural Research Initiative (iAGRI), is a project that is being implemented within the framework of the US Government's Global hunger and Food Security Initiative (GHFSI). This study was commissioned by iAGRI to develop a research background paper on crop improvement strategies for maize, rice and selected horticultural crops, the focus crops of Feed the Future project. The information was obtained through review of available literature and consultation with relevant scientists and stakeholders.

Keywords: Crop improvement, plant breeding, Rice, Maize, Horticulture crops, Research gaps

Introduction

Tanzania has a land area of 948,000 square km, with a complex climate, soils, and topography. The total population grew from about 33 million people (Census 2002) to 44,928,923 (Census, 2012), under increasing production biotic and abiotic stresses. Rainfall patterns vary across the country; some areas have unimodal patterns, while others have bimodal patterns. According to Agriculture Sector Review and Public Expenditure Review

(2008/09), Agriculture is the key economic sector in the country, accounting for 60% of the Gross Domestic Products (GDP). It also provides 85% of recorded export earnings and 90% of the country's rural employment (DTMA 2010). Major cash crops grown in the country include coffee, cotton, sisal, tea, tobacco, cashews, and pyrethrum. Food crops include maize, rice, sorghum, wheat, barley, legumes, millets, bananas, sweet potatoes, potatoes, and cassava. Horticultural crops grown include

tomatoes, cabbage, carrots, onions, eggplant, zones.
pepper, okra and garlic.

The Department of Research and Development (DRD) of the Ministry of Agriculture, Food Security and Cooperatives (MAFC) is responsible for and coordinates all agricultural research and training, as well as maintaining contacts with international research organizations and national institutions. DRD has a network of 22 research stations and sub-stations in seven research zones (Appendix 1). Sokoine University of Agriculture (SUA) currently under the Ministry of Education and Vocational Training is responsible for higher education and training in agriculture, basic and adaptive research while limited basic research is conducted at the University of Dar-es-Salaam (UDSM).

Tanzania is divided into seven research zones, Northern, Southern, Southern highland, Central, Western, Lake and Eastern, each having a list of research priorities according to the agreed criteria (URT, 2011). According to the DRD's National and Zonal Research priorities, the priority 1 crops for the Northern zone include the focus crops of iAGRI (maize, rice) and several horticultural crops such as, onions, banana, lima bean, mangoes, tomato, carrot, and spices. The Southern zone priority 1 crops include maize, rice, cassava, sorghum, cashew nuts, pigeon peas and sesame. In the Southern Highlands, the priority 1 crops are maize and rice.

The Central zone priority 1 crops are maize, sunflower, sorghum, pearl millet and groundnuts. In the Western zone, maize and rice are priority 1 crops, together with plantains, cassava, coffee, beans, tobacco and groundnuts. Priority 1 Lake zone crops include maize, rice, banana sorghum, cotton, sweet potato, cassava, beans and coffee, while in the Eastern zone priority 1 crops include maize, rice, cassava, sugarcane, sorghum, cotton, beans and coffee. Thus maize and rice are priority 1 crops in all zones except in Central where rice is priority 2. Except for the Northern zone, most horticultural crops are in priorities 2 and 3. However, banana featured in priority 1 in Northern, Western and the Lake

This paper is therefore aimed at providing research progress for crop improvement of the four selected commodities (maize, rice, tomatoes and banana), major challenges facing crop improvement research, the existing research gaps and subsequently suggesting research themes and sub-themes for crop improvement research in Tanzania.

Review of crop improvement research of priority crops

Maize (*Zea mays*): Overview and trends

Maize production is higher than that of any other cereals in Tanzania, totaling 2,617,115 metric tons and representing 74% of total cereal production (Crop sector national report 2006). The area used for maize production has been estimated at between 1.7 and 2.0 million ha (Pangali 2001). Data from the national report on the crop sector 2006 indicated that the average yield was 1.4 t ha⁻¹ (DTMA 2010), which decreased to 1.26 t ha⁻¹ in 2008–2010. Thus, efforts should be directed toward attaining a potential production of 5 t ha⁻¹ (Lyimo 2005). The per-capita utilization of maize is about 114 kg, contributing an estimated 61% of total dietary calories (Kirway *et al.*, 2000). The national demand for maize used in food was estimated at 3.6 million tons and is growing at a rate of 2.5% (DTMA 2010). It is estimated that maize production must increase by 3.0–3.5% annually to satisfy demand reflected by high population growth rate which exceeded 2.0% over the past two decades (Lyimo 2005). This cannot be achieved without using improved varieties, expanding area under maize production, and intensifying production to increase yields, while taking into consideration the challenges posed by climate change.

Maize crop improvement in Tanzania

Development of maize varieties

Over the past 20 years, only 63 hybrids and 21 open pollinated varieties (OPVs) have been developed and utilized in the different agro-ecologies (Appendix 2), 31 of which were released by National Maize Research Program (NMRP), and the rest were released by various

seed companies that operate in the country. According to Lyimo (2005) and Moshi *et al.* (1997), the most preferred are eight OPVs (Staha, Staha-St, Kilima, Kilima-St, Katumani, TMV-1, ICW, and UCA) because they are high yielding under low risk management technologies, resistant to pests and diseases, drought tolerant and early maturing. They are also palatable and seeds are easily available and relatively cheap. These varieties are recommended for the Central, Eastern, Lake, Northern, Southern, Southern Highlands, and Western zones. Traits incorporated in the breeding program mostly include tolerance to Maize streak virus (MSV), leaf blight, Triticum leaf blight, cob rot, Gray leaf spot (GLS), and common rust. However, traits associated with tolerance to abiotic stress, such as early maturing and protein quality are not given as much priority in breeding programs. There is therefore a need to incorporate traits associated with a tolerance to abiotic stresses, particularly drought and high temperatures.

Adoption of improved varieties and other technologies

Maize farmers have benefited from investment in maize research and adopted many improved varieties and management practices. A study on adoption of maize production technologies in Southern Tanzania conducted by Katinila *et al.* (1998) showed that farmers easily adopted improved maize technologies that required little cash (row planting, weeding), but only a few farmers adopted the more costly technologies, such as fertilizer, herbicide, and disease control measures. The study also showed that many respondents were unaware of improved maize technologies, especially the use of fertilizers, improved varieties, ox-drawn implements, herbicide use and disease control measures.

Sources of seeds

Nkonya and Mwangi (2004) evaluated the economic rationale for recycling hybrid seeds in northern Tanzania, and reported an 80% recycling rate for hybrids and open pollinated seeds for 3–6 years as a response to cash constraints and as a hedge against production and financial risks. Farmers stated that they realized profits when recycling their improved

seeds, even when the producer price of maize fell by 46%. Hence the researchers concluded that seed recycling is an economically rational behavior. The implication of these findings is that researchers in Tanzania need to enhance the distribution of improved seeds in order to ensure its availability in the country and develop hybrid maize varieties that may be recycled without significant inbreeding depression. In addition to that, breeding for open pollinated varieties should also be enhanced.

Maize tolerant to abiotic stresses

Among the abiotic stresses, drought is the most limiting constraint to maize production, especially under current global climate change. It is one of the most important criteria farmers consider when selecting varieties (Lyimo *et al.* 2001). Mduruma and Ngowi (2000) reported that in most of the maize-growing areas, the crop is subjected to frequent drought due to erratic rainfall. Crop losses can be up to 50% in some seasons. Mduruma and Ngowi (2000) evaluated the early-maturing varieties and hybrids and found that early-maturing varieties were sensitive to early-season stress and yields were low.

Nutrient deficiency, especially of Nitrogen (N), is widespread because of limited fertilizer inputs and lack of crop rotation. Therefore, breeding for drought resistance and low N use efficiency can potentially increase and stabilize maize yields. Over the past five years, more than 34 new drought-tolerant maize varieties have been developed and deployed to over 2 million smallholder farmers in sub-Saharan Africa, empowering them to cope with the impacts of climate change on their livelihoods and food security (DTMA 2012). Drought tolerant varieties such as Selian MH 07 (Hybrid), Vumilia K-1 (OPV) (released in 2007), STUKA and STUKA M-1 were reported (DTMA 2010). Several other seed companies, such as FICA Seeds, Kenya Seed Co. Ltd., ASA, Kibo Seeds, Krishna Seed Co. Ltd., Meru-Agro Tuors & Consultants Ltd., Ndola Oil Storage Company (NOSCO), Zanolbia Seed Co. Ltd., and SATE, have also developed drought-tolerant maize varieties,

By testing maize varieties for drought tolerance from all over the world, CIMMYT, IITA, and national scientists have developed varieties adapted to conditions in Africa (Appendix 2). However, the availability of varieties that are tolerant of major abiotic stresses is still a problem due to increasing stressed environment contributed to the global climate change impacts among other factors, and this should be addressed.

Striga-tolerant maize

The obligate root hemi-parasite striga (Scrophulariaceae) is one of the most serious constraints to cereal production by smallholder farmers, not only in Tanzania, but also in sub-Saharan Africa (Mbwaga and Massawe 2001). Scrophulariaceae forbesii is of economic importance in Tanzania. Maize, sorghum, millet, and upland rice are its preferred hosts (Mbwaga and Massawe 2001). Mbwaga (1996) reported that Striga management in the Eastern zone has concentrated mainly on cereal-legume rotation, intercropping, and N fertilization practices. Efforts to develop striga-resistant maize and/or maize varieties that are tolerant to herbicides that kill striga have been conducted elsewhere. Only TAN 222 has been reported to have striga resistance and low N tolerance attributes. Therefore, resistant or tolerant genotypes with improved resistance or tolerance to herbicides that kill striga constitute major, practical, and reliable approaches to the management of striga.

Quality Protein Maize (QPM)

Quality protein maize (QPM) describes a range of maize cultivars with twice the content of limiting amino acids; lysine and tryptophan compared with conventional maize. It has been developed to help reduce human malnutrition in areas where protein deficiency is prevalent and where maize is the major protein source in the diet, as in various parts of Sub-Saharan Africa (SSA). Krivanek *et al.* (2007) reported that CIMMYT, in collaboration with the International Institute of Tropical Agriculture (IITA) and the NARS in 17 countries of SSA, has developed a broad range of QPM cultivars. Commercial QPM seed is currently available in all collaborating countries and,

based on average 2003–2005 seed production, approximately 200,000 ha of land were planted with QPM cultivars. Three varieties of QPM Lishe K1, Lishe H1, and Lishe H2 (Appendix 2) were released in Tanzania (CIMMYT, 2005; Krivane *et al.*, 2007). However, in Tanzania, the adoption of QPM is still very low. Therefore, more promotions and adoption studies need to be done.

Resistance to biotic stresses and the use of biotechnology in maize breeding

Varieties with resistance to multiple diseases have been developed under NMRP. Examples include Stuka M1, which has tolerance to maize streak and gray leaf spot, and resistance to Diplodia, Fusarium leaf blight, and Puccinia sorghi; Stuka 2 with tolerance to maize streak and gray leaf spot, and resistance to cob rots, leaf blight, and leaf rust; TMV1 with resistance to maize streak and rust tolerance; TMV2 with resistance to Turcicum leaf blight; Kilima ST with tolerance to maize streak; Vumilia – K1 with very good resistance to MSV, leaf blight, and rust; and Selian H 208 and H 308 with tolerance to maize streak and Turcicum blight (Kirway *et al.*, 2000)

The Maize Improvement Programme (MIP) at the Uyole Agricultural Research Institute conducted a massive screening and evaluation of both local and exotic commercial and pre-commercial maize varieties and inbred lines for the two most important yield-limiting maize diseases in the SH and the country as a whole -which are. Gray leaf spot (GLS) and maize streak virus. This work produced two potential new maize hybrids, one of which, UH615, was released in 2000–2001 and a GLS-tolerant hybrid, UH6303, was released in late 2004 (Lyimo 2005). Lyimo (2006) further reported that farmers preferred these varieties to have drought-tolerant traits. Efforts are therefore required for additional improvements to incorporate farmers' preferences in those varieties. Furthermore, Kiula (2007) integrated conventional breeding and DNA marker technology to increase line-combining ability and gray leaf spot resistance in maize.

Climate change has a pronounced effect on the adaptability of crop varieties to environmental stresses, especially drought tolerance, and biotechnology is a powerful tool to achieve significant drought tolerance (FAO 2000). Identifying ways to mitigate drought risk, stabilize yields, and encourage small-scale farmers to adopt best management practices is fundamental to realizing food security and improved livelihoods for the continent. However, the use of biotechnology under national programs has been limited. The African Agricultural Technology Foundation (AATF) is leading a public-private partnership, the Water Efficient Maize for Africa (WEMA), to develop drought-tolerant varieties using conventional breeding, marker-assisted breeding, and biotechnology. The benefits and safety will be assessed by national authorities in the partner countries: Kenya, Mozambique, South Africa, Tanzania, and Uganda (Otunge *et al.*, 2010).

Rice crop improvement in Tanzania

Overview and trends

Rice (*Oryza sativa* L.) is the second-most widely produced crop worldwide after wheat. It is the mainstay in the diets of more than half the world's population. Global rice consumption exceeded 430 and 672 metric tons in 2008 and 2010 respectively, which closely mirrors production (FAO 2010). Global rice production has been steadily increasing over the last four decades, averaging about 21% per decade (FAO, 2010). The production of rice in Tanzania has paralleled the global increase, rising from 132,000 metric tons in 1970 to 1.1 million metric tons in 2010 (FAO, 2010). Since consumption has been increasing, continued crop improvement is critical to reduce factors constraining rice productivity, which can impact the ability to keep up with demand. In Tanzania, the crop is grown mostly under lowland rainfed conditions (72%) and upland (20%). The remaining (8%) is produced by large-scale farmers mainly through irrigation (MAFC 2004; Kanyeka *et al.*, 1995).

Generally, rice is grown in almost all regions of Tanzania, but at various levels of importance. However, low yields ranging from 0.5 to 2.0 t ha⁻¹ and 4.5 to 6.0 t ha⁻¹ have been reported

from farmers' fields and in some irrigated rice projects, respectively (Kashenge-Killenga 2010). This is in contrast to the potential yield of improved rice varieties of 10 to 11 t ha⁻¹ under tropical humid conditions (Fashola *et al.*, 2007). The low yields realized are the result of increasing drought, the use of low-yielding varieties, declining soil fertility, inadequate use of fertilizer, weed infestation, pest and diseases infestation, inadequate use of machinery, and poor design and management of irrigation facilities (Kafiriti 2004; Kashenge-Killenga, 2010).

Rice research in Tanzania is being coordinated at the Kilombero Agricultural Training and Research Institute (KATRIN), Ifakara, Morogoro. In 2010, KATRIN became the Regional Rice Centre of Excellence (RRCoE) under the Eastern Africa Agricultural Productivity Program (EAAPP), serving Tanzania, Kenya, Uganda, and Ethiopia. The Institute collaborates closely with other national regional and international partners.

Sources of germplasm

(a) Varietal introduction and selection

The introduction of varieties from other countries is still the most important source of germplasm. For example, the Supa India (Surinam V-880) variety from Surinam is still very popular. In 1971, a number of varieties, such as IR 8, IR 54, IR 58, and IR 64, bred at IRRI were tested in different locations in Tanzania (Monyo and Mwaruka 1974). Faya Theresa, Kihogo Red (Morogoro), Afaa Mwanza, Afaa Kilombero, and Kihogo selections 7, 21, and 23 were released for rainfed lowland, while Salama and Dunduli ya Milimani were recommended for upland conditions. Kalalu was introduced through the International Network for Genetic Improvement of Rice (INGER) and released for general cultivation (Luzi-Kihupi *et al.*, 2009).

Recently, the upland varieties NERICA 1, (Baraka) NERICA 2 (Tumaini), NERICA 4, (Pato), NERICA 7 (Faraja) and WAB-450-12-2-BL1-DV4 (Ziada) introduced from AfricaRice were released in 2009 (KATRIN News Bulletin, 2011). NERICA varieties perfectly adapt to the

rainfed upland ecology in sub-Saharan Africa (SSA), where smallholder farmers lack the means to irrigate or apply chemical fertilizers or pesticides. The NERICAs have been evaluated and characterized for a range of agronomic traits and reaction to key African endemic diseases and pests. NERICA varieties generally have shorter growth duration than most traditional rice varieties. A number of NERICA varieties possess early vigor, which is an important trait for weed competitiveness in rice, thus improving the productivity of scarce labor. Moreover, some of them also have tolerance to drought and soil acidity. NERICA characteristics include cooking and eating qualities particularly acceptable to local consumers; NERICA protein content is generally higher than that of much of the imported rice widely available in African local markets.

(b) Hybridization and Mutation Breeding

Hybrid crosses between local and introduced varieties was initiated in 1971 at ARI Ilonga and an outstanding variety, Selemwa, was released. Hybridization programs aimed at developing early-maturing, high-yielding, shorter varieties with pest and disease resistance and acceptable cooking and eating quality were initiated by the National Rice Programme and some promising lines (TXD 85, TXD 88, and SARO 5) were released in 2003 (Luzi-Kihupi *et al.*, 2009).

Mutagenesis is an effective tool for improving specific characters of the existing cultivars, particularly plant height, maturity, and grain characteristics. Successful use of mutations has been reported in several improvement programs (Rutger *et al.*, 1986; Luzi-Kihupi, 2001). A program of mutation breeding in Tanzania was initiated in 1972 (Monyo, 1974) at the then Faculty of Agriculture and Forestry with financial assistance from the International Atomic Energy Agency (IAEA). Faya Theresa and Kihogo Red varieties were used in the FAO/IAEA “Coordinated mutation breeding programme for the improvement of grain protein content and quality.” Later on, mutation breeding based at SUA was utilized to reduce plant height and the maturation period of the popular indigenous cultivars while maintaining

some of the good qualities of the parents. One mutant Mwangaza resistant to rice yellow mottle virus was released in 2005 (Luzi-Kihupi *et al.*, 2008). Currently, a Coordinated Research project (CRP) funded by IAEA on heat tolerant rice is being implemented at SUA.

Breeding for resistance to biotic stresses

Rice yellow mottle virus (RYMV), rice blast (BL), and bacterial leaf blight (BLB) are the most significant biotic stresses to rice productivity and can cause up to 100% yield losses in the lowland rainfed and upland ecologies and requires suitable control measures, such as host plant resistance (ECARRN 2006; Banwo *et al.*, 2003). Development of resistant varieties is challenged by the high diversity of the pathogens causing erosion and the breakdown of resistance (Banwo *et al.*, 2001). Knowledge of population structure, diversity of the pathogens, and host-pathogen interactions in the East African region is scanty but vital in developing strategies to increase the durability of resistance (Banwo *et al.* 2003; WARDA, 2000).

Rice Yellow Mottle Virus (RYMV)

Studies on RYMV commenced in the 1990s and based on antibody detection, five serotypes were identified: S1, S2, and S3 in West Africa, and S4 and S5 in East Africa, implying much variability in the virus (Traore, 2001; Ali, 2001). Further research is still needed to characterize the pathogenicity of RYMV variants and to determine their role in disease epidemics. The virus is mechanically transmitted by Coleopteran beetles, *Sessilia pusilla*, *Trichispa serica*, and *Diclidispa viridicyanea* (Bakker, 1974). Banwo *et al.* (2001) reported that the *Chrisomelid* beetles, *Chaetocnema pulla chapuis*, and *Chaetocnema sp.nov. prope varicornis* Jakoby were also important vectors.

The use of resistant varieties, direct sowing, the removal of alternate hosts, and control of insect vectors are effective ways of significantly reducing the impact of RYMV (Mabagala and Luzi-Kihupi 2001; WARDA 2006). The extent of natural resistance to RYMV is variable and under the control of many genes (WARDA 2000). Thus, the durability of resistance cannot

be predicted (Mwalyego *et al.* 2003). Control measures call for further screening and testing in view of the variability of the virus and consumer preferences in different agro-ecological zones (Luzi-Kihupi 2001; WARDA 2008). However, the release of Mwangaza and Kalalu which are resistant to RYMV in 2005 is expected to boost production in RYMV affected areas and provide a source of germplasm for further breeding (Luzi-Kihupi *et al.* 2009).

Rice Blast (RB) and Bacterial Leaf Blight (BLB)

Rice blast caused by *Magnaporthe grisea* (Hebert) Barr, anamorphic *Pyricularia grisea* Sacc and bacterial leaf blight (BLB) caused by *Xanthomonas oryzae* pv *oryzae* (Xoo) are the most destructive fungal and bacterial diseases respectively, in most rice-producing areas worldwide (Sere *et al.*, 2007). Yield losses ranging from 70%–80% and 50%–90% for blast and BLB, respectively, have been recorded in West Africa and other parts of the world (Sere *et al.*, 2007). Yield loss due to BLB has not been quantified, but recent surveys (2011) in the ECA region recorded incidences of the disease ranging from 70%–100% (Onasanya *et al.*, 2009). The most effective and economic method is host plant resistance; however, variability in the Xoo pathogen has been reported with this method (Mew *et al.*, 1982). Such variability has made breeding for BLB difficult. In a number of studies (Mew *et al.*, 1982), 21 genes for resistance to Xoo have been identified and seven races have been described.

While disease control measures have yet to be developed for East Africa, varietal resistance and other management options have been developed and their use has resulted in reducing crop losses from 60%–100% in most Asian countries (Leach *et al.*, 2001). Partial resistance involving the combination of major resistance genes has been deployed in the development of resistant varieties against rice blast (Leach *et al.* 2001). However, efforts to identify and develop disease-resistant cultivars are now ongoing, although resistance to the two diseases is unstable in the field, leading to severe epidemics when new races overcome the resistance of

released varieties (Mew *et al.*, 1982). In order to contribute to the development and deployment of durable disease-resistant cultivars in ECA, a good understanding of pathogen variability and genetics is essential.

Breeding for resistance/ tolerance to abiotic stresses

Drought and Heat

Drought in Tanzania and other East Africa countries causes crop and animal losses. Its frequency seems to have increased in recent years, raising prices for staple foods, including rice. Member states of ASARECA countries (Burundi, Democratic Republic of Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, Sudan, Tanzania, and Uganda) have adopted, or are planning to adopt, 26 climate change strategies (Levira, 2009). Only two of these strategies are common to all the 10 countries, including the development and promotion of drought-tolerant and early-maturing crop species and the exploitation of new and renewable energy sources. In 2011, the Rice Regional Centre of Excellence (ARI - KATRIN) initiated a project under Eastern Africa Agriculture productivity program (EAAPP) funded by World Bank and made progress in the development of drought tolerant lines that are currently under evaluation in drought stressed environment (KATRIN News Bulletin, 2012).

High temperatures are critical in rice production, particularly during flowering and ripening stages, and high night temperatures can reduce grain yield and quality. Day temperatures exceeding 35°C during the flowering stage have decreased grain yields in older miracle rice varieties developed in the 1960s. Plant breeders at IRRI are developing heat-tolerant varieties that will flower normally and set seed at higher temperatures as well as varieties that flower earlier in the day, thereby minimizing reproductive impacts later in the day when temperatures are higher. Currently, SUA in collaboration with Africa Rice Centre are developing heat tolerance rice cultivars in Tanzania

Salt-affected soils

Salt stress (both salinity and alkalinity/sodicity) is a worsening problem in inland areas because of salt build-up due to the use of irrigation with improper drainage, poor-quality irrigation water, or salt soils developed from salt-bearing rocks. This problem is currently threatening lowland rice productivity. Kashenge-Killenga *et al.* (2012) revealed that seven of nine surveyed rice irrigation schemes have been affected by salts. Soils with electrical conductivity (EC) of up to 10.5 dSm⁻¹ and sodium adsorption ratio (SAR) of 72 have been reported, indicating extreme levels of salinity and sodicity, respectively. Canals serving surveyed schemes also had slight to moderate sodicity (EC_w of 0.08–0.47 dSm⁻¹; pH of 6.9–7.8; and SAR of 7.3–15.1) while in-field water samples had significantly higher salinity and sodicity levels with an EC_w of 1–3.16 dSm⁻¹, SAR of 17–20, and pH of 7.2–8.2. Thus both primary and secondary salinisation occurred. Suitable salt-tolerant varieties are lacking and awareness of the problem's current status and future expansion is generally low (Kashenge-Killenga *et al.*, 2013). Advances have been made since 2011 at RRCOE - ARI KATRIN under AGRA funded project to develop a rice population which is tolerant to saline and sodic conditions. Twenty seven F5 promising lines were selected from Mombo – a saline environment (pH of 6.4 and Ec of 8.5 dS/m), Ndungu and Mkomazi – saline-sodic environments (pH 7.8; Ec 8.4 dS/m and pH 8.2; Ec 8.5 dS/m respectively) and Dakawa – Sodic environment (pH of 8.4 and Ec of 0.67 dS/m). These lines are available for further evaluation and selection for salt tolerance in various sites (Kashenge-Killenga, 2013).

Low soil fertility

One of the key constraints to production is declining soil fertility, especially N and P deficiencies, which is often associated with high N depletion and P fixation under acidic soils (Gupta and O'Toole, 1986). Furthermore, P and other nutrient deficiencies will be particularly important in drought-prone environments because the mobility of nutrients decreases sharply as soil dries (Garrity *et al.*, 1990). However, traditional upland rice cultivars appear

to be tolerant to both low P and high acidity relative to other cereals (Garrity *et al.*, 1990). Therefore, studies on the evaluation of locally improved material to reflect tolerance for low P, N, and high acidity in rice production conditions are very few in Tanzania. There is urgent need therefore, to test and develop varieties that are nutrient efficient and tolerant to low N and P.

Horticultural crops

Tanzania has a high potential for the production of tropical, subtropical, and temperate fruits, vegetables, and spices because of its varied agro-climates. Despite this, horticulture is only relatively well developed in the northern regions (Arusha, Kilimanjaro, and Tanga), southern highlands (Mbeya and Iringa), and Morogoro. The lack of proper infrastructure and access to market and investment programs are bottlenecks to other regions with the potential to develop a commercial and export-oriented horticulture sector.

Tomato (*Lycopersicon esculentum* Mill L.)**Overview and trends**

Over the past 30 years, world tomato production has increased at 43%, averaging 1.3 million metric tons per year. Much of this increased production has been channeled into processing, which has seen a dramatic increase, especially of canned tomatoes. Most of this increase occurred in Italy (for paste production), Greece, and France. The cultivated tomato is adapted to very diverse climates and there have been successful crop improvement programs through breeding in the United States, Canada, the Philippines, and at the world Vegetable Centre (AVRDC). To date, the diverse genetic resources available for tomatoes have been used most extensively in developing disease-resistant cultivars. Lately, biotechnological and genomic approaches have enabled the introduction of genes to allow the plants to withstand unfavorable conditions.

Tomato production is higher than that of other vegetable crops in Tanzania, with a total annual production of 129,578 tons, representing 51% of total vegetable production (Mtaita 1994; Mwasha 2000; de Putter *et al.* 2007). However, the average yield is 2.2–3.3 t ha⁻¹ (URT 2003),

which is far below the world average yield of 27.5 t ha⁻¹ (FAO 2005). According to Minja *et al.* (2011), the low productivity is caused by increasing abiotic stresses, such as salinity, drought, excessive heat, and declining soil fertility, and biotic stresses (pests and diseases), poor crop management, and lack of well-adapted, high-yielding varieties (Mtaita 1994; Lynch 1999). Various improved tomato varieties are grown, but they are not very tolerant to pests and diseases and are low yielders with a short shelf life (AVRDC 2006). In 1997, AVRDC successfully released two high-yielding varieties, Tanya and Tengeru 97, that were firmer and less susceptible to pests and diseases (AVRDC 2006) compared to former varieties, such as Money Maker, Roma, and Marglobe.

Source of germplasm

Breeding material and varieties with resistance to diseases such as tomato yellow leaf curl virus (TYLCV), bacterial wilt (BW), Fusarium wilt, grey leaf spot, early blight, and nematodes are available. However, there are no varieties with resistance or tolerance to these stresses that are also adapted to Tanzania's agro-ecological conditions. In their field experiment, Minja *et al.* (2011) showed that based on tolerance to nematodes, good fruit characteristics, and high market acceptability, Tengeru 97 and Meru were the most promising varieties. These were, however, susceptible to early blight. LBR-6 and LBR-11, which are early maturing and blight resistant, were rated excellent for taste and had high market acceptability, but were susceptible to nematodes. A release of Tengeru 2010 and Duluti varieties in 2011 has also been reported recently. Tengeru is resistant to root-knot nematodes, tomato mosaic virus (ToMV) and Fusarium wilt while Duluti is tolerant to early and late blight. These varieties are also high yielding with firm and large fruits (Samali Njau, Personal Communication). Research is therefore needed to further test these varieties in disease hot spots, along with integrated pest management strategies that focus on nematodes and early blight.

However, varieties tolerant to abiotic stresses are currently unavailable. Therefore, in order

to increase the yield and quality of tomato production, there is a need to develop a long-term breeding program aimed at introducing pest- and disease-resistant and abiotic stress-tolerant cultivars adaptable to different production areas.

Bananas

Overview and trends

Bananas remain the forefront crop for food security on the Eastern African Plateau, where the crop is the staple food for over 20 million people. Moreover, the crop's role in food import-substitution in the region cannot be over emphasized in some parts of the region. In Tanzania, banana is a key food and commercial crop and/or a major source of raw materials for both beverage and handcraft industries. While the Musa gene pool around the Great Lakes, including the Kagera area in Tanzania, has completely been identified, collected, and duplicated in vitro over several decades (Karamura, 1999), this process has not been conducted in other areas of Tanzania or Kenya, beyond the rather sketchy collection mission carried out by Baker and Simmonds more than 50 years ago (Baker and Simmonds 1952).

The majority of farmers use local varieties, which are less productive and susceptible to biotic and abiotic stresses. Moreover, poor agronomic practices and pest infestations represent major constraints where more efforts should be directed. Recently, the use of improved varieties (FHIA 23, FHIA 17, Yangambi Km5, and Pelipita) coupled with good agronomic practices and integrated pest management has led to higher yields (Msogoya *et al.*, 2011). However, the innovations were only tested in a few villages; thus there is a need to scale up the technology. It was observed that the demand for improved banana varieties by nearby villages was higher than the supply and thus farmers' lack of access to clean and adequate planting material became the major constraints.

Banana diseases in Tanzania pose varied threats according to the geographical area and dominant varieties grown. While the coastal regions of Tanzania, including Zanzibar and Pemba islands, are affected mainly by black sigatoka

(*Mycosphaerella fijiensis*), this disease is not a threat in the highlands of Kilimanjaro and Kagera or the Southern highlands. Likewise, in areas where the East African Highland banana (AAA) systems (EAHB) have been replaced by the dessert varieties due to banana weevils (*Cosmopolites sordidus*), nematodes, or poor soil fertility, the threat posed by Fusarium wilt (*Fusarium oxysporum*) has increased.

Banana improvement

Breeding for black sigatoka resistance in bananas

Black sigatoka can reduce fruit yield by 30–40% (IITA 2009). Development and deployment of resistant varieties is the most feasible and sustainable strategy to control the disease, but this has been done elsewhere and not in Tanzania. Although chemical control is possible, it is expensive and not suitable for small-scale farmers. IITA has been developing plantains and East African Highland bananas hybrids with resistance/tolerance to black sigatoka for many years and 14 resistant plantain hybrids have been registered. Off-type plants derived from shoot-tip micro propagation of the East Africa highland banana landrace “Uganda” (Msogoya *et al.*, 2008) were more tolerant to black sigatoka with an infection index of 17.5% compared to 30.1% and 22.8% for the micro propagation (MP) derived from phenotypically normal plants and conventional propagation, respectively. This is an indication that somaclonal variants could be utilized as a tool for improving plant tolerance to black sigatoka disease and increasing the plant suckering rate, especially during moisture stress.

Field assessment of banana genotypes resistant to Fusarium wilt

Fusarium wilt is a serious threat to the production of exotic bananas in the East African region. It affects mainly “Sukali ndizi” (AAB), a dessert banana, and “Pisang awak” (ABB), an important cultivar for beer making. “Sukali ndizi,” or apple banana, has potential as an export commodity for Kenya and Uganda. Host resistance has been reported to be the most effective, economic, and practical long-term option for managing Fusarium wilt. Therefore,

field screening for resistance to Fusarium wilt is worthwhile in Tanzania. Different cultivars respond differently to the disease, and only a few cultivars exhibit high levels of resistance to Fusarium wilt (de Langhe *et al.*, 2001)

Screening banana hybrids for resistance against banana weevils

The banana weevil (*Cosmopolites sordidus*) is the most important insect pest constraining banana production in East Africa. The development of resistant cultivars is a long-term and more sustainable control strategy for weevils (IITA 2009), but has not featured prominently in any breeding program. This is probably due to the absence of good sources of resistance, and the lack of a quick, reliable, and simple screening method, preventing breeders from rapidly pinpointing resistance across the available germplasm. Therefore, studies focusing on rapid and reliable genotype screening are highly advocated. A rapid bucket screening method is being evaluated using three known resistant and three known susceptible banana cultivars (IITA 2009). Preliminary findings show that the method is promising and can be adopted for use.

Breeding for drought tolerance in bananas

Banana, being a food security and income-earning crop, needs to be bred for drought tolerance. Commercial plantations supplement rainfall with irrigation, but for small farm holders this is not feasible. Water is one of the most limiting abiotic stress factors in banana production. Bananas need at least 25 mm of water per week and an annual rainfall of 2000–2500 mm evenly distributed along the year is considered optimal for banana production. When there is no access to irrigation, mild drought conditions are responsible for considerable yield losses. Yield loss of up to 65% when the annual rain fall was below 1100 mm was reported (Van Asten *et al.*, 2011). Studies on tolerant to drought are currently lacking. There is thus a need to develop standard protocols to screen bananas and plantains for drought tolerance, with priority on reference collection for water-deficit conditions. These genotypes can be used for the development of

new cultivars with wider adaptation. Tissue-culture-derived plants are often vulnerable to abiotic stresses, but the mechanisms underlying such responses are hardly known. A study which evaluated the mechanisms underlying the drought stress vulnerability of in-vitro derived banana cv. "Uganda" (Msogoya and Grout 2012) showed that tissue culture process increases the vulnerability of in-vitro banana regenerants to water stress as a consequence of increased leaf stomatal density, which is possibly under the control of cytosine DNA hypomethylation.

Use of hybrids

In the mid-1990s, new banana planting materials were introduced into Tanzania in response to increased pest and disease pressures, coupled with a lack of chemical inputs to combat these constraints (Nkuba *et al.*, 2006). Among them were the first banana hybrids, bred by the Fundación Hondureña de Investigación Agrícola (FHIA). These materials were disseminated to farmers in Kagera through trials, demonstrations, and "mother gardens." On-farm testing commenced in 1997 and was conducted concurrently with their multiplication and the dissemination of planting materials to farmers in the region (Nkuba *et al.* 1999). Results showed that on average, the new varieties yielded a bunch weight of 18.9 kg, compared with 9.7 kg for local varieties (Nkuba *et al.* 2002). Initial assessment revealed that these varieties are acceptable to farmers for their multiple uses (consumption as fruit; by cooking, roasting, or drying; and fermentation for the production of beverages) and good marketability. An initial adoption study conducted in 2002 indicated that 29% of 177 households surveyed from the five districts of the Kagera Region had planted at least one new banana variety (Weerdt 2003).

Research gaps in maize, rice, tomato and banana crop improvement

Based on the literature survey on crop improvement and the major challenges facing crop improvement research, the following research gaps were identified.

Research information sharing

A number of information gaps were identified

through a review process and evaluation of available reports, as well as through the stakeholder consultation that occurred during the development of this document. Lack of proper documentation and limited linkages between researchers pose problems in various institutions. Poor information monitoring and coordination within research systems are among the reasons for the failure to obtain information from research findings.

Breeding and selection.

Conventional or formal plant breeding (FPB) programs conducted by international agricultural research centres or national programs in developing countries have been criticized for ignoring indigenous germplasm, failing to breed for conditions facing poor farmers, and emphasizing selection for broad versus local adaptation. The systematic breeding program geared toward breeding varieties adapted to adverse environmental conditions in Tanzania is poor. For maize, breeding and selection for various stresses (Biotic and abiotic) has been undertaken in various Agricultural research institutes such as Selian, Ilonga and Uyole. The main rice breeding and selection centre is currently at the regional rice centre of excellence (RRCoE) located at ARI KATRIN, with the main focus on improving rice crop for tolerant to drought, salt, RYMV, good grain quality and aroma. SUA, Cholima, and Ukiriguru agricultural research institute are also involved in rice crop improvement as well as selection of suitable varieties. However, generally conventional breeding dominates. In most cases, breeders depend on a selection of improved varieties bred from outside. There is no breeding program for horticultural crops.

Inadequate development of varieties that are high yielding, nutritious and tolerant / resistant to biotic and abiotic stresses.

Breeding for crop improvement is a long-term process but on a near-term basis, germplasm screening can be accelerated to identify selections adapted to different agro-ecological zones. This can be achieved by screening currently available germplasm for tolerance and resistance to biotic and abiotic stresses,

including diseases and insects, early maturity, and quality protein.

Inadequate information on the availability of quality seed, storage conditions, and facilities

The availability and provision of open pollinated seeds that can be saved and reused annually, especially in geographic regions where varietal adoption is low, would constitute an important intervention. In the short term, surveys can be conducted to gather information on seed availability. Novel seed storage methods to increase shelf life and seed quality can be explored not only for consumption but also for propagation.

Inadequate information and knowledge on the prevalent pests and pathogens and their variability on crop damage and yield

The diversity among strains of a pathogen may be due to differences in climate, host type, and other factors present in various geographical areas. In Tanzania, information on pathogens variability is lacking and this will likely hamper the strategic use of varietal resistance in disease management. Pest population surveys can be conducted and proven disease and pest control methods evaluated on the selected crops in the major geographic regions.

Inadequate human resources

The major challenge for crop improvement programme in Tanzania is inadequate number of plant breeders and expertise related disciplines such as plant pathologists, entomologists, agronomists and biochemists. There are a total of 56 plant breeders working on an array of crops. Some of these are about to retire, some are on contract after retiring and some are not active because they have other administrative assignments.

There is only one Agricultural University in Tanzania, Sokoine University of Agriculture (SUA). The University is constrained by limited number of staff and teaching facilities. Only a few crops receive attention of the faculty members. The Agricultural Training Institutes under the Ministry of Agriculture are charged with the responsibility of producing support

research staff at certificate and diploma levels. These institutes just like the research institutes operate at below capacity due to lack of finances, inadequate facilities and low number of tutors who are underpaid and lack incentives.

The priority research themes for maize, rice, and selected horticultural crops in relation to crop improvement

Given the challenges and research gaps constraining crop improvement research, as outlined above, response to these challenges and research gaps are described in the following six themes and sub-themes.

Theme 1: Characterization of available germplasm for traits conferring resistance /tolerance to biotic/abiotic stresses and enhanced nutrition

Tolerance for biotic and abiotic stresses and enhanced nutrition are priority traits in many rice-growing environments. Important genes that confer resistance to different stresses have been identified and cloned elsewhere (Kashenge – Killenga, 2013). These genes and their closely linked markers have facilitated efforts to improve different traits of various crops through marker-assisted selection (MAS). The strategy of this theme will be to use routine conventional selection methods combined with molecular procedures to screen, identify, and characterize the available maize and rice germplasm for traits conferring resistance to biotic and abiotic stresses as well as nutritional qualities. Furthermore, the identification and characterization of important pathogens and pests will be important for pyramiding resistant genes into farmers' preferred varieties.

Sub-themes:

- i) Identification and characterization of the pests impacting maize, rice, and selected horticultural crops
- ii) Identification of traits conferring tolerance /resistance to abiotic and biotic stresses and enhanced nutrition qualities
- iii) Identifying donors and genes/QTL conferring valuable traits

Theme 2: Development of improved maize and rice varieties which have resistance/

tolerance to biotic/abiotic stresses and enhanced nutrition

Tolerance to biotic and abiotic stresses and enhanced nutrition are priority traits for maize, rice, and horticultural crops. The strategy of this theme will be to use routine conventional breeding activities combined with molecular breeding procedures to transfer useful traits from donor varieties to farmers' preferred cultivars and elite breeding lines that have good adaptability in Tanzania in order to improve their tolerance to abiotic and biotic stresses.

Sub-themes:

- i) Breeding varieties tolerant/resistant to biotic and abiotic stresses using conventional and marker-assisted selection to incorporate important traits into the farmers' preferred cultivars and elite breeding lines
- ii) Breeding for varieties of rice, maize, with acceptable nutrition/grain qualities

Theme 3: Development of improved tomato and banana varieties which are resistant/tolerant to biotic/abiotic stresses

There are no or very few tomato varieties with resistance or tolerance to tomato yellow leaf curl virus (TYLCV), bacterial wilt (BW), Fusarium wilt, grey leaf spot, early blight, and nematodes adapted to Tanzania's agro-ecologies. Therefore, to increase the productivity and quality of tomato production, there is a need to develop a long-term breeding program aimed at introducing pest and disease resistance and abiotic stress tolerance genes to cultivars that will be adaptable to different production areas.

The majority of banana farmers use local varieties, which are less productive and susceptible to biotic and abiotic stresses. The genetic diversity available from indigenous and exotic germplasm can be used to introduce new useful traits and create new gene combinations in order to breed bananas tolerant to biotic stresses, such as Black sigatoka, Fusarium wilt, and banana weevil.

Sub-themes:

- i) Development of tomato varieties with resistance to diseases, such as tomato yellow leaf curl virus (TYLCV), and bacterial wilts (BW)

- ii) Breeding banana varieties resistant to black sigatoka, Fusarium wilt, and banana weevil

Theme 4: Accelerating the development, delivery, and adoption of improved varieties of maize, rice, tomato and banana crops using Participatory Varietal Selection (PVS)

Participatory Varietal Selection (PVS) involves testing and selecting new varieties developed by the research institutes within farmers' fields and at local research stations in various environments in order to allow farmers to compare the performance of these varieties with the local varieties. Improved technologies for maize, rice and some horticultural crops will be tested using PVS, which will enable farmers to have a wider range of options to independently choose from.

Sub-themes:

- i) Conduct multi-environment testing of improved technologies by using PVS
- ii) Evaluate the effectiveness of a variety of release mechanisms and seed systems (storage, quality, and viability) for the delivery of high-quality seed of new varieties
- iii) Introduce improved post-harvest technologies/value addition and marketing

Theme 5: Develop appropriate effective Integrated Pest Management (IPM) Strategies to control virus, fungal and bacterial diseases, and insects and pests

One of the biggest problems with many of the developments in IPM over the years has been the tendency to generalize and make recommendations for farmers across large and highly heterogeneous areas. This has been true for all manner of input recommendations, including fertilizers, pesticides, and crop varieties. This problem, ecological heterogeneity associated with blanket recommendation, has also severely limited the effectiveness of government monitoring and forecasting systems. All of these practical issues vary on a small spatial scale. This local specificity requires that farmers become IPM experts.

IPM strategies vary for different crops and depending on the local varieties used, local

agronomic practices, and the various crop protection options available. IPM can never be delivered in a “package;” it needs to be developed, adapted, and tailor-made to fit local requirements.

Sub-themes:

- i) Evaluate IPM technologies for maize, rice, and horticultural crops in major growing areas of respective crops
- ii) Evaluate management options for control of post-harvest pests
- iii) Development and dissemination of practices that reduce post-harvest losses

Theme 6: Strategic capacity building to enhance research in crop improvement of the focus crops

Strengthening the human and institutional capacity of the institutions and various partners working together on crop improvement is necessary to achieve a self-sustained research impact. The approaches include training (formal and informal) and mentoring, and infrastructural improvement through the provision of capital items to NARS institutions as needed for the implementation of planned activities.

Sub-themes:

- i) Support institutional capacity building
 - Provision of modern functional facilities at Research institutions
 - Provision of communication facilities in order to enhance information sharing, networking and co-ordination of research activities to avoid duplication
- ii) Improve human capacity by supporting post-graduate training in crop breeding and molecular biology and short-term training in biotechnology, seed technology, and marker-assisted selection (MAS).
- iii) Financial support to crop improvement research

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Appendix 1. Tanzania Agro-Ecological zones and associated research profile

Zone	Regions Covered	Research stations	Year established	Researches done
Eastern	Dar es Salaam, Morogoro, Pwani, Tanga	ARI-Ilonga, Kilosa Zonal Centre)	1943	Maize, sorghum and millets, grain legumes, soil and water management, cotton, sesame, soybean, sunflower, Agricultural and home economics,
		KATRIN, Ifakara	1963	Rice, Spices
		Cholima-Dakawa, Morogoro	1996	Rice, maize, Horticulture, (okra, tomato, amarathus, bitter tomato cucumber)
		ARI-Mikocheni, DSM	1996	Coconut, Biotechnology, Agricultural economics and home economics
		SRI-Kibaha, Pwani	1970	Sugarcane, cassava, sweet potato
Western	Kigoma, Tabora	ARI-Mlingano, Tanga	1934	Soil and water management, sisal, spices
		ARI-Tumbi, Tabora (Zonal Center), Sub stations Seatondale-Iringa, Mtanila	1930	Maize, Rice, Sorghum, Beans, cassava, oil palm, groundnut, sunflower, tobacco, Agroforestry, home economics, dairy
Northern	Arusha, Kilimanjaro, Manyara	ARI-Selian, Arusha (Zonal Centre)	1980	Wheat, bean, barley, maize, soil and water management, Agricultural economics and home economics, Agroforestry, Agricultural Engineering, Mechanization
		HORTI-Tengeru, Arusha	1952	horticultural crops
Southern Highlands	Iringa, Mbeya, Rukwa, Ruvuma	ARI-Uyole, Mbeya (Zonal Center)	1970	Maize, bean, vegetables, fruits, pyrethrum, Irish potato, soybean, soil and water management, home economics, Agroforestry, Agric, Engineering and mechanization.
Southern	Lindi, Mtwara	Kifyulilo-Mufindi	1986	
		ARI-Naliendele, Mtwara (Zonal Centre) Sub station: Mtopwa	1972	Cashew, groundnuts, sesame, sunflower, cassava, sweet potato, soil and water management, Intercropping

Central	Dodoma, Singida	VRC-Makutupora, Dodoma (Zonal Center)	1979	Grapes,
		Hombolo, Dodoma	1972	Sorghum and millets
Lake zone	Kagera, Mara, Mwanza, Shinyanga	ARI-Ukiriguru, Mwanza (Zonal Center)	1932	Cotton, rice, sweet potato, cassava, maize, pigeon pea, dengu
		ARI-Maruku, Bukoba	1947	Banana, maize, cassava, sweet potato, Irish potato, bean, vanilla, millets, rice, fruits, spices, magimbi, soil and water, Agroforestry.

Appendix 2: List of released varieties of various crops (1992-2011)

1992-2001	Tomato	CAL-J Rossal (Recommended)	Uyole
	Avocado	Weisal, Fuerte, Ex-Tengeru, Haas (Recommended)	Uyole
	Peaches	UK82, UK91	Ukiriguru
	Maize	UH615, CH-3, Kilima-ST, Kito-ST, Katumani-ST, CG 4142, C 6222, PhB 3253, PAN 6549, PAN 695, PAN 6481, PAN 6195, CG 4141, PhB 3253, PAN 6549, PAN 695, PAN 6481, PAN 6195, CG 4141, C 5121, C 5051, Phb 30A15, CRN 3631, DK 8071, PAN 6243, PAN 67, H 513 PAN 77,	NMRP NMRP In collaboration with private seed companies
	Tomato	Tengeru 97, Tanya	HORTI-Tengeru
2002-2011	Maize	Bora	Ilonga
		UH6303,UHS 5350,UHS 5210	Uyole
		Staha-ST C (Recommended)	Uyole
		Lishe-KI, Lishe-H1 (Chotara), Lishe-H2 (Chotara), Situka-1, Situka-M1,Selian-MH07 Chotara), Vumilia-K1, Selian H208 (chotara), Selian H308 (chotara, Vumilia H1	Selian
	Rice	TXD 85, TXd 88, TXD 306 (SARO 5)	Katrin (In collaboration with Dakawa)
		NERICA 1, NERICA 2, NERICA 4, NARICA 7, WAB450-12-2BLB-DV4	KATRIN (In collaboration with Dakawa, Ukiriguru, Uyole & Naliende
		Kalalu Mwangaza	SUA (In collaboration with Uyole)
	Tomato	Meru, Kiboko, Duluti, Tengeru 2010	Horti-Tengeru

Cabbage	Glory FI, Prucktor (Recommended)	Uyole
Onion	Mang'ola Red(Recommended)	Uyole
Grapes	Makutupora Red, Chenin nyeupe	VRTC-Makutupora
Loshuu/figiri	Rungwe & Arumeru	HORTI-Tengeru
Bitter tomato	DB 3	HORTI-Tengeru
Night Shade	Olevolosi & Nduruma	HORTI-Tengeru
Ethiopian Mustard	Ethiopian Mustard	HORTI-Tengeru
African Egg plant	African Egg plant	HORTI-Tengeru
Amaranthus	Madira and Madiira 2	HORTI-Tengeru
Avocado	Simmonds, Ikulu, Ex-Mwaikokesya (Recommended)	Uyole
Banana	FHIA 17, FHIA 23	SUA (In collaboration with Uyole)
