



NATIONAL AGRICULTURAL RESEARCH ORGANISATION



ANNUAL REPORT
2017/2018

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Vice President of Uganda, Edward Kiwanuka Ssekandi visiting NARO Village during the National Source of the Nile Agricultural and Trade Show, July 2017.

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NATIONAL AGRICULTURAL RESEARCH ORGANISATION

Co-ordinating, Overseeing and Guiding Agricultural Research

National Agricultural Research Organisation (NARO) is the apex body for guidance and coordination of all agricultural research activities in Uganda. It is composed of 16 public agricultural research institutes spread all over Uganda, both at national and zonal levels. NARO is committed to generating and disseminating appropriate, safe, and cost effective technologies for sustainable agricultural productivity, economic growth, food security and poverty eradication.

Vision

A market responsive, client-oriented and demand-driven national agricultural research system

Mission

To generate and disseminate appropriate, safe and cost effective technologies

For more information visit; www.naro.go.ug

CHAPTER 1

Governance



“

I, therefore, call for more investment and partnerships in the agricultural sector and research in particular to enhance our potential towards Vision 2040.

Message from the Chairperson NARO Governing Council

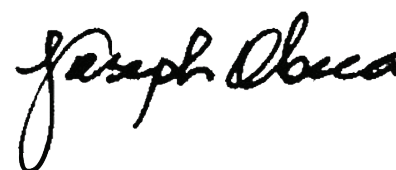
The financial year 2017/2018 was remarkable for NARO with development of cutting-edge scientific innovations for socio-economic transformation. These achievements were guided by the NARO Strategic Plan 2007/8 - 2017/18 which was ratified by the NARO Governing Council as a framework in coordinating our research thrusts.

NARO prides in these milestones and pledges continued commitment in future for the development of this nation through public-private partnerships whose role cannot be underscored.

I, therefore, call for more investment and partnerships in the agricultural sector and research in particular to enhance our potential towards Vision 2040.

On behalf of the NARO Governing Council, I would like to recognize the support from the government of Uganda, development partners

and staff, and thank them for significant contributions to our efforts.



Prof. Joseph Obua
Chairperson, NARO Governing Council

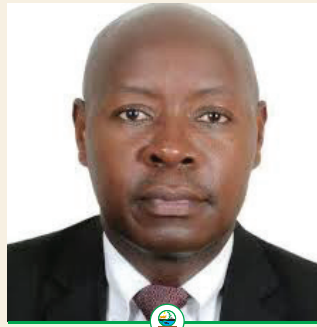


NARO Governing Council



Professor Joseph Obua

Chairperson and Eminent Scientist



Mr. Pius Wakabi

*Permanent Secretary, Ministry for
Agriculture, Animal Industry and
Fisheries*



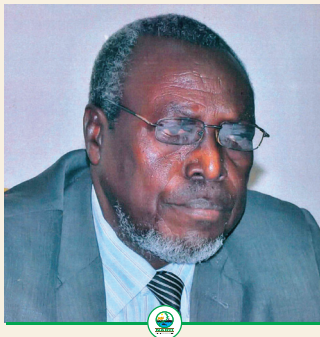
Mr. Titus Kajura

*Representative of the Permanent
Secretary of the Ministry for
Finance, Planning and Economic
Development*



Mr. Haruna Mawanda

*Representative of Uganda Local
Authorities Association*



Capt. Tisasira Esau

*Uganda National Farmers
Federation
Representative of Farmers*



Mrs. Monica Kabatooro

*Chairperson, Hoima District
Uganda National Farmers
Federation
Representative of Farmers*



Mr. Patrick Cheborton

*Chairperson Farmers Forum,
Kapchorwa
Representative of Farmers*



Mrs. Margaret Ebuu

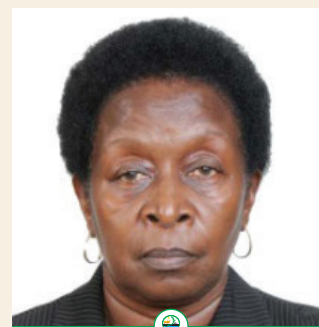
*Uganda National Farmers
Federation
Representative of Farmers*



Hon. Idah Mehangye
Representative of Uganda Non-Governmental Organizations Forum



Dr. William Wagoire
*Director NaCORI
Representative of Public
Agricultural Research Institutes*



Dr. Sengooba Theresa (PhD)
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Mr. Samuel Katambi Mugasi
*Executive Director, NAADS
(Ex-Officio)*



Dr. Ambrose Agona
*Director General, NARO
(Ex-Officio)*



Overall, NARO delivered on all targets set against the key performance indicators for the FY 2017/18.

Message by the Director General, NARO

The overall goal of NARO is to enhance the contribution of agricultural research to sustainable agricultural productivity, economic growth, food security, wealth and job creation through generation and promotion of appropriate technologies, knowledge and information.

The core business is grounded on generation and promotion of Technologies, Innovations and Management Practices (TIMPS) in crops, livestock, fisheries, forestry and integration of Indigenous Knowledge with modern scientific methods including biodiversity conservation, characterisation and bio-prospecting.

During the FY 2017/18, progress was made in plant variety and animal breed genetic improvement; developing improved animal and crop management practices; plant and animal health management; product development and diversification along the value chain; agro-machinery and cross-cutting research areas. Through the Competitive Grants Scheme (CGS), NARO operates a pluralistic research agenda that brings on board the private sector, academia, farmers groups, Non Governmental Organisations (NGOs), and Community Based Organisations (CBOs).

A total of 96 technological innovations were generated, well over the planned target of 80. A total of 41 new varieties were submitted to Variety

Release Committee for possible release to the farming communities. A total of 30 technological innovation platforms were supported to facilitate uptake of improved technologies. A total of 47 Research studies were supported under the CGS to address innovative non-core research area priority interventions. A total of 121 technological innovations were delivered to uptake pathways, over and above the set target of 116.

Overall, NARO delivered on all targets set against the key performance indicators for the FY 2017/18.

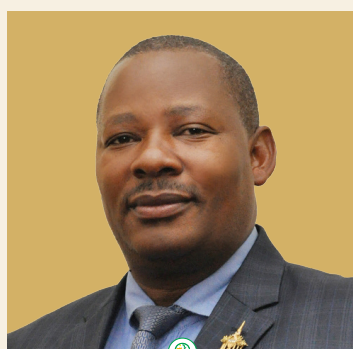
I, therefore, would like to take this opportunity to indulge you in getting details of the accomplishments I have enlisted above in the proceeding sections of this report.

A handwritten signature in black ink, appearing to read 'Dr. Ambrose Agona', with a stylized flourish at the end.

Dr. Ambrose Agona
Director General, NARO



NARO Top Management



Dr. Ambrose Agona

Director General, National Agricultural Research Organisation



Dr. Yona Baguma

Deputy Director General - Research Coordination



Dr. Imelda N. Kashiija

Deputy Director General - Agricultural Technology Promotion



Prof. Justus Rutaisire

Director Corporate Services



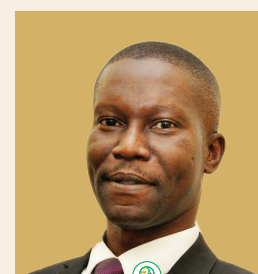
CPA Mary Kiggundu

Director Finance



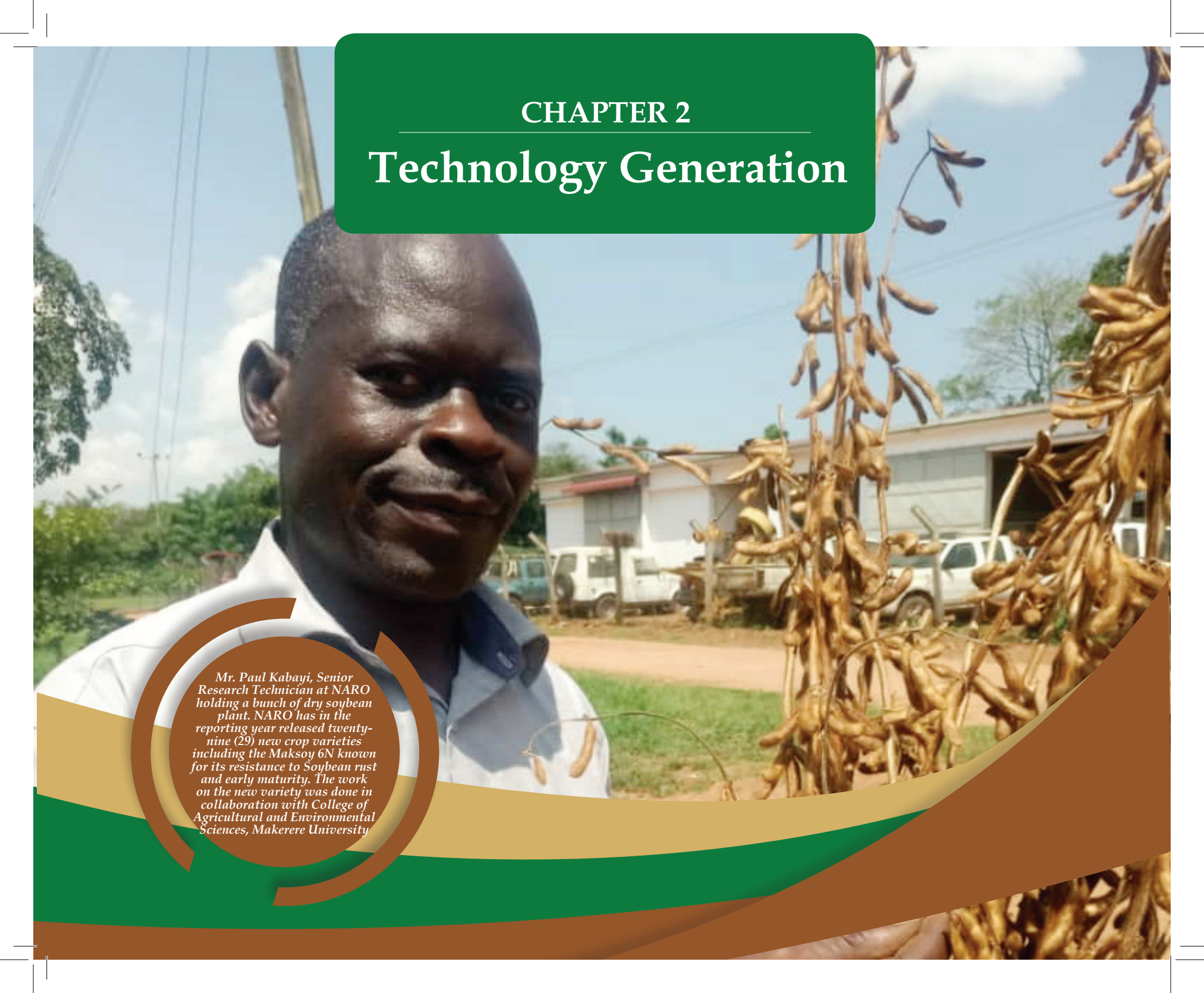
Mr. Robert Bagonza

Director Human Resources



CPA Denis Owor

Head Internal Audit

A photograph of Mr. Paul Kabayi, a man with short dark hair and a light blue shirt, holding a large bunch of dry, golden-brown soybean plants. The background shows a rural setting with a white building, a white pickup truck, and some trees under a clear sky. The image is framed by a green banner at the top and a brown and green wavy banner at the bottom.

CHAPTER 2

Technology Generation

Mr. Paul Kabayi, Senior Research Technician at NARO holding a bunch of dry soybean plant. NARO has in the reporting year released twenty-nine (29) new crop varieties including the Maksoy 6N known for its resistance to Soybean rust and early maturity. The work on the new variety was done in collaboration with College of Agricultural and Environmental Sciences, Makerere University

Crops sub-sector

NARO submitted to the Variety Release Committee a total of forty-one (41) new crop varieties out of which twenty-nine (29) varieties with special attributes including drought resilience, pest and disease resistance, high yielding, enhanced nutritional value and early maturity have been released in FY 2017/2018.

Four banana hybrids released

In November 2017, four (4) East African highland banana hybrids were officially released as NAROBAN1, NAROBAN2, NAROBAN3 and NAROBAN4 common-

ly known as M19, M20, M25 and M27 respectively). The hybrids are resistant to black Sigatoka, tolerant to banana weevils and nematodes with a yield potential of

over 50t/ha/yr which doubles that of their landrace parents which yield 24t/ha/yr. They are acceptable to consumers and increase the plantation life by over 10 years.



NAROBAN1
(54.9ton/ha/yr)



NAROBAN2
(60.4ton/ha/yr)



NAROBAN3
(64.7ton/ha/yr)



NAROBAN4
(68.8ton/ha/yr)

Newly released banana hybrids by NARO

Five improved maize varieties released

The maize bumper harvest experienced by Ugandan farmers during the first season of the 2018 calendar year was not just a mysterious miracle.

Behind the heavy yields is a team of dedicated NARO researchers who worked relentlessly to address key stresses to maize production including, drought, low Nitrogen, economic diseases such as Maize lethal necrosis, and pests such as the fall army worm.

As reported by Knoema, an online data services Cooperation, maize production for Uganda in 2017, was 3.02 million tonnes, increasing from 341,884 tonnes in 1968 and growing at an average annual rate of 6.07 %.

This turn around has widely been associated with the fact that during the FY 2017/2018 NARO focused on supporting and backstopping the development of a vibrant maize seed industry through training, quality assurance, provision of breeder and foundation seed.

In the same year, NARO released a total of five improved varieties to addresses particular constraints at the time of release.

These included three Striga-resistant (IR) hybrids (NAROMAIZE 58-IR, NAROMAIZE 59-IR, NAROMAIZE 60-IR) and two highland varieties (BH31 and BH33) subsequently released as NAROMAIZE731 and NAROMAIZE733 (Table 1).

Table 1: The unique attributes of the released varieties

Variety name	Year of release	Optimal Altitude range	Days to maturity	Yield (tons/ha)	Special attributes
NAROMAIZE 731	2017	1400-2400	144	8.2	MLN tolerance Sweet tasting
NAROMAIZE 733	2017	1400-2400	154	7.2	MLN tolerance Sweet tasting
NAROMAIZE 58IR	2017	1000-1600	120	5.8	Herbicide (Imazapyr) Striga resistant
NAROMAIZE 59IR	2017	1000-1600	125-130	6.3	Herbicide (Imazapyr) Striga resistant
NAROMAIZE 60IR	2017	1000-1600	130	6.7	Herbicide (Imazapyr) Striga resistant

Three coffee wilt disease resistant and high quality clones released

The Variety Release Committee released three (3) of NARO-developed coffee varieties that are coffee wilt disease resistant and high cup quality clones. The varieties NARO KR8, NARO KR9, and NARO KR10 yield 3.1, 3.9 and 4.8 t/ha/year respectively (Table 2). The mean yield is 3.9t/ha/year, which is worth UGX 11.7 million. In collaboration with UCDA, NARO has supported and strengthened coffee nursery operators through the provision of clean seed and planting materials, training and gap filling of coffee mother gardens.

Table 2: Coffee wilt disease resistant and high quality clones

NARO-KITUZA ROBUSTA 8 (KR-8)



Variety Attributes

1. Yield:
 - 3,120kg of hulled coffee per hectare per annum earning UGX 17.2m
 - 5.2 times more yielding and paying than traditional varieties
2. Resistant to coffee wilt disease (CWD)
3. Resistant to coffee leaf rust disease
4. Resistant to Red blister disease
5. Good cup quality (Good flavour, good taste, 73% overall quality grade)
6. Good physical been quality (large, heavy beans, 53 % retained by screen 18/64) and 92% screen 16/64
7. Suitable for cultivation in all areas suitable for robusta coffee growing

NARO-KITUZA ROBUSTA 9 (KR-6)



Variety Attributes

1. Yield:
 - 3,890kg of hulled coffee per hectare per annum earning UGX 21.4m
 - 6.5 times more yielding and paying than traditional varieties
2. Resistant to coffee wilt disease (CWD)
3. Resistant to coffee leaf rust disease
4. Resistant to Red blister disease
5. Excellent cup quality (Good flavour, good taste, 79% overall quality grade)
6. Good physical been quality (large, heavy beans, 12 % retained by screen 18/64) and 78% screen 16/64
7. Suitable for cultivation in all areas suitable for robusta coffee growing

NARO-KITUZA ROBUSTA 9 (KR-6)



Variety Attributes

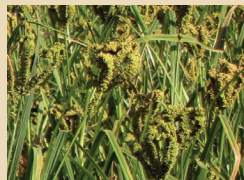
1. Yield:
 - 4,800kg of hulled coffee per hectare per annum earning UGX 26.4m
 - 8 times more yielding and paying than traditional varieties
2. Resistant to coffee wilt disease (CWD)
3. Resistant to coffee leaf rust disease
4. Resistant to Red blister disease
5. Excellent cup quality (Good flavour, good taste, 82% overall quality (premium) grade)
6. Excellent physical been quality (large, heavy beans, 55% retained by screen 18/64 and 86% screen 16/64)
7. Suitable for cultivation in all areas suitable for robusta coffee growing

Five Finger millet varieties released

In a bid to fill up the different genetic gaps in varietal choices finger millet currently available in the country, NARO, in the reporting year, developed five millet varieties, that have been released as; NAROMIL 1-NAROMIL 5. They have the following specific attributes (Table 3):

Table 3: Finger millet varieties released

NAROMIL1	Unique features/description
	Yield: 3-4.1 t/ha Maturity: 100 days Resistant to leaf blast 8-9 fingers per panicle 5-9 productive tillers
NAROMIL2	
	Yield: 2.9-4.07 t/ha Maturity: 102 days Resistant to leaf blast Diastatic Unit: 56.63
NAROMIL3	
	Yield: 2.7-4.4 t/ha Maturity: 110 days Medium tall, and erect Resistant to leaf blast Diastatic Unit: 56.63

NAROMIL4	
	Yield: 2.8-3.7 t/ha Maturity: 100 days Resistant to leaf blast Nutritionally rich grain (12.5% protein) Excellent malting quality
NAROMIL5	
	Yield: 2.6-3.5 t/ha Maturity: 100 days Drought Stay green Good brewing Resistant to leaf blast Diastatic Unit: 57.3

Six multi-stress tolerant cowpea varieties released

Six cowpea varieties NAROCOWPEA 1- NAROCOWPEA 6 have been released. The six are high yielding, between 2,100 to 2,200 kg/ha, drought tolerant and resistant to virus, scab, yellow blister and bacterial blight.



Cowpea resistant varieties yielding 1.5-22, expected to increase yields by >30%

New soybean variety released as Maksoy 6N

Considering that soybean contains at least 100% more proteins with yields of 5-10 times more protein per unit area than any other crop (Tukamuhabwa and Obua 2015) and with the readiness of technology for processing soybeans at industrial and household level, the crop has become one of the most promising food crops available to improve the diet of millions of people around the world.

In the FY 2017/2018, NARO in collaboration with Makerere University generated Maksoy 6N soybean variety bringing it to a total of seven improved recommended varieties



Maksoy 6N: Resistant to Soybean rust, matures in 93 days, yields 2-3.5 tons/ha/ and oil content of upto 20%.

released in Uganda since 2004. The Maksoy 6N has an advantage over the earlier released varieties because of its consolidated attributes of resistance to soybean rust disease, lodging and pod shattering, early maturity, high oil content, high protein content and high grain yields.

New varieties are continuously being produced and, therefore, it is important to keep up to date with their attributes as there is always an advantage over the old varieties. The comparative characteristics of released soybean varieties being grown by farmers in Uganda are presented in Table 4.

Table 4: Characteristics of commercial and recommended soybean varieties released in Uganda

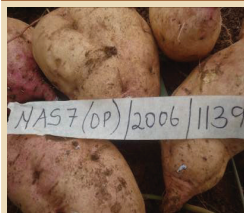
Attributes	Maksoy 1N	Namsoy 4M	Maksoy 2N	Maksoy 3N	Maksoy 4N	Maksoy 5N	Maksoy 6N
Year of release	2004	2004	2008	2010	2013	2013	2017
Soybean rust resistance	Resistant	Resistant	Tolerant	Very Resistant	Resistant	Resistant	Resistant
Stature	Short	Tall	Tall	Tall	Tall	Tall	Tall
Lodging	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
Maturity (Days)	90	100	105	100	103	96	93
Pod shattering	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant	Resistant
Seed/hilum colour	Cream/Brown	Cream/Black	Cream/Cream	Cream/Light brown	Cream/Grey	Cream/Black with white slit	Cream/Black
Seed size	Small	Large	Large	Large	Large	Large	Large
Seed storability	Very good	Good	Good	Good	Good	Good	Good
Yield (tons/ha)	2-3	2-3	2-3	2-3.5	2-3.5	2-3.5	2-3.5
Protein content (%)	41	43	38	36	38	38	41
Oil content (%)	17	20	20	22	21	19	20

Source: Phinehas et al, 2015

Five improved sweet potato varieties released

NARO has continuously released several sweet potato varieties mainly aimed at addressing nutritional deficiencies, enhancing pest/diseases resistance, resilience to changing climate, and responding to the dynamic consumer needs. For the FY 2017/2018, five (5) improved varieties were released and their unique attributes are indicated in Table 5.

Table 5: Key attributes of the released varieties

Image	Attributes
NAROSPOT 1	
	Root yield (t/ha): 32 t/ha Maturity (Months): 4-4 ½ Resistance to diseases: Moderate to SPVD, resistant to Alternaria Dry matter (%): 35.1 Root skin color: Purple red Flesh color: Cream
NAROSPOT 2	
	Root yield (t/ha): 14 t/ha Maturity (Months): 4-4 ½ Resistance to diseases: Moderate to SPVD, resistant to Alternaria Dry matter (%): 34.2 Root skin color: Purple red Flesh color: Cream
NAROSPOT 3	
NAROSPOT 4	
	Root yield (t/ha): 22 t/ha Maturity (Months): 4-4 ½ Resistance to diseases: Moderate to SPVD, resistant to Alternaria Dry matter (%): 35.2 Root skin color: Purple red Flesh color: Cream
NAROSPOT 5	
	Root yield (t/ha): 19 t/ha Maturity (Months): 4-4 ½ Resistance to diseases: Moderate to SPVD, resistant to Alternaria Dry matter (%): 35.8 Root skin color: Purple red Flesh color: Cream

NARO and partners support increased rice production in the refugee-hosting communities of West Nile

NARO through National Crop Resources Research Institute (NaCRRI) and Abi Zonal Agricultural Research and Development Institute (Abi ZARDI) in collaboration with development partners; the Japanese Government, Danish Refugee Council and the United Nations High Commissioner for Refugees (UNHCR) launched programmes to support increased rice production, which in turn would avert famine, improve food security, and improve household incomes in the refugee camps and refugee hosting communities in northwestern Uganda (Arua, Adjumani and Koboko and Yumbe districts).

Through Abi ZARDI, NARO with the support received from the Japanese government and in collaboration with UNHRC, was engaged in increasing rice seed (NERICA 4) production on-station. Rice seed from Abi ZARDI was distributed to refugees' camps and refugee hosting communities. Abi ZARDI has also been providing technical backstopping to the Farmer Field School in Miyeri village, Adjumani district.

This is an establishment by JICA PRiDe project that is being implemented in partnership



Officials from Embassy of Japan in Uganda and UNHCR checking out a tractor they donated to NARO at Abi ZARDI under the JICA-UNHCR-Abi ZARDI partnership to support refugee livelihoods in West Nile region

with the Danish Refugee Council.

In the last two years, Abi ZARDI produced rice seed from 4 ha for distribution to the communities through various channels. The rice seed has been distributed in Rhino camp Subcounty, Arua District; Lobule Subcounty, Koboko district; Ofua Subcounty, Adjumani district.

Technical backstopping was conducted in Ofua Subcounty, Adjumani district. NACRRI provided rice breeder seed and developed the extension information materials utilized during the training of trainers (TOTs) and training of farmers. Under the Rice PRIDE project, the national rice growing area expanded to 18,194 ha. The national annual rice (paddy) production increased to 49,809 tons

Forestry sub-sector

Forest cover in Uganda is faced with several challenges, key among them is deforestation. In this subsection we present achievements NARO has made during the FY 2017/2018 in an effort to increase the country's tree cover, improve household incomes and meet the ever increasing demand for construction materials and fuel wood.

Biomass-energy saving stove developed

NARO developed a more efficient option for utilising home-based biomass energy in Uganda. The biomass energy saving stove simultaneously produces charcoal and combustible gas (producer gas) from any dry biomass matter.

The gas is initially used in cooking while char may be used to enrich soil fertility, make briquettes or cook food in an ordinary charcoal stove. The stove operates with reduced carbon emissions of 8.3 ± 2.18 ppm carbon monoxide, a very poisonous gas, falling within 8-hour permissible limits of 9 ppm, according to the World Health Organisation (WHO) guidelines for indoor air quality (WHO, 2010) and high thermal efficiency of 25 to 30%.

It cooks twice as fast as conventional stoves used in over 80% of Uganda's households and uses 60 to 70% less wood fuel. This stove practically contributes



Biomass cooking stove

to reduction on deforestation rates, fire-wood scarcity and indoor air pollution. Replacing traditional stoves with this kind of stove by 100% would lead to 60

to 70% reduction in deforestation caused by increased demand for fuel wood. The biomass was granted Utility Patent No.UG/U/2018/000003

Profitability of clonal eucalyptus determined

Investment in one hectare (ha) of clonal eucalyptus growing for either construction poles or transmission poles in perpetuity and being harvested on a 3 and 8 year rotation period can earn a present value of perpetual periodic payment of UGX 5,744,199 and UGX 29,696,410 respectively at 10 % interest rate (Table 6).

Investment in 1 ha of eucalyptus landraces harvested on a 4-year rotation period can earn a present value of perpetual periodic payment of UGX 4,553,162 (Gombya Ssembajjwe, 1999).

Table 6: Present values of clonal eucalyptus under different management objectives

Area (1 ha)	Construction poles (UGX)	Transmission poles(UGX)
<i>Establishment</i>	1,604,000	1,254,300
<i>Maintenance</i>	334,670	785,217
<i>Revenue</i>	3,840,000	36,000,000
<i>Perpetual periodic annuity @10 %</i>	5,744,199	29,696,410

Farmers will earn more from investing in clonal eucalyptus plantations given the short payback period compared to using eucalyptus landraces.

Herbal hand and body lotion developed

NARO formulated and produced a herbal lotion from a plant resource.

The herbal lotion contains antimicrobial agents that reduce and prevent pathogenic micro-organisms on skin surface and prevent excessive microbial recolonization of the skin after considerations.

This lotion is made on the strength of natural plant extract that has the ability to sanitize and disinfect the skin without causing any skin irritation.

In addition, the lotion inhibits growth of spoilage organisms in the product during storage, making it self-preserving.



NARO-CARIS hand and body Lotion

Optimal carbon absorption capacity of planted forests established

Uganda has an estimated 100,000 ha of plantation forests, comprising mainly of pine and eucalyptus. However, only 0.5% of these forests generate revenue from trade in carbon.

In efforts aimed at enabling tree farmers to benefit from this untapped resource, NARO investigated optimal carbon sequestration (absorption) capacities for *Pinus caribaea* and Clonal Eucalyptus with ranges from 29.3-46.5 and 18.5 -55.5 metric tonnes of carbon

dioxide sequestered per hectare per year respectively.

This translates into revenue of between UGX 342,250 - 1,026,750 to 542,050 - 860,250 per hectare per year for pine and eucalyptus farmers.

Inadequate policy designs, weak institutional linkages, unclear subsidies, asymmetrical information on baselines, above-ground carbon sequestration and costs of carbon se-

questration, high transaction costs in carbon insecure property rights, have for long prevented most commercial tree growers from benefiting from carbon trade.

For Uganda to promote sustainable carbon plantation forestry for improved livelihoods, the country needs to put in place a cost-effective carbon policy design that engenders stakeholder participation, equity in benefit-sharing, and collective actions to reduce carbon transaction costs.



NARO Scientists taking an inventory of clonal Eucalyptus plantation in Mayuge District.

Six hectares of degraded forest rehabilitated in Mukono

NARO rehabilitated and restored 6 hectares of unproductive and degraded forest land using various species of Bamboo at Kifu in Mukono District.

After 15 months, the canopy closure was

75%, 60%, 45%, and 15% for *Dendrocalamus giganteus*, *Bambusa vulgaris*, *Dendrocalamus strictus*, and *Phyllostachys aurea* respectively. This demonstrates a high potential of Bamboo to restore degraded sites.

Investment in bamboo for culms

Established that investment in bamboo for culms (poles) at an interest rate of 10% is profitable based on a positive Present Value (UGX 5,979,093) of a perpetual periodic payment.



15 months-old *Bambusa vulgaris* in the restored forest at Kifu in Mukono District



Livestock sub-sector

According to FAO 2018, the livestock sector can contribute directly or indirectly to each of the SDGs: strengthening the assets that rural households use to achieve their livelihood objectives; helping to generate income; supporting the creation of employment opportunities; providing the world with sufficient and reliable supplies of meat, milk, eggs and dairy products, among others. In another report FAO estimates that livestock contributes over 5 percent of Uganda's GDP (FAO 2005). Below are some of the key achievements by NARO for improved livestock productivity in the FY 2017/2018.

Out-scaling artificial insemination in pigs

With the per capita consumption at 3.5 kg, Uganda is the biggest consumer of pork in Africa and second to China globally according to Dr. Ben Lukuyu, a nutritionist and the Uganda country representative of the International Livestock Research Institute, (The New Vision, and December 7, 2016).

In order to meet the insatiable demand for pork, NARO has come up with a new innovation of artificial insemination of pigs for timed and multiple births leading to an increased income for farmers. Unlike artificial insemination in cattle where there is use of frozen semen, the technology in pigs takes use of fresh semen which can be preserved for three days under a minimum temperature of 16°C.

A survey done by NARO in collaboration with Makerere University in Kabarole district in 2016 indicated that breeding in pigs was limited to natural methods (mating) where 72.2% is uncontrolled and 28.8% is controlled.

Uncontrolled breeding where the sow mates with boar as and when the opportunity presents itself while under controlled breeding a farmer hires a good breed of a boar to mate with the sow. The current dominant breeding methods (uncontrolled Natural breeding) are a limiting factor which is being addressed through Artificial insemination (AI) technique.

Artificial insemination technology in pigs

has given a litter size of up to 12 piglets with a single dose as opposed to natural breeding methods that can give a litter size of 5-10 piglets depending on management practices.

In AI, a well-maintained breeding boar for semen collection can be used at least once a week before a second semen collection is done. While a single ejaculation (collection round) of a boar can give 10 doses of extended semen.

This demonstrates that each ejaculate can serve 10 sows/gilts on heat thus maximum use of good breeding boar when using this technology other than the use of natural methods

Boosting goat productivity in Karamoja

It is estimated that 80% of households own livestock in Karamoja sub-region, with 16% of the national goat population coming from this area (Uganda Investment Authority- Karamoja Profile, 2016).

The region has vast areas of land for grazing and browsing, offering a great opportunity for investment in goat production to meet the growing demand for meat in the local, regional and international markets.

Although Karamoja goats are relatively tolerant to drought and diseases, the goats suffer from diseases/conditions, namely diarrhea caused mainly by worms and coccidiosis (especially in the wet season), skin diseases, brucellosis (leading to abortions) and pneumonia. This leads to deaths, reduced live market weight and an increase in costs of control and treatment. NARO scientists have identified constraints to indigenous goat production; as limited knowledge on prevention, control and treatment of diseases, feeding, breeding and housing.

Thus, NARO undertook research and development on improvement of the productivity of goats through the introduction of Mubende goats in the region.



Training livestock keepers in Karamoja sub-region on good management practices for various goat breeds to improve goat productivity. Mubende goats (in the foreground) have adapted well to the relatively high temperature and humidity in the region.

The goats were introduced and assessed for adaptability and productivity in the region; and their live mature weight has been found to be 31 to 35 kg, compared to other Small East African goats, which weigh 20-25 kg with a good twinning rate of 77-80%. They have adapted well to the relatively high temperature and humidity in Karamoja, and the scarce feed resources in the dry season with an increase in number from 13 to 52 since their introduction in February of 2017.

The Mubende goats have also been dis-

seminated to the farmers by availing start-up stock for breeding. This has led to an increase in size of goat herds for regular and quick cash income for livestock keepers

In 2008, NARO in collaboration with Makerere University introduced Mubende goats in west Nile region and they have been widely adopted.

Training livestock keepers in Karamoja sub-region on good management practices for various goat breeds to improve goat productivity continues.

Aflatoxin-sequestering feed additives for contaminated livestock feed in the offing

The productivity and profitability of intensive dairy and poultry industries in Uganda is currently undermined by the detrimental effects of aflatoxicosis; a syndrome resulting from ingestion of feeds contaminated with aflatoxins. Most of the feed manufacturers in Uganda tend to use mould infested ingredients in maize bran and germ, cotton seed cake, soya bean and silver fish (Mukene) among others all of which are suspected fungal and aflatoxin contamination.

Earlier studies on the safety of commercial feeds by Scientists from Makerere university's food bioengineering department indicated that, the mean aflatoxin concentration in broiler starter, broiler finisher, layer mash and dairy meal was 40.5 parts per billion (ppb), 42.8 ppb, 67.5 ppb and 6.4 ppb, respectively. These concentrations are significantly higher than 20 ppb, the critical aflatoxin concentration beyond which feeds are considered unsafe for animal consumption. Ingestion of feeds containing such alarming levels of aflatoxin is associated with growth depression owing to reduced feed intake, impaired nutrient utilization and decline in feed quality.

It is estimated that with each mg/kg in-



Poor feed storage facilities, a source for mycotoxin contamination

crease of Aflatoxin the diet, the growth rate for broiler birds would be depressed by at least 5%. In laying birds, aflatoxicosis reduces egg production and egg size by 10% and 5%, respectively. In addition to impairing semen quality, aflatoxins are immune-suppressants and aflatoxicosis has been noted to escalate the susceptibility of birds to infectious diseases such as Newcastle disease.

In terms of carcass quality, broilers fed diets contaminated with aflatoxins often have low dressed weight with the carcass containing less fat and protein. In dairy cattle, aflatoxicosis leads to feed refusal, reduced growth rates, decreased milk production and decreased feed use efficiency. Such detrimental effects of aflatoxicosis on ani-

mal growth, immune systems and carcass quality translate into low productivity and market value and hence low profitability of products of intensive livestock production systems.

The exposure of livestock to feed loaded with these toxins therefore means loss of money in poultry and dairy industries and the country at large. Once formed, it is difficult to destroy Aflatoxins thus necessitating the invention of an efficient and cost-effective method to detoxify them if detected in feedstuffs. The most worrying bit is that, the aflatoxin in livestock feed leads to excretion of aflatoxin metabolites into livestock products such as milk and eggs, hence exposing consumers of these products to possible cancer infections. The problem of Aflatoxicosis is reflected in a report by UN's Food and Agricultural Organisation which indicates that, over 60 countries have either legislation or proposed legislation for the control of mycotoxins in both human and animal feed.

In an attempt to alleviate aflatoxicosis and consequently boost livestock productivity and ensure safety of livestock products to consumers, NARO embarked on a con-

trolled feed safety research aimed at exploring the potential of two binder prototypes with exciting aflatoxin sequestering and suppressing abilities in poultry and dairy animals, alongside the commercially available feed additives. NaLIRRI has since recommended two prototype binders code named NARO-UGAB-1 and NARO-UGAB-2 and has developed a protocol for processing the binder and incorporation into livestock feeds that effectively targets the toxins to bind them and deter their absorption into body tissues.

It was established that by incorporating aflatoxin binders, NARO-UGAB-1 and NARO-UGAB-2 at 1-2% in broiler and layer feed contaminated with experimental aflatoxin results into improved feed intake, weight gain, Feed and Protein efficiency ratio in both broilers and layers as well as hen day egg production, intake per kg of eggs and egg mass per bird.

Most importantly, addition of aflatoxin binders to the contaminated diets resulted into improved immunity against the most economically Important diseases in Uganda as well as the size of important internal body organs of the experimental birds. Generally, the type of binder and its inclusion level significantly increased geometric mean anti body titres for Newcastle and infectious bronchitis by about 60% and 50% respectively. In terms of weight of important internal organs, the relative weights of the liver increased by 27.5% and 28.4% while that of the kidney increase of 21.8% and 21.7% was obtained with UGAB-1 and UGAB-2 inclusion.

On the other hand, incorporation of the adsorbents at 2.0% inclusion level reduced total tissue aflatoxin carry over to nearly undetectable levels in the liver and kidney tissues. It was thus concluded that Addition of aflatoxin binders obtained from Uganda to the contam-

inated diets resulted into improved performance and immunity against Newcastle and Infectious Bronchitis, and alleviated aflatoxin carry-over into tissues, thus making animal product safe for human consumption.

“For a long time, food and crop scientists have been tackling the aflatoxin challenge in food crops with little or no tangible progress in the livestock sector. We are excited that NARO has effectively implored the use of biotechnology tools to test the additives and we hope the results may offer a chance to address the mycotoxin contamination challenges. We call upon the Ministry of Agriculture Animal Industry and Fisheries as well as Uganda National Bureau of Standards to take advantage of the results in their efforts to operationalise the Animal feeds policy,” says Dr. Mugerwa Swidiq, the Director of Research, the National Livestock Resources Research Institute (NaLIRRI).

A rapid a diagnostic kit for African swine fever in the offing

African swine fever (ASF) is a highly contagious viral disease of swine with no effective vaccine or cure and therefore requires quick detection to enable cultural control measures.

Although several diagnostic tests are commercially available for the detection of ASF, majority of them are expensive or require

highly skilled personnel.

In order to address these challenges, NARO has therefore developed a lateral flow assay (LFA) for quick detection of African swine fever virus (ASFV) antigen in the field. The kit is specific, simple, robust and reliable, hence could be used for rapid diagnosis of ASFV especially under field conditions.

However, the assay could further be optimized to improve its performance and validation using a large sample size (>500) to evaluate the sensitivity, specificity, predictive values and reliability. This developed lateral flow assay could be a useful tool for ASF control programs and supporting poorly equipped laboratories.

Fisheries sub-sector

The fisheries sector of Uganda has enormous potential to contribute towards national development goals, yielding benefits to communities, the private sector and the state through incomes, profits and public revenues. In this chapter, we highlight key achievements in fisheries research during the FY 2017/2018.

Bio-control agent to improve fish health management developed

Intensification of aquaculture systems is increasingly challenged with disease incidences, thereby reducing income to producers. Farmers, therefore, apply chemo-therapeutants to prevent or treat fish diseases but considered unsustainable practice. Recent sustainable control strategies include the application of bio-control agents like plant extracts. Of four indigenous plant extracts with antibiotic and anti-oxidant properties evaluated to control infectious

fish pathogen (*Aeromonas hydrophilus*), one plant extract (*Plant N**) emerged the best with a potential to reduce fish pathogen (*A. hydrophilus*) cells by 30% and improves survival rates of farmed Nile tilapia fingerling ($4.97 \pm 0.42\text{g}$) by 10% when fed with fish feeds infused with *Plant N* extract. Furthermore, under controlled conditions, infected Nile tilapia juveniles could survive longer (65-83%) with improved health when raised on infused *Plant N* feeds (1% replacement)

for more than 8 weeks. Therefore, *Plant N* is a good biological control candidate for *A. hydrophila* infections of farmed Nile tilapia. Future research will focus on up-scaling this technology with producers (especially hatcheries) and evaluate mechanisms in 25 which *Plant N* extracts improve health (e.g. gene expressions), productivity (yields in ponds and cages) and profitability of farmed Nile tilapia and African catfish.



Left to right: Infected Nile tilapia not fed with *Plant N* extract; healthy fish exposed to pathogen, and fed 1% *plant N*; and infected but healing tilapia juvenile fed 0.5 % *plant N* extract

*N** acronym is a safeguard for Intellectual Property Rights

Fishers earning big from bee keeping and mushroom growing as alternative livelihood options on Lake Edward

In a bid to reduce the burden on Ugandan waters due to high levels of dependence on fishing, NARO is stepping up efforts to diversify livelihood sources in fisher communities. In order to examine the viability of the diversification, beekeeping, and mushroom growing were piloted on Lake Edward in the FY 2017/2018. A total of 41 males and 38 females farmers were involved in the mushroom pilot whereas 57 males and 32 females were involved in the beekeeping pilot.

The options were deemed suitable especially for fisher communities who do not own ample land at fish landing sites and can generate relatively better earnings compared to that from fisheries. For example, with a start-up capital of about UGX 500,000, mushrooms can generate a profit of about UGX 2,375,000m in three months.

Pilot-follow up studies indicated that members who had adopted bee keeping were: 3 females and 12 males for Kishenyi, 8 females and 16 males for Kayanja, two males for Kazinga whereas for mushrooms, it was two males at Kazinga. 57.7% fishers who were engaged in piloted-livelihood options had reduced the number of days spent doing

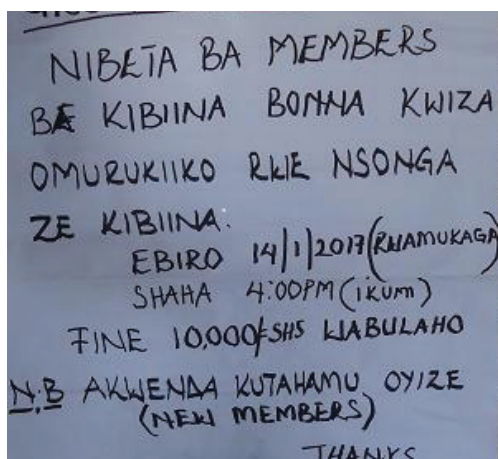


Pilot of Mushroom gardens at Kayanja at, Kazinga

fisheries activities from 6 to 3.

Earnings from livelihood options had been used to pay school fees (40%), enhancing food security (20%), house construction (13.3%) and land acquisition (13.3%). The study recommends integration of livelihood

options into the Operation Wealth Creation (OWC) and District Production plans. In addition, livelihood options should be promoted along other fisheries law enforcement mechanism especially the ones that may reduce the number of people depending on the fishery



Notice of call for mushroom growers meeting



Hives belonging to individuals at a landing site



Some hive products in which fishers acquired skills

Recovery of fish stocks on Lake Victoria on the increase

Fisheries stock monitoring on Lake Victoria between 2012 and 2017 aimed at providing information on status of fish stocks in terms of sustainable biomass, effort and yield/catch; to guide planning and management decisions.

Substantial increase in both the legal and illegal fishing effort, with a corresponding decline in stock biomass and catches of the major commercial fisheries was observed.

The fishing crafts almost doubled from

15,544 to 30,390 (95.5%) between 2000 and 2016 while the fishing crew increased from 34,889 to 66,869 (91.7%). The gill-nets and long-line hooks increased from 297,663 and 1,276 to 407,051 and 6,336, respectively. The study determined the Maximum Sustainable Yield (MSY) and allowable (optimal) fishing effort (number of boats) on Lake Victoria for the three-commercial species as follows; Nile perch (47,367 tonnes and 10,882 boats), Mukene (91,335 tonnes and 6,003 boats) and Nile tilapia (12,848 tonnes and 6,204 boats).

These recommendations based on MSY and number of boats are being enforced by the UPDF Fish Protection Unit, whose efforts have resulted into recovery of Nile perch stocks from 393,353 tonnes in 2016 to 457,248 t (18%) in 2017. These interventions if strengthened and sustained are envisaged to fast-track the recovery of stocks of the major commercial fish species in the lakes, hence improve the catch landings, economic revenue and employment opportunities for the youths and women engaged in the fisheries sector.

Appropriate harvesting technologies established for Angara and Ngassia on Lake Albert

The multi-species nature of Lake Albert may demand a species-specific management strategy for the exploited stocks. The diverse exploited species mature at varied sizes/lengths thus require different harvesting technologies in terms of gears, gear sizes and methods of operation.

The under-size (< 4 inches or < 101.6 mm) gillnets on Lake Albert have increased by 31% from 56,600 and the fishing crafts by

45% from 5,766 between 2007 and 2016. The increase coincided with a drastic decline in the commercial catch landings of Angara (*Alestes baremose*) and Ngassia (*Hydrocynus forskahlii*), the main target by these under-sized nets.

The two species previously contributed over 80% to the commercial catches in the 1980s but substantially reduced to < 10% by 2014. The gear selectivity experiments of

this study therefore determined and recommended the 76.2 mm (3 inch) gillnet mesh size for harvesting the two declining species on the lake, to be operated in the deep open waters (> 20 m).

Adoption of the proposed gill-net mesh size and a reduction in effort targeting the two species will facilitate their recovery and boost their contribution to the commercial landings.

Profitability indices for aquaculture enterprises developed for Western and S. Western Uganda

In western Uganda, fish farmers were found to be making losses on tilapia-only ponds of UGX -2,683,654 and catfish only ponds of UGX -1,507,236 but made gross profit on mixed tilapia and catfish ponds of UGX 6,604,203 per production cycle.

The average break-even point per production cycle for a tilapia only pond was 3,855 kg, 1,794 kg for a catfish only pond and 1,112 kg for a mixed tilapia/ catfish pond. The payback period was one production cycle for mixed tilapia and catfish ponds. In South Western Uganda, gross profit per production

cycle was UGX 1,061,085 million for mixed tilapia/ catfish ponds, 829,177 for tilapia only ponds. Break-even points were 1,020 kg for mixed ponds and 1,300 kg Pay-back period was 1.6 production cycles for tilapia only ponds and 1 for mixed species ponds.

On average, cage farmers were making a profit ranging from UGX 6,000,000 to 8,605,000 per production cycle per cage depending on the size of investment, quality of feeds, quality of seeds and cage management. The average break-even point per production was 3,248 kg and

subsequent payback period was 1.5-production cycle for tilapia, the species farmed in cages. The cost of cage materials was still high ranging from UGX 3,500,000 to 5,000,000/= per cage depending on the size of the cages. These achievements are expected to result into improved enterprise selection among fish farmers, in terms of species or their combinations selected and levels of production that are profitable. These could in turn lead to improved incomes for fishers and fish farmers and increased returns on investments for fishing and fish farming enterprises

Technology for weaning African catfish larvae developed

African catfish is an important farmed fish species but most hatcheries in Uganda experience low productivity due to poor survival (less than 10%) and growth of catfish larvae/fry mainly due to inappropriate feeding. Most farmers use egg yolk which negatively affects water quality and dry feed that larvae are incapable of digesting because their digestive system is not well developed.

Live food organisms are appropriate for fish larvae/fry as they contain enzymes that facilitate digestion.

A technology for sustaining mass production of live feed (Moina) for nursing African catfish larvae and a protocol for utilising them in commercial hatcheries were developed.

Nursing period of larvae to fingerlings

was shortened from 3 to 1.5 months with use of Moina and a sevenfold increase in fry production and sales attained on-farm.

Weaning starting on day 9 after hatching with feed ration of 75% live feed and 25% dry feed, day 10 with 50% live feed and 50% dry feed, day 11 with 25% live feed and 75% dry feed and thereafter 100% dry feed in the diet.

Fish feed technologies for enhanced productivity and profitability of Nile tilapia formulated

Protein requirements for fish are higher than those of terrestrial animals and protein ingredients are the most expensive feedstuffs, largely determining feed price. Feed constitutes over 50% of aquaculture production costs. In Uganda, the commonly used feed protein source is silver fish or Mukene (*Rastrineobola argentea*).

Availability of Mukene is seasonal and prices have risen over the years due to competition with human consumption and livestock production.



Feed production at ARDC Kajjansi feed mill

Plant protein sources were evaluated for their suitability as partial replacement for Mukene in fish feed.

Two cost-effective plant-based protein feeds for Nile tilapia (powder and pellets) were developed and are in production at the Aquaculture Research and Development Centre (ARDC) Kajjansi feed factory and accessed by farmers countrywide. The ARDC will continue to ensure quality and cost-effectiveness of the diets.

Progress on Kariba Weed management

*The Kariba weed scientifically known as *Salvinia molesta* is an invasive water weed native to South America. It is rated as one of the world's worst aquatic weeds and is widespread in tropical regions of the world including many countries in Africa having been first reported in Zambia's Kariba dam hence the common name 'Kariba Weed'.*

In Uganda, the weed was first noticed in Lake Kyoga in 2013 where it first appeared as plantlets on the water surface but has since multiplied rapidly to cover the entire Kyoga-Nile-Albert water complex. Unlike most aquatic weeds that produce seeds through flowering, Kariba weed is a fern hence multiplies through spores and broken plant parts and therefore has a potential to multiply rapidly. The weed forms dense mats thereby choking water thus affecting aquatic life in addition to interfering with water transport, fishing and power generation besides affecting spawning grounds where fish lay their eggs.

Besides, the dense mats rot and reduce water quality for domestic use and animals and offer excellent environment for breeding of vectors of diseases like bilharzia and malaria. The invasion of Kariba weed in Lake Kyoga is a reminder of the threats and dangers of invasive species having experienced the devastating impact of water hyacinth several years

ago. NARO over the years has built considerable experience to deal with threats of invasive species.

Progress made

NARO conducted a socio-economic survey on the impact of Kariba weed on the fishing communities of Lake Kyoga. It was established that kariba weed affects water abstraction to fishing communities and their livestock, it affects fishing in the lake and blocks water ways.

NARO embarked on the management of the Kariba weed through the importation of the known biological control agent, *Cyrtobagous salviniae*. A total of 714 adult weevils were imported from South Africa in February 2017 and consequent generations of the bio-agents have been reared in tanks in Namulonge and periodically released in various points in Lake Kyoga following MAAIF laid down protocol.

NARO set out to determine current status and distribution of *Salvinia molesta*

in water bodies in Uganda. And the occurrence and infestation levels of Kariba weed in water bodies determined and mapped. Field surveys were conducted on water bodies including wetlands in the Kyoga lake basin and catchment areas. Of the 15 areas visited, Kibimba dam (Bugiri district), Leye dam (Kole district), Abuket (Ngora district), Okole wetlands (Oyam district) were heavily infested with the Kariba weed. Surveys will be a continuous activity to identify and guide future releases for *Cyrtobagous* weevils in water bodies.

NARO has engaged affected fishing communities to participate in the biological control of *Salvinia molesta*. At Morem fishing village in Kaberamaido district, the fishing communities were sensitized on status of the Kariba weed in Lake Kyoga, and their role in regard to biological control of the Kariba weed. Another meeting was conducted in Namasale fish landing in Amolatar district. A similar sensitization meeting was conducted for local



Kariba weed infestation at Kibimba dam (left), Abuket bridge (middle) and Leye dam (right)

government staff of Amolatar district this is to gain support and supervision to fishing communities.

NARO has trained beach management units on bio-control and management of Kariba weed. At Kibimba Rice Irrigation

Scheme, five workers of the scheme were mobilized and trained in mass rearing of the *Salvinia* weevils. The training was conducted on techniques for establishing a mass rearing facility as well as a brief introduction on the life cycle of the weevils. Students from St Mary's Secondary

School (Lugazi) were also trained on biological control of the Kariba weed.

NARO has a constructed, operationalized and maintained a number of lake-side weevil rearing units. The overall plan is to establish one lake shore rearing



A sensitization meeting for fishing community at Morem landing site, Kaberamaido district


Training of workers on the process of rearing the *Salvinia* weevils at Kibimba

Training of students on mass rearing of the *Salvinia* weevils at Kibimba

facility in each district bordering Lake Kyoga and Lake Albert in order to boost weevil production by communities. Procurement of construction materials is ongoing in an effort to equip each district bordering Lake Kyoga, Lake Albert and Albert Nile with at least one community weevil rearing facility.

Two rearing facilities one at Morem and Namasale fish landings in Kaberamaido and Amolatar districts respectively and the Namulonge rearing facility were refurbished. It involved repair of leaking tanks and refilling with clean water and fresh *Salvinia* plants. At Kibimba, the water tank that had been redundant for a long time was refurbished and filled with water and fresh *Salvinia* plants that

were infested with the weevils. Two attendants have been recruited to maintain each lakeshore rearing station at Morem and Namasale landing sites as well as Kibimba to ensure the stations are properly maintained. The stations are now capable of producing weevils for field releases.

NARO has planned to release adequate quantity of *Cyrtobagous* weevils in water bodies to manage *Salvinia molesta*. A breeding stock of adult weevils at Namulonge was established and maintained. The breeding stock comprising of 5,000 adult weevils. A total of 400 adults were collected to



Rehabilitation of weevil rearing facilities at lakeshores (left), Kibimba (middle) and Namulonge



Ongoing weevil multiplication at rearing facilities: Lakeshore weevil rearing facility (left), Kibimba weevil rearing facility (middle) and Namulonge rearing facility (right)

restock each lakeshore rearing station at Morem and Namasale fish landings and 620 adults to restock the Kibimba rearing tank. The Mass production of *Cyrtobagous* weevils was revived at two lakeshore rearing facilities in Lake Kyoga to compliment the on-going weevil production at the Namulonge rearing facility. At Kibimba, it is estimated that at least 1,000 *Cyrtobagous* insects are bred monthly from each rearing facility for field releases.

Mass releases of weevils were conducted on weed mats at various sites in water bodies. A total 681 adult weevils were collected from the Namulonge rearing facility and released in Kibimba dam, 500 adults were released in each rearing tank at the lakeshores, 400 adult weevils were released in Kole dam, 400 adult weevils were released in Namasale in Lake Kyoga and 1000 adult weevils were released at Kibuya in Lake

Kyoga. In addition, the immature weevils were released in *Salvinia* plants from both the Namulonge and lakeshore rearing tanks onto weed mats in Lake Kyoga.

NARO conducted a weevil impact monitoring on a number of sites. A post release visu-



Baseline weed cover on the water surface in Okole swamp, Apac district in May 2017



Water surface in Okole swamp becoming clear of *Salvinia* weed mats by December 2018

al survey at one release site in Okole swamp in Apac district which drains into River Nile showed visible symptoms of impact where 100 weevils were released in May 2017. The weevil feeding caused rotting and sinking of the weed. By December 2018, the water surface was becoming clear of *Salvinia* weed infestation.

Challenges in the fight against Kariba weed.

NARO has met some challenges as listed below;

- Lack of inputs for maintenance of lakeshore rearing stations
- Lack of motivation for trained workers to manage rearing stations
- Managing lakeshore weevil rearing tanks which is labour intensive and water loss from lakeshore rearing tanks due to evapotranspiration

CHAPTER 3

Research-Extension Interface

A group of men in suits and a woman in a yellow shirt and cap are gathered around a rice thresher. The woman is operating the machine, and the men are watching her. The background shows a clear sky and some structures.

Ms. Annet Nakayima, Senior Technician on rice and maize, demonstrating how to use the rice thresher to the Chief guest, the Second Deputy Prime Minister and Minister of East African Community Affairs, Rt. Hon. Kirunda Kivejinja (In yellow shirt). Looking on is the Minister of Agriculture, Animal Industry and Fisheries Hon. Vincent Bamulangaki Sempijja (in grey suit) and other dignitaries during the World Food Day 2017 in Kabale. In the background is the Director-General - NARO, Dr. Ambrose Agona.



Disseminating technologies and innovations

Over the years, NARO has generated technologies with potential to increase food security, environmental sustainability and household income. However, most of these technologies have not been effectively disseminated to end-users, resulting into limited awareness and adoption. This has been mainly attributed to a weak research-extension-farmer interface.

In the financial year 2017/2018, NARO therefore directed efforts to increasing access to information on NARO technologies and improving capacity of communities to use the technologies and innovations.

Partnerships for accelerating dissemination of improved technologies were forged with different players. Different institutes of NARO have disseminated technologies in their respective agro-ecological zones as presented below.

Adaptive Trials and Demonstrations

Several NARO-generated technologies were exposed to intended beneficiaries (farmers, processors and traders) through adaptive trials and demonstrations, both on-station and on-farm, and farmer trainings in the different agro-ecological zones. Through these interactions, technologies that proved suitable for the specific zone were selected by end-users

and recommended for up scaling.

Led by NARL, Ngetta ZARDI, NASARRI, Buginyanya ZARDI, Abi ZARDI, Kachwekano ZARDI, Mukono ZARDI, Nabuin ZARDI and NaCCRI, NARO exposed the following to farmers and other agricultural value chain stakeholders in the indicated locations.

- Eighty farmers hosting maize and rice demonstrations were trained; 8 demonstrations established at Mubuku Irrigation scheme to showcase best water management practices. The 8 host and 30 other farmers were trained on appropriate implementation of the agricultural practices guidelines.
- Forty-eight on-farm Conservation Agriculture demo trials were established in Nakasongola and Lira districts.
- Three demos of newly released crop

varieties were established in the cotton growing regions of Lira, Nebbi, Adjumani districts. Demonstrations were established of *Tithonia optimum* rates and application methods for enhanced soil fertility and cotton productivity.

- At Serere, 6 on-farm demonstrations of drought tolerant and early maturing greengram established in Okulongo and Akoboi.
- 5,036 coffee seedlings/plantlets (3,110 KR/Clonal and 1,926 Elite) availed to farmers of Mukono, Wakiso and Luwero Districts.
- Three Citrus management demonstrations were established in Kamuli and Kayunga districts
- Three cassava (*Manihot esculenta*) trials were established on-farm to demonstrate the effective options for

managing pests and disease limiting increased cassava productivity in the Karamoja sub region. The options include phytosanitary measures, application of botanicides (neem oil), chemicals (cypermethrin 5%) and tolerant varieties (NAROCASS1, 52TME14). Four cassava field sites (0.8 ha each) were established with four cassava varieties (NAROCASS1, 52TME14, Nase19, Nase18) in Iriri (Napak District), Kakomongole resource center (Nakapiripirit District), Morulem (Abim District) and at Nabuin ZARDI. The cassava fields demonstrated the performance and availability of good cassava varieties with qualities of famine control and attributes preferred by root consumers.

- Three on-farm sweet potato fields were established, demonstrating various effective measures of managing sweetpotato (*Ipomea batatas*) weevils (*Cylas* spp), virus disease (SPVD) and alternaria disease in Iriri (Napak district) Kakomongole (Nakapiripirit district) and Nyakwae (Abim district). Effective measures applied include: healthy vine selection for planting, ridging mound cracks after vine establishment, 30cm depth vine placement in soil at planting for deep root

expansion, tolerant variety Naspot8 and Naspot10 and roguing of infected plants and gap filling at two weeks after planting.

- Five demonstrations for NAROBAN varieties; NERICA 6, NERICA 10, SUPERICA 1, NAMCHE 1, NAMCHE 3, NAMCHE 4, NAMCHE 5, NAMCHE 6, NERICA 4, NERICA 6, E20, SUPERICA 1, NERICA 10, E22, NERICA 1E22 and local upland rice varieties were established in 13 sites in Mitooma and Rubirizi districts.
- One adaptive trial for 7 rice cultivars (improved genotypes), (NAMCHE 4, NAMCHE 5, NERICA 6, NERICA 10, SUPERICA 1, E22 and local upland rice varieties) were established on-farm.

Seed multiplication

Seed is one of the major inputs that drive technology adoption. Despite this fact, scarcity of quality seed has remained a challenge especially in rural areas where the bulk of farmers live. In this reporting period, NARO has continued to support seed multiplication and distribution by training more farmers and orienting them to operate as local seed business dealers. These supplement seed availed

by registered seed companies which also obtain foundation seed from NARO.

Various NARO institutes continued to produce breeder and foundation seed, availing it to the seed companies and Local Seed Business (LSB) farmers for multiplication and distribution to end-users.

In this vein, NaCRRRI maintained 12 acres of cassava seed multiplication on-station

Led by Rwebitaba ZARDI, 600kg Arabica Coffee seed was harvested and ready for uptake pathways. 15,000 tea plantlets were raised for efficient tea seed system. 10,000 tea cuttings were availed to nursery operators.

Led by Buginyanya ZARDI, 276 bags of Napier (KAKA1) planting material and 45 kg of *Chloris gayana* availed to various districts. Additional 120 and 20 bags of Napier (KAKA1) and *Chloris gayana* planting-materials were availed to farmers in Sironko and Mayuge districts respectively.

About half hectare of lowland rice (WITA 9 and NERICA 6) and 1.0 ha NERICA 4 of upland rice multiplication field at vegetative stage at Ikulwe station. 200 new apple farmers (M=104, F=96) and five ex-

tension workers from four districts were empowered on soil and nutrient management, pest and disease management and other good agronomic practices for apple orchards, one Subcounty was selected from each district that is Benet Subcounty in Kween, Sipi in Kapchorwa, Budwale in Mbale and Nabweya in Bududa districts. 1,430 banana suckers of assorted varieties were availed to individual farmers to initiate mother gardens.

One tree nursery established at Ikulwe satellite station, with capacity of producing 45,000 seedlings. 74 goats at Bulegeni for breeding herd and four breeding pure Boer bucks availed for farmers in nucleus breeding. 2.5 tonnes of seed potato harvested and cured ready for uptake. 50 bags of vine were given out to farmers in Namayingo, Namutumba, Mayuge and Pallisa districts. 200 bags of NARO-CASS1 cassava cuttings availed to farmers in the Zone.

Led by Bulindi, 1,050 banana suckers generated and accessed by 15 farmers in LACZ.

Led by Kachwekano ZARDI, 2.5 tons of bean seed were produced and stored.

Led by Mbarara ZARDI, two acres of



Vice President of Uganda, Edward Kiwanuka Ssekandi visiting NARO Village during the National Source of the Nile Agricultural and Trade Show, July 2017.

NERICA 4 was established on-farm (Mitooma and Rubirizi districts) and 1 acre (NAMCHE 4, NAMCHE 5 and NERICA 6) on-station for seed multiplication.

NARO technologies at Agricultural shows

NARO has participated in a number of agricultural shows to showcase technologies.

Key of these was the National Source of the Nile Agricultural and Trade Show in Jinja from 17th-23rd July 2019, where all institutes were facilitated to establish demonstrations and exhibitions on different commodity based technologies in line with the event's theme.

Kachwekano ZARDI hosted and NARO at large also participated in the World Food Day celebrations in Kalengyere,

Rubanda district whose theme was; Change the Future of Migration: Invest in Food Security and Rural Development.

These events pulled crowds and through them NARO disseminated technologies to over 7,000 end users including farmers, extension agents, private and public sector players, researchers, academia, partners and international stakeholders.

Farm clinics and field days

One of the vehicles NARO uses to disseminate agricultural technologies and innovations to stakeholders is through organizing farm clinics and field days.

Through partnership arrangements, NARO in collaboration with Monitor Publications held farm Clinics in NaFORRI and Mbarara ZARDI. Bulindi ZARDI participated in a honey week organized for all bee stakeholders to promote marketing of bee products. These educational events exposed NARO technologies to hundreds of farmers.

Communication materials on NARO technologies disseminated

To communicate and promote NARO technologies effectively, information, Education and communication materials were produced and disseminated during

different events.

Led by NaSARRI, a total of 2,800 copies of greengram production guides produced and distributed.

Led by NARL, Improved bean production technologies packaged into a video and training manual, mass produced and disseminated.

Eight training manuals for training trainers developed and 150 farmers trained on identifying and managing citrus diseases

Led by NaFIRRI, a set of guidelines for managing environmental factors that influence proliferation of Kariba weed on Kyoga minor lakes updated.

- A draft policy brief for improved water quality for optimal fish production on Lake Kwanja developed.
- Draft information packages (i.e. policy brief on Fish breeding and nursery areas challenges and management strategies reviewed.
- Engaged fish farmers and key stakeholders.
- Held four-day inception workshop

with 37 participants (20 males and 17 females).

- Held farmers' symposium with 231 participants (NAFIRRI)
- Led by NaFORRI, a farmers' training manual on above and below ground management of
- Tree-crop interactions were developed.
- Farmers' practical guide for managing fruit
- fly prepared.
- One poster on citrus disease identification developed.
- 500 guides on integrated weed management on rice developed

Multi stakeholder Innovation platforms: a vehicle for technology uptake

NARO is working with multi-stakeholder innovation platforms to facilitate up-take of improved technologies. In this regard, twenty-four (24) MSIPs were supported in the financial year in various areas including trainings, demand articulation, farmer mobilization among others.

Twenty-four Multi stakeholder Innovation platforms supported

NARO is working with multi-stakeholder innovation platforms to pilot up take of improved technologies through

innovation platforms. In the reporting year, twenty-four (24) MSIPs were supported in various areas including train-

ings, demand articulation, farmer mobilization among others.

Awareness campaigns on Genetically Modified Organisms

In a bid to raise awareness about genetic engineering NARO in partnership with the Cornell Alliance for Science held two screenings of the world famous Food

Evolution Movie. One of the screenings was targeted at university and secondary school students and the other at media, policy makers and other stakeholders. A

total of 400 people was reached. The movie screenings were followed by a question and answer session which was headlined by NARO scientists.



Beyond demonstration gardens to farmers' fields and to markets: The Kikandwa model village

Summary

In a bid to scale up and scale out improved technologies, NARO through Mukono ZARDI launched a three-year drive to demonstrate technology promotion using the model village as an uptake pathway. This was piloted and established in Kikandwa, Semuto Subcounty, Nakasero District.

Study Area

Adaptive trials were conducted in Kikandwa village in Semuto Subcounty located in Nakaseke District. A baseline survey conducted in 2014 established that Kikandwa has an area coverage of 210 hectares with household ownership of about 2 hectares. The village is a crop-livestock based agricultural system including off-farm activities such as charcoal burning, brick making, sand mining and boda-boda transport.

The major crops grown are bananas, beans, coffee, maize and cassava (ranked in order of importance). Animals kept are cattle, goats, sheep, pigs and poultry. Kikandwa has a total 109 households, a total population of 500 people (263 males and 237 females).

The age demographic included 22% between ages of 18-30, 17% were aged between 31-80, while 61% were under 18 years old. The village had dependency ratio of 1.45 implying that there are two dependents for every economically active adult.

Demonstration gardens and adaptive trials were set up in the Kikandwa village for five seasons in a period for two and a half years (2016-2018). Crops selected for demonstrations and adaptive trials included maize, beans, cassava, sweet potatoes and fodder pastures.

The NARO-Kikandwa undertaking was funded by the World Bank under the Agricultural Technology and Agribusiness Advisory Services Project (ATAAS: Project ID P109224)

NARO adaptive trials and demonstrations in Kikandwa village influenced an increase in:

1. Agricultural area by 35% (44 ha).
2. Seed security, access and availability of high yielding sweet potato, cassava and bean varieties.
3. Cassava production by 52% and Cassava productivity by 58%.
4. Bean productivity by 70%.
5. Total village income and Household income by 49%.
6. Daily household income increased from US\$0.9 to US\$1.9 (the national poverty line)
7. Need for safely nets to reduce household vulnerability (not to fall back to poverty)

Short comings

1. Fall army worm reduced maize production and productivity by 63% and 69% respectively
2. Climate variability reduced bean production by 3%
3. Access and availability of maize seed is still a challenge (the hybrid challenge)

Participatory variety selection

The first farmer participatory adaptive trial was conducted in 2016 to allow farmers participate in variety selection of cultivars that were about to be released by NARO. In this trial two experiments of maize and beans were planted on the 26th -29th April, 2016.

The maize varieties were UH5658, UH5659, UH5660, WE3106, WE3109, LONGE 10H and a local check. The bean varieties were SCN 1, SCN 11, SCR 26, RWR 2154, RWR 2245, MOORE 88002 and a local check. The local checks were determined by farmers, according to their most popular varieties in the village.

For maize, the local check was Longe 5 while for beans, it was 'Nambale Omumpi'. Both are old varieties released by NARO many years before indicating that new varieties were not accessible to farmers. Data collection on maize included flowering, plant and ear height, lodging, field weight, grain moisture, husk cover, ear rot, disease incidence, ear and plant aspect.

On beans, data was collected on vigour, disease incidence, number of pods and plant aspect. These parameters were used to calculate yield of each variety. Farmers on the other hand selected the best performing varieties according to their judgment. Farmers were asked to stand in the plots that they visualized to be the best and worst performing and give reasons for their judgment.

A questionnaire was used to identify farmer's perceptions on a given variety and these were recorded. The farmers preferred WE varieties and Longe 10H for maize while in beans they preferred the RWR lines and their local check that showed the tolerance to drought during the season.



Other stakeholders and farmers listen a host farmer explaining what his group learnt from demos and adaptive trials in Kikandwa village.

Drought management in maize and beans

The 2nd Farmer Participatory adaptive trial was conducted in 2017 to demonstrate drought management in maize and beans to small-scale farmers. High yielding drought tolerant maize and beans varieties BAZOOKA and NABE 16, respectively, were planted on 0.4 ha plots for each crop and were hosted by two farmers. A female farmer hosted the maize adaptive trial while a male farmer hosted the bean trial. In this trial four water management treatments were demonstrated. These included (i) small irrigation technologies. That involved construction of water harvesting dams from which runoff from the village main roadside would collect water during the rainy days and then pumped to irrigate the plot during dry days, using; (i) manual treadle pumps; (ii) Planting basins, that involved digging square foot holes in the ground in which four maize seeds were sown while six bean seeds were sown. Planting basins are used in conservation agriculture to conserve moisture; (iii) Super absorbent agricultural hydrogel crystals (trade name Belspar), which is an inert substance that swells up when in contact with water and has a water holding capacity of up to 4,000 times its weight. Two grams of the hydrogel were added to each plating hole (vi) Rain-fed; where

no treatment was included but was left to by ambient precipitation during the season. Results showed yield variations between the different types of irrigation with irrigated using manual treadle pumps being the best and planting basin method being the least for maize production.

Popularizing improved maize varieties

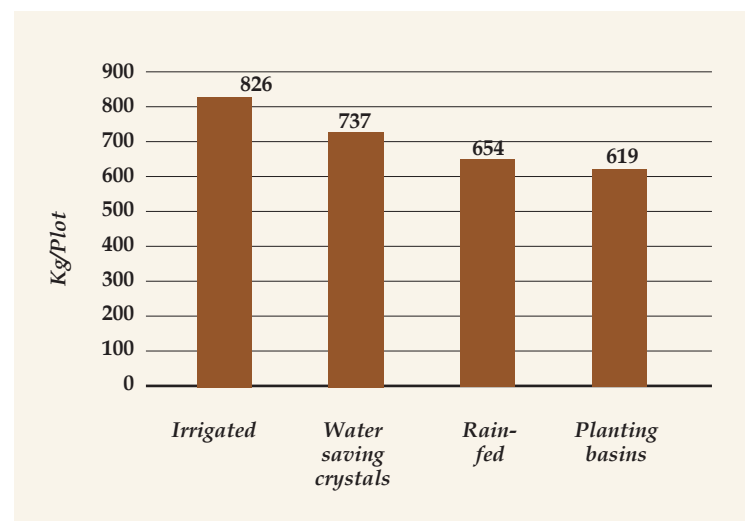
The third farmer participatory adaptive trial was conducted in the same season 2017 season A to address lack of knowledge about existing improved NARO maize varieties. In this respect, 42 Maize varieties that have ever been released by NARO were planted in lattice design experiment with two replicates.

Post-Harvest handling

Three trainings on post-harvest handling were conducted for maize and sweet potato. Farmers' capacities were built on the knowledge and principles of post-harvest handling and storage; value-addition and marketing. Losses after harvest mainly occur during and after harvesting in fields, drying, processing, storing, transportation and marketing. Causative agents, types and points where the loses occur were identified and mitigation/management methods were made.

Different precautions that farmers can take to minimize losses included; use of clean tarpaulins without holes at harvesting, use of maize shellers, packing and storing in Purdue Improved Crop Storage (PICS) bags and their preferences and storing on raised platform. Other improved post-harvest handling technologies demonstrated included hermetic bags, raised pallets and moisture meter. Farmers were urged to dry produce and even test for the moisture content. A simple and cheap technique of mixing salt and maize grains in a dry mineral water bottle was demonstrated. For safe grain storage, grain moisture should not exceed 14%.

Value addition



Performance of water management technologies in maize to manage drought



A sign post showing a maize adaptive trial on water management technologies in Kikandwa

Sweet potato value addition was introduced in Kikandwa village, Nakaseke district by MUZARDI with the aim to help farmers consume and increase income using sweet potato products in different forms. New improved sweet potato varieties that were introduced in Kikandwa village included NASPOT 8, NASPOT 11, New Dimbuka and Orange fleshed varieties (NASPOT 12 and 13).

The farmers were trained on the principles and importance of value addition and also the respective ingredients required in the whole process. Fields of orange fleshed sweet potatoes were established and managed by farmers in this village. Products like cakes, cookies, buns and bread were made by the four groups respectively. Farmers were able to make cakes, bread, dough nuts, crisps, daddies, cookies and biscuits from sweet potato flour and other baking ingredients.

Sweet potato peelings were mixed in poultry feeds, cassava flour, piggery feeds, among others. Products were produced, packaged, labelled and exhibited to the members. Farmers were able to witness and practically have a hand in value addition for sweet potatoes. They were able to make a variety of products from Sweet potatoes i.e., cakes, bread, buns, cookies, donuts, among others. Farmers also prepared vegetables from Sweet potato leaves together.

Linking farmers to markets

Farmers were linked to markets using Multi Stakeholder Innovation Platforms (MSIPs). A sweet potato innovation platform was established from the Kikandwa NARO Village farmers group. The sweet potato MSIP supported through value addition, post-harvest handling equipment and sweet potato chippers.

A maize MSIP was established and supported by linking farmers to markets through contract farming. Contract terms included provision of inputs, 21 acres of Longe 10H maize planted, Selling price



Farmers exposed to motorized maize shellers.

1000 per kilo. The MSIP was strengthened with post-harvest handling equipment, Maize shellers, Maize cribs and PICs backs (Storage).

Table 7: Change in Kikandwa village agricultural acreage

Total hectares / commodity			Change (ha)	% Change in acreage
Crop	2014	2017		
Maize	32	64	32	50 %
Sweet potato	1	25	24	96 %
Beans	20	26	6	22 %
Cassava	28	10	-18	-63%
Total	81	125	44	Overall 35%

During the intervention in Kikandwa village, there was 35% (44 ha) increase of agricultural land area as shown in Table 7. The reason being that there was increased land opening though popularized mechanized ploughing (tractor). With introduction of new maize varieties, the acreage under maize doubled, new land 24 ha was



Trainers demonstrating the use of Purdue Improved Crop Storage (PICS) bags and portable silos to farmers in Kikandwa

opened up for sweet potato production while the acreage under cassava was reduced to accommodate maize or sweet potato production and account for reduction in cassava production to -63% as shown in Table 8.

Table 8: Change in Total village production

Total village production (kg/season)			Change (Kg)	% Change in production/season
Crop	2014	2017		
Maize	66,000	40,415	25,585	-63 %
Sweet potato	1,000	39,178	38,178	97 %
Beans	9,000	8,777	-223	-3 %
Cassava	1,000	2,070	1,070	52 %
Total	77,000.0	90,440.0	13,440	Overall 15%

The reduction in maize production was attributed to Fall Army worm infestation. The reduction in bean production attributed to high rainfall towards harvest (Climate change). Increase in Sweet potato and cassava production attributed to NARO's improved high yielding varieties introduced in 2016 NASPOT 8, 11, 12, 13 and New Dimbuka and cassava varieties NAROCASS 1 and 2 (Table 9).

Table 9: Change in village productivity

Yield (kg)/ha/season			Change (Kg)	% Change productivity/season
Crop	2014	2017		
Maize	2,062.5	631.5	-1,431	-69%
Sweet potato	800.0	1,632.9	833	51%
Beans	450.0	1,521.5	1,071	70%
Cassava	357.0	856.3	499	58%
Total	3,669.5	4,642.2	973	Overall 21%

Village productivity of maize was greatly influenced by lack of knowledge in management of Fall Army worm. Increase in Sweet potato, beans and cassava production/ha attributed to NARO's high yielding varieties introduced in 2016, NASPOT 8, 11, 12, 13 and New Dimbuka. For cassava NAROCASS 1 and 2 while beans NABE15 and NABE16 (Table 10).

Table 10: Change in commodity prices

Average price, UGX/season			Change (UGX)	% Change in price/season
Crop	2014	2017		
Maize	500	1,400	900	64%
Sweet potato	200	430	230	53%
Beans	1500	2,000	500	25%
Cassava	300	570	270	47%
Total	2500	4,400	1,900	Overall 43%

Increase in commodity prices greatly influenced the increase in household income. E.g. Despite low maize productivity, the price increased by 3 fold (Table 10).

Table 11: Change in Household income

Estimated income (UGX)/ household /season			Change (UGX)	% Contribution to Household income /commodity
Crop	2014	2017		
Maize	302,752	519,092	216,339	52 %
Sweet potato	1,835	154,555	152,721	37 %
Beans	123,853	161,046	37,193	9 %
Cassava	2,752	10,825	8,072	2 %
Total	431,193	845,518	414,325	Overall 49%

Kikandwa women farmers launch Bakyala Tusekimu Women Savings group

The lives of the group members greatly changed in terms of food security and income so much to the extent that the women in the group formed 'Bakyala Tusekimu' (*Smiling women*) Women Savings group; a cooperative initiative that will help them manage their finances better. The group launched the cooperative at Kikandwa Community Centre and has invited NARO-MUZARDI as a key player that has contributed to the improvement of their welfare. The occasion was graced by their area Member of Parliament and political leaders.



Kikandwa community meeting the NARO team comprising the NARO Council User's committee, staff of NARO Secretariat and Mukono ZARDI.

Operation Wealth Creation excited by the Kikandwa experience

The Government programme of Operation Wealth Creation has picked interest in the success of the NARO - Kikandwa village model to the extent that they want the whole experience to roll out to the entire Semuto sub county.



Major Peter Rwego, (in army uniform) the Operation Wealth Creation Liaison Officer to NARO interacting with women of Kikandwa village on value addition on sweet potatoes.

CHAPTER 4

Agriculture Capacity Strengthening



*A newly constructed
modern cowshed at the
National Livestock Research
Resources Institute in
Nakyesasa.*

Human capital development

NARO prides itself in the result-oriented culture among its wider human capital development strategy. In this section we bring you some of the key achievements in the FY 2017/2018.

Performance management

In order to enhance a performance culture among staff, NARO introduced a new performance management system which resonates on institutionalizing a framework for performance planning, monitoring and performance evaluation. This approach is anchored on five courses of action namely:

1. Aligning individual performance expectations with the goals and objectives of NARO.
2. Setting performance targets against which staff are evaluated at midterm and at the end of a performance cycle
3. Ensuring a fair and equitable evaluation of staff performance and recognition of performance which exceeds agreed targets and satisfactory delivery on both core and leadership competencies
4. Providing feedback on levels of performance against set targets or expectations and
5. Identifying performance gaps and designing training and development programs aimed at addressing the shortfall.

The new performance management system was operationalized through a performance management and appraisal procedures policy which become effective on 1st July 2017.

On boarding of new staff

In order to maintain research capacity at the desired levels, a total of thirty new staff were recruited including fifteen scientists of whom six were females. The recruitment was targeting the replacement of staff who left the organization during the previous financial year.

Table 11 : Recruited staff numbers during FY 2017/2018

	Male	Female	total
Scientist	9	6	15
Support Staff	4	5	9
Technician	3	3	6
TOTAL	16	14	30

Human Resource retention

In the financial year 2017/18 we had a relatively low level of staff turnover of 45 staff representing a total turnover rate of 5%. This includes 16 departures representing a voluntary turnover rate of 1.8% and 29 departures representing an involuntary turnover rate of 3.2%.

Table 12 : Summary of NARO staff separations - FY 2017/2018

Cause of turnover	Scientists	Technicians	Support Staff	Total
Resigned	11	–	5	16
Retired	7	5	6	18
Death	2	1	5	8
Contract Terminated	2	–	1	3
Total	22	6	17	45



Training and Staff Development

Over the last six years, NARO has invested heavily in human capacity development through the sponsorship of staff for long and short term training programs. During the period under review, eleven and eight scientists completed PhD and Master's degree training respectively. These scientists are expected to significantly contribute towards the attainment of NARO's research agenda. Staff sponsored for long term training are bonded to service NARO for a minimum of three years after the training. During the same year NARO supported 125 staff to attend short term training courses. Of these thirty-five (35) members of PARI training committees attended a short course in assessing the impact of training on staff performance. Fifteen (15) monitoring and evaluation officers were trained in Project planning and management while 75 Mid-level management staff attended

leadership and management training. In addition, 16 Stores Assistants, 35 Administrative Assistants and 50 Drivers attended refresher courses in their respective functional areas. Two study tours lasting one week were also supported where six tea research scientists visited the Kenya Tea Research institute at Kericho and another two scientists visited the stingless bee keeping center in Tanzania.

Three (3) scientists were supported to present scientific papers in International Conferences in Crop Science, Cotton research and aquaculture. Under the continuous professional development program, seventy-five (75) members of staff were supported to attend workshops and seminars arranged by different professional associations and through payment of membership and subscription fees.

Forty-seven research studies supported under the Competitive Grants Scheme

The National Agricultural Research Policy (2003) and the National Agricultural Research Act (2005) provide for all qualified agricultural research service providers in public and private sectors to participate in conditioning agricultural research and providing services. This is a departure from the past where NARO was the major entity providing agricultural research services.

The establishment of the Competitive Research Grant in the National Agricultural Research Systems (NARS) through mobilizing the best available scientific expertise in the public and private sectors is to work on specific high priority projects in accordance with the national agricultural devel-

opment strategies, promote research partnership and collaboration; improve research quality and increase total research.

In a competitive research grant scheme, research providers are selected on a competitive basis, using calls for proposals and scientific peer review to allocate set funding.

In the reporting year, a total of 47 research studies handling different areas of strategic importance were supported under the Competitive Grant Scheme.

They are expected to generate different problem-solving technologies in the crop, livestock, fisheries and agro-engineering sectors.

Financial Resources

NARO operates with two sources of funding namely; Government of Uganda, local and international development partners. In the FY 2017/18, a total of UGX 91.738 billion was approved, out of which 88.641 billion was released and 99.3% of the released funds were effectively spent.

Table 13: Budget Performance for 2017/18

1. Excluding Arrears		Approved Budget	Releases	Spent by end Jun 2018	% Budget Released	% Budget Spent	% Release Spent
Recurrent	Wage	22.472	22.472	22.472	100.0%	100.0%	100.0%
	Non-Wage	7.319	7.319	7.319	100.0%	100.0%	100.0%
Development	GoU	8.780	7.122	7.122	81.1%	81.1%	100.0%
	Donor*	45.540	45.540	45.540	100.0%	100.0%	100.0%
GoU Total		38.571	36.913	36.913	95.7%	95.7%	100.0%
Total Gou + Donor (MTEF)		84.111	82.453	82.453	98.0%	98.0%	100.0%
2. Arrears		-					
	Total Budget	84.111	82.453	82.453	98.0%	98.0%	100.0%
3. Non-Tax Revenue		7.627	6.188	5.590	81.1%	81.1%	90.3%
	Grand Total Excluding Arrears	91.738	88.641	88.043	96.6%	96.0%	99.3%

Table 14: Summary of NARO 2017/18 Key Performance Indicators

NARO Key Performance Indicator	Planned Target FY 2017/2018	Actual Achieved	Reasons for the Variations in 2017/18
New varieties submitted to Variety Release Committee	60	41	Drought, FAW out-break and inadequate budget support
Production technologies generated and released	80	96	Effective evidence based target setting
Research studies under CGS	47	47	Effective review and award systems
Technological innovation platforms established/supported	39	24	Decline in NAADs activities, drought and inadequate funding
Technological innovations delivered to uptake pathways	116	121	Recruitment of more extension staff and increased demand for improved technologies/innovations



Physical resources and other research-support services

This section presents an outline of major achievements made in regard to the physical resources and other research-support services in the FY 2017/2018.

Category of works

1. A Milking Parlor constructed at Nakyesasa under NaLIRRI
2. Office buildings constructed in Nabuin, Sererere, Kajjansi, Mbarara and Bulindi were handed over by the contractors to NARO
3. A nitrogen and generator house at Nakyesasa constructed under NaLIRRI.
4. A nursery bed constructed in Kiige, a sub-staion of NaCRRI
5. Staff houses constructed under Nabuin ZARDI

6. Director's House under constructed in Bulindi ZARDI

Category of Consultancies

1. Development of Technology and Dissemination Information Materials to support all PARIs and the National Secretariat completed
2. Consultancy Services in procurement and Civil Engineering concluded.
3. Brand Reputation and Media Monitoring covering all PARIs and NAROSEC completed

Developing capacity for climate smart-agriculture

NARO has started developing and strengthening the existing capacity for climate smart-agriculture using online applications. The climate smart-agriculture online applications provided consistent seasonal weather forecasts, monitoring and early warning products for drought, floods and pests and disease surveillance. A team of experts from NARO, MAAIF and Uganda National Meteorological Authority (UNMA), was hosted at the Kenya Agricultural and Livestock Research Organization, Nairobi.

The team consisted of Dr. Damalie Akwango-Aliu (NARO), Mr. Milton Waiswa (UNMA), M/s. Imelda Kanzomba, Mr. Amos Mpungu (MAAIF), Mr. Jonathan Lwanga (NARO) and M/s Sylvia Namusoke (NARO). The training was facilitated by the Agricultural Cluster Development Project (ACDP), in MAAIF. ACDP is a world Bank funded project.

The training was on Climate smart-agriculture online application called **aWhere agricultural intelligence platform**. The *aWhere agricultural intelligence platform* is an agricultural Observatory training tool used for developing agronomic specific weather advisories. *aWhere* system can extract reliable 7-day weather forecasts representative to a radius of 9km, hence providing a farmer with weather forecasts that are closer to his/her locality compared to the regional forecasts that UNMA currently provides. *aWhere* agricultural intelligence platform provides weather forecasts, monitoring and early warning products for drought. *aWhere* system gives access to past data for 30 days on the weather parameters of temperature, precipitation, sky, solar energy, relative humidity and wind. This enables farmers to make timely decisions on when to plant, apply fertiliser, spray, and harvest among others. The training include hands-on and virtual trainings.

The outputs from the training included increase in capacity of

the Uganda Officers to use scientific weather tools to link to global weather systems and generate localised weather forecasts, source for historical weather data and produce localised agro-meteorological advisories.

Piloting the agricultural observatory advisory in Iganga, Bugiri, Namutumba districts

As a follow up on the training on the **aWhere agricultural intelligence platform**, the Uganda team have developed a proposal to pilot the rainfall and weather data into Farmers' Hands in the above districts. The pilot project will provide localized, real-time weather data and insights to farmers and decision makers, training for scientists, agronomists, and analysts on using analytical and modeling tools (R programming and QGIS) and interpreting ag-weather data so they can provide relevant and accurate information to the farmers. The opportunities and benefits from the **aWhere agricultural intelligence platform** will include; advisory services at farm level; Market intelligence and Commodity pricing; Financial services (e.g. drought-based insurance), weather and agronomic tips, financial services, early warnings of pest and disease outbreaks; Early drought detection and warnings for food security. Each of these services can build a farmer's resilience to climate change and allow for more effective, informed decision-making by the farming community, policy-makers, and governments.

Towards effective Intellectual Property Management in NARO

Intellectual Property (IP) remains pivotal in NARO work as a tool for enhancing sustainable creativity and innovativeness by providing incentives for research and product development. NARO recognizes the need for becoming a premier research institution by using IP for socio-economic transformation and development. This is expected to be achieved by transfer of IP enabled technologies through commercial and public routes for accelerated and efficient transfer of generated technologies for public access.

NARO has over the years generated high-impact research technologies with IP and commercial potential across numerous agricultural technology fields for a greater public good. Therefore, as a center of excellence for agricultural research in the region, NARO aspires to pioneer a new **Research-Industry** alliance coordinated by the established Intellectual Property management structures which will enable deployment of generated technologies for utilization by the industry/ private players for enhanced access of these technological products on the market and hence societal transformation. Considering the above and in efforts towards effective IP management, NARO in FY 2017/2018 undertook a number of proactive steps and made a number of achievements which include:

1. Development and approval of the Institutional Intellectual Property Policy and the operationalization guidelines. In the Council meeting of 18th December 2017, the NARO Governing Council approved the NARO IP policy and guidelines. This policy is aimed at providing a framework that guides effective management of IP and stimulate creativity in NARO.
2. Appointment of the Intellectual Property Management Committee (IPMC) which is a supreme body that provides guidance for effective and efficient implementation of the NARO IP policy. The IPMC provides guidance on IP protection, commercialization, negotiations for licenses, benefits sharing, dispute resolution among others.
3. Continued to create awareness of IP to NARO fraternity through one-on-one sessions, high level workshops and Information materials including the '**Researchers' guide to IP Management in NARO**'.
4. Continues to run one of the most vibrant Technology Innovation Support Centres (TISCs) in the country with technical support from the Uganda Registration Services Bureau (URSB) and the World Intellectual Property Organization (WIPO). These platforms are helping to provide access to high quality technology information services and other related services to researchers in NARO hence enhancing research product and investment value.
5. In way of contributing to the National Plant Variety Protection System, NARO received a sub-grant of US\$ 25,000 from the African Agricultural Technology Foundation (AATF) to support IP related initiatives and efforts to strengthening the Plant Variety Protection (PVP) system in Uganda. This resulted into the process of developing PVP regulations to operationalize the PVP Act, 2014.

IP protection in 2017/18

NARO through the Intellectual Property Office continued to identify and protect a number of technologies identified to have IP and com-

mercial potential. The table below shows the technologies protected in 2017/18 and ready for deployment and commercialization.

No.	Technology	About the Technology	Form of Protection
1.	Bioacaricide Lead Inventor - Dr. Richard Alingu	This technology relates to a process of developing a formulation comprising of entomopathogenic fungal spores of <i>Beauveria</i> and <i>Metarhizium</i> species used for biological control of disease causing organisms to hosts. The formulation has characteristics of high efficiency, environmentally friendly and low cost.	Utility Model and ready for commercialisation.
2.	Biomass cook stove Lead inventor- Mr. Turinayo Yona	The technology relates to an alternative affordable, environmentally friendly and fuel saving cooking stove that simultaneously produces charcoal and combustible gas (producer gas) used for cooking in process of combustion. The stove design comprises a combustion chamber with two parts that is, the solid biomass combustion chamber and the producer gas combustion chamber.	Utility model and ready for commercialization.
3.	Tick vaccine Lead inventor- Dr. Fred Kabi	The technology relates to the novel approaches for controlling <i>Rhipicephalus appendiculatus</i> , <i>Amblyomma variegatum</i> and <i>Rhipicephalus</i> (<i>Boophilus</i>) <i>decoloratus</i> and the diseases they transmit using recombinant subolesin antigens as anti-vaccines. The antigens disable tick feeding, reproduction and pathogen transmission.	Regional Patent, product development underway to get it ready for commercialisation
4.	Wound Healing formulation Lead inventor- Prof. Baruga Evarist MRC-NARO collaboration	This technology relates to the process and method of preparing a rapid and more effective external and internal wound healing formulation from the stem bark of <i>Zanthoxylum</i> species by isolating and culturing active components of the plant.	Patent and product ready for final clinical trials and commercialisation.
5.	Food Smoking device Lead Inventor - Eng. Chandia Alphonse	The technology relates to a device and process of hot smoking and dehydration of polycyclic aromatic hydrocarbons (PAH) free foods for human consumption. Device comprises a smoke generation unit, smoke delivery system, smoke filter and dehydration chamber best suited for smoking fresh and perishable foods, such as fresh fish and fresh meat. The appliance provides a mechanism that enhances the integrity, safety and quality of the smoked fish, meat and other products as well as ensuring compliance to international quality standards.	Regional Patent and ready for deployment/ commercialisation

Partnerships in NARO intellectual properties

NARO continues to maintain and strengthen partnerships with various organizations on financial and technical support and capacity building initiatives. These organizations include but not limited to the National IP Office- Uganda Registration Services Bureau (URSB), the World Intellectual Property Organization (WIPO), the African Regional Intellectual Property Organization (ARIPO) and the African

Agricultural Technology Foundation (AATF).

NARO calls upon business and industry players interested in taking up some of the above technologies for commercialization through licensing to express interest to the Director General, NARO for formal transfer and utilization.

CHAPTER 5

Report and audited accounts

Statement on Internal Audit

The mandate of the Internal Audit is derived from Public Finance Management Act 2015 (PFM Act 2015) and National Agricultural Research Act 2005 (NAR Act 2005). Section 48 (1) of the Public Finance and Management Act 2015 provides that, 'Every vote shall have an internal Auditor. (2) An internal Auditor shall:

a) Appraise the soundness and application of the accounting functional and operational controls of a vote; b) Evaluate the effectiveness and contribute to the improvement of risk management processes of a vote; and c) Provide assurance on the efficiency in the efficiency, and the effectiveness of the economy in the administration of the programmes and operations of a vote. It is management's responsibility to ensure that an effective system of internal controls is maintained and operational. This responsibility takes account of the requirements of the Public Finance and Management Act 2015.

Governance

NARO has an Audit and Risk Committee (ARC) comprising four members, one of whom is the Chair. The Committee comprises of members with both financial and audit expertise. The functions of the ARC are guided by the Audit Committee Charter. Internal Audit report functionally to the ARC and administratively to the Director General.

Purpose of the system of internal control

Internal control systems are designed to provide reasonable as-

urance that policies, processes, operations and other aspects of an organisation, taken together are effective and efficient in ensuring that the entity achieves her objectives.

Risk Management

Internal controls are designed to manage risk to a tolerable level rather than to eliminate it. Internal controls can therefore, only provide reasonable and not absolute assurance that assets are safeguarded, transactions authorized and properly recorded and that material errors or irregularities are either prevented or detected in a timely manner

Management has established risk management systems which include, risk identification, risk assessment, risk treatment, implementation of the mitigation measures, review and evaluation of the control measures to determine their effectiveness.

Risk and control framework

NARO has put in place a risk register of key potential risks across NARO. These risks are ranked and graded according to their significance. The register is reviewed and updated by the

ARC on a quarterly basis and forms the basis of preparing a risk based audit plan for the financial year. We confirm that elements of the control environment containing are in place;

1. there was an appropriate budgeting system with an annual budget which is kept under review by top management,
2. procedures for all key business processes have been documented,
3. financial responsibilities have been assigned at management level with corresponding accountability,
4. there were systems aimed at ensuring the security of the information and communication technology systems,
5. there were systems in place to safeguard the assets, and
6. control procedures were in place over grant funding (Off Budget) to outside agencies ensure adequate control over approval of grants and monitoring and review of grantees to ensure grant funding has been applied for the purpose intended.

Monitoring and review

Formal procedures were in place for monitoring control processes and control deficiencies. These were communicated to those charged with the responsibility for taking corrective action and to management where applicable, on a timely manner. We confirm that the following ongoing monitoring systems were in place:

1. key risks and related controls were identified and processes put in place to monitor the operation of those key controls and report any identified deficiencies,
2. reporting arrangements were established at all levels where responsibility for financial management were assigned, and
3. regular reviews were conducted by top management of periodic and annual performance and financial reports which indicated performance against budgets/ forecasts.

Review of effectiveness

NARO has put in place procedures to monitor the effectiveness of its risk management and control procedures. NARO top management is responsible for the development and maintenance of the internal control framework. Monitoring and review of the effectiveness and efficiency of internal control systems is informed by the work of internal and external auditors. The Audit and Risk Committee of the Governing Council oversees the work of the Internal Audit function.

On this basis, the Internal Audit conducted an annual review of the effectiveness of the internal controls, risk management and governance's processes for 2017/2018. The audit findings and recommendations for 2017/2018 were discussed by management, the Audit and Risk Committee and adopted by the Governing council for implementation.



Opinion of the Auditor General on the Financial Statements of National Agricultural Research Organisation for the year ended 30th June 2018

Article 163 of the Constitution of the Republic of Uganda, 1995 (as amended) and Section 13 and 19 of the National Audit Act, 2008 gives the Auditor General the responsibility to audit and express opinion on the financial statements of NARO. Below are excerpts from the Auditor Generals report;

Opinion

I have audited the accompanying financial statements of the National Agricultural Research Organisation for the year ended 30th June 2018. These financial statements comprise of the statement of financial position, the statement of financial performance, and cash flow statement together with other accompanying statements, notes and accounting policies.

In my opinion, the financial statements of the National Agricultural Research Organisation for the year ended 30th June 2018 are prepared in all material respects, in accordance with section 51 of the Public Finance Management Act, 2015 and the Financial Reporting Guide, 2018.

Basis of Opinion

I conducted my audit in accordance with International Standards of Supreme Audit Institutions (ISSAIs). My responsibili-

ties under those standards are further described in the Auditor's Responsibilities for Audit of Financial Statement's section of my report. I am independent of the organisation in accordance with the constitution of the Republic of Uganda (1995) as amended, the National Audit Act, 2008, the International Ethics Standards Board for Accountants Code of Ethics for Professional Accountants (Part A and B) (IESBA Code), the International Organisation of Supreme Audit Institutions (INTOSAI) Code of Ethics and other independence requirements applicable to performing audits of Financial Statements in Uganda.

I have fulfilled my other ethical responsibilities in accordance with IESBA Code, and in accordance with other ethical requirements applicable to performing audits in Uganda. I believe that the audit evidence I have obtained is sufficient and appropriate to provide a basis for my opinion.

CHAPTER 6

Challenges and Recommendations

Implementation of the previous strategic plan for the FY 2017/2018 encountered several challenges. In this chapter we present to you a raft of the key challenges as well as lessons learnt during the implementation propositions to address in the subsequent years.

a) Adjusting to frequent institutional structural reforms and emerging government programmes: institutional structural reforms and emerging government programmes were inevitable. However, slow adjustments to these reforms by the implementing partners distorted the flow of technologies from researchers to end users. Some of these reforms changed the strategic direction considerably thus affecting project plans, budgets and partnerships.

b) Inadequate funding for sustaining agricultural research: NARO did not have adequate and stable funding to deliver on her mandate. This weakened implementation of the research agenda and hindered generation of technologies and innovations.

c) Operating under competing land-use interests: NARO operated under uncertain land ownership and nagging pressure from investors with immense interest on land designated for agricultural research. Many parties were interested in NARO land for private use. This slowed down investments

in research infrastructure and interrupted effective implementation of land-use plans. Furthermore, it adversely affected relationships with potential partners.

d) Timely enactment of new laws and passing of policies: delayed enactment of new laws and passing of related policies resulted in, among others, failure in application of modern tools in agricultural research and innovation. This limited provision of solutions to challenges in the agriculture sector and curtailed opportunities for advancing agricultural research to address farmers' problems. Similarly, delays in reviewing the NAR Act 2005, as necessitated by the prevailing circumstances, hindered NARO's redirection and effective management of the research agenda

e) Evaluating the performance and impact of NARO's technologies: NARO generated many technologies whose performance and impact were not adequately evaluated. This limited NARO's visibility, relevance and ability to negotiate for additional resources

from Government to support research as well as infrastructure development and rehabilitation.

Lessons learned

The following lessons were learned:

a) Stakeholders' participation, commitment to and ownership of research and development initiatives, right from design to implementation, is fundamental and critical in the success of the initiatives.

b) An effective PM&E system enhances project success, learning, reporting and sets a good foundation to inform decision-making.

Recommendations

a) Increased and sustainable funding; enhanced governance and management; improved human resource capacity, improved research infrastructure and functional and sustainable partnerships and collaborations

b) Increasing public-private partnerships with industry for joint technology development and promotion.

CHAPTER 7

NARO List of Publications 2017/2018

Journals

Crops

1. Abera N.M., Odong, T.L., Kasozi, L.C., Edema, R., Gibson, P. and Kwemoi, D.B. 2018. Yield stability analysis of open pollinated maize (*Zea mays* L.) and their top-cross hybrids in Uganda. *World Scientific News*, 95: 75-88.
2. Abera, N.M., Odong, T.L., and Kasozi, L.C. 2018. Determining the heterotic groups of nineteen open pollinated maize varieties from their top-crosses with inbred line testers. *Journal of Scientific Research & Reports*, 18(1): 1-7.
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