Forage Research and Development in Uganda

Kabirizi Jolly

Importance of dairy production in the Ugandan economy

Dairy cattle production in Uganda is among the priority sectors to spur poverty eradication under the Vision 2040 development framework "*A transformed Ugandan society from a peasant to a modern and prosperous country within 30 years***"**, and the Second National Development Plan (NDPII). Compared to other ruminants, dairy production has the advantage of instant benefits from daily production of milk whose demand in country is continuously increasing due to high population growth rates and urbanization.

Dairy production system plays a crucial role in food and income security in Uganda. Dairy products notably milk provide a significant nutritional supplement to vulnerable groups such as infants, pregnant mothers and the sick; increase the resilience of smallholder households in the face of food crises and; help to maintain traditional social safety nets. The dairy sector provides manure for both food and fodder production.

Challenges to dairy production in Uganda

Major constraints affecting dairy production systems in Uganda include socio-economic, technological, institutional and financial constraints. The major technical constraints are availability and quantity of feed, reproductive inefficiency, poor breeds, breeding programmes and policies, and health and diseases. The introduction of high producing cows of large frame size accentuates the nutritional deficiency problem particularly of lactating dairy cows and this could undermine reproductive functions, lactation and growth of the animals.

Thus, inadequate nutrition as a result of low quality and quantity of forages and feeds and use of unimproved practices has been identified as a major constraint in all dairy production systems in Uganda leading to low milk yield, long calving intervals and sometimes death of the animals. In order to address the challenges associated with inadequate feeding in the country, the National Livestock Resource Research Institute (NaLIRRI) and Makerere University have executed basic and adaptive research with the objective of enhancing availability of adequate and superior quality feed resources for dairy cattle production.

The role of pastures in dairy nutrition

Feeds contribute over 80% of the total cost of production in dairy production systems. Feeding of dairy cattle continues to pose many problems due to: (a) inadequate feed quality and quantity, (b) poor storage facilities for feed conservation as well as insufficient water, (c) lack of information on composition and, (c) utilization of locally available feed resources. These problems are aggravated by lack of access to and high cost of feed inputs. The use of cheap and readily available local feed resources has great potential to increase small-scale dairy cattle productivity.

Pastures are grasses and legumes that are either native or introduced for cut and carry, grazing, and hay or silage crops. Historically, the term **forage** has meant only plants eaten by the animals directly as pasture, crop residue, or immature cereal crops, but it is also used to include similar plants cut for fodder and carried to the animals, especially as hay or silage. Pastures play important roles in crop-livestock farming systems of Uganda.

(a) Cheapest source of feed

Pasture is the cheapest form of animal feed available. Livestock requires pasture species that give a high yield of palatable and digestible herbage, containing adequate nutrients for the animal. As improved animal breeds are becoming increasingly popular the provision of forages with better nutrition is important to attain maximum benefits from livestock farming.

(b) Soil fertility improvement

Nitrogen is one of the fundamental constituents of living beings, and adequate supplies of nitrogen are essential for the normal growth of all plants and animals. Forage legumes have special ability to fix atmospheric nitrogen and incorporate into their tissue proteins. All grass covers are able to build up soil fertility. Decaying plant material, and the minerals through deeply penetrating roots increase the organic matter content of the soil.

(c) Soil erosion control

As the physical structure of the soil deteriorates, the risk of erosion is greatly increased. Grass and legume covers are some of the best safeguards against erosion. Their finely branched root systems help to consolidate and hold the soil, while the rapidly-growing tufted or creeping shoot system produces an efficient above ground protection and rebuild the physical structure of the soil.

(d) Source of income

The demand for fresh and conserved (hay and silage) fodder is high in Uganda due to increased number of smallholder dairy farmers with limited to produce pastures. The demand for high quality forage seed for development of livestock feed resources is increasing rapidly in Uganda. This demand is fuelled by the expanding dairy production occasioned by the increased demand from rising population and improved income particularly in the urban centres. Further, the need to restore degraded natural pasture (the major source of livestock feed) through reseeding and/or over-sowing interventions emphasize the urgency for concerted efforts to ensure availability of large quantities of good quality seeds.

(e) Control of pests and diseases

Napier grass has been an important trap crop for managing stem borers in maize and sorghum. The technology was developed for subsistence farming in Africa and relies on semio-chemicals produced by plant species grown in companion cropping, i.e. intercropping for the push and trap cropping for the pull. Although the areas under main crop get reduced in push–pull system, higher yields are produced per unit area.

Opportunities for developing pasture in Uganda

(a) *Achieving self-sufficiency in meat, milk and other livestock products***.** Forages are the cheapest source of feed for ruminants. Given the well-distributed rainfall and fertile soils, Uganda has abundant of green forage available for most parts of the year.

(b) *Targeting commercial agricultural production***.** Forage seed production will expand as farmers diversify cash crops from the traditional ones. The sale price for forage seeds is good compared to many food crops. The knowledge that dairy cattle production can be profitable has created a willingness amongst farmers to take up new technologies aimed at increasing livestock productivity; pasture improvement is just one of them.

(c) *Improving and strengthening of agricultural research and extension***.** The National Agricultural Research Organization (NARO) was established to develop agricultural technologies including forage improvement for all categories of farmers. NARO and Makerere University have established collaborations with international research organisations interested in livestock nutrition.

(d) *Favourable government policies*: Uganda Vision 2040 prioritized dairy enterprise as high returns to investment and with high potential agriculture sector to accelerate national development.

(e) *The agricultural extension system*: The extension system in the country is gradually evolving with provision of agricultural staffs at district, sub-county and parish level. There is on-going in-service training of all front-line livestock extension workers on pasture improvement and seed production. Uganda has several universities and agricultural colleges that train agricultural personnel with specialisations.

(f) *Urban, peri-urban and rural commercial dairying depends on fodder availability*. The farmers involved in dairying have good exposure to training and understand the values of good pastures. One way of reducing dairy production costs is to grow fodder to provide all-year round feed.

(g) *Increase in number of dairy cattle farmers.* The number of dairy farmers in Uganda has increased in the last last decade leading to increased demand for forage technologies and livestock products.

(h) *Non-government organizations, community-based organisations and producer associations involved in dairy cattle production are growing rapidly*. They organize training and extension program to help farmers on forage and livestock feeding.

(i) *The fertile soils and favourable climate* of Uganda are a good potential that will favour all pasture and fodder development efforts in the country.

(j) *The forage seed production industry* is being revived and is catching up well. Government efforts to privatise the industry locally will go a long way in stimulating local production and creating a demand for pasture seeds.

(k) Modern biotechnology offers opportunity for improvement of forage quality through breeding and other modern technologies.

Pasture research institutions in Uganda

The National Agricultural Research Organization is the apex body for guidance and coordination of all research activities in Uganda. In the NARO system, forage research is the mandate of the National Livestock Resources Research Institute (NaLIRRI). Other major institutions involved in forage research are Makerere University, NARO Zonal Agricultural and Development Research Institutes (ZARDIs), Bukalasa Agricultural College and Arapai Agricultural College, belonging to the Ministry of Education.

Historical highlights of forage research prior to 1960

Until 1947, grasses in Uganda were typically used for resting land in the crop rotation system or shifting cultivation. Emphasis was put on soil conservation rather than grazing as this was considered detrimental to the soil fertility and subsequent crop production. The grazing of the "resting" land was beneficial. These findings created a new awareness about forage research that could be considered as a "true crop".

A brief chronological listing of pasture research in Uganda up to 1960 is indicated below:

1906 Introduction of legume species primarily for vegetative cover and soil conservation.

1925 A collection of pastures grasses started near Kampala.

1930 Selected species from the 1925 planting were established in larger plots at Bukalasa for general observations on grazing and feeding.

1931 Grass collections were started at Ngetta and later at Serere in northern and eastern Uganda, respectively.

1932 Continuous cultivation of arable crops even with green manures was shown to result in decreased crop yields when compared to crop yields under shifting cultivation at Serere

Research Station now known as National Semi-Arid Resources Research Institute.

1933 All government farms changed their crop rotations to include a two to forty near planted grass rest (ley) phase. This policy gave the first impetus to research on local grasses.

1945 *Stylosanthes gracilis* was introduced to Uganda from Australia and planted at Kawanda now known as National Laboratories Research Institute, Kawanda (NaLR) and later at Serere.

1948 *Chloris gayana* was recommended as the best grass species for the grazed temporary ley in Uganda. In some areas, Napier (*Pennisetum purpureum*) was also commonly used for the temporary ley phase, but it proved difficult to eradicate from cropland. It requires vegetative planting, and it was better adapted as a fodder crop than for direct grazing.

1954 Detailed systematic work on grass and grass-legume mixtures was initiated at Serere.

1956-1958 Introduction of legume spp. for the "forest area" was initiated at Kawanda in addition to the earlier grass museum. These initial studies included over 100 grass species of temperate and tropical origins, and approximately 60 different tropical and temperate legumes.

1960 Comparison of chemical composition and nutritive values of grasses throughout the year were initiated at Serere Research Station.

Forage research after 1960

The introduction of exotic cows from Europe after 1960 was an impetus to extensive grassland improvement. Introduced and local forage species have, over the years been screened for: response to fertilizer regimes; persistence to drought; herbage dry matter yield and nutritive quality; compatibility of grass or cereal crops with forage legumes; tolerance to Napier stunt disease; seed production and animal productivity. Some of the technologies that have been developed and disseminated to farmers are highlighted below:

1. Forage species screening and evaluation

Forage legumes and grass germplasm comprising of local and introduced accessions from CIAT, South America and the International Livestock Research Institute (ILRI) in Ethiopia genebanks were selected for their potential suitability to tropical environments and were evaluated in other agro-ecological zones of Uganda. Some of the species that showed high persistence at both semi-humid and semi-arid sites were: *Macroptilium atropurpureum*, *Clitoria ternatea*, *Centrosema pubescens*, *Neonotonia wightii*, *Brachiaria hybrid* cv *mulato*, *Brachiaria brizantha*, *Brachiaria brizantha* (cv Toledo green, *Lablab purpurens*, *Desmodium uncinatum* (cv silver leaf desmodium), *Canavalia brasiliensis*, *Stylosanthes guianensis* (Cook), *S. guianensis*, *S. hamata* (Verano), *S. scabra.*

2. Evaluation of performance of asture grass-legume mixtures

Research was conducted to assess the compatibility of various pasture grasses intercropped with forage legumes with the intention to improve forage quantity and quality. In cases where the grass component is a food crop such as maize, incorporation of legumes was intended to improve grain yields in addition to enhanced quality and quantity of maize stover-legume fodder.

3. Development of supplementary feed rations

Appropriate supplementation with commercial concentrates is an effective way of enhancing the utilization of low quality feed resources such as crop residues thus sustaining dairy cattle performance especially during periods of pasture scarcity. However, in Uganda, the use of conventional dairy concentrate feed supplements is not a feasible option because of their high cost and inaccessibility. There are a variety of low cost homemade dairy concentrates that dairy farmers can use to overcome the challenge of fluctuations in quantity and nutritional quality of conventional cattle feeds in Uganda. The following feed rations were developed and disseminated to dairy farmers:

(a) Homemade concentrate

Homemade concentrate supplements were developed based on maize bran, cottonseed cate, calliandra leaf hay and mineral premix. A simple cost-benefit analysis showed an increase of 5% in gross margin when cows were fed on supplemented ration.

(b) Feed ration based on Wild Mexican Sunflower (Tithonia diversifolia)

To harness massive quantities of locally available sorghum stover, Wild Mexican sunflower based supplementary feed rations were formulated and evaluated. The study showed that sorghum stover and *Tithonia diversifolia* leaf hay have the potential to sustain milk production during the dry season, when hardly any pasture is available but best results can be achieved when the two feed resources are supplemented with maize bran and sugarcane molasses.

(c) Nutrient feed blocks

Nutrient feed block (NFB) technology is an innovative approach for supplying the necessary nutrients (protein, energy, vitamins and micro and macro minerals) to ruminants so as to take maximum advantage of poor quality forages and crop residues. The blocks were developed using locally available crop residues, agro-industrial by-products, conserved forages and farm waste.

(d) Maize stover-bentonite feed block

Maize stover is frequently contaminated with Aflatoxins, which are a group of closely related, biological active mycotoxins that are highly toxic, and carcinogenic fungal metabolites produced mainly by *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxins reduce growth and feed efficiency, and cause liver and kidney damages, immuno-suppression and changes in relative organs weight, increased mortality and enhanced susceptibility to infectious diseases. The inclusion of Calcium bentonite clay in a maize stover feed block in animal feeds leads to detoxification of aflatoxin-infested feeds. Supplementation of lactating cows with the ration resulted in doubling of milk production as compared to blocks lacking calcium bentonite. The increment was attributed to provision of minerals for animal physiological processes and sequestration of aflatoxins in dairy feeds.

(e) Sweetpotato vine-based partial milk substitute (PMS)

A study conducted to investigate the potential of a sweetpotato vine-based partial milk substitute (PMS) on feed intake and growth performance of Friesian bull calve showed improved dairy weight gain of calves. Weaning weights were higher among calves fed on PMS (64.9kg) compared to 53.94kg for the control. The results showed that PMS diets can be used as substitutes to reduce the cost of rearing a calf without adversely affecting its health and yet save more milk for consumption and processing. The results further demonstrate that the Friesian bull-calf can be raised with minimum resource input to add to the financial benefit of livestock farmers.

(f) Dairy cow pellets

NARO/NaLIRRI dairy cow pellets technology was based on the concept that feeding dairy pellet concentrates: (a) allows an animal to take in uniformly mixed diets with proportions of nutrients that have been formulated based on recommendations for the intended levels of production; (b) minimize feed wastage through reducing spillage leading to enhanced dry matter intake, digestibility of the basal feed and animal performance and (b); NARO/NALIRRI dairy pellets concentrates are produced from locally available crop residues and agro-industrial by-products thereby providing low cost and nutritious supplements to animals. Key achievements from the project activities included: (a) improved milk yield (3-4 litres/kg/cow/day); (b) increased household income (Ushs 2,000 3,000 per kg of pellets fed); (c) high demand for dairy pellets within Uganda and neighbouring countries; (d) the project has created employment opportunities for the youth and some of the group members have been able to invest in other businesses and; (e) the project has improved knowledge and skills of the youth and other stakeholders on commercial dairy farming.

(g) Sweetpotato silage as a supplement to lactating dairy cows

Sweetpotato is the third most important food crop after cassava and bananas in Uganda. Sweetpotato contributes about 20% of total crop by-products in form of vines, non-commercial sweet potato roots and sweet potato peels. Sweet potato residues can therefore be an emergency supply of feed for dairy cattle during periods of dry seasons. One major negative attribute of sweetpotato by-products is that although it is a good source of energy (roots) and protein (vines), they are highly perishable. There are times after harvesting that farmers have a lot of residues which are wasted in the fields. Yet these same farmers have pigs and/or dairy cattle which would feed on these residues. In order to make good use of sweetpotato residues a technology was developed by the International Potato Centre (CIP) in collaboration with NaLIRRI to conserve them in form of "**silage"** which has the potential to mitigate seasonal feed shortages and assist in coping with seasonal feed prices fluctuations that many smallholder livestock farmers experience. Sweetpotato silage technology as a supplement has been tested on farms in Wakiso and Masaka districts. Reports from small-scale dairy farmers in Wakiso and Masaka districts showed that sweetpotato silage as a supplement to dairy cows fed low quality basal feeds experienced an improvement of about 15% in milk yield The technology is one of the interventions to reduce feed cost and feed shortage and improve dairy cattle production in Uganda.

(h) Maize stover-molasses Total Mixed Ration

Although maize stover has a potential of becoming a major feedstock for ruminants where pastures are seasonal and scarce, poor nutritive quality limits its use. Maize stover, a post-harvest material left after the removal of the primary feed (grain) forms the bulk of unutilized feedstock in Uganda. The major challenge with maize stover as a feed resource is its low protein content. Although biological processing technology may enhance nutritional quality of maize stover while protecting the environment, it depends on fungal specie, biophysical conditions and substrate pre-treatment for desirable response on lignocellulosic biomass degradation. Solid-state fermentation of maize stover with a consortium on edible *Pleurotus* fungal species and molasses has a great potential to benefit both maize and livestock farmers in Uganda. The vast quantities of maize stover generated and discarded in the country annually, usually through burning, can be transformed into nutritive animal feed using this technology.

4. Forage seed production

Appropriate small-scale forage seed production technologies such as use of trellis to increase forage seed yields were developed for *Centrosema pubescens* (centro) and *Microptilium atropurpureum* (siratro) leading to increase in seed yield of 20%. Amendment of soil with phosphorus fertilizers is critical in enhancing lablab seed production of Phosphorus fertilizer. The highest increments in lablab seed yield of 40% were obtained at 30 kgP_2O_5 kg SSP in Uganda.

5. Silage and hay production for year around feed supply

The supply of nutrients in Uganda is seasonal because of the rainfall pattern. During the rainy season, there is luxuriant growth of pastures and during the dry season, pasture is very scarce with resultant decline in animal performance. Hence the need to conserve forage to bridge the nutrient gap during periods of scarcity. Studies have shown that conservation of forages in form of hay, haylage- or silage allows for intensive dairy farming with a higher stocking rate than would otherwise be possible.

Brachiaria hybrid cv. Mulato, a drought tolerant forage was introduced in Uganda in 2005 as an alternative to Napier, the predominant forage for dairy cattle in zero-grazing systems. Results of a study conducted in Masaka district showed that sowing forage legumes, including *Centrosema molle* (formerly *C. pubescens*) and *Clitoria ternatea*, with Napier or *Brachiaria* hybrid cv. Mulato improved both yield of forage and protein concentration.

Brachiaria mulato planted together with forage legumes increases fodder availability by milk yield and cash incomes by over 52 percent. The results confirmed that the currently recommended acreage of 0.5 ha of a mixture of Napier and forage legume cannot sustain an economically producing dairy cow and its calf for a full year. Therefore, establishment of an additional 0.5 ha of a mixture of the drought-tolerant Brachiaria with a forage legume is recommended for feeding during the dry season, when production of Napier monocrop is disadvantaged due to drought, the stunt disease and poor agronomic practices.

A number of factors affecting utilization of conserved forages (silage and hay) in smallholder dairy production systems were identified. They included: land shortage, high cost and unavailability of labour, economical-interest and benefits, market, lack of storage place and information source.

6. Methane emission from smallholder dairy feeding strategies

Modification technologies that directly influence rumen fermentation are rare practices on smallholder dairy farmers in Uganda. A study was conducted to evaluate the contribution of different feeding strategies on methane losses per unit of milk produced. Feeding strategies with adequate protein requirements for maintenance, production and pregnancy lead to production of more milk and increased methane losses. Findings of the study revealed that there is a great possibility for development of feed management strategies to mitigate methane emissions from cattle through enhancing animal production and reducing the amount of methane produced per unit of milk.

7. The Decision Support Tool (*Endiisa tool*)

A decision support tool (DST) (http://www.naro.go.ug/endiisa/tool.html) was developed to provide information on the low status of feeding of dairy cattle in the Central zone of Uganda. The tool helps to improved cattle feeding status and increase milk production by 24%. These were developed for a daily ration for a lactating cow of 4-6 lactations in its early stage of lactation (1-3 months) and weighing 450 kg.

8. Forage diseases

Napier grass production in Uganda is threatened by Napier stunt disease. The disease was first observed in central Uganda in 2002. The disease has been spread rapidly to over 100 districts where smallholder dairy cattle production is a major enterprise, causing up to 60% reduction in fodder yield within the first year. This has led to increased price of Napier grass in highly affected districts, insufficient feed for cows and selling off of animals by some farmers. This implies negative impact of NSD on millions of Ugandan farmers. Research on NSD focussed on: (a) assessing status of NSD and documenting farmers management practices, (b) characterizing the causal organism, (c) determining the effect of the disease on fodder yield, (d) screen Napier grass accessions for tolerance to NSD, and (e) characterizing Napier grass accessions based on simple sequence repeat markers. Studies have been conducted to:

(a) Assess status of NSD and document farmers management practices

(b) Identify causes of Napier stunt disease

This was the first report of a 16SrXI Group phytoplasma (*Candidatus Phytoplasma oryzae*) associated with Napier grass stunt disease in Uganda

(c) Evaluate Napier accessions for dry matter yield, nutritive quality and tolerance to Napier stunt disease

Research was conducted to screen Napier grass accessions that were found to be tolerant to NSD in Kenya. Among the 22 introduced Napier grass accessions: 105, 112, 16702, 16789, 16805, 16815, 19, 75, Kakamega 1, and Kakamega 2 did not show disease symptoms up to seventh harvest. Annual dry matter yields of the cultivars ranged between 17 and 42 t/ha with Kakamega 1 and Kakamega 2 producing the highest (40 to 42 tonnes/hectare respectively). Kakamega 1, Kakamega 2, 112, 16702 and 16805 were recommended for multiplication in NSD “hot spot” areas.

9. Socio-economic benefits from improved forage technologies

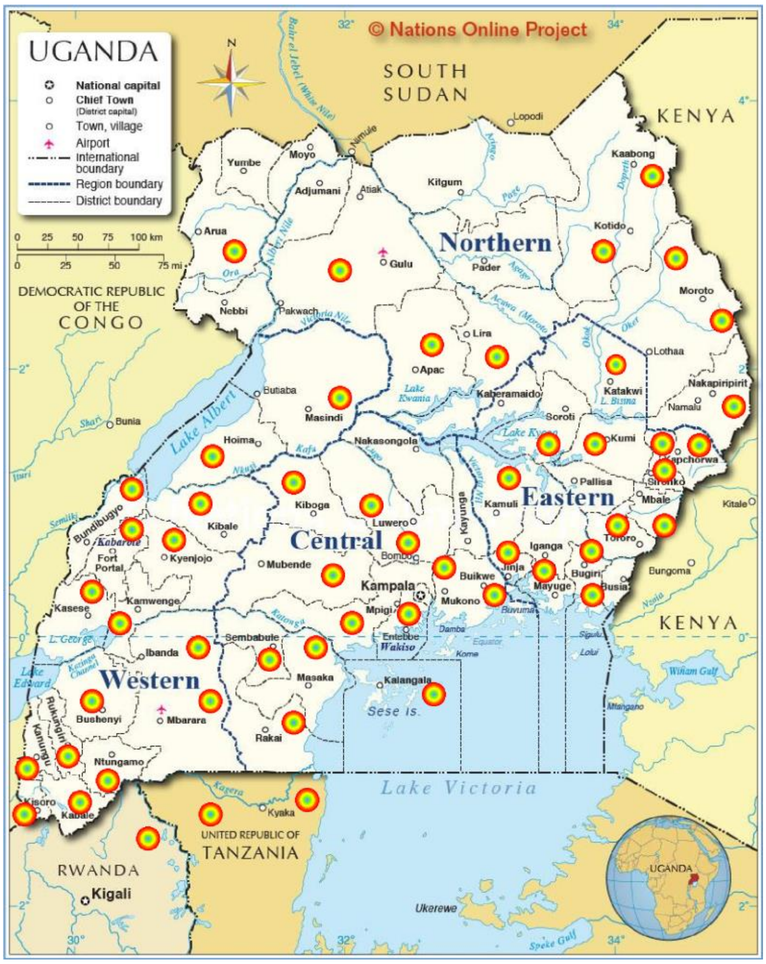
*S*tudies conducted to compare the profitability of dairy cattle enterprises that uses improved forage technologies (IFT) and local technologies showed that farmers who use IFT had significantly higher gross margins than those using local feeding methods.

(a) Farmers using IFT produced more milk than IFT non-users and generated a five times bigger margin per cow per season than IFT non-users.
(b) Farmers using local grazing methods had an average return on inputs of 3.1%, a profitability level that is competitive with "safe" input investments, but not as competitive as 12.3% for farmers using IFT.
(c) The higher return of farmers using IFT was related to commercialized production, high milk yields and labour efficiency.
(d) Stocking density, improved breed and age of a farmer were found to be significant and positively related to profitability level.
(e) Access to credit had a negative and significant effect on the level of profitability. Farmers accessing credit were re-allocating money or inputs obtained on credit to other enterprises.

Contribution to technology dissemination

(a) Multiplication and distribution of forage seed

Seed and planting materials for various forage species including Napier grass varieties that are tolerant to Napier stunt disease, lablab, Rhodes grass, Brachiaria grass, Siratro, Style, Alfalfa, Centro, Desmodium, and *Clitoria ternatea* among others, have been bulked and distributed to stakeholders. Over 500 tons of high quality pasture seed was produced and marketed during the period of 2010 to 2016. The seed was produced both on farmers' farms and government farms.



Map showing areas where pasture seed was produced and forage technologies disseminated

Major challenges to pasture research in Uganda

A number of key constraints affecting forge research and utilization include:
(a) Limited capacity and competences in forage breeding;
(b) Limited research infrastructure/facilities e.g. equipment such as isotope analysis facility: water use efficiency for drought tolerance;
(c) High cost and/or poor-quality inputs (seed, fertilizers etc). Pasture seed is not available and if available it is too expensive;
(d) Poor persistence of forage legumes in grass/legume mixture;
(e) Emergence of new forage diseases and pests;
(f) Low level of adoption of forage technologies that would alleviate seasonal shortages;
(g) Weak research programmes particularly in the area of forage improvement and contribution of forages to carbon sequestration and mitigation of ruminants methane emissions;
(h) Low investment in research on animal nutrition and forage research programmes;
(i) Few studies have been conducted to assess socio-economic benefits of forage technologies.

Future research priorities

(a) Continue to collect and conserve native biodiversity of forages;
(b) Strengthen forage breeding research work for biotic and abiotic stresses;
(c) Conduct cost benefit analysis of pasture farming based dairy production system;
(d) Capacity building of scientists and other stakeholders.
(e) Identify best options for dissemination of forage technologies for increased adoption;
(f) Strengthen forage seed (systems) industry;

(g) Research on microbial manipulations for increased pest and disease tolerance and drought.
(h) Develop methods and decision support tools for feed budgeting and rationale utilisation of available feed resources;
(i) Establish regional forage improvement programmes for increased quality herbage productivity and tolerance to biotic and abiotic stresses;
(j) Promote exploitation of desirable attributes of forages in the mitigation of ruminants greenhouse emissions and access to carbon credit market.
(k) Develop crop residue conservation, processing and utilization technologies to ensure adequate feed supply throughout the year;
(l) Develop and promote forage/pasture cultivars that can grow in synergy with food crops for crop-livestock integration;
(m) Conduct research on microbial manipulations for increased pest, disease and drought tolerance.

Sources of funding for pasture research

Revitalization of forage research in Uganda from 1990s is credited to the National Agriculture Research Organization (NARO), National Livestock Resources Research Institute (NaLIRRI), Makerere University; the World Bank, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Ministry of Agriculture, Animal Industry and Fisheries, Government of Uganda; Eastern Africa Agricultural Productivity Project (EAAPP); Agricultural Technology and Agribusiness Advisory Services (ATAAS); The Rockefeller Foundation; Food and Agriculture Organization (FAO), International Potato Centre (CIP), CIAT, ICRAF, DANIDA, The Green Elephant (U) Ltd and the International Livestock Research Institute (ILRI).