NAPIER GRASS FEED RESOURCE: PRODUCTION, CONSTRAINTS AND IMPLICATIONS FOR SMALLHOLDER FARMERS IN EAST AND CENTRAL AFRICA

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Preface

Milk is an important part of the diets of people in Eastern and Central Africa (ECA) and makes a major contribution to national food security, income generation and rural development. Smallholders produce the vast majority of milk in ECA. Napier grass (*Pennisetum purpureum* Schumach) constitutes 40-80 percent of forages used by smallholder dairy farmers. The productivity of Napier grass in the region is currently threatened by stunt and smut diseases causing yield reduction of over 40 percentage.

Responding to Eastern Africa Agricultural Productivity Project (EAAPP) Thematic Area 4: fodder and pasture research along the dairy value chain, the regional project “Enhancing adoption of Napier grass and alternative fodder grasses resistant/tolerant to stunt and smut diseases for increased feed availability in smallholder systems in Eastern and Central Africa region” generated and disseminated technologies and innovations for managing Napier stunt and smut disease in the ECA. The project improved capacity of stakeholders to utilize technologies for managing smut and stunt diseases through awareness creation and encouraged information sharing to enhance the adoption of high yielding alternative forages and tolerant Napier grass accessions in the region to alleviate feed shortages, improve milk yield and household income. The grasses tolerant to stunt and smut diseases produced higher dry matter yields and were integrated into the cropping systems.

Adoption of genetically diverse, high yielding and climatically adapted fodder plants will improve the performance of the dairy sector, alleviate the current shortages and environmental crises associated with forage diseases, pests and climate change and create employment opportunities. This will contribute to food and nutritional security, social and gender protection, poverty alleviation and environmental sustainability.

The lessons learned are particularly valuable for dairy farmers, students, development parteners, policy makers developing national and regional dairy strategies and for those planning national food security and human development programmes.

This book is one of numerous outputs of a collaborative project between the Eastern Africa Agricultural Productivity Programme (EAAPP), Association for Strengthening Agricultural Research in Easterns and Central Africa (ASARECA), National Agricultural Research Organization (Uganda); National Livestock Resources Research Institute (Uganda); National Crops Resources Research Institute (Uganda); Kenya Agricultural and Livestock Research Organisation (Kenya); International Livestock Research Institute (Kenya); International Centre of Insect Physiology and Ecology (ICIPE-Kenya); International Centre for Tropical Agriculture (CIAT-Kenya); Rwebitaba Zonal Agricultural Research and Development Institute (Uganda); Biosciences Eastern and Central Africa - International Livestock Research Institute (BecA - ILRI) Hub (Kenya); Alupe Research Station (Kenya); Department of Biological Sciences, Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam (Tanzania); Masinde Muliro University of Science and Technology (Kenya); Makerere University (Uganda) and Tanzania Livestock Research Institute (Tanzania).

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Abbreviations/Acronyms

AfDB	African Development Bank
AEZ	Agro-Ecological Zones
APSK	Animal Production Society of Kenya
ASAL	Arid and semi-arid lands
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CAADP	Comprehensive Africa Agricultural Development Programme
C.A.N.	Calcium ammonium nitrate
CIAT	International Center for Tropical Agriculture
DAP	Di-ammonium Phosphate
EAAPP:	Eastern African Agricultural Productivity Project
ECA	Eastern and Central Africa
ESAZ	Eastern Semi-Arid Zone
FYM	Farm Yard Manure
ft	feet
GDP	Gross Domestic Product
HIV/AIDS	Human immunodeficiency virus infection/acquired immune deficiency syndrome
IFAD	International Fund for Agricultural Development
ICIPE	International Centre of Insect Physiology and Ecology
BecA - ILRI	Biosciences eastern and central Africa - International Livestock Research Institute Hub
ILRI	International Livestock Research Institute
IPM	Integrated Pest Management
KALRO	Kenya Agricultural and Livestock Research Organisation
KW4	Kawanda variety 4
LVB	Lake Victoria Basin
m	Meter
MDGs	Millennium Development Goals
MoLD	Ministry of Livestock Development
N	Nitrogen
NaCRRI	National Crops Resources Research Institute
NaLIRRI	National Livestock Resources Research Institute
NARS	National Agricultural Research Systems
NEPD	New Partnership for African Development
NGO	Non-Government Organization
NSD	Napier Stunt Disease
P	Phosphorus
P99	Pennisetum 99 hybrid
P2O5	Single super phosphate
PCU	Project Coordination Unit
RAB	Rwanda Agriculture Board
RCoE	Regional Centre of Excellence
RDCoE	Regional Dairy Centre of Excellence

SDP	Smallholder Dairy Research and Development Project
T	Tonne
TBC	Tanzania Broadcasting Corporation
TALIRRI	Tanzania Livestock Research Institute
TSAP	Tanzania Society of Animal Production
UNDP	United Nations Development Programme
USD	United States Dollars
WR	Western Rangelands

CHAPTER 1: Smallholder Dairy Industry in Eastern and Central Africa

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1.1 Smallholder Agriculture in Eastern and Central Africa (ECA): Trends, Constraints and Opportunities.

Ethiopia, Kenya, Tanzania and Uganda can be characterized as "agriculture-based," that is, agriculture is the backbone of these economies (Adeleke Salami et al., 2011). In Ethiopia and Tanzania, agriculture remains the main contributor to the Gross Domestic Product (GDP), contributing 47% and 43%, respectively. In Uganda and Kenya, however, the rapid development of the service sector with a growth rate of about 9.5 percent, has outpaced agriculture, contributing 45% and 60% of the GDP, respectively, far above agriculture's contribution of 30 and 34%. Nevertheless, agriculture still accounts for about 75% of the labor force in all the ECA countries, underscoring the importance of the sector in job creation and poverty reduction across countries.

Agriculture is dominated by smallholder farmers who occupy the majority of land and produce most of the crop and livestock products. According to Adeleke Salami et al. (2011), African smallholder farmers can be categorized on the basis of: (i) the agro-ecological zones in which they operate; (ii) the type and composition of their farm portfolio and landholding; or (iii) on the basis of annual revenue they generate from farming activities. In areas with high population densities, smallholder farmers usually cultivate less than one hectare of land, which may increase up to 10 ha or more in sparsely populated semi-arid areas, sometimes in combination with livestock of up to 10 animals defined smallholder farmers on the basis of land and livestock holdings, cultivate less than 2 hectares of land and own only a few heads of livestock.

The key long-standing challenge of the smallholder farmers is low productivity stemming from the lack of access to markets, credit, and technology, compounded by the volatile food and energy prices and very recently by the global financial crisis.

1.2 Smallholder Dairy Production in ECA

Livestock, and especially cattle, have historically played multiple roles both in economic life and in socio-cultural traditions of African people. Cattle have been valued not simply as a source of food (milk, blood and meat) and hides but also as a visible form of wealth and a source of social prestige. In certain parts of the region, cattle still provide a valuable source of draft and traction power both for the plough and for transportation carts whereas in Arid and semi-arid lands, cattle still provide a valuable security against famine.

The dairy industry plays an important role in food security, employment creation, income generation, and enhancement of the livelihoods of dairy farmers, traders, processors and all participants engaged in the entire milk supply chain (Muia et al 2011). Studies by Njarui et al (2011) showed that milk and milk products are an important dietary component for all social strata. In coastal lowlands of Kenya, Nicholson et al (2004) reported that for each cow owned, mean household income increased by 53% compared with households without dairy cows.

Studies conducted in ECA region have shown that women are the caretakers where dairy cattle are stall-fed (Kabirizi, 2006; Njarui et al., 2012). This provides women with access to the benefits of dairy keeping, such as the opportunity to sell products like milk. The income helps the women to meet their immediate needs and to enhance their status in the household and at the community level. Given the current trade and economic imbalances.

Dairy development may play a crucial role in diversifying the income base of farmers who are affected by low prices for primary commodities on the world market.

The contribution of dairy cattle to the reduction of child mortality is well demonstrated through the enhanced capacity of poor households to meet health related expenses from the income earned from sale of milk and other products (Nicholson et al., 2004). Besides, studies have indicated a generally positive interaction between livestock and human health, as high value nutrients from milk contribute to the health conditions of vulnerable. For maternal health, milk and milk products, and occasionally meat contribute massively to the nutritional status of women. Dairy production is very useful as a mitigation strategy for HIV/AIDS affected families (Vorster et al. 2004).
Dairy plays crucial roles in recycling of waste products and residues from cropping systems through feeding while dung and urine from the livestock is a good source of manure for enhanced soil fertility in cropping systems. In the high potential areas, the economic importance of the cow has increasingly shifted to commercial milk production while at the same time retaining the complementary role of sustaining soil fertility for sustainable agricultural production. In such area, increasing population pressure interacting with the need to sustain soil fertility has driven the change in production structure with dairying becoming an important component of agricultural production

Eastern Africa is Africa's most promising region for dairy production. The region holds over 40 percent of Africa's cattle resource of about 222 million (FAO, 2010). There are differences in development of dairy sub-sector between countries within the ECA region, with Kenya having a longer history in dairy farming than the other countries (Omore et al., 1996).

The dairy industry's contribution to Gross Domestic Product (GDP) is 3 percent in Kenya, 5 percent in Tanzania, and 8 percent in Uganda (FAO, 2011). Milk production is estimated to be five million tonnes per year, 60 percent of which is produced in Kenya (FAO, 2011). More than 80 percent of the milk is traded informally as raw milk. Within sub-Saharan Africa, Eastern Africa has the highest concentration of traditional cattle and improved dairy cattle. Kenya, with over 2.7 million improved cattle, accounts for about 75 percent of improved dairy cattle in Eastern and Southern Africa, and about 20 percent of the estimated 17.9 million tonnes of milk produced in sub-Saharan Africa in 2003 (Muriuki and Thorpe 2001). Smallholder dairying dominates in the region and Kenya is the major regional producer, processor and exporter of dairy products.

Exotic dairy cattle were first introduced in Kenya from Europe by white settlers in 1920s, who established dairy farms in Central highlands and Rift Valley region. Although few farmers in the semi-arid region of Eastern Kenya commenced dairy farming in 1960s, it was not until in 1980s and onwards when there was accelerated adoption of dairy farming (Njarui et al 2009). On the other hand, dairy farming is relatively young in Uganda with the first introduction of dairy cattle from Germany in 1980s (Kabirizi et al., 2006). In the recent past, there has been a steady growth of dairy farming in the region and it has increasingly become an important source of livelihoods.

Smallholder dairy farming is growing in Tanzania at a rate of 6% per year, with an estimated 190,000 registered farmers (Anon, 2002). Despite the fact that smallholder dairy farming is widespread in different parts of Tanzania where the climate is appropriate, the supply of milk and milk products in these regions has not kept pace with the rapid increase in the human population. Productivity in existing smallholder dairy herds is constrained by the small size of farms and their distance from markets, animal health and reproductive problems and lack of good-quality animal feeds in sufficient quantities. Other constraints include lack of infrastructure for input and output markets, unfavourable regulatory and taxation policies, poor flow of information, restricted access to credit and limited supply of dairy cattle. Nevertheless, the sector is acknowledged for its contribution to household food security, employment opportunities and as a regular source of income for farmers. Dairy production integrated into rural, peri-urban and urban smallholder mixed farming systems may increase and stabilize farm incomes and act as a catalyst for agricultural development and improved standards of living. The authors conclude that smallholder dairy production is an important undertaking and, if adequately supported by appropriate policies and adaptive research technologies, it may contribute significantly towards the household economy, self-sufficiency in milk and national gross domestic product.

The expanding smallholder dairy industry in the ECA region is fuelled by increased urbanization and improved income, resulting in high demand for milk and milk products. Consequently, many dairy farms have been established in peri-urban areas of major commercial urban centres with increased adoption of improved dairy cattle of European breed (Bos taurus); Holstein-Friesian, Aryshire, Guernsey, Jersey and their crosses with local zebu (Bos inducus). The production is mainly dominated by smallholders who own few dairy cattle. As smallholder farmers make major shift towards market-oriented dairy production, they are faced with several challenges.

1.3 Major Constraints to Smallholder Dairy Production in ECA

Smallholder agriculture in the Uganda, Kenya, Ethiopia and Tanzania has been facing numerous constraints. While some are unique to each of the countries, most are of a similar nature, implying that common solutions would address them across countries

(a) Land tenure, access rights and land management

The uncertainties regarding land tenure and the inadequate access to land have been a critical challenge to smallholder farming in ECA region (Kabirizi et al., 2011). The constraints related to the tenure system, such as insecurity of land tenure, unequal access to land, lack of a mechanism to transfer rights and consolidate plots, have resulted in under-developed agriculture, high landlessness, food insecurity, and degraded natural resource. Furthermore, the available land in East Africa is overly subdivided into small and uneconomic units, resulting generally in fragmented production systems and low productivity. In fact, the farm sizes range from as low as about 1ha per household in Ethiopia and 2.0 ha in Tanzania and 2.5ha in Uganda and Kenya (Njarui et al., 2012).
The land ownership issues go well beyond small sizes of plots. For example, in Ethiopia, all land

is state-owned, according to the country's 1994 constitution. In practice, traditional land tenure arrangements prevail as an outcome of subsistence agriculture, with peasant associations responsible for allocating land to residents (Kamara et al 2004).

Equally important, in terms of access to additional land, is proper management of the existing one. According to Kimaru and Jama (2005), in East Africa sustained gains to agricultural productivity are threatened by land degradation, especially land erosion and loss of fertility. Adeleke Salami et al. (2011) recommended that clear land-use and agricultural policies need to be developed to provide a framework for researchers, extension workers and smallholder farmers on environmentally-sensitive practices. Nevertheless, the lack of clarity of property rights and un-equitable access to land exacerbate the land degradation problem.

Studies conducted in Uganda showed that land scarcity and land tenure system have direct implications on the quantity and quality of feed or level of feed investment smallholder farmers can make for improved dairy cattle production. (Kabirizi et al,, 2006). In customary land system, the right over land is regulated by local customs and is acquired through inheritance. Security of land is therefore minimal and there are sometimes conflicts among clan members. Under customary land tenure system, women are most discriminated against in the administration and dispute settlement of customary land. Even after planting the forages, there are times when clan leaders sell or give away the land. This is one of the reasons for not planting large acreages of forages because of fear of loosing the land after investing a lot of resources. Information from farmer groups showed that 67% of the women had access to land through their husbands or male relatives but when widowed or divorced, 7% of the women lost this access and had to return to their parents' land. This was a major problem especially where the woman had already invested in a dairy cattle enterprise and had planted fodder.

(b) Access to input and output markets

Improved access to input and output markets is a key precondition for the transformation of the agricultural sector from subsistence to commercial production. Smallholder farmers must be able to benefit more from efficient markets and local-level value-addition, and be more exposed to competition. The ECA countries are still grappling with marketing of both agricultural inputs and outputs, with markets not adequately equipped to serve the needs of the poor.

On the input side, the average application rates of fertilizer for arable crops in ECA countries are estimated to be 30 kg/ha/year in Kenya, 14 kg/ha/year in Ethiopia, 5kg/ha/year in Tanzania and1 kg/ha/year in Uganda – far less than the world average of 100kg/ha/year (Smaling et al , 2006) . There is also the problem of high cost and waste of key inputs such as seed and fertilizers. For this reason, it was reported in UNDP (2007) that farmers have substantially reduced use of quality inputs such as seed, fertilizer, and pesticides and that the respective use of improved seeds, fertilizers, agro-chemicals and manure were only 6.3 per cent, 1.0 per cent, 3.4 per cent and 6.8 per cent of the parcel of agricultural land in Uganda.

Limited access to market-related information e.g. on prices, value chains, competitors, consumer preferences leads to either high or low production of some products and the related marketing constraints. Among the consequences of lack of market information is the presence of a multiplicity of intermediaries which increases the charges and shades the transparency of the operation. The presence of so many actors/many informal channels means less profits per actor but expensive prices and longtime taken by product to reach consumers. The risks of product adulterations also increase as actors increase along the value chain.

(c) Inadequate feeds

Limited feed resource is a major constraint that hinders the growth of dairy farming in ECA (Njarui et al. 2012). The limited feed resource is attributed to limited amount of rainfall, punctuated with frequent drought, leading to poor growth of pastures. The situation is exacerbated by shrinking land holdings due to increased population and cultivation of food crops. This has negatively affected the number and type of animals that farmers keep and, manure quantity and quality. Nutrient deficiencies in the soil in the EAC region has greatly affected feed supply for the dairy subsector (Mubiru et al., 2003). This is caused mainly by excessive removal of vegetation through grazing and harvesting feeds. Often, these nutrients are not replenished or unevenly deposited back in the soil.

(d) Climate change and related food security challenges

Climate change, resulting mostly from global warming, has been among the major causes of reduced agricultural production and productivity in many parts of Africa, including ECA region. Most crop and livestock farming is rainfed, and therefore, susceptible to weather fluctuations. Over the last three decades the frequency of droughts and floods in ECA region has increased, resulting in crop failures and loss of livestock (Ericksen, 2010). Ethiopia has been hit hardest by persistent drought, making food security the key issue for poverty reduction. Furthermore, with increasing land degradation, land resilience has been reduced and the effects of drought and floods exacerbated.

(e) Infrastructure

Poor infrastructure continues to impede agricultural activities in ECA region. The key challenges are inadequate and poor conditions of the market facilities and transportation systems, including road and rail. Previous infrastructural investments were often ineffective as a result of poor design and poor maintenance, sometimes due to stop-go practices of donors funding these investments. The road system, which is the most important for market development in terms of distribution of inputs and output to and from farms, is the most serious infrastructural bottleneck facing agricultural development. As a result of poor road network, smallholder farmers depend on inefficient forms of transportation including use of animals. In addition, irrigation facilities are poor as less than 4 percent of all agricultural output is produced under irrigation compared with about 33 percent in Asia (AfDB/IFAD, 2009).

(f) Agricultural extension and innovation

Research and extension services in most of the ECA countries have been disintegrated and ineffective for any technological transformation to take effect. Despite various attempts to strengthen them, the linkages between research, extension and training are weak, and collaboration between public and private partners limited.

(g) Processing and marketing

Although crop and livestock production in the ECA region is largely subsistence, the trend is gravitating towards commercialization. Njarui et al. (2010) observed that about 15% of dairy cattle farmers in Kenya produce between 11-20 litres of milk/day resulting into surplus milk available for direct sale and for processing into other milk derivatives. Further the study revealed that 43% of the milk producers lacked market for their milk during the milk glut period.

(h) Increasing labour productivity

The ECA region will probably be transformed from a mostly rural to urban population due to rural – urban migration caused mainly by difference between urban and rural wage rates, probabilities of obtaining urban jobs, and the demand for labour force. Majority of the urban migrants are youth (especially male), as such continuous migration from rural to urban area will in a long run affect the labour availability in the rural area as the rural farmers age.

(i) Poor livestock breeds

Many improved breeds of dairy cattle exhibit an inherently low genetic potential for productivity traits. Even the exotic cattle reared under tropical conditions suffer a lot from heat stress and vector-borne diseases due to their poor adaptability. According to Petrus et al (2011), use of improved breeds in developing countries presents farmers with a major challenge as the breeds require intensive management for them to realize full production potential. Attempts to increase cattle productivity through crossbreeding between local and exotic breeds have not always been successful because of inefficient breeding programmes characterized by ambiguous breeding goals, poor records, inadequate feeding; limited technical personnel among others.

(j) Animal disease and parasites

In most ECA countries, animal health is probably the area which has benefitted the most from government efforts. Since colonial days, the delivery of health services has long been a major concern. Currently, livestock health services are supported by several sub-regional vaccine laboratories, and a few regional reference diagnostic laboratories. Training of veterinarians is quite widespread in Africa. But these research and training efforts are adversely affected by improvisation, lack of concerted action and coordination and a poor definition of real needs. Consequently, the smallholder dairy farmers are still plagued by major contagious diseases (rinderpest, contagious bovine pleuropneumonia (McDermott, 1999).

(k) Processing and value addition constraints

Because of the high perishability of animal products, timely processing and value addition is an important step in the dairy value chain to ensure sustainable supply of products, preventing loss and associated healthy risks. There are, however, several constraints to realizing this important value chain component: (i) lack of processing and preservation facilities for the extended storage life of meat and milk. Technology is either not available, expensive or no power to operate machinery and, (ii) poor quality of finished products (e.g. packaging, standards): This is caused due to poor understanding of each value chain plays' requirements, thus substandard products delivered along the value chain.

(l) Gender issues affecting dairy production

Despite their considerable involvement and contribution, women's role in smallholder dairy cattle production has often been underestimated or, worse, ignored. Gender-blindness is partly the result of a paternalistic bias, but also women's attitude which may have been conditioned by their culture and society to undervalue the worth of the work they do. Yet in most systems, women provide labour for the various tasks related to dairy production but may or may not control the process of decision-making, particularly over the disposal of animals and animal products and also may not own the means of production e.g.livestock, land and water. Kabirizi et al. (2006), noted that husbands and wives both usually have control over the use of resources, although there may be "unequal, often conflicting claims on resources for the satisfaction of basic needs". Men's de jure ownership rights over animals are guaranteed by a near universal set of inheritance rules that are gender biased and rooted in religion and patriarchal kinship systems.

(m) Lack of business skills

Lack of business management skills (e.g. production planning) and, in particular, inadequate access to the knowledge and technologies needed to meet rising sanitary standards, making it extremely difficult for smallholders to gain credible certification of compliance with marketing requirements (Lundy et al. 2008).

(n) Financing Agriculture and Access to Credit

For investment, smallholder dairy farmers in ECA countries depend on savings from their low incomes, which limits opportunities for expansion. Because of the lack of collateral and/or credit history, most farmers are bypassed not only by commercial and national development banks, but also by formal micro-credit institutions. In addition to own sources, farmers thus rely on incomes of friends and relatives, remittances, and informal money lenders (Mahieux et al. 2011).

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CHAPTER 2: Eastern Africa Agricultural Productivity Project (EAAPP)

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2.1 Background

Agricultural technology is fundamental to productivity growth and requires effective and efficient innovation systems in order to generate high returns in investments. According to the 2008 World Development Report, the policy environment for agriculture in much of Africa has much improved relative to earlier years. This justifies increased investment in agricultural technology development in order to negate losses in foregone returns. Among the foregone returns are gains from economies of scale that would arise from the assembly of the critical mass of researchers and facilities needed to address the complex problems of African agricultural innovation systems and commodity value chains.

The East African Agricultural Productivity Programme (EAAPP) was conceived in 2009 by the governments of Ethiopia, Kenya, Tanzania and Uganda in partnership with ASARECA and the World Bank. EAAPP addresses the constraints related to low productivity in cassava, wheat, rice and dairy in the project countries of Uganda (cassava), Kenya (dairy), Tanzania (rice), and Ethiopia (wheat). The specific objectives of EAAPP are to: (a) enhance regional specialization in agricultural research; (b) increase regional collaboration in agricultural training and dissemination; and, (c) facilitate increased sharing of agricultural information, knowledge and technology across national boundaries.

These objectives are being pursued through: (i) strengthening the existing Uganda national agricultural research program in cassava so that it becomes a RCoE; (ii) supporting regional research, training and dissemination of relevant technologies; and, (iii) supporting increased availability of improved genetic materials (planting materials, seeds and livestock germplasm) in the selected commodities in participating countries.

2.2 The Regional Dairy Centre of Excellence (RDCoE) overview

Kenya is amongst the biggest per capita milk producing and consuming countries in the region. There are more than 1 million smallholder dairy farmers, according to surveys done by the Smallholder Dairy Research and Development Project (SDP), contributing more than 70 percent of gross marketed production from farms (FAO, 2011)..

The dairy sector in Kenya is dominated, at the producer level, by smallholders farmer and at the marketing level by informal sector traders and hawkers. At present, a large proportion of marketed milk (86%) is sold informally (FAO, 2011). The livelihoods of millions of people in the country depend on these informal milk markets, which are often the sole source of income for small-scale dairy producers and jobs for thousands of unskilled youth. It is estimated that, from smallholder farmers (producers) to milk hawkers, nearly 1 million households and businesses are involved. Informal milk sector accounts for more than 70% of 40,000 jobs in dairy marketing alone and further directly supports over 350,000 others in formal employment. Considering that there are 1 million smallholders' farmers, for whom dairy is a family business, it is likely that more than 2 million people derive living from the dairy sector through their involvement in production, marketing and service provision.

Kenya was selected to host the dairy Regional Dairy Centre of Excellence (RDCoE) because it is a national priority with;

(1) Proven potential for sub regional spillovers
(2) Proven potential for leadership in dairy
(3) It is aligned with regional priorities as defined by ASARECA
(4) Proven potential to address both immediate and long-term food security needs and
(5) Kenya demonstrated interest to support the development of the RDCoE

The goal of the RDCoE is to improve the livelihoods of smallholder dairy farmers within the Eastern Africa region. The purpose of the RDCoE is to develop, test and disseminate technologies, knowledge and information that will assist in building a globally competitive dairy industry in the region.

The RDCoE objectives are:

(a) To provide state-of-the-art analysis of feeds and dairy products in the region
(b) To develop, test and disseminate improved dairy technologies in the region
(c) To build scientific capacity to carry out quality dairy research in the region
(d) To build the capacity of other stakeholders in the region to provide support services to the dairy sector in the region. Together with other stakeholders generate information that will assist in the development of enabling dairy policies in the region.
(e) To establish an elaborate communication strategy both nationally and regionally to ensure real-time information exchange

The regional Priority areas of focus

(a) ***Animal genetic improvement*** (Covering genetic resource characterization, breeding, germ-plasm multiplication, upgrading of local genetic resources, gene-environment interaction/ matching, related policies, etc)
(b) ***Feed resource utilization*** (covering fodder/pasture, crop residues, fortified feeds, ration formulation, pasture/forage breeding, seed multiplication, feed conservation, feed safety, farming systems) Animal health (Covering all aspects of animal health, policy, regulatory services)
(c) ***Processing and value addition*** (covering all aspects of dairy products value addition to increase competitiveness in the regional and world markets)
(d) ***Socio-economics*** (covering policy analyses, farmer oriented socio-economic studies, trade, management of information systems, monitoring and evaluation, impact assessment studies, feasibility studies, input/output markets, gender studies)

Expected outcomes

(a) A state of the art Dairy Centre of Excellence with the necessary support systems that will underpin a competitive dairy sector in the region is established.
(b) Competitiveness, productivity and sustainability of the regional dairy industry is improved through development, validation, dissemination and up-scaling of appropriate technologies to stakeholders.

(c) Linkages between the regional scientific and farming community with the various Eastern Africa governments'
policy-making organs and the general integration of regional economy catalysed.

(d) Capacity of all dairy industry stakeholders (researchers, extension, farmers, private entrepreneurs, policy-makers, etc) improved through formal training and learning exchange visits.

(e) Information flow in the region reinvigorated through establishment of region-wide information exchange network. Dairy data, analytical reports, publications, extension messages and experiential knowledge can have wide circulation and therefore readership also improved.

(f) Overall, an improved dairy industry, will impact positively on both national and regional economy. In particular, it will directly contribute towards poverty reduction and creation of employment

2.3. Thematic areas of the RDCoE

1. Feeds and feeding systems
2. Crop residues and agro-industrial by-products research
3. Dairy breed development and germplasm multiplication
4. Dairy Feed Safety Research
5. Dairy Health Research and Development
6. Farming Systems Research

2.4. RDCoE approved projects

1. Enhancing adoption of Napier grass accessions tolerant to Napier stunt and smut diseases for improved feed resources availability in smallholder dairy systems.
2. Enhancing Adoption of Appropriate policies and safety standards of feeds and milk for improved livelihoods in the ECA countries.
3. Improving value addition and marketing of milk for smallholders In East African Region
4. Improving indigenous cattle for dairy productivity through targeted selection and cross breeding in ECA countries.
5. Improve East Cost Fever control by contributing towards efficient vaccine development.

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CHAPTER 3: Napier grass: Challenges, Establishment, Management and Utilization

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3.1 Introduction

Napier grass, commonly known as elephant grass (*Pennisetum purpureum*) was named after colonel Napier of Bulawayo in Zimbabwe who early in the 19th century urged Rhodesia's (now Zimbabwe) Department of Agriculture to explore the possibility of using it for commercial livestock production (Boonman, 1993). In Uganda, Napier grass used to be promoted in Uganda for soil conservation and for mulching coffee. According to Acland (1971) it turned out that very few smallholders mulched their coffee and found it more profitable to sell Napier grass to coffee estates or feed the grass to their livestock. Napier grass has advantages over other grasses because of its high yielding capacity and ease of propagation, and management within a wide ecological range (0 < 2,000m ASL) (Orodho 2006). It has so far become the most important fodder for cut-and-carry especially in Kenya, where it is mainly propagated through cuttings (Humphreys 1994).

3.2. The role of Napier grass in smallholder dairy farming systems

(a) Napier grass as major feed resource in intensive and semi-intensive dairy systems

Napier grass is a major forage for dairy cattle in intensive and semi intensive systems, grown by over 70 percent of smallholder dairy farmers in Kenya (Abate 1992; Staal et al., 1998; Orodho 2006; Mulaa et al., 2013); Uganda (Kabirizi et al., 2006) and Tanzania (Pallangayo et al., 2008). It constitutes between 40 to 80% of the forage for the smallholder dairy farms (Staal et al., 1997). Because of high population pressure farms are small, with an average holding size of 0.9-2.0 ha (Gitau et al., 1994); and are still decreasing. Animals are, therefore, confined in stalls and fed mainly on Napier grass under zero grazing.

(b) Soil fertility improvement

Napier grass is widely used for soil and water conservation in hilly slope areas. In Uganda and Kenya, for example, vigorous campaigns are being undertaken to sensitise and encourage farmers to take on Napier grass cultivation for fodder and as a measure to control stem borers and soil erosion.

(c) Control of stem borers in maize and sorghum crops

Napier grass has been identified as an important tool in the integrated management of stem borers of maize and sorghum due to its importance as a trap crop for these pests (Khan, et al., 1997; Midega et al., 2010).

A maize field infested by stiga weeds

Push and Pull technology

The push–pull effect is established by exploiting semio-chemicals to repel insect pests from the crop ('push') and to attract them into trap crops ('pull') e.g. Napier grass. The systems exemplified here have been developed for subsistence farming in Africa and delivery of the semiochemicals is entirely by companion cropping, i.e. intercropping for the push and trap cropping for the pull. The main target is a series of lepidopterous pests attacking maize and other cereals. Although the area given to the cereal crop itself is reduced under the push–pull system, higher yields are produced per unit area (Ahmed Khan, et al., 1997).

An important spin-off is that the companion crops are valuable forage for farm animals. Leguminous intercrops especially Desmodium species also provide advantages with regard to plant nutrition and some of the trap crops help with water retention and in reducing land erosion. A major benefit of intercropping desmodium in the push-pull technology of controlling stemborers is that it provides dramatic control of the African witchweed (striga) (Khan et al. 1997). Animal husbandry forms an essential part of intensive subsistence agriculture in Africa and developments using analogous push–pull control strategies for insect pests of cattle are exemplified.

(d) Source of income

Many farmers without animals produce Napier grass fodder for sale to dairy farmers in form of fresh or conserved (silage) fodder.

(e) Other uses

The grass serves as mulch in banana farming regions of Uganda, Kenya and Tanzania. Other uses of Napier grass are: wind and fire break. Matured grass turned into reeds can be used for cheap farm construction. It serves as a wind break in maize fields and stabilizes soil by holding particles together thereby preventing soil erosion (Cook et al., 2007; Khan et al., 2014).

3.3 Establishment, management and utilization of Napier grass

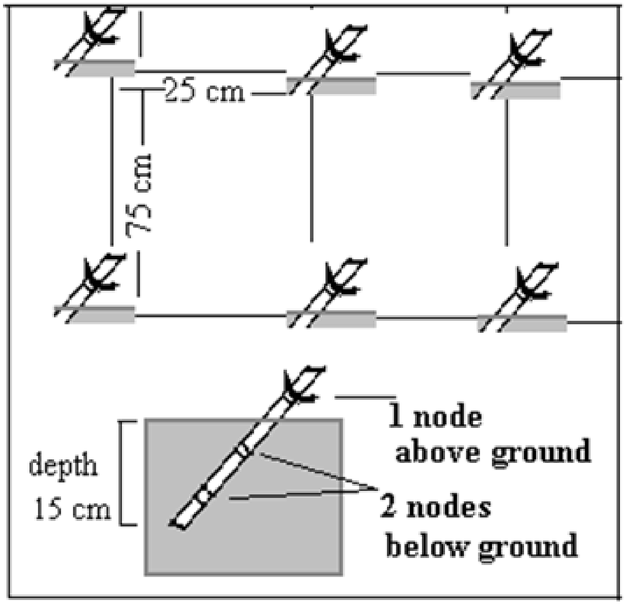
Napier grass is a fast growing, deeply rooted, perennial grass growing up to 4 metres tall that can spread by underground stems to form thick ground cover. Napier grass is easy to establish and persistent; drought tolerant; suitable for cutting and very good for silage making.

(a) Climate and soils

Napier grass can be grown at altitudes ranging from sea level to 2,000m above sea level. When grown at altitudes above 2000 m, growth and regeneration after cutting is slow and it may die due to frost. It does best in high rainfall areas, over 1500 mm per year. Napier grass can grow in almost any soils; but does best in deep, fertile, well-draining soils. It is however very drought tolerant and can be used as dry season reserve in dry areas.

(b) Establishment

Napier grass is established in well-prepared land (ploughed and harrowed) from root splits, canes with 3 nodes or from whole canes. The material is planted 15-20 cm deep with splits planted upright, three node canes planted at an angle of 30-45o while whole canes are buried in the furrow 60-90 cm apart.



Vegetative (stem cutting) propagation

Whether root splits or canes are used, they should be sufficiently mature to tiller well and produce tall and high yielding forage plants. Cane planting materials should be obtained from plants about to flower where the stems are still green.

(c) Spacing

The spacing may vary depending on the annual rainfall of the area; usually the higher the rainfall the closer the spacing. Root splits and canes are usually spaced at:

- 50 - 60 cm x 50- 60 cm in areas receiving rainfall of above 1800mm per year.
- 50-60cm x 90-100 cm is used in areas receiving 900 – 1800 mm of rainfall per year,
- 90-100 cm x 90-100cm in low rainfall areas receiving 700 - 900 mm of rainfall.

(d) Methods of Establishing Napier grass

Two methods may be used, namely: (i) conventional and (ii) Tumbukiza (micro-catchments)

(i) Conventional method

- Plough and harrow the field well before planting
- Dig planting holes 15-12 cm deep, or spacing
- In each hole apply: 2 handfuls of farmyard manure (FYM) or a soda bottle full of DAP or both a handful of FYM and 1/2 soda bottle top of DAP
- Place 3 nodes piece of cane ensuring two nodes are covered or place a root split of Napier planting material in the hole
- Cover the planted material with soil
- Intercrop with forage legumes

ii) Tumbukiza technology (micro-catchments) method

"Tumbukiza" is a method where the planting is done in round or rectangular pits of 60 cm wide diameter and 60 cm deep, filled with a mixture of topsoil and manure in the ratio of 1:2. The rows of pits should be 60 cm apart.

- Plough and harrow the field well
- Dig pits with spacing of 60x 60 cm or 60 cm x 90 or 90 x 90 cm depending on moisture regime
- Mix 1 tin (20 liter) of top soil with 1 0r 2 tins of FYM
- Put the soil-farmyard manure into the pit leaving 1 cm space at the brim
- Plant 5-10 cuttings/canes/root splits per hole


"Tumbukiza" pits for improved fodder productivity

This method gives higher herbage yields even during the dry season than the conventional method. Napier grass can also be established by the

(e) Varieties

Kenya

- Conventional varieties promoted are: Bana grass, French Cameroon, Clone 13 and Pakistan Napier hybrid.
- Napier clones and alternative fodder grasses tolerant to stunt disease currently being promoted in western Kenya and other areas where stunt disease is a serious problem are: South Africa, Ouma 2 and 3
- Alternative fodder grasses are: Brachiaria hybrid cv Mulato II, Sorghum var. 6518, Giant Panicum, Guatemala grass and Giant setaria.
- Napier clones tolerant to stunt disease being promoted in Central and Eastern Kenya where smut disease is a serious problem are: Kakamega 1 and Kakamega 2
- Newly identified Napier clones tolerant to smut disease that are being multiplied by Kenya Agricultural and Livestock research Institute are: ILRI accession 16806, ILRI accession 16782, ILRI accession 16789, ILRI accession 16805, ILRI accession 16811, ILRI accession 16783, ILRI accession 16800, ILRI accession 16835
- In addition, some of the tolerant Napier clones identified in Kenya as listed above are being screened for tolerance to Napier stunt and smut diseases in Uganda, Tanzania, Rwanda and Burundi and tolerant clones have been multiplied and distributed to farmers.

Uganda

- A number of Napier grass leafy varieties e.g. Kawanda variety 4 (KW4) and Pennistum 99 (a hybrid between KW4 and Bulrush millet) are available.
- In addition, 22 Napier grass accessions obtained from the Alupe Research Institute in Kenya were screened for tolerance to Napier stunt disease, dry matter yield (DMY) and nutritive quality. Kakamega 1, Kakamega 2, 112 and 16072 produced the highest yields DMY of 40 to 42.0 kg/ha. The accessions were recommended for multiplication in NSD "hot spot" areas of Uganda as a way to improve feed availability and NSD in an environmentally friendly and cheaper means. Napier grass accessions Kakamega 1, Kakmega 3 and 16805 were promoted in Rwanda and Burundi.

(f) Intercropping with forage legumes

Generally planting Napier grass with herbaceous legumes increases the dry matter yield and crude protein of the forage (Mwangi, 2002; Kabirizi et al., 2006); those that are compatible and give high yields include:

- Giant vetch (*Vicia dasycarpa*) at higher elevations;
- Silverleaf desmodium (*Desmodium uncinatum*), greenleaf desmodium(*D. Intortum*), stylo (*Stylosanthes guianensis*) and glycine (*Neonotonia wightii*) in high and medium altitudes;
- Centro (*Centrosema pubescens*), siratro (*Macroptilium atropurpureum*), butterfly pea (*Clitoria ternatea*), lablab (*Dolichos lablab*) and stylo in the semi-arid coastal regions.


Napier grass intercropped with forage legumes

This legume should be planted at a spacing of 1 m x 1 m and a seed rate of 1 -4 kg/ha near the grass rows or in between the rows. The legume helps to control the weeds and contribute to herbage production without competing with the grass. It also improves the Nitrogen content of the soil and the grass.

(g) Fertilizer application

Because of its rapid growth and high yields Napier grass requires regular application of nitrogen (N) and phosphorus (P) in the form of fertilizers or farm yard manure (FYM) (Orodho, 2006). High yields of Napier are maintained with the following rates of application:

- 20 kg/ha/year of P in the form of either single or triple superphosphates (SSP or TSP) at a rate of 100 kg/ha applied twice a year as a ring application around the stools at the beginning of the long and short rainy season on weeded plots.
- 75 kg/ha/ of N usually in the form of Calcium Ammonium Nitrate (CAN) at a rate of 300 kg/ha to be applied in splits after every grass harvest (except the harvest taken during the dry season, because of low soil moisture) or in three equal doses in a year, during the long rains and short rains.
- Dairy cattle slurry: this is a mixture of cow dung, urine, and feed left over, available from the zero-grazing stable. The rate of application is 5.5 tons of DM/ha/year or 55 tons of liquid slurry. This should be buried between Napier grass rows to avoid loss of nitrogen by volatilization. The slurry is applied after the onset of long and short rainy seasons.

(h) Weeding and inter-Row Cultivation

Napier should be weeded regularly in order to maintain the grass in a vigorous and productive condition.

- It should be weeded as early as possible and at least twice after planting and kept weed free throughout growth especially after cutting.
- Aggressive weeds such as couch grass (Digitaria sp.) are best controlled during the dry season
- Regular weeding helps to ensure that fertilizer applied after harvest will only be utilized by the forage crop.
- Regrowth can be harvested when it reaches 2-3 feet (60-90 cm) high which means a period of 6-8 weeks between cuts

(i) Harvesting

Napier grass is ready for harvesting 3-4 months after planting and harvesting can continue at an interval of 6-8 weeks for 3 5 years depending on its management, soil fertility and soil moisture. Leave a stem length of about10 cm from the ground at harvesting.

A farmer cutting Napier grass fodder

(j) Potential Yields

Yields depend on agro-ecological zone and management but on average Napier grass can give 12 to 25 tons/ha of dry matter yield. Under optimal management practices Napier grass can give yields 40 t/ha/year in high rainfall (1200 mm to 2400 mm of rainfall).

(k) Feeding management

- Chop the harvested mixture of Napier grass and Desmodium to reduce wastage while feeding it to the animals.
- Do not graze animals directly on Napier grass.
- Feed 70 kg or 7 head loads of fresh Napier grass to a dairy cow per day.
- Two acres of Napier grass planted by the conventional method can give enough feed for 1
- dairy cow for a full year.
- One acre of Napier grass planted by the Tumbukiza method can give enough feed for 2 to 3 dairy cows for one year.

3.4 Challenges to production of Napier grass

(a) Poor agronomic conditions

- The agronomic conditions under which the Napier grass is grown affect its yield per unit area and quality.
- Rainfall, and drought are among the key constraints to Napier grass production, unfortunately are beyond the producer's or farmer's control.
- Phosphorus (P) and Nitrogen (N) have a large influence on forage yield and quality but the fertilizers are expensive for farmers to afford and apply in adequate amounts.
- Legumes can substitute N fertilizers when intercropped with grasses but the seed is either unavailable or too expensive for farmers

(b) Pests and Diseases

Napier stunt and head smut diseases, caused by phytoplasma and a fungus Ustilago kameruniensis, respectively, have in the recent years caused forage yield reduction of up to 90% (Mulaa et al., 2013), and are currently the biggest threats to forage production and hence dairy sector in the region. In Western Kenya, stunt disease has resulted in an estimated milk yield reduction of 20-40% due to under feeding and destocking due to inadequate feeds (Mulaa et al., 2013).

Both diseases have been recorded in Kenya, Tanzania, Uganda, Ethiopia and Rwanda, and Burundi with cross boarder movement of livestock and people carrying Napier grass with them.

3.5 Napier head smut

Napier grass head smut is a fungal disease caused by Ustilago kamerunensisis which is a serious problem in central and eastern Kenya but has also been reported in Tanzania, Uganda, Rwanda and Congo (Mulaa et al., 2010). The disease is spread rapidly by wind and infected plant material.

Napier grass head smut disease

Early flowering with smutted heads, stunted plant with thin leaves and lots stems, these lead eventually to tillers dying. Symptoms start on some tillers and eventually affect the whole plant. Infected stems are smaller, thinner and shorter, with few, small and sometimes distorted leaves. Re-growth of infected plants is slow after cutting. They flower early and the flower head becomes a mass of black spores. The total dry matter is reduced, after 2-3 cuttings, the entire stool dries.

3.6 Napier stunt disease

Napier stunt disease leads to reduction in area under Napier by about 40 per cent (Nanyeenya et al., 2014). In Uganda Napier Stunt Disease (NSD) has been reported in 97 per cent of farmers' fields causing stunting, curling/twisting of leaf tips leading to up 50 per cent reduction in biomass yield (Kabirizi et al., 2014).


Symptoms of Napier stunt disease

Many smallholders in Kenya have lost up to 100 percent of their Napier crop and are forced to de-stock or sell off their entire herd because of lack of sufficient feeds farmers in the study area retained their herd sizes (4.6 heads of cattle) (Orodho, 2006) and Mulaa, 2010). Farmers have however, struggled to make up for the lost biomass due to NSD by stepping up feed supplementation resulting into an increase in cost of supplements per day by 200 per cent. Time taken to fetch feeds is also greater by 43 per cent.

The disease is much more severe and prevalent in poorly managed fields and farmers have noted that in well-weeded and heavily manured fields, disease severity is reduced (Orodho 2006 and Kabirizi et al. 2014). From recent surveys, incidences of between 30% and 90% infections by Napier stunt disease has been recorded in many smallholder fields (Mulaa et al., 2010). In some parts of Eastern and Central Africa, women and children use plenty of time looking for pastures or stall feeding. This translates to time and economic loss to these growing economies.

3.7 Efforts to improve Napier grass productivity in ECA

Under EAAPP funded regional project "Enhancing adoption of Napier grass and alternative fodder grasses resistant/tolerant to stunt and smut diseases for increased feed availability in smallholder systems in Eastern and Central Africa", the following research activities were implemented in the Kenya, Uganda, Tanzania, Rwanda and Burundi during the period of 2011-2015:

- (a) Status of Napier grass stunt and head smut disease, current germplasm and implication on smallholder dairy production in Kenya, Uganda, Tanzania, Ethiopia and Rwanda, Burundi.
- (b) Screening for Napier grass (Pennisetum purpureum) accessions for resistance/tolerance to stunt disease pathogen
- (c) Screening for Napier grass (Pennisetum purpureum) accessions resistance/tolerance to head smut pathogen Ustilago kamerunensis
- (d) Evaluation of alternative forage species for yield and resistance/tolerance to stunt disease
- (e) Epidemiology of Napier stunt disease and progress in the search for tolerant cultivars
- (f) Epidemiology of Napier head smut disease and progress in the search for tolerant
- (g) Characterization of Napier germplasm in the region
- (h) Agronomic management of the identified tolerant Napier grass clones to stunt and smut diseases in Kenya
- (i) Cultural practices (Integrated pest management – IPM) of Napier Stunt and smut Diseases
- (j) Forage/crop/livestock integration
- (k) Strategic utilization of crop residues and alternative forages/feed resources

Detailed activities are described in the Chapters that follow.

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CHAPTER 4: Status of Napier grass stunt diseases in the East African region

4.1 Status, Napier stunt and smut disease and farmers management practices in Uganda

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Introduction

Agriculture is considered the most critical economic pillar throughout the region contributing over 45% of the regional GDP's and directly employs over 75% of population; its revitalization is likely to yield wide range of positive impacts. In line with the Millennium Development Goals (MDGs) of halving global poverty by 2015, the New Partnerships for Africa Development (NEPAD) through the Comprehensive Africa Agricultural Development Plan (CAADP) and in collaboration with development partners initiated a regional outfit to spearhead revitalization of agricultural productivity throughout the Eastern Africa sub-region. This new outfit was dubbed EAAPP, anchored in CAADP pillar IV focusing on improving agricultural research, technology generation, dissemination and adoption.

A baseline survey was carried out in three districts purposely selected to represent three agro-Ecological Zones (AEZ) of Uganda. The districts included Jinja, Kiruhura and Katakwi which represented the Lake Victoria Basin (LVB), Western Rangelands (WR) and the Eastern Semi-Arid Zone (ESAZ), respectively. The survey examined farmers' perceptions on feeds and feeding. The key stakeholders included crop-livestock farmers, community extension staff and local government agricultural production staff among others.

Methodology

The study design was cross sectional and both qualitative and quantitative data were employed to gain an in-depth understanding of farmers' socio-economic factors, livestock feeds and feeding systems, livestock breeds and breeding methods and livestock health in three agro-ecological zones of Uganda. The study sites were purposively selected based on their relevance to study questions. The District Livestock Production Department provided a sampling frame which contained all livestock keeping households from the selected districts. After consultations with the district extension staff, fifty households were then selected from each district using the sampling frame following systematic random sampling procedures. The total number of livestock keeping households in each district was divided by 50 to obtain an nth value. The first household was chosen randomly but the subsequent households were chosen after every an nth value until all the 50 households had been selected. In totality, we administered questionnaires on 150 respondents.

Data sources and collection methods

Primary qualitative and quantitative data was obtained using semi-structured pre-tested questionnaires administered by way of one on- one direct interview while secondary data was got from published articles and reports among others. Secondary data was mainly used compare survey results with existing trends as well as to discuss the survey results.

Validity of the questionnaire

Lawshe's content validity ratio was used to measure the validity of study as described below: CVR = (ne − N / 2) / (N / 2) where CVR = content validity ratio, ne = number of farmers indicating "essential", N = total number of farmers. For essential validity content validity ratio was 0.8. The ratio formula yields values which range from +1 to -1; positive values indicate that at least half the farmers rated the item as essential. The mean CVR across items may be used as an indicator of overall test content validity.

Data collection and analysis

Data was collected by trained enumerators using a structured questionnaire. Data was analysed using Statistical Packages for Social Sciences (SPSS). Graphs and cross tabulation tables were drawn using Statistical Packages for Social Sciences (SPSS). Farmers' responses on the constraints faced in utilization of feeds in the three agro-ecological zones was subjected to nonparametric statistics (Kruskal–Wallis one-way analysis of variance) to determine if significant differences existed between the different constraints. Six constraints were ranked by farmers using a scale of 1 to 6, with 6 being the least important constraint and 1 the most important factor. The computed sum and mean of ranks were compared using multiple pair wise comparisons to establish the significance differences among different constraints (Dinno, 2015).

Results and Discussion

Gender and age classification of respondents

Majority of the respondents were males with only 36, 17 and 22% of the respondents being females in the ESAZ, LVB and WR respectively (Table 4.1.1). Most of the respondents were within the age category of 21 - 40 and the mean household size was highest in ESAZ (14 members) and lowest in the LVB (10 members).

Table 4.1.1: Gender and age classification of respondents

Household Composition	Agro Ecological Zone (%)		
	ESAZ	LVB	WR
Respondent's Gender			
Male	64	83	78
Female	36	17	22
Mean Household size (numbers)	14.19	10.12	11.17
Age Category			
Male 5-10	15.4	10.9	8.3
Female 5-10	9.7	7.9	6.0
Male 11-20	15.7	15.3	15.6
Female 11-20	11.4	14.4	13.9
Male 21-40	14.9	14.4	22.9
Female 21-40	16.2	11.9	12.8
Male 41-50	5.7	8.9	5.3
Female 41-50	4.9	10.4	6.4
Male>60	2.7	4.0	4.5
Female>60	3.5	2.0	4.3

ESAZ= East Semi-Arid Zone, LVB= Lake Victoria Basin and WR = Western rangelands

Livestock inventory and ownership

The three AEZ differed significantly (p = 0.001) in possession of livestock types (Table 4.1.2).

Table 4.1.2: Means of livestock types in the different Agro-ecological Zones

AE Z	Livestock Type							
	Cows	Breeding bulls	Oxen	Heifers	Calves	Sheep	Goats	Chicken
WR	50.54^{a}	1.81^{a}	1.67^{b}	22.92^{a}	21.46^{a}	3.04^{a}	28.75^{a}	8.16^{b}
ESAZ	9.78^{b}	1.25^{ab}	4.34^{a}	4.63^{b}	4.72^{b}	3.7^{a}	10.97^{b}	20.22^{a}
LVB	3.24^{b}	0.4^{b}	0.08^{b}	1.44^{b}	1.44^{b}	0.08^{b}	3.52^{b}	7.79^{b}

^{AEZ} Agro-ecological zone, ^{ab} means with different superscripts across each column are statistically
different at p= 0.05

The vectors for number of breeding cows (2426), breeding bulls (87), heifers (1100), calves (1030) and goats (1380) were increasing in the direction of western rangeland ecological zone (WR) indicating that these livestock types were most abundant in the WR. On the other hand, chicken (647) and oxen (139) were more abundant in the ESAZ compared to the WR and LVB.

Land ownership and tenure

The mean number of acres per household was highest in WR (279.3 acres) and lowest in the LVB (4.7 acres) indicating that respondents in the LVB are largely smallholder farmers with limited land resources for agricultural production (Table 4.1.3).

Table 4.1.3: Land Ownership and Tenure

Land Ownership and Tenure	Category	Agro Ecological Zone		
		ESAZ	LVB	WR
Average Land area	Size (acres)	30.2	4.7	279.3
Land Ownership and Tenure (percentage)	Freehold with title	3.1	8	48.0
	Freehold without title	93.8	92	52.1
	Rented from other individual	0	0	0
	Communal	3.1	0	0
	Informal	0	0	0
Mode of Acquisition (%)	Purchase	28.1	48	75
	Inherited	71.9	48	25
	Rented	0	4	0
Main Land Use (%)	Crop Production	93.8	56	66.7
	Livestock	6.3	36	33.3
	Homestead		8	
Male 41-50	5.7	8.9	5.3	
Female 41-50	4.9	10.4	6.4	
Male>60	2.7	4.0	4.5	
Female>60	3.5	2.0	4.3	

Interventions that enhance agricultural productivity per unit of available land are thus more important in the LVB than in any other region. The major system of land tenure was reported to be freehold system but without titled followed by freehold system with titles. Communal land

Cultivation and management of Napier grass

In the ESAZ, only 4% of the farmers grow Napier grass with mean acreage of 0.25 acres. In the LVB, 88% of farmers grow Napier with mean acreage of 1.13 acres while in the WR only 14.6% of farmers were growing the fodder with a mean acreage of 0.27 acres. Discriminant analysis biplot (Figure 4.1.1) indicated that farmers in the LVB mostly cultivate improved Napier varieties with a few of them still cultivating the local varieties.

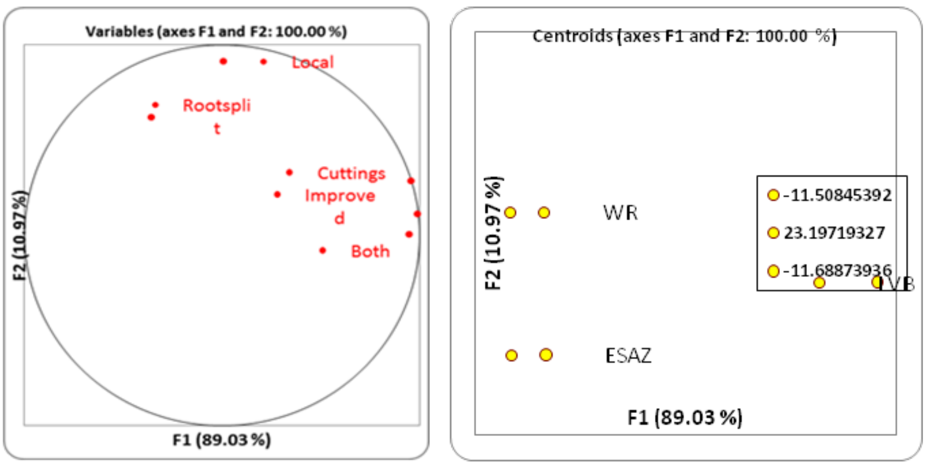

Figure 4.1.1: Discriminate analysis biplot showing the varieties and propagation methods of Napier grass in the three agro-ecological zones

Overall, the percentage of land used in production of improved forages is 0.53%. Farmers mostly use stem cuttings for propagation of the fodder. The farmers in the WR mostly cultivate local Napier varieties and commonly use root splits for propagation. Farmers noted that weeding and application of animal manures were the most common agronomic practices undertaken to improve productivity of fodder and pasture. Other forage management practices included uprooting of diseased Napier plants, spraying of pesticides, fencing off fodder fields to deter animals from destroying the fields. Occurance and severity of Napier stunt disease. Majority of the farmers (76% of the respondents) in the LVB reported the occurrence of Napier stunt disease on their farms (Table 4.1.4).

Table 4.1.4: Occurance of Napier stunt disease in the three agro-ecological zones

Agro-ecological zone	Presence of Napier stunt disease (%)			
	Yes	No	WR	
Lake Victoria basin	75.9	24.1	Research institutions	Extension worker
West rangeland	31.5	68.5	4.5	4.5
Eastern Semi Arid	0	100.0	12.5	0
Overall	37.1	64.2	6.7	3.3

Thirty two (32) percent of the respondents reported the disease in the WR while no respondent reported the occurrence of the disease in the ESAZ. The high prevalence of the disease in the LVB was attributed to the increased cultivation of improved Napier varieties that are highly susceptible to the disease. The reported absence of NSD in the ESAZ may not necessarily mean that the disease had not affected the region but because farmers devote no efforts on fodder cultivation making it difficult to notice such diseases. Farmers in the ESAZ mostly depend on natural Napier swards in the wilderness which are either tolerant to NSD or farmers have not taken time to diagnose the disease. There is hence a need for field diagnosis.

Also, because only few farmers had taken the initiative to cultivate Napier in ESAZ, the farmers were ignorant of the occurrence of the disease but yet in the actual sense, they had the disease. This was evidenced during the survey when the farmers mistook the disease for inadequate soil nitrogen implying that many could be ignorant about this disease. Fifty percent of the farmers faced with disease ranked it as high (>10 diseased plants in 20 plants) while 35% ranked it as moderate (between 5-10 diseased plants in 20 plants). Only 15% of the affected respondents ranked it as low (< 5 diseased plants in 20 plants) (Figure 4.1.2).

Irrespective of the level of severity, dedicated efforts need to be focused towards the management of the disease to control its spread to non-diseased plants since it is transmitted by leaf hoppers that jump from one plant to another. So although the farmers may rank it as low, it can spread quickly as long as there are diseased plants in the field. Majority of the farmers (70%) reported that they source planting materials from other farms implying that this could also be a source of inoculums for the disease. This also partly explains why the disease is more severe in the LVB where majority of farmers obtain planting materials from other farms and these may be infected already.

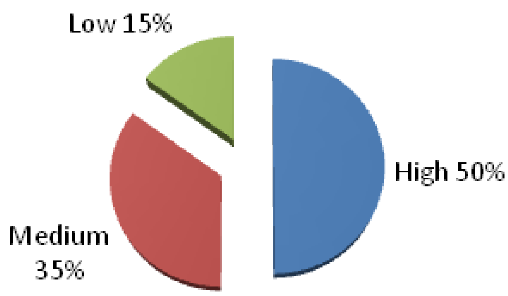

Figure 4.1.2: Severity of Napier stunt disease amongst farmers

Table 4.1.5: Sources of Napier planting materials

Agro-ecological zone	Source of Napier planting materials (%)			
	Yes	No	WR	
	Own farm	Other farms	Research institutions	Extension worker
Lake Victoria basin	9.1	81.8	4.5	4.5
West rangeland	50.0	37.5	12.5	0
Overall	20.0	70.0	6.7	3.3

Conclusions and recommendations

Based on findings of the survey, the following conclusions were made:

a) Napier grass and natural pastures constitute the major sources of forages for feeding livestock in the three agro-ecological zones.
b) Napier stunt disease is a major constraint to productivity of Napier grass and hence sustainability of Napier based feeding systems.
c) The level of adoption of forage conservation practices is still very low with only 20% of the respondents involved in forage conservation and preservation.
d) Maize bran and dairy meal are the main feed stuffs used to supplement animals in the LVB while farmers in the WR and ESAZ largely use minerals to supplement their animals.
e) Maize stover and banana peels are the major crop residue types utilized by farmers for feeding livestock.
f) The level of nutritional improvement on crop residues is still very low with only 14% of the respondents adding molasses to crop residues before feeding them to animals.
g) Forage scarcity and high costs of feeds were noted as the most important constraints limiting animal feeding systems in the three agro-ecological zones.

Recommendations on feeds and feeding

a) There is need to develop appropriate Napier stunt management interventions/technologies to control the disease as well as to reduce the susceptibility of the plants to the disease.
b) It is imperative to elucidate the socio-economic determinants of adoption of forage conservation and preservation technologies with the aim of enhancing their adoption.
c) There is a need to undertake focused field surveys in the ESAZ to make logical conclusions on the occurrence of NSD
d) There is an overwhelming need to develop socially acceptable and affordable area-specific interventions for nutritional improvement of crop residues in addition to molasses.
e) There is a need to enhance forage conservation practices in order to alleviate the problem of feed scarcity

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4.2 Napier Stunt Disease in Uganda: farmer perception and effect on fodder yield

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Introduction

The success of the smallholder dairy sector in Uganda depends on elephant grass (Pennisetum purpureum), also known as Napier grass. This forage, whose high dry matter yields average about 16 tonnes/ha/year has become the country's main fodder source grown by over 80% of smallholder farmers in Uganda. It provides over 70% of the feed, and many farmers earn cash incomes from selling Napier grass fodder to farmers who have insufficient land to grow their own feed (Kabirizi, 2006). The grass also serves as mulch in banana farming regions in Uganda.

Napier grass production in Uganda is threatened by the emergence of Napier stunt disease (NSD), which undermine the contribution of the dairy value chain in poverty reduction programs (Kabirizi et. al., 2004). Napier stunt disease (NSD) was first observed in central Uganda in 2002. The disease has been reported in over 40 districts where Napier grass fodder is a major forage for dairy cattle (Kabirizi et. al., 2010). In view of the importance of Napier grass fodder in the smallholder dairy production systems, surveys and on-station studies have been conducted to:

a) Identify symptoms of the disease;
b) Assess farmers' perception of the disease, its management and socio-economic impact on dairy cattle production.
c) Establish the presence of phytoplasma in affected plants and.
d) Determine the effect of the disease on napier grass fodder production.

Materials and methods

Description of study area

Surveys were conducted in Masaka district located between 00 15' and 00 43' South of the equator and between 310 and 320 East longitude. The average altitude of the district is 1,115 meters above sea level. The total geographical area is about 6413.3sq km out of which y 1,221 hectares are under cultivation (Anon, 2009). Annual average rainfall ranges between 1100 mm–1200 mm with 100–110 rainy days. The soil texture varies from red laterite to sandy loam but is productive. The district has about 944,200 people (about 49% women) with an annual population growth rate of 3.0% (Anon. 2009). The district has a cattle population of about 162,171 with about 8% of the cattle population being improved breeds (Anon, 2008).

Survey procedure

An intensive survey procedure was adopted in which a structured questionnaire was administered to 120 smallholder dairy farmers with 1-3 dairy cows. The sample farmers were selected from 12 villages in 4 sub-counties (Kingo, Bukulula, Kalungu and Mukungwe) with the highest population of improved stall-fed dairy cows. Thirty fields were randomly selected for a detailed study. At each site, the farmer's Napier grass field was assessed to record incidence and severity of the disease and extent of stunt. Within each field, 5 plants along two diagonals were recorded in detail. For each plant, the presence or absence of the disease was noted, symptom types recorded and stunt scored on a 1 to 3 scale (1= no stunt, 2= moderate stunt and 3= severe stunt). The incidence of the disease was calculated from the number of affected plants as a percentage of the total number of plants assessed in a field. Herbage biomass yield was estimated using methods described by Kabirizi (2006). Plant height and root length were measured for randomly selected plants representatives of disease-free and affected plants in each quadrate. In addition, participatory rural appraisal sessions were held with 2 farmer groups that comprised of dairy farmers who had benefited from in-calf heifer projects. The objective was to document farmers' perception of the disease, its management and socio-economic impact on dairy cattle production.

Establish the presence of phytoplasma in Napier grass stunted plants

Samples of Napier grass leaves from plants with symptoms of stunt disease were taken from the Lake Victoria Crescent zone (Wakiso, Jinja, Kampala and Masaka districts); the north-eastern area (Iganga, Lira, Soroti and Tororo districts) and from the highland areas of south-western Uganda (Kabale and Kabarole districts). The districts represented the major agro-ecological zones of Uganda. The leaves were air dried and mailed to University of Aahus, Faculty of Agricultural Sciences in Denmark. Presence of phytoplasma was tested according to Nielsen et al. (2007). A nested PCR using primer pairs P1/P7 and either R16R2/R16F2n (Gundersen et al. 1996) or P3/P7 (Smart et al. 1996) was used to generate template for sequencing. Sequencing primers were R16R2, R16F2n, P3 and P7. Sequences were aligned using Vector NTI (Invitrogen, Carlsbad, USA).

Results and discussion

Napier Stunt Disease symptoms

The most obvious symptoms of NSD observed on farmers' fields were stunt, twisting/curling and cupping of leaf tips and yellow/purple streaking/vein clearing at leaf tips. Affected leaves often had mosaic rather than a normal evenly and slight curved edge, were yellow in colour and in most cases showed signs of wilting. Leaves of severely affected plants were reduced to short sword-like stubs that were often less that one-third of leaves of unaffected plants. Affected plants also had retarded poor root formation and could easily be uprooted. In extreme cases, affected plants lost leaves entirely and the stem was unusually short and thick. Shoot proliferation was also observed especially for rationed stools, but the plants remained stunted with tiny leaves.

Napier grass disease incidence and severity

Napier stunt disease was present in 29 out of 30 fields assessed. The overall incidence of the disease was 42.3% (Table 4.2.1).

Table 4.2.1: Incidence and extent of Napier stunt disease in Masaka district

Sub-county	Number of fields	Mean incidence (%)[1]	Mean stunt[2]
Mukungwe	11	25.1	2.3
Kingo	1	33.3	2.2
Municipality	2	53.3	2.6
Bukulula	16	57.0	2.4
Mean		**42.3**	**2.3**

[1]The number of affected plants as a percentage of the total number of plants assessed in a field;

[2]Scored on a 1-3 scale (1 = no stunt, 2 = moderate stunt and 3 = severe stunt)

Significant ($p<0.05$) differences were noted between sub-counties and between individual fields in a sub-county in the incidence of the disease. The greatest incidence was 57%, recorded in a field in Bukulula sub-county. Overall mean stunt was 2.3 and sub-county means were greatest in Municipality compared to rural areas (Bukulula, Mukungwe and Kingo sub-counties) (Table 4.2.1). Affected plants appeared to be randomly distributed in the field. Severely affected plants and normal plants were observed to be growing side by side.

Effect of Napier stunt disease on plant height, root length and fodder yield

Mean plant height and root length decreased by about 50% in diseased plants when compared to healthy plants (Figure 4.2.1).

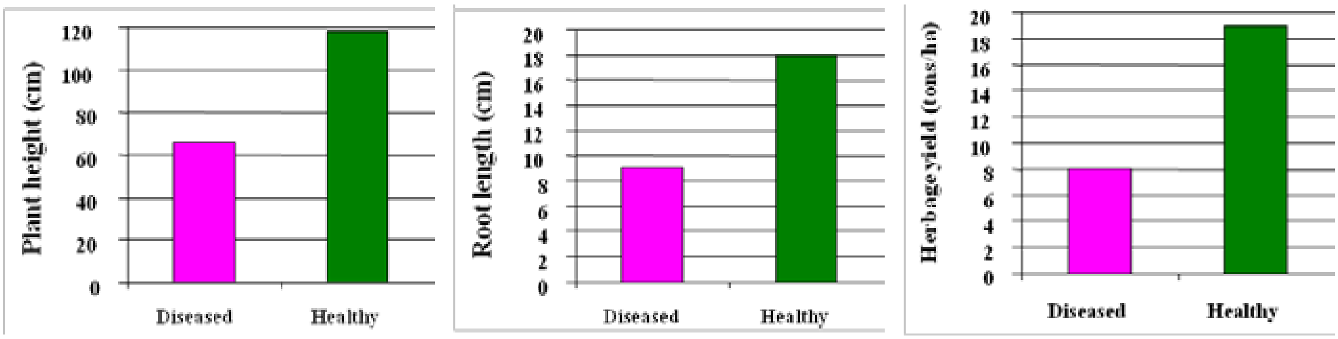

Figure 4.2.1: Effect of Napier stunt disease on plant height, root length, herbage biomass yield and number of shoots

Herbage biomass yield decreased by over 55% in diseased plants when compared to healthy plants (Figure 4.2.1). The reduction in herbage biomass yield was partly due to rouging. Field observations showed that the incidence was higher in pure stands of elephant grass than where Napier grass was planted with a forage legume.

Farmers' perception of the disease, its management and socio-economic impact on dairy cattle production

Information from individual interviews and group discussion showed that farmers were able to recognize the disease and branded it as the most important disease of Napier grass in the area. Many farmers recalled that they first noticed the disease in 2000, but reckon that it is becoming more prevalent and severe. The farmers asserted that the problem is a disease, but not a pest attack, nutritional disease or any other environmental stress. They observed that the disease occurs throughout the year but is more severe during the dry season probably due to moisture stress. Most (65%) farmers were of the view that the disease occurs under all soil and field management conditions but poor soils and poor management (weeds and harvesting) aggravate the disease. They also observed that affected plants often completely degenerate by the third harvest. Even plants that are apparently healthy during the primary growth often had symptoms after rationing. Management practices used to control Napier stunt disease in the study areas are shown in Table 4.4.2.

Table 4.2.2: Major management practices used by farmers to reduce NSD incidence

Strategy	Percentage of respondents (%, n=120)
Weeding	2
Rouging	27
Use clean planting materials	7
None	2
Rouging and manure application	62

About 60% of the farmers reported rouging and manure application as the major strategies they use to reduce disease incidence. A few (7%) of the respondents selected clean Napier planting materials from vigorous, disease free plants. However, they noted that using clean planting materials is not a guarantee that the plants will sprout without disease or will be affected later.

Applying manure and rouging in Napier grass fields, as they did, had the potential to reduce the effect of the disease as the unaffected tillers flourished although they were not aware of this. Farmers reported a decline of about 25% in NSD incidence which they attributed to manure application. Manure enhances growth and establishment of plants through enriching the soil with the required nutrients. In light of this, plants become less susceptible to disease stress than already stressed plants (Mpairwe, 1998). It is also possible that manure interferes with multiplication and survival of disease organisms through modification of the micro-environment or through enhancement of natural enemies to disease causing organisms (Mugerwa, 2010; personal communication).

During focus group discussions, farmers estimated managing (rouging and manure application and replanting) the Napier stunt disease in the affected fields, would cost them US $ 200-400 per ha. The farmers estimated loosing up to 50 percent of the fodder due to the disease which would translate into a reduction in milk yield of over 30%. Nevertheless, none of the farmers had ever abandoned crops or particular Napier grass cultivars on their farms because of the problem.

Establish the presence of phytoplasma in Napier grass stunted plants

Out of 31 samples collected from 10 districts, 17 tested positive for the phytoplasma (Table 4.2.3). Phytoplasma was detected in two of the three main Napier grass growing areas. However, as only 5 samples from the south western area were analysed, it cannot be concluded that the disease is absent in this region. Whether the inability to detect phytoplasma in a number of samples with symptoms is caused by inadequacy of the PCR methods, uneven distribution of phytoplasma in the plant, inadequacy of the method of storing sampled leaves (air drying) or that the stunting symptoms may be caused by other factors remains to be investigated. To investigate possible molecular variation between samples, seven samples from different districts were sequenced in the R16R2/R16F2n PCR fragment of the 16S rRNA gene (app. 1.2 kbp) and the P3/P7 PCR fragment of the 16S/23S intergenic spacer (app. 0.3 kbp) (Nielsen et. al., 2007).

Table 4.2.3: Results of PCR-tests of leaf samples of stunted Napier grass from 10 districts in Uganda

Sub-county	District	No of localities	No. positive loc/ total loc	No of samples sequenced
North-Eastern	Iganga	5	4/5	1
	Lira	3	3/3	1
	Soroti	3	3/3	1
	Tororo	1	0/1	1
Lake Victoria Shore	Jinja	3	2/3	1
	Kampala	3	1/1	1
	Masaka	8	3/8	2
	Wakiso	2	2/2	1
South-Western	Kabale	4	0/4	0
	Kabalore	1	0/1	0

Loc. = location,

The seven sequences derived from the 16S/23S intergenic spacer did not show any variation either, although this region is generally more variable than the conserved 16S rRNA (Nielsen et. al., 2007). The sequences were most similar to Bermuda grass white leaf phytoplasma ribosomal sequences (there are no Napier grass stunt phytoplasma sequences from the 16S/23S intergenic spacer in the GenBank). The identical sequences of the Kenyan and Ugandan isolates of phytoplasma combined with the very quick spread of the disease in the East African Region points to that the phytoplasma originates from a common source. However, the new knowledge that phytoplasma isolated from Ethiopian Napier grass with stunt disease symptom belongs to another phytoplasma group, namely 16SrIII Group phytoplasma, than the Ugandan and Kenyan isolates indicates that reality is more complicated. More data of sequences of isolates from the region are necessary to give a more complete picture of the sources and migration of the stunt disease.

Conclusion

The results presented in this paper represent the first systematic quantification in Uganda of the prevalence of the Napier grass stunt disease, the extent of damage it is causing and farmers' attempts to control it. Generally, the problem was highly prevalent in Masaka district, although incidence levels varied with location. It is also clear that the disease is seriously damaging Napier grass, causing significant reductions in herbage biomass yield. In view of the importance of livestock to the livelihoods of the smallholder dairy farmers in Uganda and the dramatic symptoms of this Napier grass stunt disease there is a need to continue monitoring the occurrence and spread of the disease. Existing Napier grass varieties should be screened to assess the impact of the disease on their productivity. Additional work should be initiated aimed at providing farmers with resistant Napier grass planting materials.

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4.3 Status, Napier stunt and smut disease and farmers management practices in Western and Central Kenya

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Introduction

Napier grass constitutes between 40 to 80% of forages used by smallholder dairy farmers in Kenya. The productivity of Napier grass in western and Central Kenya is currently threatened by stunt and smut diseases causing yield reduction of up to 90% (Mulaa and Ajanga 2005). Stunt disease is more prevalent in western (Mulaa and Ajanga 2005), while smut disease is more restricted to Central Kenya Mwendia 2007). Both diseases cause stunted growth in plants with low biomass that are unable to sustain the feed requirements of dairy cows. Farmers are forced to reduce herd size with related reduction in farm income in the absence of alternative feeds. Majority of the farmers have land size due to a high human population and as a result have adopted semi or zero grazing systems. Such systems demand readily available forage. This translates to time and economic loss if farmers have spent time looking for grass far away from their farms. Although farmers in western and Central Kenya have benefited from the management strategy measures that have been packaged by KARI and other stakeholders through extension offices at various levels of administration they are still demanding for a solution to the severe losses that they suffer due to the effects these diseases. The objective of this study was to determine the current dairy and Napier grass management practices, the spread and severity of Napier stunt and smut diseases and farmers copping strategies in the management of these diseases.

Methodology

The study design was cross sectional and both qualitative and quantitative data were employed to gain an in-depth understanding of farmers' socio-economic factors, livestock feeds and feeding systems, livestock breeds and breeding methods and livestock health in six districts in Kenya. The study sites were purposively selected based on Napier grass production and utilization in the intensive and semi-intensive dairy production systems. Other factors considered in selecting the survey area were the level of smut and stunt disease incidence and severity (Agro-ecological Zones having unique climatic conditions for stunt and smut disease occurrence) and actual and potential suitability for diary production. The districts surveyed were: Bugoma, Mumias/ Butere(Low Dryland), Busia (Lake region) in Western Kenya and Kiambu and Muranga (High altitude) in Central Kenya. Total of 551 Households with a minimum of 71 respondents were surveyed. Transects were selected, mainly following roads and households were selected randomly with every 5th house interviewed. The data was entered in the spreadsheet analysed using SPSS.

Disease incidence was determined using a scale of 1 – 4 whereby 1 = Nil (no plants with symptoms, 2 = Mild (< 25% of plants with disease symptoms), 3 = Moderate (25 – 50% of plants with disease symptoms) and 4 = severe (> 50% of plants with disease symptoms). Disease severity was determined using a scale of 1 - 4 whereby 1 = Nil, 2 = Mild (<25% of tillers with disease symptoms), 3 = Moderate (25 – 50% of tillers with disease symptoms) and 4 = severe (> 50% of tillers with disease symptoms).

Baseline information

Majority of the households had between 1 to 5 people (Table 4.3.1). There males and youths were more household than females in all the districts. The number of improved dairy cattle was low (ranging 21.2% and 30.8 %) in Western Kenya compared to Muranga and Kiambu (49.4% – 77.6%). Most of the farmers kept one to two animals and there were more famers in Central Kenya than in western Kenya (Table 4.3.2). Milk production during the rainy (good) season differed between districts. In western Kenya, majority of the farmers in Bungoma and Butere produced 3 to 6 litres of milk per day, while the majority (25%) in Busia produced 1 to 2 with some 20% producing over 20 litres and those of Mumias produced 9 to 10 litres per day (Table 4.3.3). Milk production per household was higher in Central Kenya than in western Kenya with over 47.2% farmers in Kiambu producing over 12 litres of milk per cow per day and 27.8% of Muranga' producing 9 to 10 Litres. During the dry season majority of farmers in western produce 1to 4 litres while those in Central produce 4-6 litres of milk per day (Table 4.3.4). Between70-95% of the milk produced in all the districts was sold. Majority of the farmers in Central Kenya practice intensive zero grazing while in western the most practiced system was semi-zero and tethering (Table 4.235).

Table 4.3.1: Proportion of male, female adults and youths per household in western and Central Kenya

Sources of forage	Percentage (%) respondents by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Males						
1 - 2	49.1	50.0	35.2	48.0	31.8	56.3
3 - 5	26.8	27.1	38.5	32.0	51.8	37.5
6 - 8	13.4	12.5	15.4	12.0	11.8	5.0
9 – 12	7.1	10.4	9.9	8.0	4.7	0
13 - 15	0.9	0	1.1	0	0	1.3
Over 15	2.7	0	0	0	0	0
Females						
1 - 2	69.1	67.3	71.6	86.0	72.8	82.9
3 - 5	26.4	30.6	26.1	14.0	23.5	17.1
6 - 8	2.7	0	1.1	0	3.7	0
9 – 12	1.8	2.0	1.1	0	0	0
Number of teenagers per household						
1 – 2	59.3	52.6	58.5	62.9	71.8	60
3 – 5	33.7	34.2	34.1	28.6	20.5	28.0
6 – 8	5.8	7.9	5.7	7.7	7.7	8.0
13 - 15	1.2	5.3	0	0	0	4.0
9 – 12	0	0	0	2.9	0	0

Table 4.3.2: Number of improved dairy cattle per household in western and Central Kenya

Number of improved dairy cattle	Percentage (%) response by districts				
	Bungoma	Mumias	Butere	Busia	Kiambu
None	53.5	55.8	64.5	61.5	10.3
1—2	28.9	30.8	21.5	21.2	49.4
3—5	12.3	9.6	8.6	17.3	27.6
6−10	5.3	3.8	5.4	0	12.6

Table 4.3.3: Percentage (%) range of milk production in litres per day during good (rain season) months in western and Central Kenya

Range of milk production Litres/day	Percentage (%) response by districts					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Less than 1	2.1	5.0	1.6	2.5	0	0
1-2	19.1	10.0	18.8	25.0	1.4	4.2
3-4	29.8	15.0	28.1	17.5	0	9.7
5-6	26.6	15.0	26.6	12.5	12.5	23.6
7-8	6.4	15.0	4.7	7.5	5.6	12.5
9-10	6.4	25.0	14.1	12.5	25.0	27.8
11-12	2.1	5.0	0	2.5	8.3	5.6
Over 12	7.4	10.0	6.3	20.0	47.2	16.7

Table 4.3.4: Average milk yield in litres per day during the dry season in western and Central Kenya

Range of milk production Litres/day	Percentage (%) response by districts					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Less than 1	17.0	17.5	15.9	12.5	1.4	4.2
1-2	45.7	17.5	34.9	35.0	5.6	19.4
3-4	22.3	27.5	27.0	15.0	20.8	34.7
5-6	10.6	20.0	12.7	5.0	16.7	19.4
7-8	2.1	12.5	3.2	5.0	16.7	9.7
9-10	1.1	2.5	3.2	12.5	19.4	6.9
11-12	0	0	0	2.5	4.2	1.4
Over 12	1.1	2.5	3.2	12.5	15.3	4.2

Table 4.3.5: Dairy cattle production system in western and Central Kenya

Livestock production systems	Percentage (%) respondents by districts					
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Extensive grazing	**11.5**	**6.8**	**8.9**	**9.5**	**3.6**	**5.4**
Semi intensive	53.8	33.3	25.8	35.7	13.5	22.5
Tethering	20.0	35.0	39.5	34.5	1.6	5.4
Intensive/ zero grazing	7.7	24.8	25.8	20.2	81.3	66.7

In western the major sources of livestock feeds were own natural pasture/ fallow and rented natural pasture/ fallow with own planted pasture contributing less than 10% of the feeds available (Table 4.2.6). On contrary, farmers in Muranga' obtained most of the feeds from own planted pasture/ fodders and own natural pasture/fallow while those in Kiambu depended more on communal grazing than own planted pasture/fodders. Farmers in all the districts depended more on purchasing Napier grass followed by other grasses to meet the feed shortage gap during the dry season (Table 4.2.7). Purchased fodder was mainly from neighbouring farms and only less than 20% was obtained from markets (Table 4.3.8).

Table 4.3.6: Sources forage available to farmers in western and Central Kenya

Sources of forage	Percentage (%) respondents by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Own planted pasture	7.7	9.2	2.4	7.9	8.6	28.8
Rented planted pastures	2.1	3.4	1.2	0	3.2	0
Own natural pasture/ fallow	62.7	57.5	70.7	58.7	12.9	27.4
Rented natural pasture/ fallow	20.4	14.9	4.9	14.3	5.4	2.7
Own planted forage	2.8	6.9	11.0	9.5	17.2	23.3
Rented planted forage	1.4	0	0	0	2.2	1.4
Communal natural pasture	2.8	8.0	9.8	9.5	50.5	16.4

Table 4.3.7: Important copping strategies when fodder is short supply in western and Central Kenya

Copping strategies during times of feed shortage	Percentage (%) respondents by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Buy Napier grass	37.4	54.4	57.7	61.4	60.7	65.3
Feed all animals less	0.5	1.0	0	1.4	3.4	5.3
Buy other fodder	5.5	10.7	1.0	7.1	18.0	7.4
Feed some animals less	4.4	0	0	1.4	.6	0
More animals	4.9	10.7	0	11.4	0	0
Rent grazing	7.7	0	1.0	8.6	0	3.2
Feed on other grasses	25.8	16.5	26.8	7.1	13.7	13.7
Feed on crop residues	13.7	6.8	7.2	0	1	5.3
Sell animals	0	0	6.2	1.4	1.1	0

Table 4.3.8: Sources of purchased fodder in western and Central Kenya

Sources of purchased fodder	Percentage (%) response by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Neighbour	78.8	88.3	87.5	90.0	71.4	94.7
Market	11.1	11.7	12.5	10.0	25.5	5.3
Public institution	10.1	0	0	0	0	0
Farmers' group	0	0	0	0	3.1	0

Napier grass production and management

Area planted with Napier grass ranged between 0.25 to over 10 acres, with majority planting less than 0.5 acres (Table 4.3.9).

Table 4.3.9: Area planted Napier grass in Western and Central Kenya

Land in acres under Napier grass	Percentage (%) response by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Less than 0.25	57.0	45.0	44.9	30.5	31.8	39.1
0.25-0.5	23.8	37.4	23.8	32.4	25.1	33.9
0.5-1	13.1	7.6	16.3	17.1	26.1	12.2
1-2	4.7	5.3	8.2	14.3	10.9	13.0
2-3	0.5	2.3	4.1	1.9	2.8	17
3-5	0.5	1.5	2.7	3.8	3.3	0
Over 10	0.5	0.8	0	0	0	0

Most farmers plant 1-2 varieties of Napier grass while some farmers in Mumias, Busia, Kiambu and Muranga plant 4-5 varieties. Bana is the most preferred variety in the 6 districts surveyed (Table 4.3.10) followed by French Cameroon, a local variety and narrow leaved variety. In Kiambu Napier variety Ex-Githunguri was also one of the preferred varieties.

Table 4.3.10: Preferred Napier grass varieties in Western and Central Kenya

Napier grass variety as identified by farmers	Percentage (%) response by districts					
	Western Kenya			Central Kenya		
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Bana grass	51.8	53.5	52.7	57.7	42.1	33.0
Clone 13	0.6	-	-	1.0	-	-
French Cameroon	2.9	2.4	-	2.9	3.3	17.9
Hairless	5.3	3.1	4.1	-	1.4	4.5
Hairy	5.3	4.7	2.7	2.9	1.9	3.6
Local	7.1	9.4	22.3	3.8	18.7	34.8
Narrow leafed	27.1	24.4	16.9	30.8	8.1	3.6
Kakamega 1	-	2.4	-	-	5.7	1.8
Mixture	-	-	0.7	-	-	-
Uganda hairless	-	-	0.7	1.0	-	-
Agriculture	-	-	-	-	7.2	-
Ex-Githunguri	-	-	-	-	11.5	.9

The most important criteria used by farmers for selecting Napier varieties were herbage yield followed by fast growth (Table 4.3.11).

Table 4.3.11: Criteria used by farmers when choosing Napier grass variety to plant in western and Central Kenya

Farmers Napier grass selection criteria	Percentage respondents on criteria for selecting Napier grass					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Fast growing	10.2	14.8	25.9	20.0	18.7	18.4
Disease resistant	6.2	3.9	2.9	4.0	2.0	0
Drought resistant	4.0	3.9	0	6.0	5.4	4.4
Herbage Yield	40	52.3	48.9	51.0	50.7	58.8
Number of tillers	0	1.6	5.8	1.0	9.9	12.3
Color of leaves	0	10.2	6.5	0	3.0	1.8
Length of reed	0	12.5	3.6	4.0	4.9	0
Any Napier material	0	0.8	6.5	10.0	4.9	3.5
No hairs	0	0	0	4.0	0.5	0.9

Disease tolerance, drought tolerance and absence only accounted for less than 6%. The source of planting materials for the preferred varieties was mainly from Neighbours (58-73.8%). This was followed by own farms in Kiambu (19%) and Murang'a (31%). Research Institutes and Government training institutes provided the least (< 10%) possibly because of the distance. In Busia, NGO's was also a major source of planting materials. Most farmers interviewed had maintained the Napier grass for more than 4 years (Table 4.3.12) and had cut it at least 6 times in a year especially in Mumias, Butere, Busia and Kiambu (Table 4.3.13).

Table 4.3.12: Period of maintaining Napier grass stand in same farm in western and Central Kenya

Period in months and years Period in months and years	Percentage of respondents					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Less than 6 months	6.5	3.1	4.7	1.0	5.2	3.5
6-12 months	14.0	11.7	14.7	9.6	6.2	12.2
1-2 years	14.0	22.7	18.7	21.2	15.2	15.7
2-3 years	15.0	21.9	16.7	11.5	7.6	10.4
3-4 years	16.8	7.8	11.3	15.4	17.1	11.3
More than 4 years	33.6	32.8	34.0	41.3	48.6	47.0

The common frequency of cutting Napier grass was after every 4 weeks during the wet season and between 6-8 weeks during the dry season. Most farmers cut their Napier when it is 80cm-100cm tall. Most farmers don't sell their Napier grass. A few who sell do so between February and March and between October and November. Months of Napier shortage are between January and March and November and December, while in Kiambu and Muranga the shortage occurs in August and September. Most farmers who buy Napier usually do so between January and February and in December when there is shortage due to drought.

Table 4.3.13: Number of harvest made on Napier grass by farmers in western and Central Kenya

Number of harvest	Percentage of respondents					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
1st harvest	5.1	3.1	3.5	1.9	4.9	2.8
2nd harvest	3.7	3.8	2.8	1.9	3.3	4.6
3rd harvest	13.6	5.3	6.3	8.6	29.0	19.3
4th harvest	18.7	10.7	12.5	18.1	8.7	35.8
5th harvest	12.6	3.8	3.5	7.6	1.6	14.7
6th harvest	44.9	73.3	71.5	61.9	52.5	22.9
7th harvest	1.4	0	0	0	0	0

Important practices used by majority of farmers to improve Napier yields are mainly weeding and use of manure (Table 4.3.14).

Table 4.3.14: Napier grass management practices adopted by farmers to improve yields in western and Central Kenya

Napier grass management practices	Percentage of respondents					
	Western Kenya				Central Kenya	
	Bungoma	Mumias	Butere	Busia	Kiambu	Murang'a
Weed	53.5	68.7	81.5	85.7	55.5	43.5
Manure	35.7	26.7	15.9	13.3	42.1	56.5
Remove infected tillers	2.8	1.5	0.7	1.0	0.5	0
Remove infected plants	5.6	0.8	0.7	0	1.9	0
Add chemical fertilizers	2.3	2.3	1.3	0	0	0

Few farmers (<5%) remove infected tillers and plants. The least used methods are adding chemical fertiliser. Most farmers in western use cuttings to establish new Napier plots, while those in Kiambu (49.0%) and Muranga (77.2%) mostly use root splits. In western some farmers (<3%) use whole canes. Most farmers (82.5-84.5%) especially Kiambu and Muranga districts get their planting materials from within 1km from their farms and the majority (57 92%) plant their Napier grass in plots. In western 26–34% in addition plant Napier grass on boundaries either to control soil erosion or in the push-pull technology to control stemborers.

Napier grass stunt and smut diseases

Most farmers in western (94-99%) had noticed Napier stunt disease in their districts and 18-28% had noticed on their farms compared to less than 16% in Central Kenya (Table 4.3.15). On the contrary more farmers in Central Kenya had observed smut disease their districts and farms (68.9 and 44.9% respectively in Kiambu) and (80.5 and 47.8 % respectively in Murang'a) compared to western Kenya where farmers only farmers in Bungoma (5.8%) and Busia (1.4 %) had observed smut the disease (Table 4.3.15). Also fewer farmers in western Kenya had observed both diseases on their farms than those in Central Kenya.The farmers in Central Kenya claimed that smut disease first appeared in in Kiambu in 1972 and stunt disease in Mumias in 1975. Smut disease became serious as from 2000 in Muranga and 2007 in Kiambu.

Table 4.3.15: Presence of Napier stunt farmers own farm and within the district in western and Central Kenya

District	Napier stunt disease - Percentage respondents who have seen the disease on their own farm			Napier headsmut disease -Percentage respondents who have seen the disease within the district			Both Napier stunt and smut diseases - Percentage respondents who have seen the disease within the district		
	Own farm	District	No. respondents	Own farm	District	No. respondents	Own farm	District	No. respondents
Western Kenya									
Bungoma	27.7	94.2	98	5.8	3.8	4	12.5	1.9	2
Mumias	22.0	97.5	78	0	0	0	12.5	2.5	2
Butere	27.7	99.0	98	0	0	0	6.3	1.0	1
Busia	18.9	95.7	67	1.4	1.4	1	12.5	2.9	2
Central Kenya									
Kiambu	2.0	15.6	7	44.9	68.9	31	43.8	15.6	7
Murang'a	1.7	14.6	6	47.8	80.5	33	12.5	4.9	2

Napier stunt disease was more severe in western Kenya than in Central Kenya (Table 4.3.16).

Table 4.3.16: Napier stunt disease severity in farmers own farm and within the district in western and Central Kenya

District	Percentage response on Napier stunt disease severity					
	Mild (1 in 20 stools)		Moderate (1 in 4 stools)		Severe (More than 1 in 4 stools)	
	Own farm	District	Own farm	District	Own farm	District
Western Kenya						
Bungoma	28.6	44.8	28.3	29.3	21.7	12.9
Mumias	14.3	31.3	25.8	37.3	33.3	27.7
Butere	28.0	50.5	28.3	33.7	17.4	11.9
Busia	20.9	48.1	15.0	22.8	18.8	16.5
Central Kenya						
Kiambu	4.4	18.2	2.5	6.8	7.2	11.4
Murang'a	3.8	8.2	0	0	1.4	1.2

Among the Central Kenya districts the disease was comparatively more severe in Kiambu than Murang'a. Napier headsmut disease on the other hand was severest in Central Kenya districts than western Kenya with Kiambu being more affected than Murang'a (Table 4.3.17)

Both diseases usually appears after 1st cut but the severity increases between 4th and 5th cut for stunt and between 3rd and 5th cut for headsmut disease. In terms of altitude headsmut disease was observed mostly between altitude 1727 and 2191 meters above sea level in Kiambu and Muranga, but was also observed at lower altitude of 1365 metres in Busia district. Some Kiambu and Muranga said they had planted smut tolerant Napier varieties mostly Kakamega 1and had given some of those varieties to other farmers.

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Table 4.3.17: Napier head smut disease severity within farmers own farm and within the district in western and Central Kenya

District	Percentage respondents of farmers on Napier headsmut disease severity					
	Mild (1 in 20 stools)		Moderate (1 in 4 stools)		Severe (More than 1 in 4 stools)	
	Own farm	District	Own farm	District	Own farm	District
Western Kenya						
Bungoma	0	0	10.5	2.6	0	0
Mumias	0	0	5.3	1.6	0	0
Butere	2.1	1.0	0	0	0	0
Busia	2.1	1.3	5.3	1.3	16.7	1.3
Central Kenya						
Kiambu	54.2	37.1	47.4	12.9	33.3	2.9
Murang'a	41.7	23.5	31.6	7.1	5.0	3.5

The most important methods to control and/or minimize the spread of the disease were manure application and weeding in all the districts. Uprooting, burning of infected plants, rotating with other crops and mulching was only practiced in Central Kenya districts by 2-12% of the farmers. The major sources of information on stunt and smut disease management are Ministry of Agriculture and Livestock Extension staff (68.2%) and personal experimentation (30.3-60.6). Seminars, workshops and Agricultural shows played a lesser role.

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4.4 Status of Napier Stunt Diseases in Eastern and Northern zones of Tanzania and management strategy

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Introduction

From early 1970,s – 1990's, grass pastures including Napier (*Pennisetum purpurium*), Guatemala (*Tripsacum laxum*), and Setaria (*Setaria sphacelata*) were introduced in Tanzania to alleviate dairy feed shortages and improve dairy production. Among the introduced fodder grasses, Napier is the most widely adopted due to its' high yielding and nutritional qualities. However, the production of this grass is threatened by occurrence of Napier Stunt Disease (NSD) which was reported in Tanzania in 2008 (Pallangyo et al.., 2008). Baseline survey that was conducted in 2008 reported occurrence of the disease in Eastern, Northern and Lake agricultural zones (Pallangyo et al.., 2008). By 2013, the disease had already spread to Zanzibar Islands (Maeda and Pallangyo, 2010) and Southern highlands of Tanzania mainland (Pallangyo et al.., 2014).

Serious fodder shortage was experienced by farmers leading to decline in milk productivity, sale of livestock, and shifting from Napier to alternative crops some of which had lower income value. Decline in milk productivity due to NSD led to food and income insecurity especially in rural households whose income depends on livestock farming. With shortage of fodder, women who dominate the dairy business had to travel long distances to find alternative fodder, yet fulfilling household responsibilities.

Under ASARECA Napier Smut and Napier Stunt resistant project that came to an end in 2010 and the ongoing EAAPP project titled "Exploiting Napier stunt and smut disease resistance to increase feed availability in smallholder dairy systems", NSD tolerant varieties were also identified which could be integrated with cultural practices in NSD management. Public awareness on cultural practices for NSD management was also created which led to decline of NSD incidence in affected areas. In January 2015, survey was conducted to follow up status of the disease in previously affected areas and establish current spread limit.

Specific Objectives

(a) Determine incidence and severity of Napier Stunt Disease in Meru, Muheza and Lushoto districts

(b) Create public awareness on Control measures for NSD

Methodology

The survey covered the eastern (Muheza and Lushoto districts), and northern (Meru district) agro ecological zones. The survey area represented differing agro ecological zones, presence of farmers practicing zero grazing where Napier grass is a basic fodder and where Napier Stunt Diseases have been reported. Focus Group Discussion Meetings of at least 10 stakeholders were conducted in each district to enable the selection of village sampling frame. Ward Agricultural and Livestock Extension Officers (WAEOs) were trained on enumeration, identification of NSD symptoms and control measures. The WAEOs were expected to disseminate the knowledge during enumeration and later during their routine visits to farmers. A scale of 1 – 4 whereby 1 = Nil (no plants with symptoms, 2 = Mild (< 25% of plants with disease symptoms), 3 = Moderate (25 – 50% of plants with disease symptoms) and 4 = severe (> 50% of plants with disease symptoms) was used to determined NSD incidence. NSD severity was determined using a scale of 1 - 4 whereby 1 = Nil, 2 = Mild (<25% of tillers with disease symptoms), 3 = Moderate (25 – 50% of tillers with disease symptoms) and 4 = severe (> 50% of tillers with disease symptoms). Farmers with NSD infected fields were advised to uproot and burn the infected plants to avoid spreading the inoculums. Leaf samples were taken from NSD infected plants and kept in well labeled paper bags for Disease confirmation through DNA analysis.

Results and Discussion

Survey Areas

The survey was conducted in Tanga and Arusha regions whereby 3 districts including Muheza and Lushoto (Tanga region) and Meru (Arusha region) were covered. Forty four (44) villages were sampled, 14 villages in Muheza, 19 villages in Lushoto and 11 villages in Meru districts. A total of 153 respondents were interviewed, 47 respondents in Muheza, 66 respondents in Lushoto and 40 respondents in Meru districts (Fig 4.4.1). The number of households varied depending on size of district and importance of Napier grass.

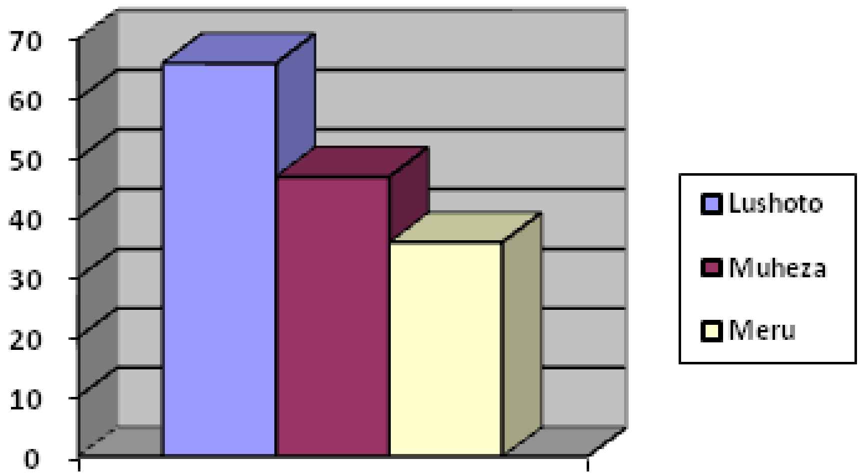

Figure 4.4.1: Sampled households in Lushoto, Muheza and Meru districts.

NSD infected area

Among the sampled villages, 19 (43%) were reported to be infected by NSD. The affected villages were found in Muheza (8), Meru (6) and Lushoto (5) (Table 4.4.1).

Table 4.4.1: NSD infected villages in Muheza, Lushoto and Meru districts

District	Sampled villages	NSd infected villages	% infected villages
Muheza	14	8	57
Lushoto	19	5	26
Meru	11	6	54
Total	44	19	43

In comparison to previous survey, the NSD infected area has expanded to cover Lushoto district which was previously free from the disease. Considering that the disease is resent in Lushoto, the number of affected villages indicates that the disease is spreading fast and hence a need for immediate intervention.

Affected households

Among the interviewed respondents, 39 reported to have NSD infected fields. In terms of percentage, Muheza district had the highest proportion of affected households (29%) followed by Meru district (Table 4.4.2, Figure 4.4.2). Although Lushoto had slightly larger number of NSD infected households compared to other districts, in terms of percentage the district had the least proportion of affected households (22%) probably due to the fact that the disease has recently invaded the area compared to Muheza and Meru where the disease is reported since 2008 (Pallangyo et al..,2008). However, the percentage of affected households in Lushoto district is expected to increase due to famer's tendency of sharing planting materials. This was witnessed in Ubiri and Mbuzii villages where Farmers reported to have shared improved Napier grass materials from infected on farm demonstration plot for Improved Napier grass varieties.

Table 4.4.2: Households with NSD infected fields in Muheza, Lushoto and Meru Districts

District	No. of sampled households	Households with NSD infected fields	% affected households
Lushoto	66	15	22
Muheza	47	14	29
Meru	40	10	25
Total	153	39	25

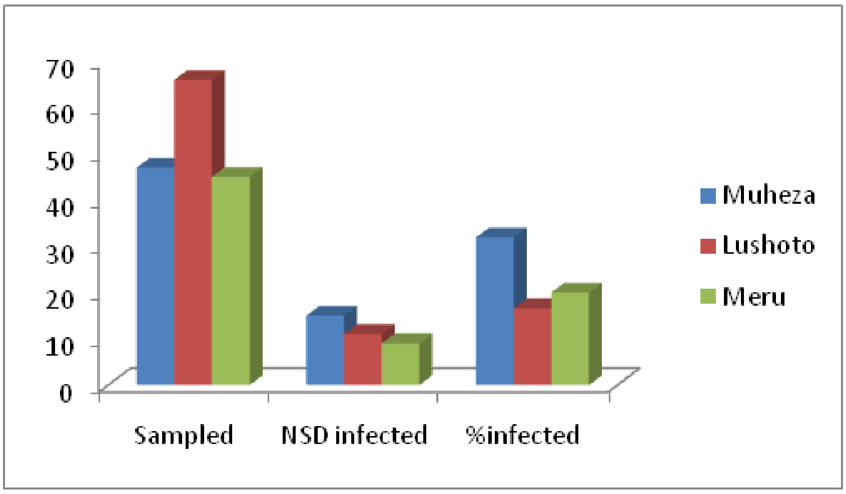

Figure 4.2.2. NSD infected households in Muheza, Lushoto and Meru districts

NSD Incidences and Severity

Low NSD incidence ranging from 1–2 was found in Muheza and Meru districts while moderate incidence ranging from 2–3 was found in Lushoto district. In terms of NSD severity, low to moderate severity ranging from 2–3 was found in Muheza and Meru while in Lushoto the severity was higher ranging from 3–4. The most severely affected fields were found in Ubiri and Mbuzii villages in Lushoto district. Among the severely affected filed included the Napier Demonstration Plots and MSc student's research trials which were established using materials from TALIRI Tanga. In Ubiri village, the most severely affected fields belonged to farmers who sourced planting materials from the Demonstration Plots. According to Mbuzii Village Executive Secretary, Mr. Karim Singano, who is also a leader of Bahati Farmers Group, at least 20 farmers have sourced planting materials from the

Demonstration plot and some have been shared with farmers from other villages thereby posing risk of spreading the disease further.

Current NSD levels in Meru and Muheza districts indicate that although farmers are aware of recommended management practices, they still exchange planting materials due to lack of reliable sources of improved planting materials. This has facilitated the spread of NSD to new areas for example in Akheri village (Meru district) and Tongwe village (Muheza district). One participant of focus group meeting in Muheza district, Mwalimu Mvungi, informed the participants that despite following the recommended cultural practices he and other farmers in Mkanyageni village lost their Napier crop due to NSD and drought stress. Due to lack of reliable source of resistant materials they had to abandon Napier farming and shifted to alternative crops including maize and cassava (Muheza district). The SMS dairy at Muheza district Ms. Juliana Swai also informed participants that the number of small holder dairy farmers has dropped substantially following the occurrence of NSD in the district.

Public Awareness on NSD management

Public awareness was created through focus group meetings at District LGAs, village meetings and field visits. A total of 238 stakeholders including District Executive Officers, District Agricultural Irrigation and Cooperatives Officers, District Livestock Officers, District Plant protection Officers, Ward Agricultural and Livestock Extension Officers, Livestock Researchers, Policy makers and farmers were reached (Table 4.4.2). The current status shows that the disease is spreading fast into new villages and districts due to inadequate awareness on control measures and shortage of improved planting materials. While multiplication of NSD resistant varieties is going on, massive public awareness is required especially in newly infected areas in order to prevent and control the disease. Decline in NSD incidence has been witnessed in previously infected areas following intensive public awareness creation and massive adoption of recommended measures for NSD management (Pallangyo et al.., 2011). Similar approach should be used to avoid further Napier yield losses.

Table 4.4.3. Composition of stakeholders who received information on NSD management

District	Administrators	Extension Officers	Researchers	Farmers
Muheza	2	20	1	50
Lushoto	2	15	2	75
Meru	1	10		60
Total	5	45	3	185
Grand total		238		

Inspection of Napier Gemplasm in TALIRI

A visit was made in Tanzania Livestock Research Institute (TALIRI) which is located some few kilometers from Tanga municipal. The Institute had a collection of Napier grass varieties including Kakamega 1, Kakamega 2, Local and Hybrid which were established in 2011 using materials from CIAT, ILRI and National Agricultural and Livestock Research Institutes. The collection served the role of germplasm introduction and evaluation, maintenance of identified forage germplasm, and multiplication of forage seeds for research and development. In March 2014, Napier grass materials from the collection were sent to Lushoto district, where they were used in the establishment of on farm demonstration plots and the MSC student's trials in Mbuzii and Ubiri villages. According to TALIRI Livestock Researchers, Mr. Mngulwi, Napier grass materials from the collection have also been used in establishment of 6 demonstration plots in Babati district. The demonstration trials and Student's trials in Lushoto district were found to be infected by NSD during the survey. According to Mbuzii

Farmers Group members, NSD symptoms were observed in the demonstration trial in November 2014, after the second cutting. Inspection of Napier collection at TALIRI was done whereby all Napier varieties were found to be infected (Figure 4.4.13 – 4.4.16) thereby associating the NSD inoculums in Lushoto with Napier collection at TALIRI, Tanga.

Recommendations

Current NSD levels in Meru and Muheza districts indicate that although farmers are aware of recommended management practices, framers still exchange planting materials due to lack of reliable sources of improved planting materials. This has facilitated the spread of NSD to new areas for example in Akheri village (Meru district) and Tongwe village (Muheza district). The shortage has also forced some farmers in severely affected areas to abandon Napier farming and shift to alternative crops some of which are of lower value compared to dairy farming.

To avoid further spread of the disease, farmers are advised to adhere to recommended cultural practices for NSD management which include uprooting and burning of infected plants and tillers. The Napier grass materials in TALIRI collection should be destroyed and the area planted with non NSD suitable host, for example cassava or sweet potato in order to break the disease life cycle. Arrangements should also be made to enable follow up NSD status in demonstration plots at Babati district to enable timely intervention. Future introduction of planting materials and any other living organisms should abide to Phytosannitary regulation as stipulated in Plant Protection Act, 1997 and Regulations, 1999).

Shortage of improved planting materials and lack of awareness on NSD management have contributed in spreading NSD in the affected areas for example in Lushoto where the disease was associated with improved materials sourced from TALIRI demonstration plots. There is a need to speed up the multiplication and distribution of NSD tolerant varieties at ARI Kibaha to address the shortage. Intensive public awareness creation is required to enable massive adoption of recommended cultural practices for NSD management to mitigate negative impact associated with the disease. Capacity of Extension service also needs to be strengthened through training on NSD etiology, symptoms and management to ensure sustainability in management of the disease.

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4.5 Status of Napier stunt and smut diseases and farmer management practices in Rwanda

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Introduction

Feed shortage is a major constraint to livestock production in Rwanda. Ruminant production in the country is predominantly based on Napier grass, natural pastures and crop residues (Mutimura and Everson, 2011). Napier grass is the most preferred because of high herbage yield (8-30 t DM/ha/yr) (Kabirizi, 2006); adaptability to low and high altitudes (Boonman, 1993); and multipurpose use options (Farrell et al., 2002). The potential contribution of the grass to livestock feed in East and Central Africa is threatened by Napier Stunt and Smut Disease (NSD), which has been reported in neighbouring countries of Uganda, Kenya and Tanzania (Nielsen et al., 2007). However, the presence and severity of these diseases has not been confirmed in Rwanda. This study was conducted to determine the incidence and prevalence of NSD in smallholder dairy systems in the country and assess farmers' knowledge, perceptions and their coping mechanism to the threat of the diseases.

Materials and methods

The study was carried out in 2013 in 14 districts of Eastern, Kigali City, Northern, Southern and Western Provinces. The districts lie within three agro ecological zones of the highland (altitude: 1,800 – 2,400m), lowland (Altitude: 900 - 1,400 m) and midland (Altitude: 1600 - 1800 m) that also differed in temperature and rainfall. Reconnaissance surveys were conducted to identify farms and plants affected NSD. Disease incidence, prevalence and severity were examined in the selected farms. The severity of the disease was scaled from 1 to 5, and 5 was considered as very high severity. Structured questionnaires were administered to 391 dairy farmers to determine level of farmers' awareness of NSD. Data were analysed using descriptive statistics.

Results

Household composition

The gender disaggregated household composition and average number persons in each province are presented (Table 4.5.1). Majority of the male and female farmers were in the age bracket of 11 to 40 years old in all the provinces except in the Northern Province where the majority were 21 to 60 year. Most of the respondents during the survey were male though the proportion varied between districts (Figure 4.5.1). The highest female respondents were in Gasabo followed by Nyaruguru, Kayonza and Gakenke districts and this could be partially attributed to the of women empowerment through education and self-employment, one-cow-poor family (GIRINKA) and the residual impact of genocide experience.

Table 4.5.1: Gender disaggregated household composition (%) and average number of persons (heads per 100 households) by Provinces in Rwanda

	Composition			Average number of persons/100h'holds		
Province	**Age group**	**Male**	**Female**	**Male**	**Female**	**Total**
Eastern	<5	21	15	22	16	37
	6-10	42	37	57	55	111
	11-20	63	60	99	99	198
	21-40	60	51	97	74	171
	41-60	24	42	36	42	78
	>60	14	22	126	24	151
Kigali City	<5	20	14	20	27	47
	6-10	22	26	38	52	90
	11-20	54	46	108	79	187
	21-40	40	48	132	70	202
	41-60	43	33	43	33	77
	>60	14	18	14	18	32
Northern	<5	34	24	49	37	86
	6-10	42	44	61	63	124
	11-20	43	54	58	80	139
	21-40	58	72	72	90	161
	41-60	48	47	88	53	141
	>60	21	22	21	14	36
South	<5	31	33	39	40	79
	6-10	64	50	230	233	464
	11-20	79	68	247	244	491
	21-40	70	69	237	95	332
	41-60	55	21	194	353	547
	>60	21	35	230	217	446
West	<5	18	13	20	16	36
	6-10	36	22	47	43	90
	11-20	55	55	88	86	174
	21-40	47	53	67	77	143
	41-60	43	49	45	51	96
	>60	25	29	25	31	56

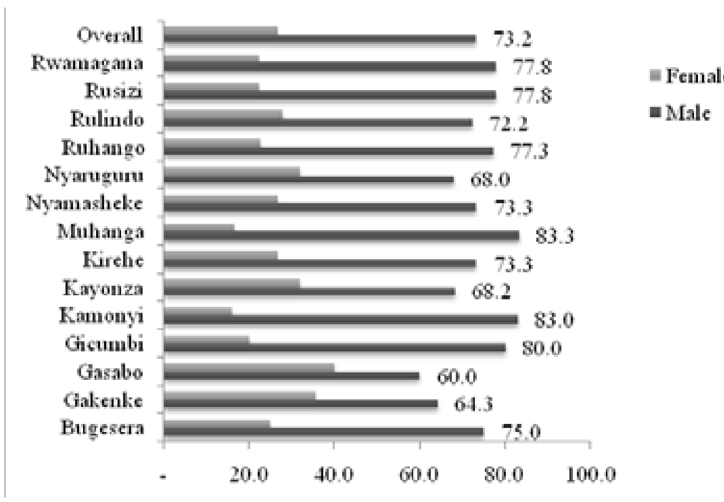

Figure 4.5.1: Percentage of male and female headed households in sample districts during Napier Smut and Stunted disease survey

Despite the high number of male headed households (Figure 4.5.1) only 31.3% of the males were respondents in the survey compared to 75% of female head of households (Table 4.5.1). In male headed household, parents of the spouse and hired workers acted as respondents compared self-participation in the female-headed households. The participation of children (sons and daughter) was generally low.

Table 4.5.2: Level of participation of different gender relations in Napier Smut and Stunt

Relationship	Male	Female
Spouse	31.3	75.0
Parent	37.5	16.7
Son	6.3	-
Daughter	-	8.3
Son-in-law	-	-
Daughter in law	-	-
Grand child	-	-
Hired worker	25.0	-
Others	-	-
Overall	100.0	100.0

Education

The overall literacy rate was generally high across the provinces. The highest literacy was in the Southern and Northern provinces where the majority reached grade 6 (Table 4.5.3). The reason increase of literacy could be that the free primary education which promoted by the government of Rwanda. The other reason is that people educated to post primary level can access alternative livelihood opportunities to agriculture because of specialized training. Similarly Eastern Province and Western province had more literacy than in other provinces. The reason could be that they offer more opportunities for skilled labour than other parts of the country.

Table 4.5.3: Education levels among dairy households encountered during Napier Smut and Stunt Disease survey in Rwanda

	Provinces					
Education Level	**East**	**Kigali City**	**North**	**South**	**West**	**Overall**
Adult	0.9	-	2.4	-	-	0.8
Grade Certificate	1.7	3.5	2.4	9.1	18.0	6.4
P1	0.9	3.5	1.2	1.0	1.6	1.3
P2	5.2	3.5	1.2	1.0	1.6	2.6
P3	8.7	10.5	4.8	4.0	-	5.4
P4	9.6	3.5	3.6	6.1	3.3	5.9
P5	10.4	17.2	4.8	9.1	4.9	8.5
P6	22.6	17.2	35.7	33.3	21.3	27.6
P7	4.4	3.5	4.8	-	4.9	3.4
P8	4.4	3.5	8.3	3.0	14.8	6.4
S1	0.9	-	2.4	1.0	1.6	1.3
S2	1.7	3.5	2.4	1.0	-	1.6
S3	6.1	3.5	3.6	2.0	3.3	3.9
S4	6.1	-	1.2	3.0	-	2.8
S5	-	-	1.2	0.0	4.9	2.1
S6	0.9	-	2.4	-	4.9	1.6
Specialized Training						
Post Primary	4.4	6.9	6.0	11.1	-	5.9
Post-Secondary	0.9	-	-	4.0	8.2	2.6
Total mean of literate	**89.8**	**79.8**	**88.4**	**88.7**	**93.3**	**90.1**

Housing structure

As a proxy indicator of improved welfare, the survey considered the materials farmers used for house construction. The majority used iron sheets for the roofs, cement for the floor and brick or stones for the walls (Table 4.5.4).

Table 1.5.4: Percentage of farmers using different housing structures

	Structure		
Material	**Roof**	**Wall**	**Floor**
Grass	1.5	-	-
Iron sheets	69.7	11.6	-
Tiles	28.7	-	1.0
Brick/stones	-	40.6	-
Mud	-	33.3	-
Wood	-	14.0	3.1
Cement	-	-	55.6
Soil	-	-	40.1
Others	-	0.5	0.3

Land Resource endowment

Due to population pressure farmers majority of the farmers own more than one parcels of land (Table 4.5.5). In the Northern, Western and Southern provinces the majority of farmers owned three parcels while in Kigali City none of the farmers owned more than two parcels.

Table 4.5.5: Percentage (%) of farmers and number of parcels owned

	Provinces					
No of parcels	**Eastern**	**Kigali City**	**Northern**	**Southern**	**Western**	**Overall**
<1	-	3.5	-	-	-	0.3
1	26.7	31.0	16.0	20.5	21.4	22.9
2	48.3	48.3	21.3	25.6	35.7	. 36.8
3	13.8	17.2	24.0	38.5	3.4	21.0
4	7.8	-	20.0	5.1	14.3	10.8
5	3.5	-	16.0	10.3		
-	7.1	7.7	55.6			
6	-	-	2.7	-	-	0.7
Total land area (ha)	1±0.2	2±1	3±0.2	3±0.2	3±0.2	2±0.1

This is because in most of the dairy farmers outside Kigali City are beneficiaries of the GIRINKA (one-cow-per poor family programme which encourage farmers to look for more land for crop and fodder production.

Farmers experience with Napier grass varieties and planting

The majority of farmers in all provinces were familiar with only one variety (Umushingiriro= vernacular name) of Napier grass (Pennisetum purpureum) while 23% in Northern and 29% in Southern were aware of a second variety (Table 4.5.6). Also more than 80% of farmers planted improved Napier varieties (French Cameroon) with the highest proportion being in Kigali. A few farmers (5 to 14%) in the northern, southern, and western provinces planted both improved and local varieties (Table 4.5.6). Majority of the farmers (over 63%) in all the districts use cuttings for planting. Among the provinces it is only in the northern and southern where 20 to 23% of the farmers use root splits (Table 4.5.6).

Table 4.5.6: Napier varieties used

	Provinces					
No of varieties	Eastern	Kigali City	Northern	Southern	Western	Overall
1	87.6	88.9	74.4	69.8	93.5	88.8
2	11.5	11.1	23.1	29.2	6.5	18.1
3	0.9	-	2.6	-	-	0.8
No. varieties planted					3.4	21.0
Improved	80.5	96.4	76.9	75.3	88.3	80.9
Local	11.5	3.6	9.0	15.1	6.7	10.5
Both	-	-	14.1	9.7	5.0	8.6
Planting materials used					-	0.7
Both	6.1	7.1	15.9	13.7	8.9	10.7
Cuttings	77.2	89.3	63.4	73.2	97.5	73.1
Root Splits	16.7	3.6	20.7	23.2	3.6	16.3

Reasons for growing Napier grass

Napier grass is mainly grown for feeding livestock followed by erosion control in all the provinces (Table 4.5.7). Use of Napier grass for mulching featured prominently in the second and third priority in Eastern, Northern and Kigali City provinces. Growing for sale was a conspicuous feature in is second priority level, especially in Kigali City, Western and Northern provinces.

Table 4.5.7: Reasons for planting Napier grass

		Reasons				
Province	Priority Status	Feeding	Erosion Control	Sale	Mulching	Stakes
Eastern	1	91.9	4.5	3.6	-	-
	2	3.5	77.6	6.9	10.3	-
	3	-	10.0	20.0	70.0	-
	4	100.0				
Kigali City	1	96.4	-	3.6	-	-
	2	-	64.3	35.7	-	-
	3	-	50.0	-	50.0	-
	4	-	-	-	-	-
Northern	1	97.5	1.3	1.3	-	-
	2	-	60.5	39.5	-	-
	3	-	60.0	-	40.0	
	4	-	-	-	100.0	-
Southern	1	92.8	1.0	6.2	-	-
	2	-	74.3	25.7	-	-
	3	-	75.0	-	25.0	-
	4	-	-	-	-	
Western	1	89.5	-	10.5	-	-
	2	-	66.7	33.3	-	-
	3	-	-	-	-	-
	4	-	-	-	-	-
Overall	1	93.3	1.9	4.8	-	-
	2	1.4	71.0	4.1	22.7	-
	3	-	42.9	32.1	7.1	17.9
	4	33.3	66.7	-	-	-

Majority of the farmers in all the provinces reserved land solely for growing Napier grass but the acreage varied between districts. The majority allocate less than 0.5 acres to Napier grass while 42.1% of household allocated more than 0.75ha of Napier. Among the districts famers in Gicumbi (82.1% of households) allocated the smallest area (less than 0.5 ha) while those in Nyamasheke district (56%) allocated the largest (more than 1.0 ha per household) to Napier grass (Figure 4.5.2)

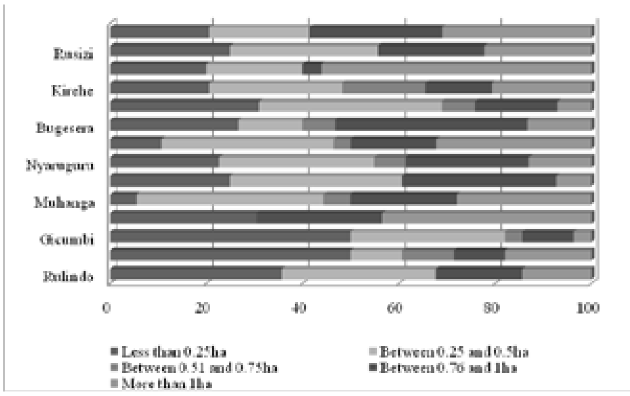

Figure 4.5.2: Land use pattern (proportion of farmers) for Napier production in selected districts of Rwanda

Sources of Napier grass planting material varied between districts. In Bugesera and Kirehe distrcts, 67.7% obtained planting materials from neighbours while in Rusizi the farmer's field contributed 68.6% of planting material. Research institutions played a minimal role as sources of planting material in Gakenke (20%) and in Nyamasheke (16.1%) while extension workers and NGOs contributed less than 2%.

Farmers' awareness about the Diseases

The survey team encountered some farmers who could recognize Napier stunt disease in all provinces except Kigali City. However, the level of awareness was very low, especially in the southern province, where only 1% of the farmers could recognize the disease. The disease was new in the country because the majority (85%) noticed it within the last two years (2011-2013). The main symptoms farmers associated the disease with were yellowing and stunting (Figure 4.5.3). A small proportion (5%) of farmers observed that the diseased plants dry and die. These symptoms were confirmed during field surveillance where clumps were severely stunted and biomass yield were low. Other symptoms farmers associate with the disease were pale yellow-green and seriously dwarfed shoots, especially during after or before harvesting. There was not symptoms of smut disease in all surveyed districts. This suggested that stunt disease was the only major disease threatening Napier grass.

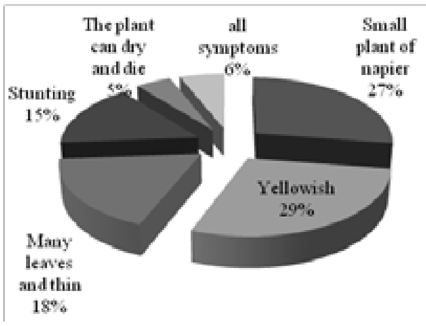

Figure 4.5.3: The proportion of farmers that recognized specific symptoms of the stunt disease

Napier stunt disease incidence and severity

The severity was scaled from 1 to 5 where scale 5 was considered as being very high. Napier stunt disease was observed in only 8% (31 fields out of 383) of fields assessed. The highest disease incidences (35.17%) were in Kirehe district followed by Rwamagana, Kayonza, Nyamasheke and Gasabo with less than 5% (Figure 4.5.4). The disease was higher in the middle altitude than in the high and low altitude zones. The severity of the disease was highest in Kayonza and Rusizu followed by Kirere and Rwamagama (Figure 4.5.4) among other selected districts.

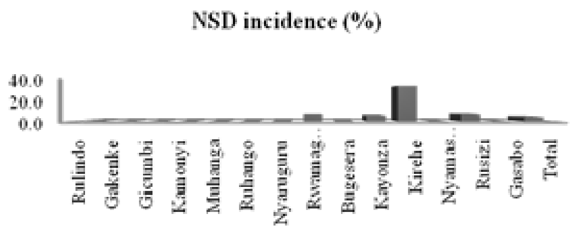

Figure 4.5.4: Napier stunt disease incidences (%) in selected districts of Rwanda

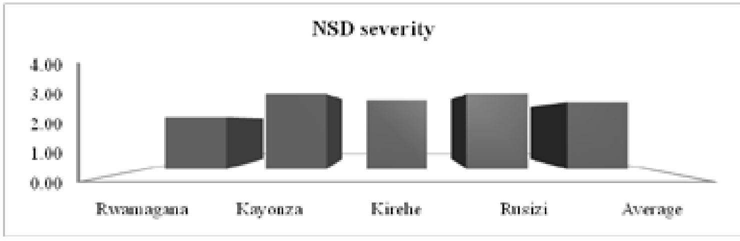

Figure 4.7: Napier stunt disease severity among selected districts of Rwanda

Napier grass management practices

Weeding is the common practice used to improve the yield of Napier grass and to control the disease according to respondents in the districts surveyed. Some farmers combined weeding with manure application while others use a combination of three practices i.e. weeding, manure application and recommended harvesting methods.

Discussion and conclusion

The demographic structure of Rwanda smallholder dairy household was generally similar. However family size in southern province tends to be larger than in other provinces. The family size in Kigali City and Western province tend to be lower than in other provinces. The level of participation of female farmers was higher than male spouse. Therefore they are likely to be more active in NS management than their spouse. The majority of the economically active farmers in the dairy are literate, but highly dominated by primary school leavers. Therefore access to education is a strategy for creating alternative livelihood opportunities in Rwanda. The housing structures encountered during the survey proofed that investments in the dairy sector had improved the livelihoods of the farmers. The per capita landholdings that the farmers declared were higher than expected. In addition to improved varieties of Napier grass that most farmers use, there are local accessions, which need to be characterized. The survey confirmed the presence of the Napier Stunt disease in Rwanda for the first time but Napier head smut disease was not observed in this study. Most farmers used cuttings as planting material and the majority source them from neighbours or own farms. The incidences and severity was greater in the medium altitude zones, especially in Eastern province. The disease is new in the country and only a few farmers were aware of it. Sole reliance on Napier grass as a fodder, low awareness and propagation through vegetative cuttings from neighbours and own farms is likely to enhance the spread of the disease. Therefore there is need for awareness creation and dissemination of management practices including tolerant/resistant varieties that can control or minimize the spread of the disease in Rwanda

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CHAPTER 5: Napier Grass Resource Evaluation

5.1 Evaluation of Napier grass (Pennisetum Purpureum) accessions for dry matter yield, nutritive quality and tolerance to Napier stunt disease in Uganda

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Introduction

It is estimated that 12 to 14% of the world population, or 750 to 900 million people live on dairy farms or within dairy farming households and production of 1 million litres of milk per year on small-scale dairy farms creates approximately 200 on-farm jobs (FAO 2010). Smallholder dairy cattle production in Eastern and Central Africa (ECA) improves food security of milk-producing households, creates numerous employment opportunities to many resource poor people throughout the dairy value chain and provides manure for crop production (Njarui et al., 2012).

The success of the smallholder dairy sector in ECA region depends on Napier grass (Pennisetum purpureum), commonly known as elephant grass (Kabirizi et al., 2006; Orodho, 2006). The grass, whose herbage dry matter yield ranges between 16 and 30 t/ha/year is the main fodder source grown by over 80% of smallholder farmers in ECA and contributes 60-80% of the forages fed (Jones et al., 2007). Some farmers earn cash incomes from selling Napier grass fodder to dairy farmers who have insufficient land to grow their own feed (Kabirizi et al., 2006).

The major threat to the use of Napier grass fodder is the Napier stunt disease (NSD) caused by 16SrXI Group phytoplasma (Candidatus Phytoplasma oryzae) (Nielsen et al., 2007; Mulaa et al., 2010). Studies conducted in Uganda have shown that all Napier grass accessions are susceptible to NSD (Kabirizi et al., 2010). Affected shoots become pale yellow in colour and seriously dwarfed. Often the whole stool is affected, with yield reductions of 40-100% and eventual death of the plants (Nielsen et al., 2007). This has led to increased price of Napier grass in worst affected districts, insufficient feed for cows and selling off of animals by some farmers.

Efforts to identify resistant/tolerant Napier grass accessions to NSD have intensified in the last 5 years through the Regional Dairy Centre of Excellence (RDCoE) at Kenya Agricultural and Livestock Research Organisation and the International Centre for Insect Physiology and Ecology (ICIPE) in Kenya (Mulaa et al., 2010). Some resistant accessions have been recorded (Mwendia et al., 2006 and Mulaa et al., 2010). These accessions would be evaluated in Uganda and if found suitable, disseminated to farmers.

Adoption of genetically diverse, high yielding and climatically adapted Napier grass accessions tolerant to NSD will improve the performance of the dairy sector, alleviate the current feed shortages and environmental crises associated with NSD. This will contribute to food and nutritional security, social and gender protection, improved incomes, poverty alleviation, environmental sustainability and sustainable natural resource use in the region. The objective of the study therefore was to evaluate Napier grass accessions for dry matter yield, nutritive quality and tolerance to NSD.

Materials and methods

Description of study site

The study was conducted at the National Crops Resources Research Institute (NaCRRI), Namulonge in Central Uganda. Namulonge is located on latitude 00 5′ 320 61′. The area lies at an altitude between 900 and 1340 m above sea level. Namulonge lies in the sub-humid Uganda with a mean annual rainfall of 1270 mm per year which is bimodally distributed with peaks in March to May and September to November, while the dry months are January to February and July to August (Figure 5.1.1). Namulonge has a tropical wet and mild dry climate with slightly humid conditions (average 65%). Mean annual temperature is 22.2 0C (mean maximum temperature =28.4 0C and mean minimum temperature = 15.9 0C). The vegetation is wooded savanah with tall trees and tall grasses dominated by Pennisetum purpureum and Parnicum maximum.

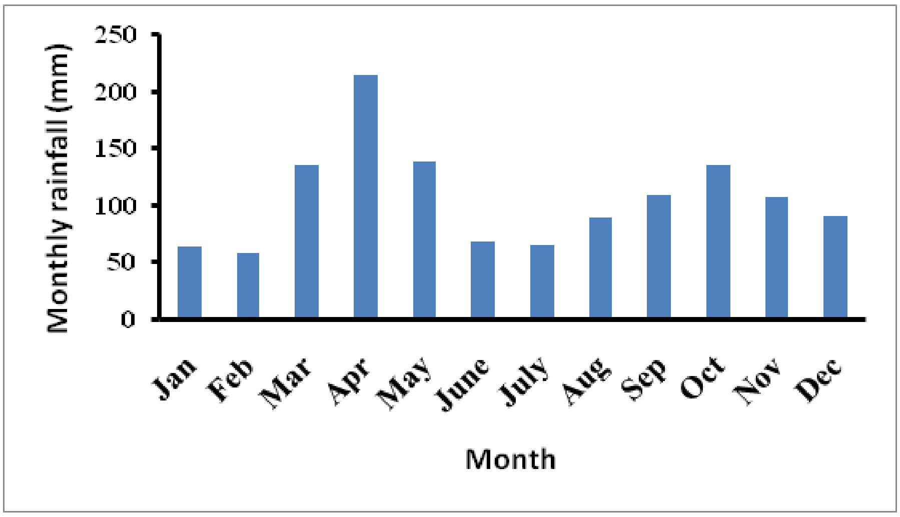

Figure 5.1.1: Monthly rainfall totals for NaCRRI (2012)

Experimental procedure

Twenty two (22) Napier grass accessions acquired from Alupe Research Institute in Kenya were planted in plots measuring 3m x 3m with intra and inter row spacing of 1.5m at NaCRRI in September 2011. The plots were arranged in a Randomized Complete Block Design replicated three times. The experimental plots were surrounded with stunt-disease infected Napier grass plants to facilitate transmissibility of the disease to the healthy Napier grass accessions.

Data collection started two months after planting and the subsequent sampling was done at 8 weeks intervals. At each harvest, scoring for disease incidence was done based on visual observations on disease incidence per plot and carried out just before harvesting, using a scale of 1 to 5 where 1 = no symptoms, 2 = very mild symptoms, 3 = medium mild symptoms, 4 = severe symptoms and 5 = very severe symptoms. Herbage biomass yield was estimated by cutting fodder at ground level from the whole plot and weighed. At each time of data collection, the grass was cut back to a height of 5 cm above ground and left to allow regrowth. Sub-samples of about 0.3 kg of Napier grass fodder were randomly taken and oven dried at 600C for 72 hours to constant weight. The dried samples were used for dry matter (DM) estimation and chemical analysis. Samples were analysed for crude protein (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) Calcium (Ca) and Phosphorus (P) contents using methods described by A.O.A.C. (2001).

Analysis of Variance (ANOVA) was carried out using Genstat statistical package 14th edition and significantly different means separated using Least Significant difference (LSD) at 5% level of significance.

Results

Effect of Napier stunt disease on herbage dry matter yield

Mean herbage dry matter (DM) yield for 7 harvests (56 weeks) ranged between 16 and 43 t/ha (Table 5.1.1).

Table 5.1.1: Effect of Napier stunt disease on herbage biomass yield of introduced Napier grass accessions

Napier grass variety	Mean herbage biomass yield for 7 harvests (ton/ha/year)
Kakamega 1 (ILRI 16791)	41.95b
Kakamega 2 (ILRI 16798)	40.4b
112	39.46b
16702	36.81b
97	35.3b
16805	32.3ab
41	29.1a
75	28.0a
105	26.87a
103	26.41a
16814	26.3a
76	26.05a
Kakamega 3 (ILRI 16786)	26.05a
16815	25.75a
79	25.5a
19	24.4a
117	23.52a
16789	23.5a
Alupe Napier Field	22.85a
79Sugarcane+Napier	21.2a
104	17.92a
River Bank	17.05a
SEM	**4.66**
LSD	**13.15**

Mean with different superscript in the same column are significantly different at $P<0.05$

SEM = Standard Error of the Means;

Based on total accumulated herbage dry matter yield of 7 harvests, Kakamega 1 and Kakamega 2 produced the highest yields compared to all other accessions. The lowest yielding accession was 104 (18.9 t/ha) and River bank (RBN) (17 t/ha).

Napier stunt disease severity among Napier grass accessions

Napier grass accessions significantly differed in severity and the period taken to show disease symptoms (Figure 5.1.2).

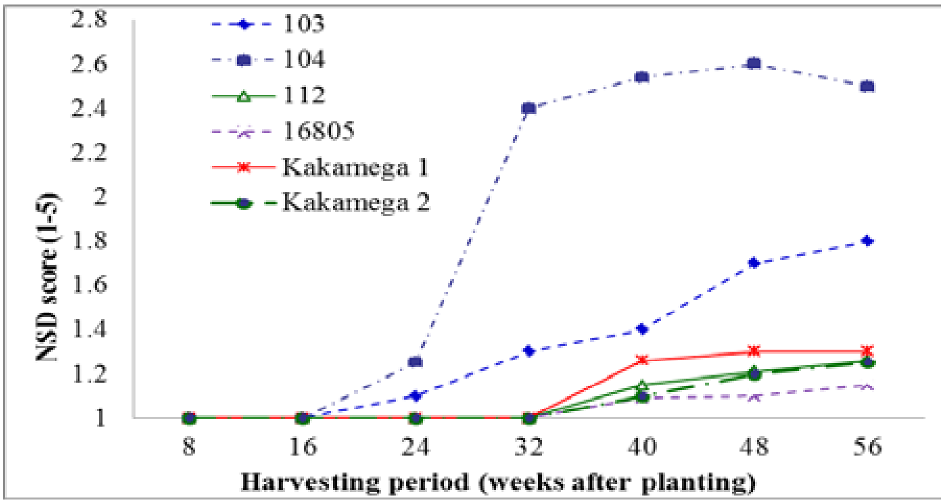

Figure 5.1.2: Napier stunt disease progress on some of the Napier accessions over time

Some accessions showed disease symptoms as early as after second harvest while others showed tolerance up to the fourth harvest. The most susceptible accessions were 104, 117, 76, and 79 SN medium mild symptoms at the second harvest representing 18.2% of the total number of accessions. At the 3rd harvest, accessions 104 and 117 showed medium mild symptoms while accessions 76, 41, 79, 79SN, 103, and River Bank Napier showed very mild symptoms. By the fourth harvest, 97 which was among the high yielding promising accessions showed very severe symptoms. Accessions 105, 112, 16702, 16789, 16805, 16815, 19, 75, Kakamega 1, and Kakamega 2 did not show disease symptoms up to seventh harvest. On the contrary, the accessions which had more disease build-up, on average had higher biomass (t/ha).

Nutrient composition of Napier grass accessions

The nutrient composition of the Napier accessions differed significantly (P=0.05). All the accessions had NDF content ranging between 55.5% (79 SN) and 62.8% (ANF) (Table 5.1.2). The percentage of crude protein was low, 6.4% (ANF) to 9.2% (79 SN). All accessions had very high dry matter content ranging from 89.9% to 90.6%.

Table 5.1.2: Nutrient content (%) of different Napier grass accessions

Accessions	CP (%)	DM (%)	NDF (%)
103	6.78	90.4	62.5
104	6.8	90.1	60.2
105	8.3	90.4	59.2
112	7.7	90.5	58.2
117	7.6	90.1	58.9
16702	7.4	90.2	58.6
16789	7.7	90.3	60.4
16805	8.0	90.3	60.1
16814	8.5	90.2	58.4
16815	8.4	90.1	58.0
19	7.3	90.4	61.2
41	8.4	90.4	58.2
75	7.4	90.4	61.8
76	6.7	90.3	62.3
79	8.5	90.6	58.5
79SN	9.2	90.0	55.5
97	7.3	90.1	59.0
ANF	6.4	90.3	62.8
Kakamega 1	7.3	89.9	58.8
Kakamega 2	7.3	90.3	59.7
Kakamega 3	7.1	90.3	61.2
RBN	8.9	90.3	56.0
LSD	1.1	0.4	2.1

Discussion

Effect of Napier stunt disease on Napier grass dry matter yield

The significant differences in dry matter yield (DMY) of Napier accessions could be attributed to genetic differences (Muyekho et al., 2008; Snijders et. al., 2011) and severity of NSD of the accessions. The sharp decline in DMY for the 2nd harvest could have been due to the effect of the dry season since the first and second harvests were done in November and February, respectively. The low DM yields recorded in this study could also be attributed to poor soils since no fertilizers were applied throughout the study time. Masinde et. al. (2012) reported that total dry matter yield of Napier grass-legume intercrops or Napier grass grown alone significantly increased when 60 kg diamonium phosphate per hectare or 5 t FYM per hectare +30 kg diamonium phosphate per hectare was used.

Napier stunt disease severity

The results on tolerance of Kakamega 1 differed from the findings of Muyekho et al. (2008) who reported that the accessions succumbed to NSD after the 3rd harvest in Kenya with very mild symptoms. Kakamega 3 showed disease symptoms by the fourth harvest which results differ from the findings of (Muyekho et al., 2008) who reported the same accessions to succumb to the disease after the first harvest in Kenya. The difference in the findings could have been a result of variation in soil fertility as Napier growing on fertile soils tends to be more tolerant to Napier stunt disease (Mulaa et al., 2007). Field observations have shown good management practices such as manure application reduce NSD severity on affected fields and (Kabirizi et al.; 2007; Mulaa et al., 2007).

There was an increasing trend in incidence and severity of NSD with number of harvests with the first mild symptoms appearing at the 2nd harvest concurring with findings of Mulaa et al. (2007) who reported that NSD affects plots that have been cut more than twice. The reason for the increase in incidence and severity with increased number of harvests could be that when the fodder grass is harvested, the leaf hoppers that spread NSD tend to move to other plants for survival. When the plants are regenerating, the leaf hoppers then move back to the young soft and juicier plants thus spreading the disease.

Nutrient composition of Napier grass accessions

The results on nutritive quality showed that the protein content of Napier grass accessions was low (6.7-9.2%). The CP levels were below the minimum recommended levels (16%) for production and maintenance of a dairy cow (NRC, 2001). Forage yield and nutritional qualities of pastures are influenced by numerous factors representing genetic, ecological conditions and management practices (Sarwat et. al., 2002; Lanyasunya et. al., 2006). Those factors include frequency of cutting, species composition, stage of maturity of plants, climatic conditions, soil fertility status and season of harvesting. Sarwat et. al. (2002) reported that crude protein content of grasses decreased with maturity of plants. They further reported that highest CP (7-9.6%) was found to be at vegetative stage and the maximum decrease in CP was found to be between the flowering and mature stage. The low CP reported in this study could therefore have been partly caused by poor soils since there was no fertiliser application throughout the study period. Rafiqul et. al. (2010) reported that application of approximately 70 kg of biogas slurry N per hectare will improve the production of biomass and nutrient content in maize fodder. The high NDF observed in this study could have been caused by maturity of the plants. Nutritive value of forages is greatly influenced by the growth stage of the forage when harvested. With advancing maturity, the plant contains low protein and high fibre content (Mahala et. al., 2012). In addition, as the plant matures, the plant cell wall of the stem becomes lignified and fibre becomes less digestible (Van Soest, 1994). Orodha (2006) reported that in East Africa, dry and wet season influence the dry matter yield and quality of Napier grass fed to dairy cattle. Van Soest (1994) noted that second cuttings has lower digestibility than first cuttings of the same chronological and physiological age, because plant growth begins at relatively high temperatures, usually after cutting or when rains ends a dry spell. DePeters and Kesler (1985) also observed that nutritive quality of forage reduced at the second and third cuttings of permanent pasture harvested as dried forage.

Conclusions and recommendations

This study has shown that Napier stunt disease tolerance exhibited by the accessions such as 105, 16789, 16825, 19 and 75 despite having relatively low yields suggest that these accessions can be very useful candidates in breeding programmes for resistance against Napier grass stunt disease. Accessions Kakamega 2, 16805, 112 and Kakamega 1 were among the accessions with the highest DMY and were tolerant to NSD up to the 7th harvest; therefore the accessions can be grown in NSD "hot spot" areas as a way to improve feed availability and NSD in an environmentally friendly and cheaper means. Farmers should be taught and encouraged to carry out specific agronomic management practices such as; manure application to improve soil fertility, weed control, proper cutting height and frequency and use of disease free planting materials that reduce the severity of NSD for such accessions to be disseminated. Sudies are proposed to assess the effect of different locations (a wider range of soil, rainfall, and temperature combinations); types of manure application and cutting intervals on severity of NSD.

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5.2 Epiphytology of Napier head smut disease and progress in the search for tolerant cultivars

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Introduction

Napier head smut(*Ustilago kamerunensis P. & H. Sydow*) is a hemibiotrophic pathogen causing very significant biomass losses (25-46%) in *Pennisetum purpureum* (Farrell, 1998; Farrell et al., 2000; NAFIS, 2012). Across the world, the disease has only been reported in Africa, especially in Eastern Africa where almost each country in the region has had a case of the disease. In Kenya it's widespread in the Central region where over 70% of the smallholder dairy farmers grow the crop (Bayer, 1990; Mwangi, 1994; Staal et al., 1998). A survey by Mwendia et al. (2007) has shown that 62.8% of the farmers in Central Kenya acknowledge the disease as a challenge to Napier grass production. The Central region is a high potential market oriented dairy zone second to Rift-valley region (Owango et al., 1998; Omore et al., 1999). Despite this region's milk production potential, it's presumed that the strain of the pathogen in the area is the most virulent in Eastern Africa or the Country's cultivars are more susceptible basing on the high herbage losses comparatively (Kung'u and Waller, 2001; Farrell et al., 2002b). In a bid to manage this disease, a host plant resistance strategy has been used due to its ease of adoption and cost effectiveness (Parry, 1990). However, Napier head smut disease has continued to spread gradually to new areas due to compromised cultural practices that are used in tandem with the host plant resistance approach to combat the disease in an integrated strategy. This is manifested by wind and through one of the common practices by farmers - uprooting diseased smutted tillers and disposing them poorly by the roadsides, thus end up growing voluntarily. This creates natural reservoirs of the disease which eventually reduces the efficacy of the integrated approach (Mwendia et al., 2007).

Napier head smut disease, distribution and research

Napier head smut pathogen; *Ustilago kamerunensis* belongs to the Ustilago Genus, Family Ustilaginaceae, Order Ustilaginales, Class Ustilaginomycetes and Phylum Basidiomycota (Begerow et al., 1997; Piepenbring, 2003). This genus contains most species of the smuts of the grasses with its spores used to distinguish the genera being characterized by smooth verruculose and reticulate walls (Fischer, 1953; Talbot, 1971). Spores germination in the genus is via a septate promycelium bearing sporidia that initiates the spread within a host tissue (Vanky, 1987). The genus infects at least 27 genera of angiosperms (Fischer and Holton, 1957). Napier head smut disease is currently a major concern affecting this vital but comparatively ignored crop (Farrell et al., 2002b). This is based on the limited research that has been conducted on the disease since it was reported (Farrell et al. 2002a; Mwendia et al. 2007). Most of the research on the disease is centered in Kenya at KARI-Muguga and Kakamega with the only research outside the continent having been its molecular characterization by Arocha et al. (2009) through a collaborative research between ICIPE-Kenya and Rothamsted research centre in the United Kingdom.

In Kenya the entry route of the disease to the country is mapped from West Africa, through Uganda (1930), Rwanda (1963), Tanzania (1975), and eventual establishment in the country in the 1990s where it was first reported in press affecting Central's Lari division in Kiambu district by Kung'u and Waller (Farrell, 1998; Farrell et al., 2001; Kung'u and Waller, 2001; Farrell et al., 2002b). Since then, its distribution within the several divisions of the region has been very notable and logarithmic (Farrell, 1998; Kung'u and Waller, 2001; Mwendia, 2007). This is compounded by some worrying reports of its occurrence in other parts of the country like; in Rift-valley at Molo and Londiani and the lower Eastern region at Meru north and south (Lukuyu et al., 2012).

Etiology of the disease

Ustilago kamerunensis, the causative agent of Napier head smut, grows within the plant's cells and slowly spreads systemically to the entire plant's tissues. Its hyphae that are branched with internal partitions (septate) produce lobed and curved haustoria that form the feeding structures of this parasite in the host plant. Its ustilospores are sub-globose, slightly flattened, thin walled and light brown in colour with an estimated 5 to 7µm diameter. The spores on media germinate after 8 hours of culture on media (in vitro) ranging from; tap water agar, malt extract agar to potato dextrose agar (Arocha et al., 2009). At reproduction the spikelets confine the sori with the ustilospores becoming a black loosely attached mass for easy dissemination (Farrell, 1998). Because of this, the reproductive capacity by this systemic pathogen using the host's resources is quite significant that it reduces the plant's biomass extensively. Thus, affecting directly the importance of Napier grass as feed quantitatively (Farrell et al., 2002a). This is compounded by its perennial life cycle, where it produces ustilospores continuously in huge amounts to the soil (Farrell, 1998).

Epiphytology of Napier head smut

Epiphytotics of Napier head smut can be attributed to certain abiotic conditions like; temperature range of between 5oC and 35oC with an optimum witnessed around 20oC highly favouring the establishment of this pathogen. Moreover, high relative humidity ranging between 65-90% enhances the disease's initiation on susceptible host. This is after successful Ustilago kamerunensis spread from a sick crop to a health susceptible one that is primarily facilitated by wind transfer of ustilospores. Secondary transmission of the pathogen is through; animal carrying stuck ustilospores on them, animal's waste fed on the smutted crop, clothes of passersby and planting of diseased canes carrying the pathogen within their tissues (Farrell, 1998; Mwendia et al., 2007; ASARECA, 2010; NAFIS, 2012). The most susceptible stage of the crop is during the development stage of the buds into shoots (shoot infection) of a respective cane or when the buds are pushing through the soil. This factor explains why the disease is so severe in the regrowth of a second crop after the first harvest due to the many buds that provide extensive shoots to infect and the damaged stem tissues which also provide entry points of the pathogen (Farrell, 1998).

Napier head smut symptoms

The disease firstly manifests itself in susceptible hosts through induced premature flowering covered in a black mass of ustilospores (Figure 5.2.1) commonly referred to as the smut. This occurs even in plants that are below 1.5m height which is not usually the case in health plants that usually flower in heights above 1.5 to 8 metres depending on the variety of the grass (Farrell, 1998). This visual sign is later compounded by other severe symptoms up on first harvest and regrowth influenced largely by the levels of susceptibility of the grass type including; slow regrowth after cutting, withering and chlorosis setting in with gradual browning towards drying and death of the entire stool of the crop within the subsequent 2-3 cuttings in severe cases (ASARECA, 2010; NAFIS, 2012). Besides the above primary signs, other secondary characteristics of the disease like; induced dwarfing (stems are thinner and shorter than normal less than 1.5m in height) has been observed in serious cases, characterized by short internodes with distorted leaves in shape that are reduced in number and size on stools, with an increased tillering scenario (Farrell, 1998; Mwendia, 2007; NAFIS, 2012).

Figure 5.2.1: A smutted Napier crop head

Progress in the search for tolerant cultivars to head smut disease

The search of tolerant cultivars to head smut disease has been tremendous characterized by new revelations and insights courtesy of the efforts of funding and technical support by the Eastern Africa Agricultural Productivity Project (EAAPP). The major focus has been to develop an effective and sustainable host plant resistance management strategy of the disease. Superior clones development; in terms of yielding and resisting the disease for farmers is being done while cautious of various intervening variables that might influence and probably compromise the identified tolerance or resistance; top of the list being the genotype-environment interaction effects on plant's phenotype. Some of the questions addressed are whether there are resistant/tolerant and high yielding Napier grass accessions and whether

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(a) Identification of Napier accessions tolerant to Napier head smut disease

The management of head smut disease in Eastern Africa region has been for a long time over relied on the host plant resistance of two varieties Kakamega 1 and 2, since their selection a decade ago as resistant to head smut disease by Farrell (1998, Mwendia et. al. 2007). This has been largely due to the ease of implementation and cost effectiveness of the approach (Parry, 1990). However, one factor of concern has been the narrow pool of resistance genes within the two varieties being used to combat the disease amidst a likely co-evolving pathogen to survive the plant's resistance pressure. This concern has been rife despite the enhancement efforts of the varieties resistance for a sustained management, using compromised cultural practices, targeted in reducing the amount of initial pathogen inoculum as explained earlier in the chapter.

One of the limitation in the adoption of Kakamega 1 resistant variety by farmers in Central and parts of Eastern Kenya is the low leaf-stem ratio compared to the most farmer preferred susceptible cultivars like Bana grass, French Cameroon and Clone 13. Thus, there is need to widen the genetic diversity of resistant clones at farm level by screening for more productive and diverse cultivars with the desired traits such as ability to produce high quality forage (Mwendia, 2007; Awalla et al., 2010). This is to widen the pool of resistant genes used to manage the disease so as to avert a likely breakdown of resistance soonest than anticipated.

In order to address the problem effectively, efforts have been made under the Eastern Africa Agricultural Productivity Project to address the question. The efforts were based on the premise that; with a very narrow pool of resistance genes provided by Kakamega 1 and 2 varieties, the pathogen is likely to break down the genes soonest due to co-evolution phenomenon to avoid being driven to extinction due to unsuitable host-scenario resulting from the resistance in the varieties (Rausher, 2001; Friedman and Baker, 2007).

Three studies aimed at unearthing more tolerant or resistant clones of Napier grass to head smut were carried out by Omayio et al. (2013a). The first experiment involved screening of 56 ex ILRI Napier accessions for resistance against head smut disease through artificial inoculation without any other stress to the treatments in a glasshouse. The second experiment evaluate the eighteen accessions identified from the first experiment as being tolerant/resistant to Napier head smut disease (listed on Table 5.2.1) under cutting and different water stresses also in a glasshouse. The third experiment analyzed the tissues using microscopic techniques and molecular diagnosis for the presence of the smut pathogen in the seventeen tolerant accessions identified in the first study.

The first experiment identified 18 accessions whose characteristics were as follows: eight of the 18 were least tolerant, two were moderately tolerant and remaining eight were highly tolerant (Table 5.2.1).

Table 5.2.1: The eighteen presumed tolerant accessions selected from glasshouse level screening

Accession	Neighbour joining group	Origin	Presumed Tolerance levels	Remarks
16811	USA 1	USA	Highly tolerant	Not smutted by 11th ratoon
16783	Miscellaneous	Tanzania	Highly tolerant	Not smutted by 11th ratoon
16806	Southern Africa	USA	Highly tolerant	Not smutted by 11th ratoon
16782	East Africa	Tanzania	Highly tolerant	Not smutted by 11th ratoon
16789	Southern Africa	Swaziland	Highly tolerant	Not smutted by 11th ratoon
16800	Southern Africa	Zimbabwe	Highly tolerant	Not smutted by 11th ratoon
16835	Hybrid	Unknown	Highly tolerant	Not smutted by 11th ratoon
16796	East Africa	Zimbabwe	Highly tolerant	Not smutted by 11th ratoon
16805	USA 2	USA	Moderately tolerant	Smutted at field level
16902	Hybrid	Unknown	Moderately tolerant	Smutted at field level
16793	Miscellaneous	Cuba	Least tolerant	Smutted in glasshouse
16808	East Africa	USA	Least tolerant	Smutted in glasshouse
16785	Southern Africa	Tanzania	Least tolerant	Smutted in glasshouse
16787	Southern Africa	Swaziland	Least tolerant	Smutted in glasshouse
16786	Southern Africa	Swaziland	Least tolerant	Smutted in glasshouse
16797	East Africa	Zimbabwe	Least tolerant	Smutted in glasshouse
18448	Unknown	Unknown	Least tolerant	Smutted in glasshouse
16836	Southern Africa	Unknown	Least tolerant	Smutted in glasshouse

This was based on their smutting or non-smutting differences under disease challenge. Currently, the accessions are under field evaluation in different agro-ecological zones to evaluate their capacities to handle the disease at such a level. In the second experiment these accessions were subjected to regular cutting at eight weeks interval and regular or irregular watering without any fertilization to mimic the damage stress they undergo at farm level. The eight identified highly tolerant accessions did not show smut symptoms by the 11th ratoon crop (Table 5.2.2).

Table 5.2.2: Smutting proportions of the various screened susceptible accessions

Napier Accessions	Neighbour Joining Group	Total Number of Tillers	Number of Smutted Tillers	Proportion of Smutting	Rank
14984	USA 1	92	83	90.22%	1
16821	USA 2	55	47	85.45%	2
15743	USA 2	90	73	81.11%	3
16807	USA 2	103	83	80.58%	4
16621	Miscellaneous	51	39	76.47%	5
16798	S. Africa	44	33	75.00%	6
16818	USA 2	44	32	72.73%	7
16810	East Africa	72	52	72.22%	8
14983	East Africa	47	33	70.21%	9
15357	USA 1	52	36	69.23%	10
18662	Unknown	27	18	66.67%	11
16834	Hybrid	43	28	65.12%	12
18438	Unknown	31	20	64.52%	13
16801	S.Africa	58	36	62.07%	14
16804	S.Africa	74	45	60.81%	15
16794	East Africa	40	24	60.00%	16
16840	Hybrid	28	16	57.14%	17
16813	USA 1	27	15	55.56%	18
16822	East Africa	63	33	52.38%	19
16788	East Africa	41	20	48.78%	20
16792	S.Africa	35	17	48.57%	21
16790	USA 2	25	12	48.00%	22
16802	East Africa	29	13	44.83%	23
16814	USA 2	39	17	43.59%	24
16815	USA 1	41	17	41.46%	25
16839	USA 2	33	13	39.39%	26
16817	USA 2	28	11	39.29%	27
14982	Hybrid	34	13	38.24%	28
Clone 13	Unknown	42	16	38.10%	29
16812	USA 2	29	11	37.93%	30
16799	Miscellaneous	22	8	36.36%	31
16791	S. Africa	42	14	33.33%	32
16809	East Africa	19	6	31.58%	33
16803	S. Africa	29	9	31.03%	34
16816	USA 2	33	10	30.30%	35
1026	Unknown	54	16	29.63%	36
16795	S. Africa	18	3	16.67%	37
16837	Miscellaneous	33	5	15.15%	38
16838	Hybrid	32	1	3.13%	39

Accession 16805 and 16902 had no smut symptoms at the glasshouse level for the entire ten ratoons monitoring, but on field evaluation they produced some smutted tillers in the highly infected Murang'a and Kiambu regions of Central Kenya region. All the identified least tolerant accessions in experiment smutted within the fourth ratoon of screening in the second experiment. This actually affirms the quantitative nature of the tolerance that involves multiple genes of a plant which are also involved in the general growth of the plant. As a result, unpredictable effects from the environment that influence the plant's growth consequently affect the tolerance (Pratt et al., 2003).

Analysis of tissues using microscopic techniques and molecular diagnosis of the accessions identified in experiment 1, revealed pathogen presence in their tissues despite not smutting during the initial experiment of their selection. The strategy took taken advantage of the 56 ex-ILRI accessions that had been molecularly characterized and grouped into six neighbour joining groups by Lowe et al. (2003). Methodology used being the one used by Farrell (1998) but as modified by Mwendia et al. (2006). The motivation being the variations within the neighbour joining groups; could provide a fairly new reliable pool of resistance genes through the selected new tolerant accessions to add to those of Kakamega 1 and 2 in combat of head smut.

(b) Evaluating the possibilities virulent strain emergence with respect to origin of Napier accessions

Variations on head smut disease severity levels on different zones of Eastern Africa region have been reported especially in Central Kenya where high herbage yield losses have been witnessed (Kung'u and Waller, 2001; Farrell et al., 2002a). This report provoked the hypothetical proposition that the high severity levels on Napier grass in some zones of the region was due to the emergence of a virulent strain of Napier head smut disease. Further, the fear was magnified by the reports that low genetic diversity characterized the Kenyan and East African cultivars of the fodder grass. Hence, this had made them prone to head smut attack due to clonal propagation (Bramwel et al., 2010; Lukuyu et al., 2012). Coupling this phenomenon was the concern especially in Kenya of the continual spread of the disease to other parts of the country for instance, the Rift-valley's Molo-Londiani area and lower Eastern in Meru North and South (Lukuyu et al., 2012).

Therefore, in such a scenario where a possible virulent strain of a pathogen exists in a region, it is attributable to certain environmental pressures, top of the list being the intensity of resistance subjected to the pathogen by the host plants (Rausher, 2001). If the presumption holds according to Rausher (2001) and Friedman and Baker (2007), the scenario of a plant's resistance forcing the pathogen to evolve into a virulent strain is preceded by an initial phase, when the pathogen itself forces the plant to develop resistance against it first, through natural selection to limit overexploitation. Clues about this scenario can be estimated or predicted if the origin of the test materials and the disease's temporal and spatial distribution are known. Napier head smut is an African disease; as it has not been reported elsewhere outside the continent. It was hypothesized in a study by EAAPP that Napier grass being indigenous to the Zambezi valley in the South African region, a trend could be established based on origin of the test accessions skewed to or from the Zambezi region. This was in terms of the proportions of tolerant or resistant accessions that were likely to be selected due to effects of co-evolution after screening.

The efforts towards addressing virulent strains under the Eastern Africa Agricultural Productivity Project were based on the premise that; pathogenicity and plant's resistance influence the emergence of each other so that an equilibrium state is attained, where no subject is disadvantaged in an interaction between a pathogen and host (Rausher, 2001).

Therefore, through a study by Omayio et al. (2013a) a study was carried out to determine possibility of virulent strain emergence by evaluating the tolerant Napier grass' accessions trend of selection with respect to their center of origin. The evaluation took advantage of the 56 ex-ILRI accessions whose respective origins are known (Lowe et al., 2003). The motivation being that the information on the accessions origins could help establish some possible selection trend to the Zambezi valley region where Napier grass is considered native (Boonman, 1993). This study revealed that USA 2 and USA 1 neighbour joining groups had the most smutted accessions at 90.9% and 80% respectively. Also, these groups had the least non-smutted (asymptomatic) accessions at 9.1% and 20% respectively. The Southern Africa group had the least smutted accessions at 57.1% and the most non-smutted (asymptomatic) at 42.9%. Further, as observed in Table 2, the top four most smutted accessions came from the USA 2 and 1 neighbour joining group. Whereas of the least smutted four accessions (Table 5.2.2) non USA 1 and 2 neighbour joining groups' accessions were observed.

Coupling the above observations, the study also showed that majority of all the selected asymptomatic (non-smutted) accessions accounting for 55.56% had their origin from Africa (Figure 5.2.2). This was followed at a far second by those from outside the African continent that accounted for 27.77% proportion. Moreover, a further analysis of the accessions neighbour joining groups, a selection bias was observed. The Southern Africa neighbour joining group had majority of its member accessions selected as asymptomatic against the disease at 35.29% of the total asymptomatic accessions selected. The South Africa group was followed by East Africa group at 23.53% and the USA 1 and 2 groups exhibited the least asymptomatic accessions selected at 5.88% each (Figure 5.2.3). Moreover, within each neighbour joining group still the Southern Africa group exhibited the highest proportions of asymptomatic accessions at 42.9% (Figure 5.2.4), whereas the USA 1 and 2 had the highest proportions of smutted accessions within their neighbour joining groups (Figure 5.2.5).

This study clearly focused the conclusions towards the effects of co-evolution discussed earlier, where the pathogen being an African disease had led to development of resistance in the accessions over time in a bid to co-exist and limit severe pathogen damage (Rausher, 2001; Friedman and Baker, 2007). This is affirmed in Figure 5 where the phenomenon seems to intensify its effects towards the Zambezi valley where Napier grass traces its origin (Boonman, 1993). This convergent increase of the probability of a likely selection of an accession whose origin is closer to Zambezi valley as tolerant is explained by the East Africa neighbour joining group coming second after the Southern Africa one. Whereas USA 1 and 2 groups which are relatively far away from the region had the lowest numbers of tolerant accessions selected (Figure 5.2.6). Such a scenario is worrying as it predicts the interplay between new virulent strain emergence of U. kamerunensis and selection for resistance against the pathogen in Napier grass. A scenario likely to be owed to a second phase's selection pressure on the pathogen arising from the widespread use of selected resistant accessions against the pathogen to date.

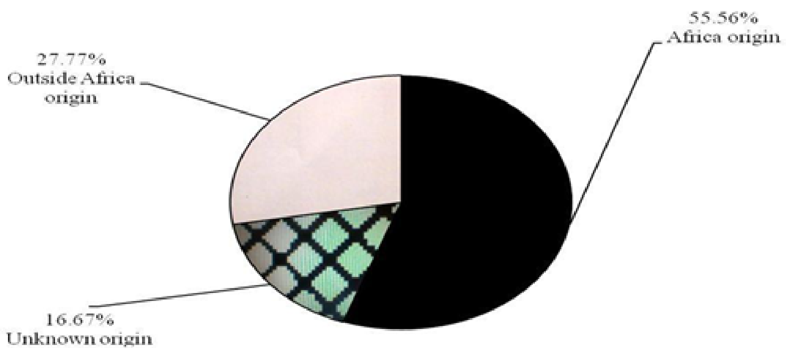

Figure 5.2.2: Potential effects of co-evolution on the selected asymptomatic (tolerant) Napier grass accessions in a region biased selection scenario during screening for resistant accessions.

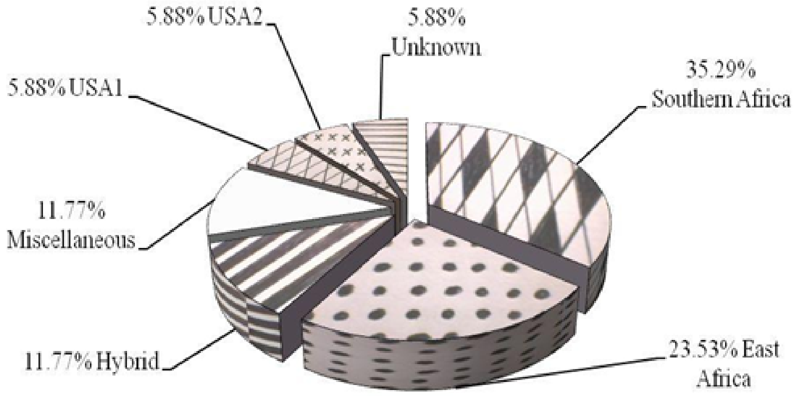

Figure 5.2.3: Proportions of asymptomatic accessions out of the total selected per neighbour joining group showing the selection orientation towards some groups in having the largest number of accessions expressing resistance selected against the head smut disease.

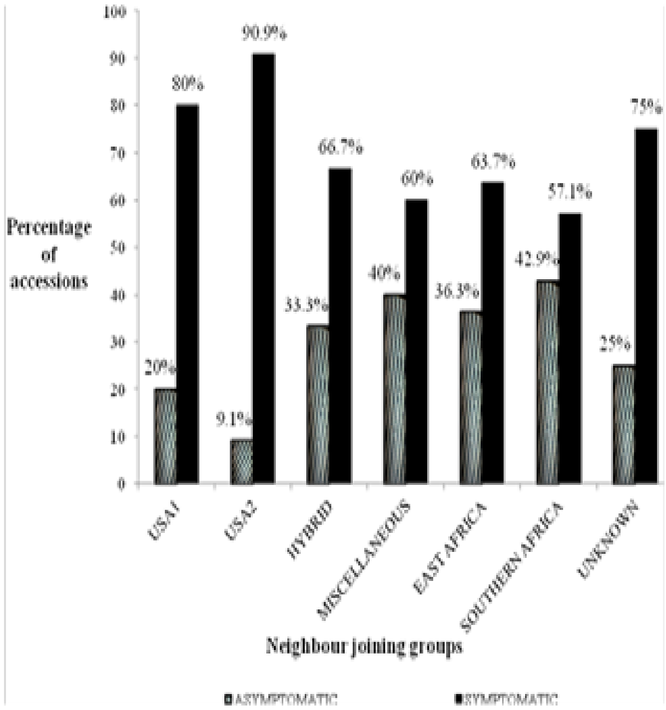

Figure 5.2.4: Proportions of asymptomatic versus symptomatic accessions selected within each neighbour joining group

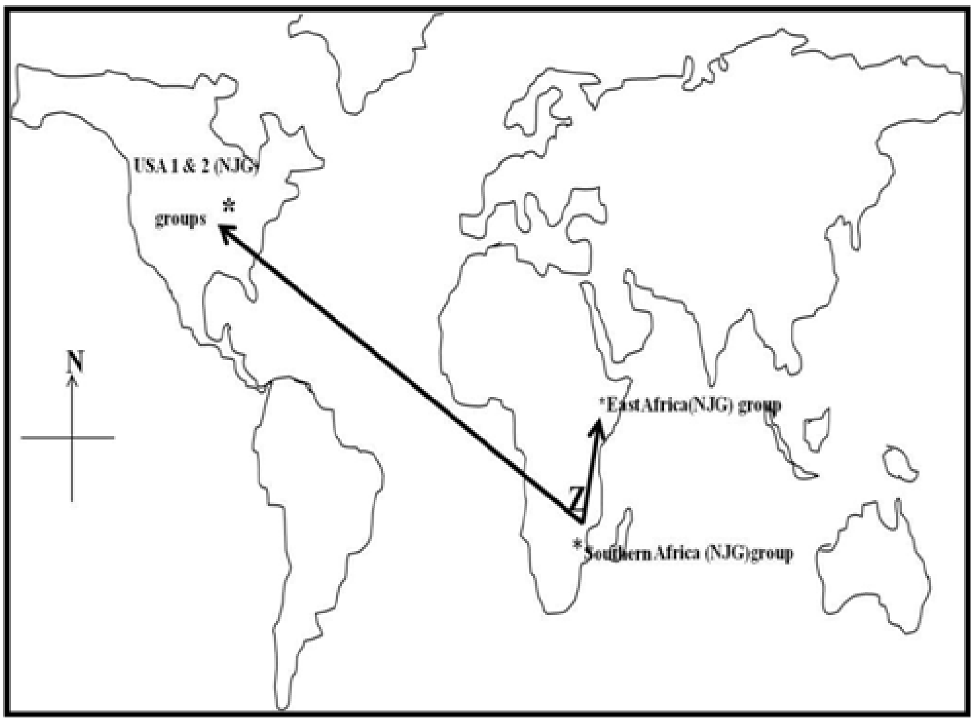

Figure 5.2.5: Global chart showing the Z- region (Zambezi valley) where napier grass is indigenous and the proximity of each neighbour joining group (NJG) to the region in terms of majority member accessions' origin.

The closest groups as indicated had their highest asymptomatic accessions selected: Southern Africa group leading with 35.29% followed by East Africa group with 23.53%. The furthest USA 1 and 2 groups with the least each had 5.88% proportion.

(c) Determination of an efficient screening procedure for resistance against head smut in terms of time and cost

The screening for resistant or tolerant Napier grass accessions against head smut disease has been a lengthy and costly mainly due to lack of a reference point of selection, on which pathologist can rely on. This problem was noticed during the lengthy unrefined screening protocol that was used by Farrell (1998) and Mwendia et al. (2006) in selection of two very dependable tolerant varieties Kakamega 1 and 2. They screened for over 40 weeks before they identified tolerant varieties; Kakamega 1 and 2 after 48 and 42 weeks, respectively. Therefore, a study was necessary to aid in the determination of a critical time line that could refine the screening procedure for resistance against head smut to reduce the cost involved. Also, to act as reference point in the phytosanitary regulation measures during Napier clones transfer across various zones by farmers, thus aid in management of the disease through legislative approach.

Efforts were made through Eastern Africa Agricultural Productivity Project towards determining an efficient screening for resistance/tolerance to Napier smut disease. This was based on the premise that; the breakdown of genetically controlled resistance in a species population occurs in a continuous manner due to variations in the threshold levels of the quality in different individuals of the population (Freeman and Beattie, 2008). Therefore, if such a breakdown and elimination of susceptible accessions can be tracked, then a stationary phase is reached where no more accessions succumb to the disease. The point marking the beginning of the stationary phase can be equated to the reference point that marks the selection point of tolerant of Napier grass accessions within their population. Therefore, to achieve this; the selection of asymptomatic accessions and the time line that determines the onset of the resistance response against the disease was determined through screening of the Napier accessions by Omayio (2013), using the methodology described by Farrell (1998) but as modified by Mwendia et al. (2006). The accessions used were the 56 ex-ILRI accessions acquired from ILRI germplasm bank which had been molecularly characterized by Lowe et al. (2003).

The results revealed the breakdown of susceptible accessions as from week 8 when the first accession succumbed. A plot of the total number of accessions screened against time showed a stationary phase that commenced as from the 21st week, which was characterized by only asymptomatic accessions (Figure 5.2.6). This 21st week timeline is considered the reference point; as it marked the onset of selecting the tolerant accessions that did not succumb. Only accession 16836 smutted (produced a single smutted tiller) after the timeline at the 28th week during the experiment (Figure 6), after the 24th week harvest point. This observation is attributed to the declining soil fertility after the long monitoring period and cutting stress introduced at week 24 on the accession during its harvesting that intensified the severity of the disease similar to what had been observed in Napier stunt infected Napier crop (Orodho et al., 2005). Also, increased tillering capacity among susceptible (smutting) accessions was observed. This result depicts survival strategy by the grasses whereby they try to compensate for the damage caused by disease on their tissues by producing more tillers. A similar case has been observed in sugarcane infected by smut pathogen Sporisorium scitaminae (Dalvi et al., 2012).

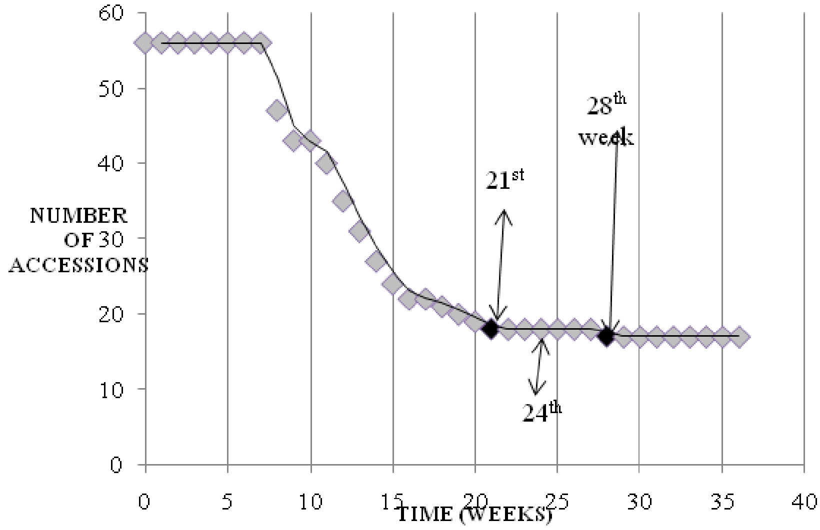

Figure 5.2.6: Trend of Napier grass accessions' selection against time without cutting back in experiment one's screening showing the 21st and 24th weeks that represent the critical timeline that marks the onset of resistance and the harvest point respectively.

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5.3 Evaluation of Napier stunt and smut tolerant napier grass clones and alternative fodder grasses for forage yield in Kenya

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Introduction

Napier stunt disease is the main limiting factor to Napier grass production in the east Africa region. Through the Eastern Agricultural Productivity Programme (EAAPP), Napier grass clones and alternative fodder grasses tolerance to Napier stunt disease and Napier head smut disease were identified (Wamalwa 2003 and Omayio 2003). However, for proper utilization of the fodder, there is need for adequate information on its biomass yield, which is currently lacking.. If found suitable, these fodder grasses will increase feed availability and thus, reduce the impact of the diseases to the livestock industry. Therefore, the objective of the study was to determine biomass production of the recently identified tolerant NSD and smut disease Napier grass and alternative fodder grass species.

Materials and methods

The study was conducted at KALRO Kakamega (high rainfall area), Alupe (low rainfall area), Muguga (high rainfall) and Katumani (low rainfall) regions of Kenya. Experiment 1 was setup at KALRO Kakamega to evaluate yield attributes of Napier stunt disease tolerant Napier grass clone cv. Ouma, South Africa, Brachiaria var. Mulato 1 and the susceptible Bana grass. Experiment 2 was setup at KARLO Kakamega and KARLO Alupe to evaluate yield attributes of two alternative fodder grasses, Guinea grass (Panicum maximum Jacq) and Guatemala grass (Tripsacum laxum Scrib and Merr) and Napier cv. Ouma 3.While Experiment 3 evaluated nine (9) ILRI Napier grass accessions tolerant to Napier head smut disease (16806, 16837, 16783, 18448, 16790, 16835, 16809, 16796 and 16808) at KARLO Muguga and KARLO Katumani. At both sites, a positive check - Kakamega 1 was included. The experiments were setup in randomized complete block design. Napier grass was planted at a spacing of 1 m by 1 m to maintain optimum plant density (Muia et al. 1999). Fertilizer was applied at the rate of 60kg/ha of P2O5 top-dressed with 100 kg of CAN.

Biomass yield was determined by hand clipping internal stools at an interval of 8 weeks for Napier grass and 4 weeks for Panicum and Guatemala grass, respectively while leaving out the outside rows. The samples were oven dried at 60 0C for 48 hours to determine percentage dry matter. Statistical analysis was done using the statistical analysis system (SAS). The data were subjected to analysis of variance (ANOVA) and the means were separated using Duncan's Multiple Range Test (DMRT) at the 5% level of significance

Results and Discussion

Results of the experiments are presented in Table 5.3.1, 5.3.2 and Figure 5.3.1. In all the three experiments, significant differences ($p \leq 0.05$) were observed in cumulative biomass yield. The Napier stunt tolerant clones cv. Ouma and South Africa produced dry matter yields that were not significantly different from the susceptible farmer preferred Bana grass, while Brachiaria var. Mulato 1 produced significantly lower yields at KARLO Kakamega (Table 5.3.1). An evaluation of Napier stunt disease tolerant Napier grass clone cv. Ouma against the tolerant alternative fodder grass showed that cv. Ouma produced significantly ($P<0.05$) higher yields than Panicum maximum and Guatemala grass at both high and low rainfall areas. However, Panicum maximum produced significantly higher dry matter yields than Guatemala grass (Table 5.3.2).

Table 5.3.1: Dry matter yields of Napier stunt disease and smut disease torelant at KARLO Kakamega in western Kenya

Napier grass/alternative fodder grass	DM Yield (t/ha)	
	Year 1 (4 Harvests)	Year 2 (4 harvests)
Ouma	28.54a	23.21a
Bana grass	33.78a	18.87c
South Africa	32.79a	24.37b
Brachiaria var. Mulato 1	18.93b	7.43d

Source: Muyekho (Unpublished data)

Table 5.3.2: Dry matter yield of selected alternative fodder grasses and, Napier stunt disease and smut disease tolerant clones at KARLO Kakamega and KARLO Alupe in western Kenya

Forage species	Mean yield (tha-1year-1)	
	KARLO Kakamega	KARLO Alupe
Napier	26.09a	25.43a
Guatemala	15.36b	12.68c
Panicum	14.71c	13.45b
Mean	18.72	17.19
CV%	5.6	3.6
LSD0.05	5.73	3.37

Within a column, means marked by different letters are significantly different at $p<0.05$ significance level; Source: Munyasi (Unpublished data)

The findings on tolerant Napier stunt clones on the basis of dry matter yields suggest that Napier grass cv Ouma and South Africa have the potential of being an alternative fodder to the current susceptible farmer preferred varieties of Bana grass, Clone 13 and French Cameroon, while Panicum maximum can be an alternative to Napier grass in the event that there are no long term tolerant Napier grass clones.

For the Napier clones tolerant to head smut disease, accession 16809 produced 23–52% more biomass yield than 16808, 16790 and 16837 in either of the sites while 16790 on overall yielded the least at both sites (Figure 5.3.1). The differences in the accessions 16809 and 16790 at Katumani of about 7.4 t/ha of DM is capable of feeding a cow (taking about 15 kg DM per day) for an extra 16 months. This is an appreciable difference in smallholder farms where at least 35% of costs in a dairy enterprise go to feeding (Lukuyu et al., 2012). Accessions 16790 and 16837 had high leaf to stem ratio than accessions 16809 and 16790 (Simon Mwendia personal communication). Cultivar 16796 had higher neutral detergent fibre (NDF) than the others (Simon Mwendia personal communication). Based on yield and NDF, cultivar 16809 would be preferable in the low rainfall area than the other cultivars in the study.

From the foregoing, Napier grass is still the best fodder for livestock feeding. Napier grass clones cv Ouma and South Africa are high yielding, as such should be promoted among farmers. However, in areas highly infested with Napier head smut disease, Cultivar 16796 should be recommended to farmers. In situations where Napier grass is not available, Panicum maximum can be a good a good substitute.

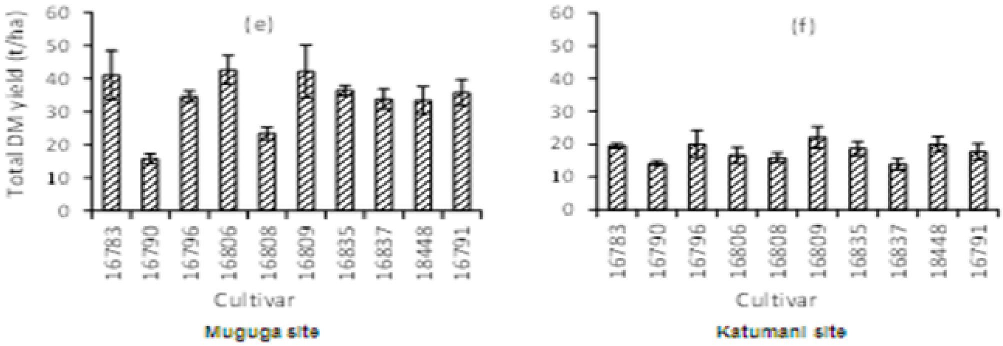

Figure 1. Napier grass Cumulative dry matter yields from six harvests at each site

Source - Solomon Mwendia unpublished data

Head smut disease free accessions; 16783, 16796, 16806, 16835 and 16971

Figure 5.3.3: Napier grass cumulative dry matter yields from six harvests at eact

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5.4 Screening Napier accessions for resistance/tolerance to NSD using the loop mediated isothermal amplification of DNA (LAMP)

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Introduction

Napier grass (Pennisetum purpureum Schumach) (Poaceae) is an important fodder crop grown in Kenya and, East and Central Africa (Abate 1992; Muyekho et al., 2003) and is associated with intensive and semi-intensive livestock production systems for milk and meat (Kabirizi et al. 2007). It is also used by more than 53, 000 farmers in eastern Africa as a trap plant for the management of cereal stem borers (Midega et al. 2013). Additionally, it serves as a wind break in maize fields and stabilizes soil by holding particles together thereby preventing soil erosion (Jones et al. 2004; Mulaa et al. 2004; Cook et al. 2007; Khan et al. 2008). Surplus Napier grass is a source of income to smallholder farmers to cater for school fees and household needs (Kabirizi et al. 2007). Napier grass has advantages over other grasses because of its high yielding capacity and ease of propagation, and management within a wide ecological range (0 < 2,000m ASL) (Orodho 2006). It has so far become the most important fodder for cut-and-carry especially in Kenya, where it is mainly propagated through cuttings (Humphreys 1994). In recent years, a disease associated with stunting, causing overall loss in biomass and death of Napier grass has been reported in Kenya, Uganda, Tanzania and Ethiopia (Jones et al. 2004, 2007). The disease known as Napier Stunt Disease (NSD) is caused by the phytoplasma Candidatus phytoplasma oryzae belonging to the 16SrXI group, is transmitted through infected planting materials (Jones et al. 2004). Symptoms expressed by phytoplasma-infected plants include small chlorotic leaves, proliferation of tillers, and shortening of internodes to the extent that clumps appear very stunted, ultimately resulting in death of the plant (Ajanga 2005). In Kenya, symptoms of Napier stunt disease were first identified in the western in mid 1990s. The disease currently affects up to 90 % of Napier plants in smallholder farms of western Kenya (Mulaa and Ajanga 2005), and has spread to central and rift valley provinces of Kenya. The dairy sector in eastern and central Africa is now under threat of this disease (Nielsen et al. 2007). A significant reduction in milk output has been reported in areas ravaged by the disease, and has led to decline in household incomes (Khan et al. 2014). The current mitigation strategies that include use of fertilizer, rouging and careful visual selection of planting material are not effective in controlling this disease. The objective of this study was to select Napier plants with resistance/tolerance to the NS-Phytoplasma among ILRI accessions (Muyekho et al. 2006) and local clones that did not develop disease symptoms in a field screening trials at Alupe, Kenya Agricultural Research Institute (KARI) farm (Mulaa et al. 2012); using the Loop-Mediated Isothermal amplification of DNA (LAMP).

Materials and methods

Napier grass accessions and preliminary screening for phytoplasma

Napier grass varieties/accessions used in the study included ILRI accessions (Muyekho et al. 2006) and those clones that did not develop disease symptoms in a field screening trials at Alupe, Kenya Agricultural Research Institute (KARI) farm (Mulaa et al. 2012). Table 1 gives the lists of accessions screened for resistance/tolerance to stunt disease, their source of origin and potential dry matter yields. These accessions were grown at same time in a screen house at icipe. One plant was planted in each pot and each accession was replicated three. Preliminary Loop mediated isothermal amplification of DNA (LAMP) screening was carried out on plants in the three replicates of all the Napier accessions to determine their phytoplasma status. Leaves were systematically sampled from the three replicates of each accession and their respective total plant DNA extracted using the CTAB procedure adapted from Doyle and Doyle (1990). Leaf samples weighing 0.3g were powdered in liquid nitrogen and DNA extracted based on Doyle and Doyle 1990. The DNA was taken through the LAMP procedure as described below by Obura (2011) to determine presence or absence of Ns-Phytoplasma.

Table 5.4. 1: Napier grass accessions, locality of origin and Dry matter yield recorded in Kenya

Napier accession	Country or locality of origin	DM yield (t/ha)	Source of information
Gold coast	Ghana West Africa	19.83	Muyekho et al. 2006
French Cameroon	Cameroon	21.67	Muyekho et al. 2006
Cameroon 4E	Cameroon	17.97	Muyekho et al. 2006
Congo Kinshasa	Republic of Congo	13.53	Muyekho et al. 2006
Ex-Nigeria	Humid west-Central Africa	17.13	Muyekho et al. 2006
Uganda hairless	Uganda	11.63	Muyekho et al. 2006
Uganda L11	Uganda	17.83	Muyekho et al. 2006
Uganda border	Uganda	19.23	Muyekho et al. 2006
ILRI 15743 Mott	USA	-	Lowe et al. 2003
Clone 13	Kitale, Kenya	21.90	Muyekho et al. 2006
Nairobi L8	Nairobi, Kenya	19.47	Muyekho et al. 2006
Nairobi L9	Nairobi, Kenya	12.5	Muyekho et al. 2006
Muguga bana	Muguga, Kenya	-	Muyekho et al. 2006
Ex-Bakole	Unknown	16.3	Muyekho et al. 2006
Ex-Matuga	Unknown	19.0	Muyekho et al. 2006
Ex-Mariakani	Unknown	9.53	Muyekho et al. 2006
Ex-South Africa L4	South Africa	11.47	Muyekho et al. 2006
Ex-South Africa L13	South Africa	22.30	Muyekho et al. 2006
Ex-Malawi	Malawi	15.80	Muyekho et al. 2006
Pakistan hybrid	Unknown	12.3	Muyekho et al. 2006
ILRI Acc. 16621 (N16621)*	Namibia	-	Lowe et al. 2003
ILRI Acc. 16791 (N16791)* (Kakamega 1)	Swaziland	23.83	Muyekho et al. 2006; Lowe et al. 2003
ILRI Acc. 16837 (N16837)*	Unknown	14.0	Muyekho et al. 2006; Lowe et al. 2003
ILRI Acc. 16812 (N16812)*	USA	-	Lowe et al.
ILRI Acc. 52503 (N52503)*	Gold Coast	14.43	Muyekho et al. 2006; Lowe et al. 2003
ILRI Acc. L16 (L16)*	Unknown	17.53	Muyekho et al. 2006
ILRI Acc. 16785 (N16785)*	Tanzania	-	Lowe et al. 2003
ILRI Acc. 16484 (N16484)*	Unknown	-	Lowe et al. 2003
ILRI Acc. 16805 (N16805)*	USA	-	Lowe et al. 2003
ILRI Acc. 16804 (N16804)*	USA	-	Lowe et al. 2003
ILRI Acc. 16792 (N16792)*	Mozambique	-	Lowe et al. 2003
ILRI Acc. 16815 (N16815)*	USA	-	Lowe et al. 2003
ILRI Acc. 16814 (N16814)*	USA	-	Lowe et al. 2003
ILRI Acc. 16794 (N16794)*	Mozambique	-	Lowe et al. 2003
ILRI Acc. 16822 (N16822)*	Malawi	-	Lowe et al. 2003
ILRI Acc. 14984 (N14984)*	Unknown	-	Lowe et al. 2003
ILRI Acc. 16803 (N16803)*	Zimbabwe	-	Lowe et al. 2003
ILRI Acc. 16789 (N16789)*	Swaziland	-	Lowe et al. 2003
ILRI Acc. 16702 (N16702)*	Unknown	-	Lowe et al. 2003
ILRI Acc. 16817 (N16817)*	USA	-	Lowe et al. 2003
ILRI Acc. 16787 (N16787)*	Swaziland	-	Lowe et al. 2003
ILRI Acc. 16808 (N16808)*	USA	-	Lowe et al. 2003
ILRI Acc. 16807 (N16807)*	USA	-	Lowe et al. 2003
ILRI Acc. 16840 (N16840)*	Unknown	-	Lowe et al. 2003

ILRI Acc. 16809 (N16809)*	USA	-	Lowe et al 2003
ILRI Acc. 15743 (N15743)*	cv.Mott	-	Lowe et al 2003
ILRI Acc. 16822 (N16822)*	Malawi	-	Lowe et al 2003
ILRI Acc. 16798 (Kakamega 2)	Zimbabwe	20.8	Muyekho et al. 2006; Lowe et al. 2003
ILRI Acc. 16786 (N16786)* (Kakamega 3)	Swaziland	22.83	Muyekho et al. 2006
ILRI Acc. 16838 (N16838)*	Unknown	6.8	Muyekho et al. 2006
ILRI Acc. 16811 (N16811)*	USA	-	Lowe et al. 2003
ILRI Acc. 16836 (N16836)*	Unknown	-	Lowe et al. 2003
ILRI Acc. 18438 (N18438)*	Unknown	-	Mulaa et. al. 2012
Bgm3(b)31	Local variety	-	Mulaa et. al. 2012
Bgm 76	Local variety	-	Mulaa et. al. 2012
Btr89	Local variety	-	Mulaa et. al. 2012
Btr23	Local variety	-	Mulaa et. al. 2012
Bgm1(A)10	Local variety	-	Mulaa et. al. 2012
Bgm3(A)16	Local variety	-	Mulaa et. al. 2012
BSA105	Local variety	-	Mulaa et. al. 2012
Btr86	Local variety	-	Mulaa et. al. 2012
Bgm20	Local variety	-	Mulaa et. al. 2012
Bgm3(B)28	Local variety	-	Mulaa et. al. 2012
BSA60	Local variety	-	Mulaa et. al. 2012
BSA31	Local variety	-	Mulaa et. al. 2012
BSA112	Local variety	-	Mulaa et. al. 2012

* Refers to coding used in Wamalwa (2013) MSc thesis

Rearing of the healthy insect vector

The insect vector Maiestas banda used in the study was obtained from the rearing screen house at icipe. These insects colony had been collected from clean Napier fields in 2007 using sucking machine, counted and introduced into the insect in wooden cages measuring 45cm x 45cm x 60cm high and surrounded with a 0.25mm netting material cages. They were reared on pearl millet. The top of each cage was covered with the net. The bottom of the cage was reinforced with a three-ply wood which supported potted plants. One side (front) of the cage was fastened with hinges to allow potted plants placed in and watered. These cages were placed on a bench 1.5m high. The bench's supports rested in plastic containers with soapy water (mots). These stopped ants from accessing the cages (Obura et al. 2009). The fitness of the vector to transmit disease in the screen house was maintained by frequent introduction of 25 males and 25 females field collected M. banda into the rearing cages to mate with the cultured insects after every two months five times in a year. In preparation for inoculation set up, fifty gravid M. banda were transferred into insect cages with diseased Napier grass var. Bana (confirmed by PCR and LAMP) in a separate screen house and set up for 30 days for the insect to acquire the phytoplasma by acquisition feeding.

Esatblishment of the accessions in the cages and introduction of Insect vector for transmission of the phytoplasma

Twenty three Napier accessions were multiplied by planting 12 stem cuttings per accession in 500 ml cups, consisting of fertile sterilized black cotton soil. The plants grown in a screen house for 50 days and were watered once daily. At 50 days of growth, six plants per accession were introduced into two of the already set up inoculation cages in a separate screen house, each with a one month set up of diseased plant (confirmed by PCR and LAMP) and fifty gravid female M. banda allowed to sufficiently acquire the stunt phytoplasma (acquisition feeding). The diseased plant was placed at the centre of the cage surrounded by 6 healthy phytoplasma free potted plants (Figure 5.4.1). For each accession there were 12 replicates planted in a randomized complete block design. The vector was used as inoculum carrier to infect the test plants following the protocol described by Obura et al. (2009). The vector was allowed to feed back and forth for a period of one month feeding to sufficiently transmit the Napier Stunt Phytoplasma to the healthy plants. Occasionally the insects were disturbed in the inoculation cages to redistribute the population. After 30 days, the inoculation setup was terminated and the exposed plants transferred to a separate screen house for phytoplasma testing and disease symptoms expression. The grasses were tested monthly until symptoms appeared. This involved taking leaf samples of the plants for phytoplasma testing through the LAMP procedure. The period taken for the plant to express the symptoms was taken as an indicator of the ability of the plant to tolerate the disease. The controls were not inoculated with the Ns-phytoplasma.

DNA Isolation from inoculated plants

Thirty day old re-growth leaves from the plants in the screen house were sampled systematically and placed in well labeled 1.5 mL reaction tubes. DNA was extracted using methodologies adapted from Doyle and Doyle (1990). Samples of 0.3g of the leaf were powdered in liquid nitrogen and DNA was extracted by adding 600 µL of Chloroform: Iso-amyl alcohol solution (24:1) and centrifuged at 4000 rpm for 10 minutes. The DNA was precipitated by adding 600µL of ice cold Iso-propanol to the aqueous isolate and incubated at -20˚c for 2 hours. The samples were centrifuged at 14,000 rpm for 30 min and the DNA pellet was rinsed in 1000µl of 70% alcohol. The DNA pellet was then dried at room temperature for two hours and then suspended in 50 µL of double distilled water(ddH2O) providing a ready DNA template that was used in the LAMP process (described below)extracted based on Doyle and Doyle (1990) procedure.

LAMP screening

The DNA isolated above was used in the LAMP protocol to amplify the 240 bp 16S gene segment (Obura et al. 2011).The LAMP screening was at two levels; a) before inoculation (Preliminary LAMP screening) where-by the phytoplasma status of the test plants was confirmed according to the protocols described in Obura et al. (2011) and b) after inoculation where-by all materials inoculated with the Ns-phytoplasma were screened for detection of the presence of the Ns-phytoplasma. In both cases total plant DNA templates were taken through LAMP procedure as described by Obura et al. (2011) but the volumes of the master mix was modified to 11.9 µL of distilled de-ionized water, 2.5 µL of 10x buffer, 2.5µL of dNTPs, 4.0µL of 4M Betain and 1.1 µL of primer mix.

Inoculation of Napier plants with the Ns-phytoplasma

The plants that were free of phytoplasma at the preliminary LAMP screening level were planted in an insect cage measuring 45cm x 45cm x 60cm. A diseased plant (confirmed by LAMP procedure) was placed at the centre of the cage surrounded by 6 healthy phytoplasma free potted plants (Figure 5.4.1). For each accession there were 12 replicates. The vector was used as inoculum carrier to infect the test plants following the protocol described by Obura et al. (2009). Then fifty gravid female M. banda insects from colony rearing cages in the screen house were introduced into each inoculation cage and allowed to feed back and forth for a period of one month for acquisition feeding to allow the insects to sufficiently acquire and transmit the stunt phytoplasma (acquisition feeding). Occasionally the insects were disturbed in the inoculation cages to redistribute the population. After 30 days, the inoculation setup was terminated and the exposed plants transferred to a separate screen house for phytoplasma testing and disease symptoms expression. The grasses were tested monthly until symptoms appeared. This involved taking leaf samples of the plants for phytoplasma testing through the LAMP procedure. The period taken for the plant to express the symptoms was taken as an indicator of the ability of the plant to tolerate the disease. The controls were not inoculated with the Ns-phytoplasma.

Figure 5.4.1: Arrangement of potted Napier plants in experimental cages during inoculation. The middle plant is the source of inoculum. The six plants surrounding it get inoculated by 50 insect vectors (Maiestas banda)

Evaluation of symptom expression

The plants were monitored for disease presence based on leaf symptoms after the first cut back (30 days after terminating the inoculation). The plants were scored using the disease response rate to show levels of tolerance. This was done on the first re-growth (two months of incubation), second re-growth (three months of incubation) and the third re-growth

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Evaluation of the effect of NSD on plant yield parameters

The study on the effect of the Ns-Phytoplasma on the Napier grass yield was carried out on eight Napier accessions which were carefully selected based on their unique response to the disease (based on both LAMP and symptom development).These Napier accessions included; Nigeria 14 (Napier accession that was 100% susceptible to the Ns-phytoplasma), Bungoma 20 and N15743 (Napier accessions that lost 100% of their plant population after the second month of incubation), N16808 (with 63.64% of plants symptomatic yet 91.91% of its plant population negative of the Ns-phytoplasma by LAMP by the third month of screening),N16807 (that indicated tolerance), N16789 (that indicated resistance) and N16812 (had symptomatic plants that reverted to asymptomatic from first re-growth to second re-growth). The yield related parameters that were studied for these Napier accessions were the effect of the Ns-Phytoplasma on plant height, leaf length and leaf width.

Plant height was measured using a tape measure from the soil surface to the tip of the youngest growing leaf. Similarly leaf length was measured from the petiole end (excluding the petiole) to the tip (Karimi et al. 2009) of two of the longest leaves per plant using the tape measure, and an average taken for the scores of each individual plant in inches. On the other hand measurements of the leaf width were carried out on the two longest leaves and an average taken for the score per plant using a ruler and was scored in centimeters.

Assessment of Maiestas banda's feeding behavior on the resistant Napier accession

The feeding behavior of the vector on the resistant Napier accession was evaluated using a technique developed by Khan and Saxena (1984). Four stem cuttings of Napier accession N16789 were grown in plastic pots separately as well as four stem cuttings of the Bana variety of Napier that was used as the control in this study. When the seedlings were 14 days old, they were removed without damaging their roots and washed thoroughly to remove soil particles. Each of the plants was then immersed in an aqueous solution of 0.2% safranine for 4 hours. The translocated dye coloured the xylem vessels red throughout the entire length of the seedlings. The treated seedlings were removed and excess dye washed off. Each single plant from each Napier cultivar was placed in a separate 250-ml beaker containing enough water to immerse the roots of the plant. Each beaker was covered with a medially perforated, 12.5 cm Petri dish through which the seedlings emerged (Figure 5.4.2). A 10.8 cm diameter Whatman filter paper disc was placed on each Petri dish around the base of the seedling and the seedling and the Petri dish were enclosed in a plastic bottle 10.5 cm width and 26.2 cm height, covered by an insect netting to allow air in. Fifteen gravid female M. banda which had been starved for one and a half hours were introduced in each set up and allowed to feed overnight. The honey dew excreted by the leaf hoppers dropped on the filter paper and was readily absorbed. The filter papers were treated with 0.1% ninhydrin-acetone solution, oven dried for one hour at 40°C and the area marked by bluish amino acid spots calculated for each Napier cultivar.

Figure 5.4.2: A set up for collecting honeydew of Maiestas banda (adopted from Khan and Saxena 1984)

Data analysis

Data were analyzed using SAS software (Version 9.1). The percentage of plants that tested positive of phytoplasma by LAMP was generated by proc freq. Percentage of plants that developed Napier stunt disease symptoms was generated in a similar manner. The scores for LAMP results, symptom development and the death of plants were analyzed using correlation analysis in proc corr. The analysis of data on plant growth parameters (leaf length, leaf width and plant height) was done by one-way Analysis of Variance (ANOVA) and single tailed t-tests. Means having significant differences were separated using Turkey's Studentized Range Tests.

Results

LAMP screening results for Napier grass accessions

At the preliminary LAMP screening, a total of 18 accessions were free of 16SrX1 phytoplasma (16621, Uganda hairless, Nigeria 14, 16791, Malawi, Clone 13, Uganda L11, Mariakani, 16812, 16794, 16822, 16789, 16817, 16808, 16840, 16809, 15743 and Bungoma 20) while 49 had the phytoplasma. The proportional infection of the accessions ranged from 33.33 to 100%. Out of the 49 accessions that had phytoplasma, five were asymptomatic indicating absence of the stunt symptoms. These were 16798 and Ex- Bakole (both with 100% plants that were phytoplasma positive by LAMP); and 16815, 18438 and 16807 (all with 66.67% plants that were phytoplasma positive by LAMP). These together with the 18 negative accessions were subjected to further screening.

Results of the selected 23 that were entered in further screening are compared at the first LAMP, second LAMP and third LAMP screening. At first level (LAMP 1) of screening (after one month of incubation), out of the 23 accessions screened, 4 accessions (Nigeria 14, Malawi, Mariakani and 15743) had the Napier stunt phytoplasma. However, the propotion of plants found with phytoplasma were less than 50% (Figure 5.4.3).

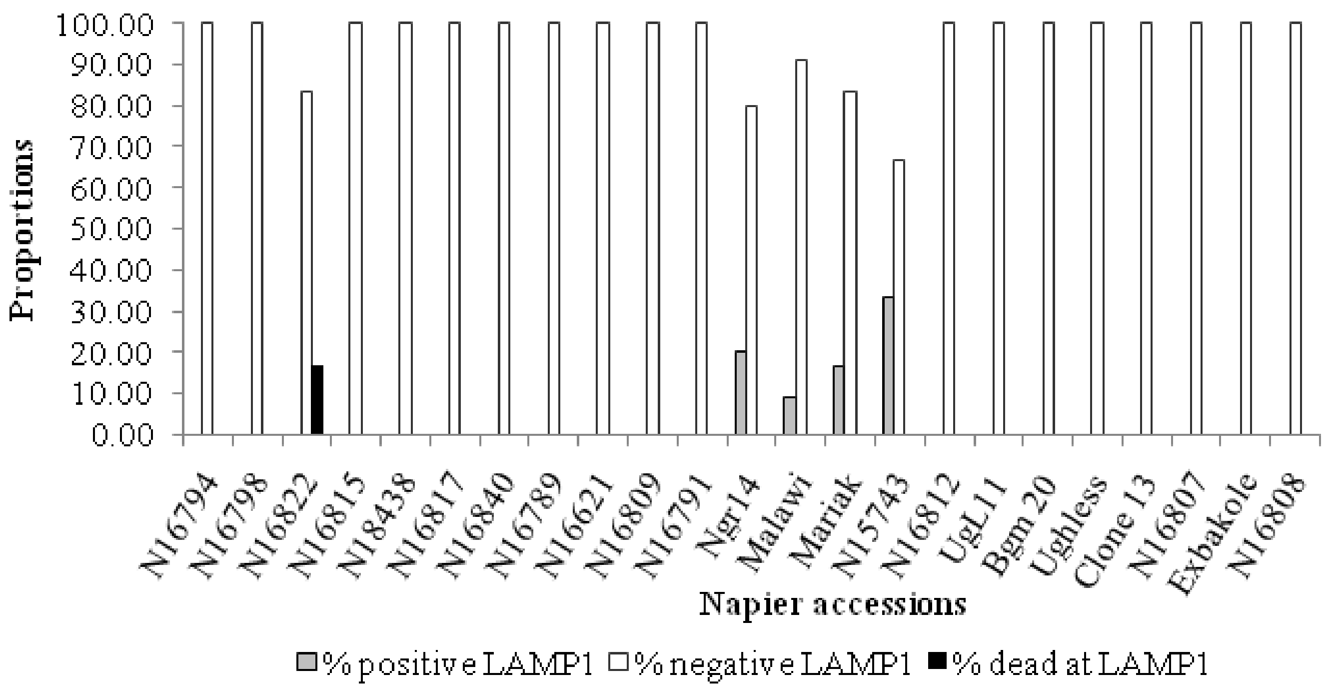


Figure 5.4.3. Comparisons of Napier accessions at LAMP 1 screening

At the second month of screening (after two months of incubation), 10 accessions were found to be phytoplasma negative by LAMP (16794, 16822, 16815, 16817, 16789, 16809, Uganda hairless, Clone 13, Ex-Bakole and 16808), while 11 accessions were phytoplasma positive (Figure 5.4.4. Among the accessions, the proportions of plants bearing the pathogen ranged from 10% in N16807 to 100% in Ngr14 (Figure 5.4.4). However, there was total mortality of accessions N15743, Ex-bokole and Bgm 20.

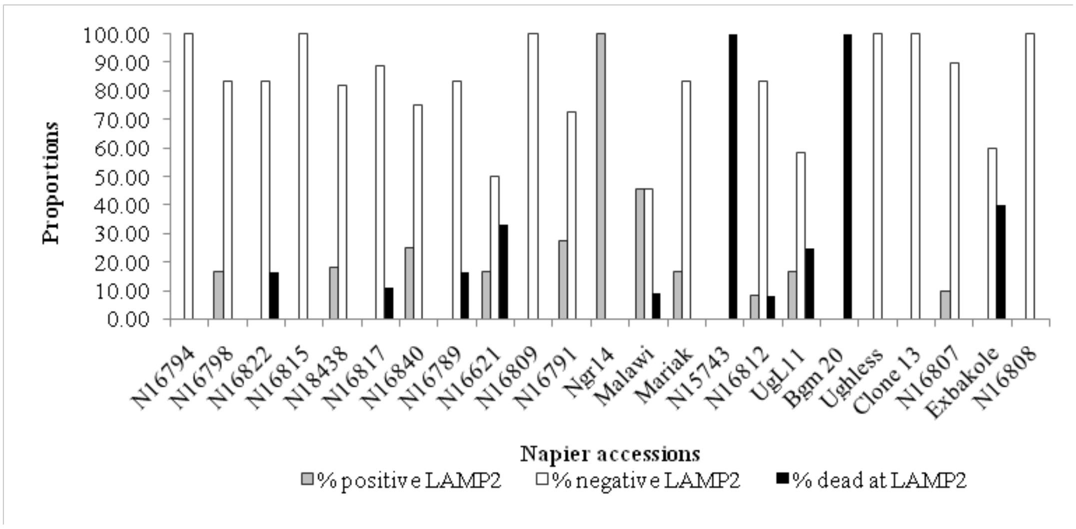
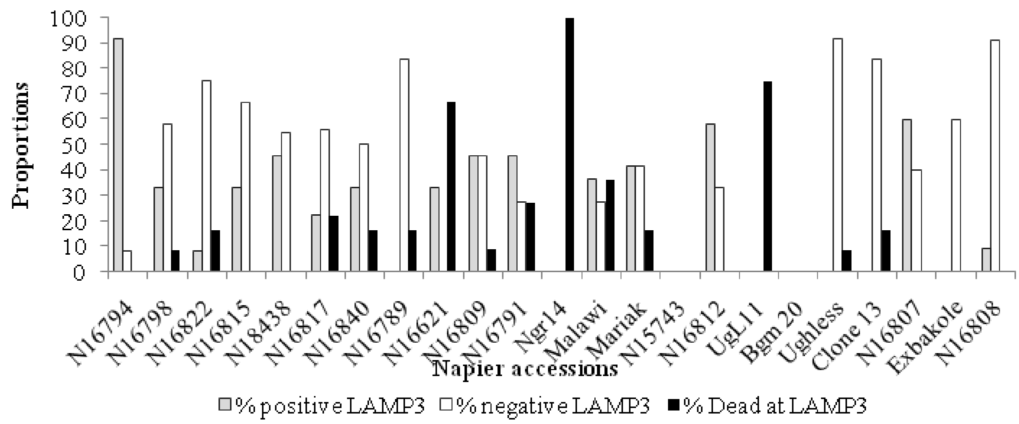


Figure 5.4.4 A chart of comparisons of Napier accessions at LAMP 2 screening

At the third month of screening, accessions 16789, Uganda hairless and Clone 13 were found to be phytoplasma negative, while 15 accessions (16794, 16798, 16822, 16815, 18438, 16817, 16840, 16621, 16809, 16791, Malawi, Mariakani, 16812, 16807 and 16808) were found to carry the stunt phytoplasma. The proportions of plants within acessions bearing the pathogen ranged from less than 10% in N16822 and 16808 to slightly over 90% in N16794 (Figure 5.4.5). However, there was total mortality of plants belonging to accessions Ngr 14.



5.4.5. A chart showing comparisons of Napier accessions at LAMP 3 screening

Symptom expression

The development of NSD symptoms on the accessions was also observed after the first re-growth, second re-growth and third re-growth at an interval period of 30 days. Out of the 23 Napier accessions screened, 10 accessions were symptomatic for NSD in the first re-growth (N16794, N16840, N16791, Mariakani, N15743, N16812, Uganda hairless, Clone 13, Exbakole and N16808) and the proportional symptom expression ranged from 8.33% to 33.33% (Table 5.4.3). In the second re-growth, 12 accessions (N16794, N16798, N18438, N16840, N16621, N16791, Ngr14, Malawi, Mariak, Ughless, Clone 13, N16808) were symptomatic. The proportional range for the symptom expression was from 9.09% in accession N16791 to 50% in accession Mariakani indicating an increase from the proportional range of the previous month (first re-growth). The number of symptomatic Napier accessions increased to 14 (N16794, N16798, N16815, N18438, N16840, N16621, N16809, N16791, Malawi, Mariakani, Uganda hairless, Clone 13, Exbakole, N16808 in the third re-growth (fourth month of incubation) with the proportional range of 10% in Exbakole to 63.64% in N16808. At the end of the experiment, 45.50% of the total plants in the 23 accessions that were screened died as a result of the Napier stunt disease compared to 10.51% that died although asymptomatic.

When comparing the proportions of the asymptomatic plants in the 23 accessions of Napier screened, a total of 12 Napier accessions were asymptomatic for NSD in the first re-growth (Table 5.4.3). The proportion of asymptomatic plants for these accessions ranged from over 75% to 100%. In the second re-growth only 7 out of the 12 accessions (asymptomatic in the first re-growth) did not show symptoms for NSD with a proportional range of about 25% to 100%. At the third re-growth, only 4 accessions (N16822, N16817, N16807 and N16789) remained symptomless with a proportional range of about 50% in accessionN16822) to 90% in accession N16817, N16807 and N16789. Out of the three, accessions 16817, 16807 and 16789 remained asymptomatic at almost constant proportions throughout the period of scoring for symptom development while accession 16822 greatly varied in the third re-growth.

Table 5.4.2. Proportions of data on symptom appearance in Napier accessions

Napier accession	Total plants	%+m1	%-m1	%+m2	%-m2	%+m3	%-m3	%+dead	%-dead
N16794	12	16.67	83.33	16.67	83.33	16.67	75.00	8.33	0.00
N16798	12	0.00	100.00	16.67	83.33	25.00	66.67	8.33	0.00
N16822	12	0.00	83.33	0.00	83.33	0.00	50.00	0.00	50.00
N16815	12	0.00	100.00	0.00	100.00	25.00	75.00	0.00	0.00
N18438	11	0.00	100.00	27.27	72.73	45.45	54.55	0.00	0.00
N16817	9	0.00	88.89	0.00	88.89	0.00	88.89	0.00	0.00
N16840	12	25.00	75.00	33.33	58.33	41.67	25.00	25.00	8.33
N16789	12	0.00	91.67	0.00	91.67	0.00	91.67	0.00	0.00
N16621	12	0.00	100.00	25.00	41.67	25.00	8.33	0.00	66.67
N16809	11	0.00	100.00	0.00	100.00	18.18	72.73	0.00	9.09
N16791	11	9.09	81.82	9.09	81.82	27.27	36.36	0.00	63.64
Ngr14	5	0.00	100.00	20.00	0.00	0.00	0.00	0.00	0.00
Malawi	11	0.00	72.73	18.18	27.27	18.18	27.27	0.00	0.00
Mariak	12	25.00	75.00	50.00	41.67	50.00	41.67	0.00	0.00
N15743	12	8.33	41.67	0.00	0.00	0.00	0.00	0.00	0.00
N16812	12	33.33	41.67	0.00	0.00	0.00	0.00	0.00	0.00
UgL11	12	0.00	100.00	0.00	25.00	0.00	0.00	0.00	0.00
Bgm 20	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ughless	12	8.33	91.67	25.00	75.00	16.67	75.00	8.33	0.00
Clone 13	12	16.67	83.33	16.67	75.00	16.67	58.33	25.00	0.00
N16807	10	0.00	90.00	0.00	90.00	0.00	90.00	0.00	0.00
Exbakole	10	20.00	50.00	0.00	50.00	10.00	40.00	20.00	40.00
N16808	11	27.27	72.73	36.36	63.64	63.64	27.27	9.09	0.00
Total								45.50	10.51

%+m1= Proportion of plants symptomatic after 1st month cut back, %-m1= Proportion of plants asymptomatic after 1st month cut back, %+m2= Proportion of plants symptomatic after 2nd month cut back, %-m2= Proportion of plants asymptomatic after 2nd month cut back, %-m3= Proportion of plants asymptomatic after 2nd month cut back and %+m3= Proportion of plants symptomatic after 3rd month cut back.

Accessions 16807 remained asymptomatic at the end of the experiment. This accession had high proportion of positive plants by LAMP (60%) but did not develop the Napier stunt symptoms nor die from stunt disease (Figure 5.4.6 and Figure 5.4.7).

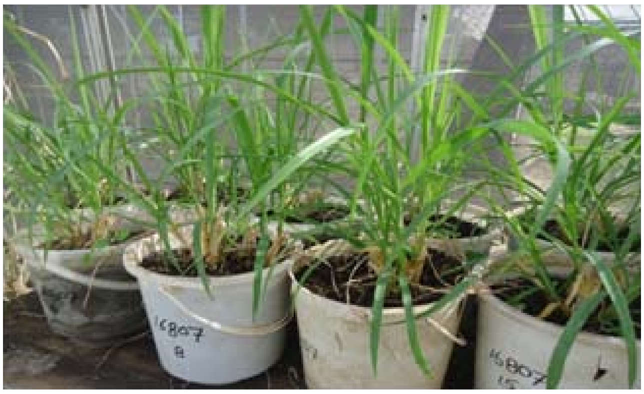


Figure 5.4.6. A picture of the third re-growth of Napier accession 16807 four months after inoculation with the Ns-Phytoplasma.

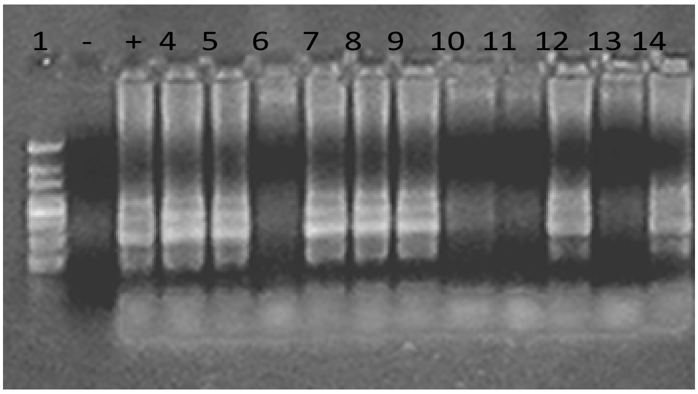


Figure 5.4.7. Amplification of accession 16807 DNA of the third re-growth (1 -100 Bp ladder (Genscript), - negative, + positive, 6 positive

Accession 16789 remained asymptomatic and had no plant that were positive by LAMP throughout the three months of LAMP screening (Figures 5.4.8 and 5.4.9)

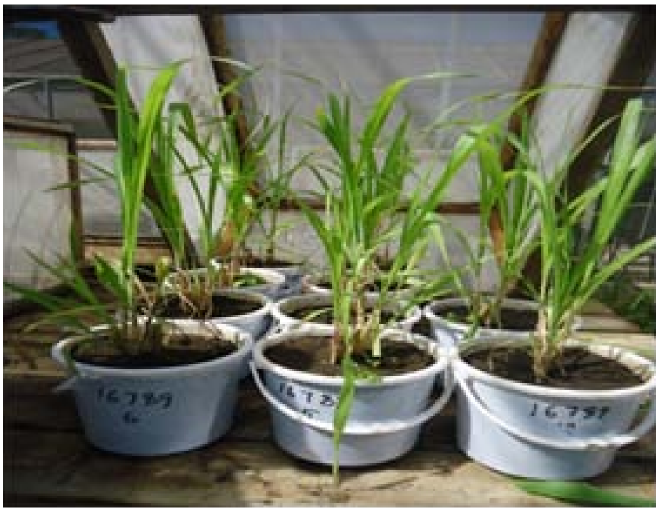


Figure 5.4.8. A picture of the third re-growth of Napier accession 16789 four months after inoculation with the NSD phytoplasma

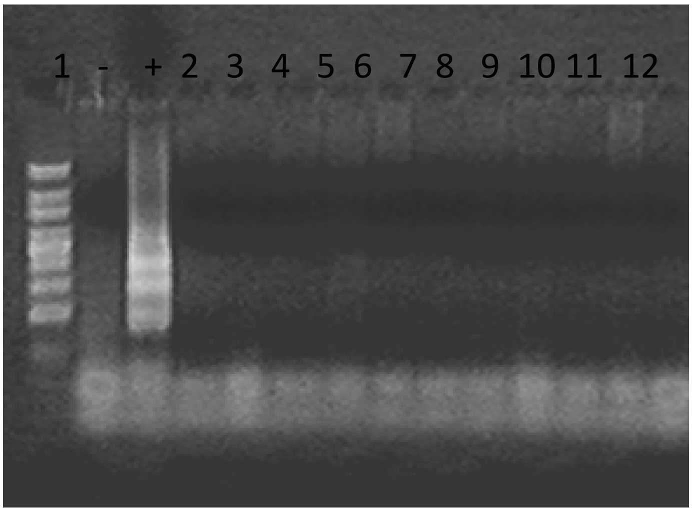


Figure 5.4.9. Amplification of accession 16789 DNA of the third re-growth (1 -100 Bp ladder (Genscript), - negative, + positive, 11plants negative by LAMP at the third month of screening).

The two Napier accesions (N16789 and N16807) when compared to the most susceptible accession N16840 (which had high proportion of plants positive by LAMP) showed severe stunt symptoms as shown in Figure 5.4.10 indicating the variation in the napier accessions' response to the Ns-Phytoplasma.

Figure 5.9.10. A morphological comparison of the accessions 16789 (resistant), 16807 (tolerant) and 16840 (susceptible) after four months of incubation

In accessions Bgm 20, Ex-Bakole, N15743, N16807, N16808 and Nigeria 14 plant height was significantly reduced while the differences between accessions 16789, and 16812 were not significantly ($P < 0.001$) different (Table 5.4.3). Leaf length was significantly reduced in accessions Bgm 20, Ex-Bakole, N15743, N16807, N16812 and Nigeria 14 but not between accessions 16789 and 16808. The leaf width was not significantly reduced in 16789, 16812 Bgm 20, Ex-Bakole, N15743 ($P < 0.001$) while in accessions N16807, N16808 and Nigeria 14 the leaf width was significantly reduced.

Table 5.4.3. Mean proportional changes in plant height, leaf length and width

Napier variety	Mean proportional difference in plant height ± (SE)	Mean proportional changes in leaf length ± (SE)	Mean proportional change in leaf width ± (SE)
BGM20	-16.71±10.64abc	-5.04±5.7a	22.27±9.89ac
ExBakole	-35.28±7.89ab	-3.97±3.01a	0.15±4.41abc
N15743	-19.61±2.95abc	-7.18±0.93a	4.55±4.55abc
N16789	17.97±6.32d	16.67±7.72ab	7.71±9.38abc
N16807	-6.68±2.35cd	-1.29±0.72a	-4.33±1.43abc
N16808	-7.74±4.73bcd	1.63±4.93a	-12.42±4.55ab
N16812	48.72±8.91e	-1.29±0.72b	0.12±8.43abc
Nigeria1	-53.99±7.80a	-23.15±6.44a	-17.06±4.99a
F	19.03	5.3	2.1
p	<0.001	<0.001	<0.001

Assessment of Maiestas banda's feeding behavior on the resistant Napier accession

The treatment of the filter paper discs with 0.1% ninhydrin-acetone solution resulted in Bluish amino acid spots, indicating that Maiestas banda fed on the phloem of both the resistant Napier accession N16789 and the susceptible (control) Bana variety (Figure 5.4.11 a & b).

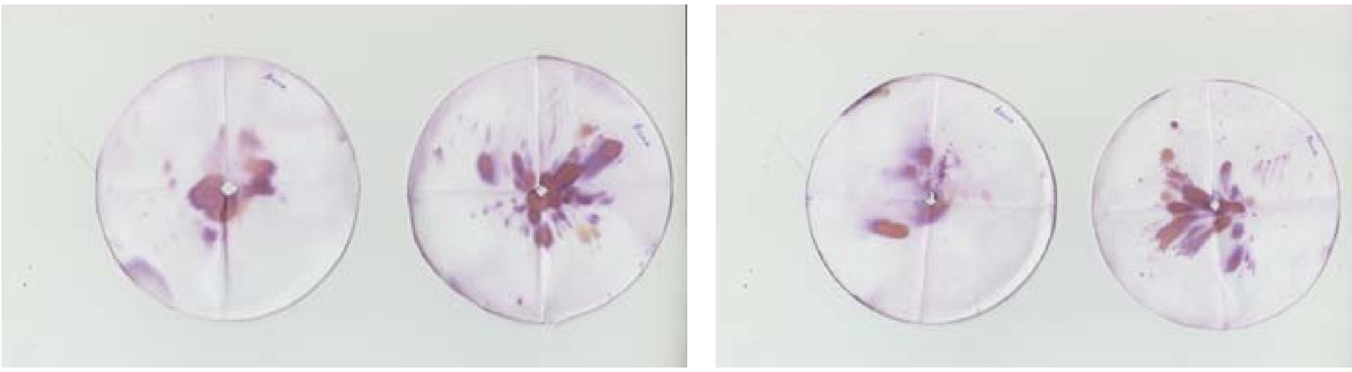


Fig. 5.4.11a: Bluish amino acid spots for the honey dew droppings of Maiestas banda on Bana variety (control)

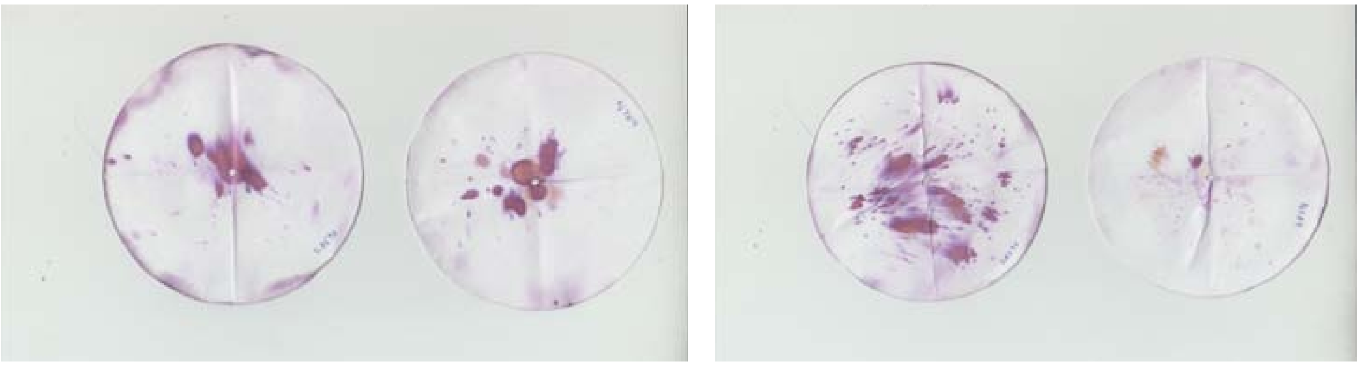


Figure 5.4.11b. Bluish amino acid spots for the honey dew droppings of Maiestas banda on accession N16789 (resistant)

Discussion

The 23 Napier accessions screened in this study differed in the time to express the Napier stunt symptoms consistent to the findings of a field experiment by Muyekho et al. (2006). At the end of the three months of screening, accession 16789 remained asymptomatic and all plants were phytoplasma negative by LAMP. At the same time the stunt phytoplasma had no significant effect on the yield parameters an indication of possible resistance/ high level of tolerance. The assessment of Maiestas banda's feeding behavior on this accession indicated that the vector was able to feed on it and hence absence of the stunt phytoplasma could not be attributed to plant escape from the vector during inoculation. These findings do point ability of accession 16789 to resist the effects of the stunt phytoplasma.

Although Napier accession 16817, 16822, 16807 remained asymptomatic, they had proportions of the test plants containing phytoplasma by LAMP hence could be considered as being tolerant. The lack of symptoms in these three accessions could be linked to uneven distribution of phytoplasmas in the phloem of infected plants, or low concentrations (especially in woody hosts) and variations in titer according to season and plant organ (Firrao et al. 2007). However, accession 16807 had the highest proportion of plants positive with the stunt phytoplasma by LAMP but with least effect of the phytoplasma on the yield parameters. Seemüller and Harries (2010) reported that phytoplasma severely affect the phloem function in susceptible plants impairing transport of soluble organic material especially to the roots; and the symptoms are mild or absent in such resistant plants. This accession could therefore be considered as being highly tolerant. On the other hand, symptomatic plants in Napier accession 16812 reverted to asymptomatic state in the second re-growth and there was insignificant effect of the stunt phytoplasma on the yield parameters of this accession indicating tolerance to the pathogen. Although there is scarcity of information on recovery responses of gramminacious plants from phytoplasma infections, this effect has been observed in grapevines infected with Bois noir disease known to be associated with the stolbur phytoplasma (STOL), which is a member of the 16SrXII-A group (Romanazzi et al. 2007), and grapevines infected with Flavescence dorée disease caused by Flavescence dorée Phytoplasma (FD) a member of the 16SrV taxonomic group (Musetti et al. 2007).

Uganda hairless and Clone 13 indicated absence of the Ns-Phytoplasma but were symptomatic for Napier stunt. This could be alluded to poor correlation between phytoplasma presence and phloem aberrations or external symptoms occurring in some parts of infected plants, where by a long-distance effect of phytoplasmal infections is hypothesized (Marcone 2010). Other factors that could contribute to the inconsistence of symptom development and detection of the Ns-Phytoplasma in the inoculated plants include strain virulence, strain interference, phytoplasma concentration, toxins, plant hormone imbalance and attachment of phytoplasmas to host cell membrane (Marcone 2010). There is need for further study on these accessions to clearly determine which among these factors led to this response. Clone 13 in this study was symptomatic; inconsistent with the findings of Muyekho et al (2006). This could be because greenhouse screening provides conducive conditions for infestation and is more reliable and rapid than field screening that depends on chance (TNAU 2008). Also field screening has a weakness such that the insect population cannot be uniformly controlled to ensure that plants that escape infestation are not graded as resistant (TNAU 2008).

Conclusion

Napier accession N16789 had no plants containing the pathogen and also showed no phytoplasma symptoms throughout the screening period. This accession could be a good source of resistance for future development of Napier grass varieties with good agronomic traits for release to farmers. Napier accession N16807 indicated high level of tolerance with high proportions of test plants positive with phytoplasma and remained asymptomatic throughout the screening period. Napier accessions N16822 and N16817 had moderate tolerance because they remained asymptomatic throughout the screening period despite the presence of the Ns-phytoplasma in some of their plant population by the third LAMP screening.

Recommendations and future research

1. Napier accession 16879 be tested under multi-location sites for yield and duration of the tolerance/resistance
2. Napier accessions 16817, 16822, 16812, 16807 were moderately tolerant should be evaluated for yield under multi-locational sites
3. Mechanism of tolerance/resistance in accession 16879 be established
4. Evaluate IPM strategies that combine tolerance/resistance in accessions 16789, 16817, 16822, 16812, 16807 and other management strategies to sustain the resistance/ tolerance
5. Tolerant materials identified for stunt and smut be subjected to study on disease interaction between phytoplasma & smut

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CHAPTER 6: Epidemiology of Napier stunt disease in Eastern and Central African region

6.1 Genetic Characterization of Alupe Napier Grass Accessions Based on Simple Sequence Repeat Markers

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Introduction

Napier grass (*Pennisetum purpureum*), also known as elephant grass is a robust perennial forage indigenous to sub-Saharan Africa (Lowe et al., 2003). The grass is dominant in the fertile crescent along north of Lake Victoria and the western Rift Valley in Uganda (Farrel et al., 2002). Currently, Napier grass is the principal fodder crop in smallholder intensive and semi intensive livestock production systems in East Africa (Staal et al., 1999), constituting 40 – 80% of forages used to meet the increasing demand for milk. The demand for Napier grass is growing, mostly among poor households in densely populated areas due to its desirable traits such as tolerance to drought, ability to grow in a wide range of soil conditions, high photosynthetic and water-use efficiency (Andreson et al., 2008). The grass can also withstand repeated cutting with rapid regeneration, producing a high yield that is very palatable to cattle in the leafy stage (Lowe et al., 2003).

Napier grass productivity in the East African region is limited by several factors especially the emerging new diseases like Napier Grass Stunt Disease and Napier Grass Head Smut Disease, thus constraining the growth of smallholder dairy industry (New Agriculturists, 2009). Therefore, continued utilization of Napier grass as a fodder will depend on exploitation of the genetic variability within and among its populations (Faisal et al., 2007) in search for resistance to these production constraints. This requires a well characterized and inventoried germplasm; which is lacking in the case of Napier grass in East African countries including Uganda (Kawube et al., 2014). In East Africa Kenya Agricultural Research Institute – Dairy Research Centre at Alupe maintains a collection of Pennisetum purpureum; obtained from within Kenya and the International Livestock Research Institute, in Ethiopia whose genetic diversity is not known.

Various methods for estimating diversity in a plant population exist and use of simple sequence repeats (SSRs) has become the method of choice because of the markers multi-allelism, genome specificity, even distribution and high polymorphism. However, the genome of Napier grass has not been sequenced, therefore, Napier grass SSR markers are not known. Besides, Napier grass is a tetraploid (2n = 4x=28) with triploid and hexaploid hybrids occurring between it and pearl millet [8]. This makes establishing microsatellites that adequately discriminate the different ploidy levels difficult. The available option is through cross-amplification using SSR markers of closely related species (Azevedo et al., 2012). This study, therefore, determined the genetic variability among Napier grass clones maintained Kenya Agricultural Research Institute – Alupe station through cross-amplification using SSR markers of closely related organisms.

Materials and methods

Sample Collection and Analysis

Twenty two Napier grass clones (19, 41, 75, 76, 79, 97, 103, 104, 105, 112, 117, 16702, 16789, 16805, 16814, 16815, 79SN, ANF, Kakamega1, Kakamega2, kakamega3 and RBN) obtained from Kenya Agricultural Research Institute – Dairy research Center Alupe and one clone - 16785 obtained from International Livestock Research Institute – Ethiopia were planted in the field at National Crops Resources Research Institute at Namulonge in Uganda in 6 replicates. Two months after planting, samples were collected from the inner most unfolded leaf on one tiller of each plant, placed in a paper bag with silica gels, packed in a box. These were transferred to Bioscience Eastern and Central Africa at International Livestock Research Institute (BecA-ILRI) - Nairobi for genotyping.

In the laboratory, 1.5 g of a leaf was extracted from each leaf sample and ground in mortar in liquid Nitrogen. Total plant DNA was extracted using cetyltrimethylammonium bromide (CTAB) method (Doyle et al., 2005) and diluted to 100µ using double distilled water. The DNA concentration was determined using Nanodrop UV spectrometry at A260 and A280 while the integrity of DNA was tested on 1.2% agarose gel electrophoresis in TBE buffer stained with gel red. From these, template DNA was made from an aliquot in a 1.5 ml tube and diluted to 50ng/µ.

DNA Amplification with Microsatellite Markers

A total of 17 simple sequence repeat microsatellite primer pairs, originally identified in maize, pearl millet and sorghum were conjugated with different dyes (VIC, NED, PET and 6-FAM). These were used in the PCR amplification in 20µl AccuPower® Taq Premix (Bioneer) to which 17µl of water and 0.5µl of 5 picomoles of each of the primer pair and 2µl of template DNA were added. The reaction mixture was subjected to the following PCR conditions: an initial denaturation of 94oC (3min) followed by 35 cycles of 94oC (30sec); specific primer annealing temperature (1min) (Table 6.1.1); extension at 72oC (2min), final extension at 72oC (10min) and final hold at 4oC. The PCR products were run on 1.2% agarose gel electrophoresis stained with gel red in 0.5X TBE buffer at 80 V for 50 minutes and visualized on trans UV and photographed in UVP DIGIDOC – IT system (UVP BioImaging systems, USA). The PCR products with clear single band amplification on the agarose gel were subjected to capillary electrophoresis with ABI3730 DNA genetic analyser for fragment analysis and allele calls were made using GENEMAPPER software v.3.7 (Applied Biosystems). Primers whose PCR products generated high quality electropherogram peaks of fluorescent intensity above 50 at differing positions in the samples were selected (Table 6.1.1) and used for amplification of all the samples.

Data Analysis

Microsatellite allele distribution data obtained from Genscan®software Version 4.1 were converted into suitable formats for statistical analysis. Allelic size data for each SSR locus was used to estimate percentage of polymorphic loci, Shannon's information index (I), Nei's gene diversity, observed (Ho) and expected (He) heterozygosities using Power Marker version 3.25 (Liu et al., 2005). Cluster analysis was performed based on Nei's distance matrix using GenALEX6.2 (Peakall et al., 2009).

Results

The SSR markers used in this study generated 90 alleles in 23 Napier grass accessions. The number of alleles detected for each primer pair ranged from 2 (CTM10, CTM59, PSMP2235, PGIRD25) to 13 (CTM8) with average of 5.29 (Table 6.1.2). The frequency of the major alleles in each marker locus ranged from 0.23 (PSMP2267) to 0.98 (PGIRD25). Polymorphic Information Content for the assayed marker loci ranged from 0.04 (PGIRD25) to 0.85 (PSMP2267) with average of 0.5. The observed and expected heterozygosity generated by the markers was moderate. Marker PSMP2267 had the highest expected and observed heterozygosity of 0.86 and 0.95, respectively while PGIRD25 exhibited the least expected and observed heterozygosity both at 0.04 (Table 6.1.2).

The proportion of rare alleles (private alleles) within the Napier grass accessions was very low with seven clones ranged from 0.00 in clones 41, 75, 76, 79, ANF, kakamega1 and RBN having while the highest number of private alleles was recorded in clone 16814. The highest Shannon information index was recorded in clone 16785 while the least was recorded in clone 16814 and 105. In relation, the highest expected heterozygosity was recorded in clone 16785 while the least was recorded in clone 16814 and 105. Napier grass accession 16785 showed the highest number of effective alleles) while accession 105 had the least. Similarly, percentage polymorphic loci ranged from 27.8% in clone 16814 and 105 to 77.8% in clone 16785 (Table 6.1.3).

Pairwise comparison of genetic distance revealed big difference among the Napier grass clones ranging from 0.11 (between Kakamega 1, Kakamega 2, Kakamega 3) to 1.00 between clone 16814 and 105 (Table 6.1.4). Principal Coordinate Analysis was calculated from dissimilarity coefficients for two first axes coordinates with positive eigen values. The axes accounted for 52.8% variation with first axis accounting for 29.8% while the second axis accounted for 23.0%. Principal Coordinate Analysis did not group the clones into clear structures. However, clones Kakamega 1, Kakamega 2, Kakamega 3 and 16805 and clone 112 and ANF grouped together, respectively (Figure 6.1.1). The UPGMA dendogram based on pairwise Nei's genetic distance showered two major clusters; one consisting of only clone 16814 and the other consisting of the rest of the clones (Figure 6.1.2).

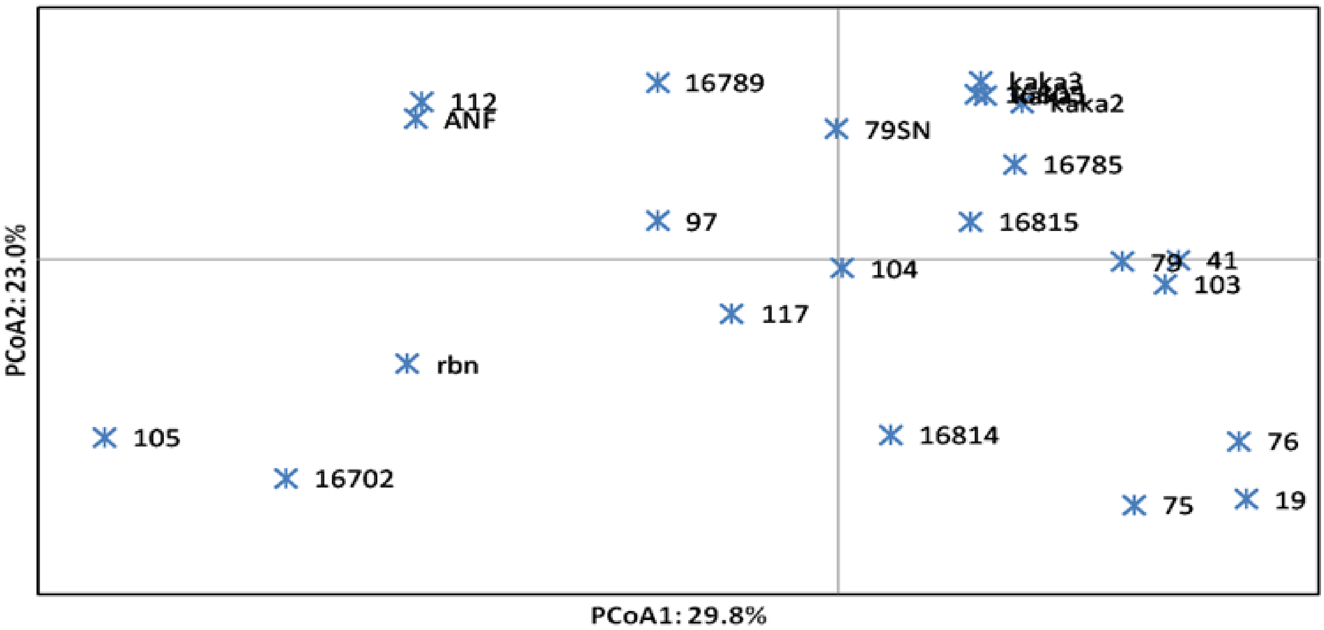

Figure 6.1.1. PCoA scatter plot showing the clustering of the 23 Napier grass clones

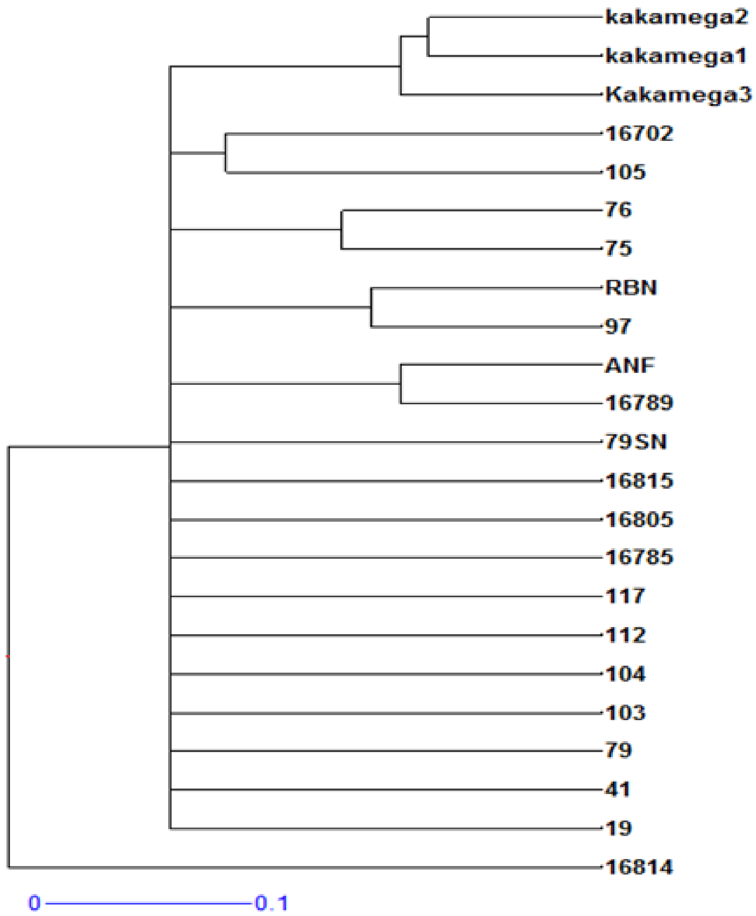

Figure 6.1.2. UPGMA neighbour joining dendogram of 23 napier grass clones computed from 17 ssr markers using darwin hierachial clustering

Table 6.1.1: SSR primers used to assess genetic diversity in 23 Napier clones

Primer name	Sequence left primer (forward 5′ – 3′)	Right primer (reverse 5′ – 3′)	Annealing temperature (oC)
CTM-10	GAGGCAAAAGTGGAAGACAG	TTGATTCCCGGTTCTATCGA	52
CTM-27	GTTGCAAGCAGGAGTAGATCGA	CGCTCTGTAGGTTGAACTCCTT	52
CTM-59	TCCTCGACATCCTCCA	GACACCTCGTAGCACTCC	54
CTM-8	GCTGCATCGGAGATAGGGAA	CTCAGCAAGCACGCTGCTCT	52
PGIRD21	GCTATTGCCACTGCTTCACA	CCACCATGCAACAGCAATAA	54
PGIRD25	CGGAGCTCCTATCATTCCAA	GCAAGCCACAAGCCTATCTC	58
PGIRD57	GGCCCCAAGTAACTTCCCTA	TCAAGCTAGGGCCAATGTCT	56
PSMP2235	GCTTTTCTGCTTCTCCGTAGAC	CCCAACAATAGCCACCAATAAAGA	54
PSMP2248	TCTGTTTGTTTGGGTCAGGTCCTTC	CGAATACGTATGGAGAACTGCGCATC	58
PSMP2255	CATCTAAACACAACCAATCTTGAAC	TGGCACTCTTAAATTGACGCAT	54
PSMP2266	CAAGGATGGCTGAAGGGCTATG	TTTCCAGCCCACACCAGTAATC	58
PSMP2267	GGAAGGCGTAGGGATCAATCTCAC	ATCCACCCGACGAAGGAAACGA	60
Xipes0093	GGATCTGCAGGTTTGGACAT	CCAAGCACTGAAACATGCAC	57
Phil227562	TGATAAAGCTCAGCCACAAGG	ATCTCGGCTACGGCCAGA	56
Xcup14	TACATCACAGCAGGGACAGG	CTGGAAAGCCGAGCAGTATG	53
Xcup63	GTAAAGGGCAAGGCAACAAG	GCCCTACAAAATCTGCAAGC	53
XTXP278	GGG TTT CAA CTC TAG CCT ACC GAA CTT CCT	ATG CCT CAT CAT GGT TCG TTT TGC TT	50

Table 6.1.2. Genetic diversity parameters averaged across all groups and loci for 23 Napier grass clones

Primer	Major allele frequency	Number of alleles	Gene diversity/ expected heterozygosity (He)	Observed heterozygosity (Ho)	Polymorphic information content (PIC)
CTM10	0.52	2	0.49	0.87	0.37
CTM59	0.96	2	0.08	0.09	0.08
CTM8	0.29	13	0.82	0.89	0.80
CTM27	0.43	4	0.64	0.96	0.57
PGIRD21	0.37	9	0.80	0.52	0.78
PGIRD57	0.76	5	0.40	0.04	0.38
PSMP2248	0.63	4	0.53	0.22	0.47
Xipes0093	0.60	5	0.58	0.80	0.53
Phil227562	0.54	4	0.58	0.93	0.50
Xcup14	0.79	4	0.35	0.36	0.38
PSMP2266	0.47	5	0.66	1	0.61
PSMP2235	0.59	2	0.48	0.65	0.37
PGIRD25	0.98	2	0.04	0.04	0.04
PSMP2267	0.23	11	0.86	0.95	0.85
PSMP2255	0.33	7	0.76	0.78	0.72
XTXP278	0.64	6	0.53	0.72	0.47
Xcup63	0.48	5	0.66	0.96	0.61
Mean	0.57	5.29	0.54	0.63	0.50

Table 6.1.3: Mean number of effective loci (ne), shannon index (i), proportion of private alleles, expected heterozygosity(he) and percentage polymorphism across the 23 Napier grass clones

Population	Ne	I	Proportion of private Alleles	He	%Polymorphism
19	1.500	0.385	0.222	0.278	55.6
41	1.667	0.462	0.000	0.333	66.7
75	1.444	0.347	0.000	0.250	50.0
76	1.667	0.462	0.000	0.333	66.7
79	1.556	0.385	0.000	0.278	55.6
97	1.389	0.347	0.111	0.250	50.0
103	1.556	0.424	0.056	0.306	61.1
104	1.611	0.424	0.111	0.306	61.1
105	1.000	0.193	0.056	0.139	27.8
112	1.278	0.308	0.111	0.222	44.4
117	1.556	0.462	0.056	0.333	66.7
16702	1.222	0.308	0.056	0.222	44.4
16785	1.778	0.539	0.111	0.389	77.8
16789	1.500	0.385	0.056	0.278	55.6
16805	1.556	0.385	0.111	0.278	55.6
16814	1.222	0.193	0.278	0.139	27.8
16815	1.556	0.424	0.056	0.306	61.1
79SN	1.444	0.347	0.056	0.250	50.0
ANF	1.333	0.308	0.000	0.222	44.4
kakamega1	1.500	0.385	0.000	0.278	55.6
kakamega2	1.556	0.385	0.056	0.278	55.6
kakamega3	1.556	0.385	0.056	0.278	55.6
RBN	1.222	0.308	0.000	0.222	44.4

Table 6.1.4: Nei's Unbiased genetic distance of the 23 Napier grass clones based on SSR analysis

19	41	75	76	79	97	103	104	105	112	117	16702	16785	16789	16805	16814	16815	79SN	ANF	kaka1	kaka2	kaka3	RBN	
0																							19
0.263	0																						41
0.312	0.259	0																					75
0.208	0.239	0.179	0																				76
0.345	0.105	0.207	0.181	0																			79
0.6	0.288	0.519	0.442	0.207	0																		97
0.412	0.155	0.315	0.238	0.262	0.373	0																	103
0.587	0.426	0.612	0.426	0.38	0.503	0.562	0																104
0.938	0.839	0.872	0.795	0.725	0.749	0.913	0.699	0															105
0.974	0.57	0.852	0.822	0.552	0.576	0.635	0.674	0.698	0														112
0.683	0.365	0.511	0.434	0.292	0.377	0.359	0.535	0.634	0.57	0													117
0.741	0.608	0.647	0.775	0.587	0.685	0.897	0.597	0.852	0.922	0.87	0												16702
0.464	0.123	0.35	0.273	0.149	0.318	0.179	0.367	0.693	0.342	0.241	0.588	0											16785
0.652	0.292	0.563	0.486	0.26	0.207	0.444	0.38	0.687	0.422	0.353	0.7	0.233	0										16789
0.652	0.235	0.462	0.451	0.158	0.285	0.38	0.55	0.805	0.453	0.292	0.783	0.176	0.234	0									16805
0.615	0.563	0.424	0.496	0.427	0.541	0.738	0.913	1.000	0.939	0.672	0.939	0.693	0.687	0.687	0								16814
0.55	0.209	0.469	0.359	0.157	0.315	0.294	0.419	0.822	0.635	0.327	0.758	0.179	0.319	0.29	0.699	0							16815
0.637	0.288	0.423	0.377	0.258	0.336	0.286	0.538	0.788	0.447	0.377	0.808	0.201	0.232	0.285	0.64	0.344	0						79SN
0.828	0.465	0.685	0.731	0.422	0.417	0.635	0.459	0.698	0.47	0.534	0.599	0.342	0.23	0.392	0.735	0.526	0.388	0					ANF
0.504	0.13	0.462	0.451	0.158	0.258	0.349	0.478	0.725	0.453	0.385	0.661	0.149	0.182	0.158	0.582	0.235	0.232	0.335	0				kaka1
0.47	0.235	0.399	0.353	0.234	0.285	0.262	0.444	0.764	0.453	0.385	0.741	0.122	0.158	0.234	0.651	0.29	0.232	0.335	0.11	0			kaka2
0.575	0.235	0.43	0.417	0.158	0.258	0.319	0.319	0.725	0.453	0.353	0.783	0.176	0.158	0.208	0.582	0.182	0.232	0.281	0.134	0.11	0		kaka3
0.7	0.465	0.611	0.534	0.364	0.332	0.597	0.561	0.629	0.708	0.465	0.634	0.475	0.308	0.422	0.698	0.459	0.509	0.533	0.392	0.422	0.422	0	RBN

Discussion

Genetic characterization of cultivars is an important step in any breeding programs for selection of appropriate parental lines (Xie et al., 2009). Several DNA marker systems for germplasm genetic characterization are available and SSRs have been found most adequate in detecting relationships among closely related materials as well as obtaining specific genetic fingerprints (Munoz-Falcon et al., 2009). In this study, 17 SSR markers used produced high mean polymorphic information content suggesting that they are highly informative and able to discriminate among the different clones. According to Elibariki, et al. (Elibariki et al., 2013) the ability to discriminate, however, varies from one marker to another, thus the most polymorphic marker was CTM8 while the least polymorphic was PGIRD25.

Both gene diversity and observed heterozygosity averaged across all loci was moderate. This result is in agreement with the findings of Wanjala et al. (2013) who while working on Napier grass from east Africa region using AFLPs found moderate diversity among accessions. According to Bhandari et al. (Bhandari et al., 2006), Napier grass is of free pollination and high genetic diversity is expected from its natural crossings. The moderate genetic diversity revealed in this study is due to the fact that Napier grass grown onfarm is predominantly propagated by cuttings and subjected to high selection intensity by farmers. The markers revealed high number of private alleles in majority of the Napier grass clones. These, if included in breeding programs increase the chances of getting clones with farmer preferred traits.

The genetic distance revealed between the clones was generally high, with the highest distance being between clones 16814 and 105. This was further supported by the dendogram in which clone 16814 clustered different from the rest. This provides a basis for developing heterotic pool (Fregene et al., 2003) from which crosses between genetically diverse parents can be made to produce progenies with higher genetic variation than those produced by closely related parents. The grouping of clone 16814 different from clone 16815 and 16805, yet all originate from United States of America (Wouw et al., 1999) shows that the clustering was not based on the origin of the clones. This view contradicts the findings of Lowe et al. (2002) who while using RAPDS reported that Napier grass accessions cluster corresponding to geographical location. However, it is in agreement with Wanjala et al. (2013) who while using AFLPs reported that Napier grass did not cluster depending on their origin. The clustering together of the other clones most of which originate in Africa is a proof that Africa is the center of diversity (Azevedo et al., 2013), as such it houses majority of the pennisetum gene pools (Techio et al., 2012). The loose clustering of accessions as revealed by PCA is possibly due to absence or low gene flow since Napier grass is clonally propagated. The genetic closeness of Kakamega 1, Kakamega 2 and Kakamega 3 indicates that they share most alleles and were collected from the same area known as Kakamega in Kenya.

Conclusion

Based on the foregoing, clones evaluated in this study are diverse with multitudes of private alleles which if found useful can be exploited in breeding to improve Napier grass. As such, Clone 16814, which is the most distant to all, is better suited for improvement of the rest of the clones if its attributes are found superior to those in others. Clones Kakamega1, Kakamega2, and Kakamega3 are more less the same, hence if any genetic improvement is to be carried out; it has to be with other distant clones.

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CHAPTER 7: Evaluation of alternative forages and feed resources to improve feed availability in smallholder dairy production systems

7.1: Dry season forages for improving dairy production in smallholder systems in Uganda

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Introduction

Smallholder dairy farming systems dominate in the rural in Eastern and Central African region, employ over 70% of the region's population and contribute 70–90% of the total meat and milk output in the region (Njarui et al. 2012). Small-scale dairy production plays a crucial role in food security, human health and overall household livelihoods, particularly among climate change-prone resource-poor households in the region. Zero-grazing dairy systems are increasingly promoted, owing to grazing land shortage and intensive dairy production requirements. Women are immense contributors to and beneficiaries from smallhold-er dairy production systems (Njarui et. al. 2012), which are progressively being devastated by rapid climate change and its attendant extreme weather conditions. The availa-bility of livestock feeds in rural households is being affected by climate change. The lack of effective adapta-tion to the adverse effects of climate change is likely to jeopardize the achievement of Millennium Development Goals 1 (eradicating extreme poverty and hunger), 7 (en-suring environmental sustainability) and 3 (promoting gender equality and empowering women) (United Nations 2010).

Napier grass (*Pennisetum purpureum*) is the major for-age in zero-grazing production systems in Masaka district, Uganda (Kabirizi 2006). However, grass productivity is constrained by long droughts, poor agronomic practices, such as lack of fertilizer application and improper cutting frequency and cutting height, and by pests and diseases, the napier stunt disease being particularly important, re-sulting in a reduction in fodder yield of up to 100% during the dry season. *Brachiaria* hybrid cv. Mulato (Mulato) has high biomass yield and tolerates long droughts and poor soils (CIAT 2001) and could be used to complement Napier grass. It is recommended that Mulato be grown to provide forage, when Napier grass production is low.

It is generally recommended, furthermore, that forages be grown in grass-legume mixtures in order to not only ensure energy-protein balance for livestock, but also har-ness atmospheric nitrogen (N) via the legume component (Thomas 1995; Kabirizi 2006). Among the best-known, but not widely used forage legumes in Uganda are *Centrosema molle* (syn. C. *pubescens*; Centro) and *Clitoria ternatea* (Clitoria); both are deep-rooting and considered as drought-tolerant. However, regardless of whether sown as a monocrop or in mixture with a legume, the officially recommended 0.5-ha Napier grass area is not sufficient to provide year-round forage for 1 cow and its calf.

This study was designed to develop economically feasi-ble strategies for year-round feed supply to dairy cattle in order to improve feed resource availability, milk yield and household income, by comparing in on-farm trials the newly introduced drought-tolerant Mulato with commonly used Napier, both grown with a drought-tolerant legume.

Methodology

Description of the study site

The study was conducted in Masaka district, Central Uganda (00°15′- 00°43′ S, 31°- 32° E; 1150 m above sea level) (Figure 7.1.1). Annual average rainfall is 800–1000 mm with 100–120 rainy days, in 2 seasons. Mean temperature ranges between 16°C and 30°C, while relative humidity is 62%. The district is typically dependent on crop-livestock systems, with vegetable production as a key income generator.

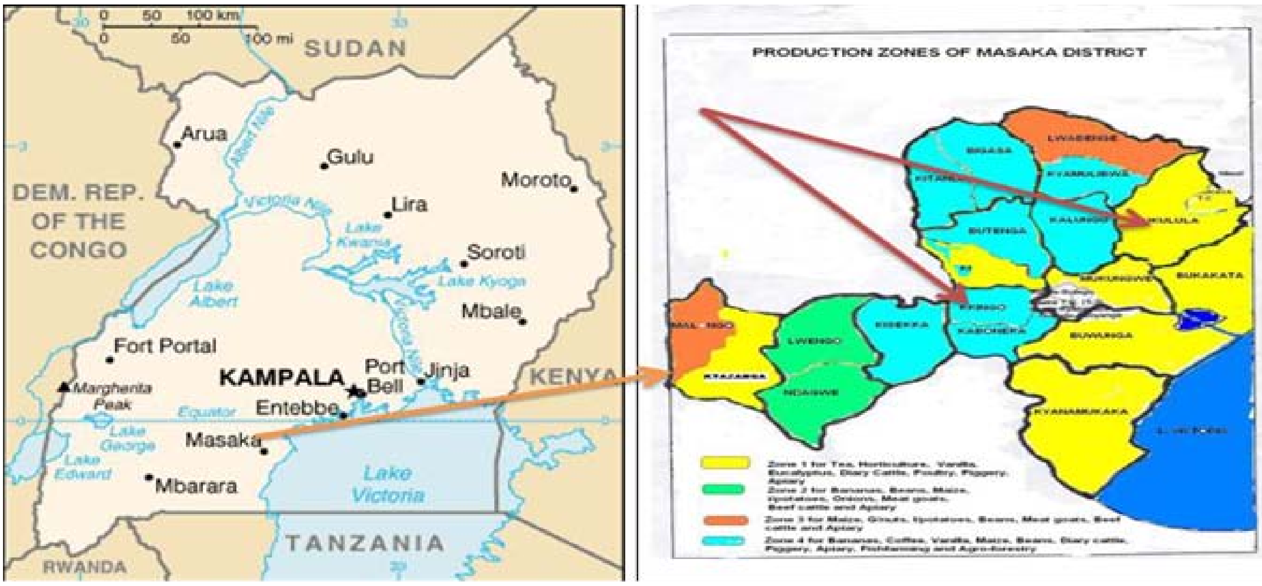

Figure 7.1.1: Maps showing study sites

The study targeted zero-grazing dairy farmers with 1–2 cows and at least 2 ha of land of which 0.5 ha was already planted with Napier grass fodder. The treatments involved 2 grass-legume mixtures: Napier with Centro and Mulato with Clitoria (Figure 7.1.2). These mixtures were established as forage banks in 0.5 ha each on 24 randomly selected farms using methods described in Humphreys (1995) and CIAT (2001). The mixtures were compared with the farmers' practice of growing Napier grass alone.

Brachiaria fodder bank

Brachiaria fodder harvested from an area of 1 m x 1 m

Figure 7.1.2: Drought tolerant Brachiaria hybrid cv Mulato 11

Farmers participated in all stages of project implementation to enhance rapid uptake of emerging knowledge and practices. The study was laid out in a randomized complete block design with household farms as replications. Fodder and milk yields from all 24 farms were recorded for 2 years. Dry matter yields and associated feeding periods were estimated using methods described by Humphreys (1995). Data were analyzed with costs of inputs and returns from milk (including home-consumed) recorded for profitability evaluation using partial budgeting.

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Beneficiary assessment of drought tolerant forages

A second study was conducted comparing the beneficiaries of the drought-tolerant forage technology (0.5 ha Napier + Centro mixture plus 0.5 ha Mulato + Clitoria mixture) with the non-beneficiaries (0.5 ha Napier monocrop). Beneficiaries (n=24) of the interventions and non-beneficiaries (n=24) were purposively selected with equal number of women and men. Three data collection approaches namely Systematic Client Consultations based on semi-formal beneficiary assessment case studies, objective data verification by direct observation and Community group discussions were used. Data associated with costs of inputs and returns from milk (including home consumed) were recorded for profitability evaluation using partial budgeting. Data was analysed using Statistical Packages for Social Sciences package (SPSS, 2002).

Results and Discussion

Intercropping Centro with Napier grass increased fodder availability by 52%, crude protein (CP) concentration by 20% and feeding period (number of days a cow was able to feed on fodder from a given area of land) by 52% (Table 7.1.1).

Table 7.1.1: Fodder availability and quality, and feeding period for different forage banks

	Forage banks			
Parameter	**Napier grass and *Centrosema molle* mixture**	**Brachiaria and *Clitoria ternatea* mixture**	**Napier grass monocrop**	**SEM**
Mean Dry matter yield (kg ha-1)	15,790	12,119	10,354	307
Feeding period (days) from 0.5 ha	254.6	195.5	167.0	20.9
Crude protein content (%)	8.4	12.1	7.0	0.14

SEM: Standard error of mean

The Mulato-Clitoria mixture provided dry matter yields and a feeding period that were intermediate between the 2 Napier treatments but the increase in CP concentration was 73 respectively 44% higher.

Higher total fodder yields and CP concentrations in in-tercrops (Table 7.1.1) could be attributed to the presence of forage legumes that improved growth of the grass. The legume acted as a cover crop to control weeds and con-serve soil moisture during the dry periods, apart from the possibility of augmenting N supply to the grass component through symbiotic N-fixation (Kabirizi 2006).

The results confirmed that the currently recommended acreage of 0.5 ha of a mixture of Napier grass with a for-age legume (Samanya 1996) will produce additional forage of higher quality than Napier grass alone but 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 Mulato with a forage leg-ume is recommended for feeding during the dry season, when production of Napier grass monocrop is disadvan-taged due to drought, the napier stunt disease and poor agronomic practices.

A second study was conducted comparing the benefi-ciaries of the drought-tolerant forage technology (0.5 ha Napier + Centro mixture plus 0.5 ha Mulato + Clitoria mixture) with the non-beneficiaries (0.5 ha Napier monocrop) (Table 7.1.2).

Table 7.1.2: Socio-economic benefits of introduced forages

	Beneficiaries(n=20)		Non- beneficiaries (n=20)		F-test	IA
Household characteristics	Mean	SD	Mean	SD		
Land size (ha)	1.7	1.2	1.6	0.9	0.12NS	
Cattle (number)	1.5	0.5	1.3	0.7	0.03NS	
Fodder area (ha)	1.1	0.3	0.5	0.3	14.4**	134.1
Feed offered cow^{-1} day^{-1} (fresh)	55.4	12.3	31.4	7.2	5.7*	76.4
Milk yield (L day^{-1})	10.6	7.2	5.9	3.1	4.3*	79.7
Revenue (US $) from milk yield cow^{-1} $year^{-1}$	676.9	48.2	444	64.1	1.66NS	52.4

***=significant at 1%, ** = significant at 5 %; NS = not significant SD: Standard deviation; IA: Intervention advantage

There were no significant (P>0.05) differences in land size and number of cattle kept between the beneficiaries and non-beneficiaries of the interventions but sowing 0.5 ha of each of the grass-legume mixtures improved milk yield and household income by 80 and 52%, respectively, over 0.5 ha Napier grass. The benefi-ciaries fed 76% more high-quality forage, i.e. the milk yield response was largely due to simply feeding more. Beneficiaries, however, had 120% more land sown to fodder, implying they were not harvesting as much forage per ha (if all harvested forage was fed to cows) or were able to sell fodder to others.

In assessing the overall benefits of this production sys-tem, it is important to remember that an extra 0.5 ha was sown to a grass-legume mixture and was no longer availa-ble for other agricultural purposes.

Conclusion

Replacing traditional Napier grass forage banks with grass-legume mixtures, including the drought-tolerant Brachiaria hybrid cv. Mulato and the deep-rooted legumes Centro and Clitoria, is a promising strategy for year-round feed supply to smallholder dairy cattle in Central and East Africa. The income foregone from the additional area sown to pasture must be taken into consideration in assessing the profitability of this practice.

7.2: Homecoming of Brachiaria: Improved hybrids prove useful for African animal agriculture

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Background

Species of the genus Brachiaria originate primarily from eastern, central and southern Africa, where they are natural constituents of grasslands (Boonman 1993). The largest impact of Brachiaria in agriculture, though, is in the Americas, especially in Brazil. Due to their adaptation to acidic, low-fertility soils, an estimated 99 million hectares of Brachiaria species have been sown in Brazil alone as improved pastures (Jank et al. 2014). This refers especially to B. *brizantha* cv. Marandu and B. *decumbens* cv. Basilisk.

Despite Africa being their center of origin and diversity, Brachiaria species had not been selected for pasture improvement in eastern Africa, when grassland research was most active in the 1960s and 1970s (Boonman 1993). The then available commercial cultivars of B. *brizantha*, B. *decumbens*, B. *ruziziensis* and B. *humidicola* were evaluated in small-plot agronomic trials in western and central Africa in the 1990s (Ndikumana and de Leeuw 1996). However, none of them appears to have found its way into commercial agriculture at a significant scale in any African country (Boonman 1993). Only Congo Signal grass (B. *ruziziensis*, K5832) has been used as a cultivated grass in some areas of Congo (DRC, formerly also Zaïre), Uganda and Kenya according to Boonman's (1993) review. This nutritious and persistent grass has been in commercial seed multiplication since 1960.

Brachiaria improvement in the Americas

Due to the susceptibility to spittlebug insect pests of B. *decumbens* in the Americas, CIAT in Colombia and EMBRAPA in Brazil initiated breeding programs in the late 1980s (Miles et al. 2004). Accessing useful resistance genes for cross-breeding was a particular challenge due to the apomictic nature of the grass. This was only made possible by applying modern biotechnological tools then available (Miles et al. 2004). The first inter-specific hybrids from CIAT's Brachiaria breeding program (cv. Mulato und cv. Mulato-II) were released in the Americas in early and mid-2000s by Grupo Papalotla (Table 7.2.1). Since 2012, cv. Cayman – as a plant with higher waterlogging tolerance – has been made commercially available by Grupo Papalotla (Pizarro 2013), and the new, relatively taller cv. Cobra that is more suitable for cut-and-carry will be soon on the market.

Table 7.2.1: Commercially available hybrid Brachiaria cultivars

Cultivar name	CIAT ID	Special characteristics	Country, year of variety protection (first release)	Reference
cv. Mulato	CIAT 36061	Spittlebug-resistant, high forage yield and nutritive quality, poor seed fill	Mexico, 2004 (2001)	Argel et al. 2007; Miles et al. 2004
cv. Mulato-II	CIAT 36087	Spittlebug-resistant, high forage yield and nutritive quality, good seed yield	Mexico, 2007 (2005)	Argel et al. 2007
cv. Cayman	BR02/1752	Higher tolerance to water logging than other hybrids	Mexico, 2013 (2012)	Pizarro 2013
(cv. Cobra)	BR02/1794	Relatively taller than other hybrids, suitable for cut-and-carry	Mexico, 2013	Pers. comms. E. Stern, M. Peters – cv. name not yet official

These interspecific hybrids originate from crosses between two (B. *ruziziensis* x B. *brizantha*) or three Brachiaria species (B. *ruziziensis* x B. *decumbens* x B. *brizantha*) and subsequent screening conducted by CIAT's Tropical Forages Program in Colombia (Argel et al. 2007). Being apomictic hybrids (i.e., reproducing asexually by seed), these cultivars are true-breeding and will not segregate from one generation to the next.

Commercialization of hybrid Brachiaria

In 2000, the Mexican seed company Grupo Papalotla/Tropical Seeds entered into agreement with CIAT for 10 years, for obtaining rights to commercialize CIAT hybrid Brachiaria cultivars by receiving first-generation hybrids bred during that period for further evaluation and determination of their possible commercial value. Papalotla is paying royalties for protected and commercialized cultivars during protection duration (E. Stern, pers. comm. 2013). After expiry of protection 15 years from first sale, according to the International Union for the Protection of New Varieties of Plants (UPOV), cultivars will pass into the public domain and no other right may prevent free use. Global variety protection for the released cultivars has been obtained in Mexico (Table 7.2.1). While Grupo Papalotla/Tropical Seeds has been marketing the seeds directly in the Americas, so far the Australian company Heritage Seeds has been responsible for countries of Oceanea, Asia, and Africa. Commercial seed production of the hybrids at low latitude in the tropics was a major challenge. Therefore, Papalotla transferred seed production of cv. Mulato-II to sites of higher latitude (≥15 °N) in Mexico and Thailand, from where most exports have been realized (Hare et al. 2009).

This study reviews research, development and incipient uptake of new hybrid Brachiaria cultivars in Africa in order to document the existing knowledge on their current use.

Hybrid Brachiaria in Africa

The first cultivars released from CIAT's breeding program, cv. Mulato and cv. Mulato-II, have likewise been researched and distributed in Africa. Seed sales (2001-2013) by Grupo Papalotla/Tropical Seeds to African countries (pers. comm. M. Peters) suggest that an area of at least 1,000 ha has been sown hitherto.

The new hybrid Brachiaria cultivars have been distributed since 2001 to Eritrea, Ethiopia, DR Congo, Uganda, Rwanda, Burundi, Kenya, Tanzania, Malawi and Madagascar according to combined information from seed sales and published research. While the largest share of known commercial seed sales of hybrid Brachiaria cultivars went to Kenya, this only reflects the fact that a big project is being conducted from Kenya (ADOPT – see further details below), from where the seed is further distributed to participants in Ethiopia and Tanzania.

Key findings from both on-station and on-farm research and develop¬ment, emphasizing agro-ecological adaptation of the plants and their acceptability for farmers, are described below.

Small-scale agronomic and participatory evaluation

Rwanda. During participatory research with farmers on sites with low rainfall and acidic soils in 2007 funded by BMZ-GIZ, Germany, cv. Mulato-II was preferred because of producing green forage all year round without any fertilizer input, high above-ground biomass production, palatability, drought tolerance, quick regrowth, persistence, being a perennial and easy for cut-and-carry (Mutimura et al., 2012). Therefore, cv. Mulato-II is considered an excellent alternative to traditional Napier grass (Pennisetum purpureum) predominantly used in zero-grazed dairy systems of the region. Napier grass, though, has been widely suffering from Napier stunt disease and smut that both decrease severely herbage production and, thus, put dairy-dependent livelihoods at risk (Khan et al. 2014b). More than 150 individual farmers and over four farmer cooperatives are now using cv. Mulato-II as erosion control on contour bunds, livestock forage and hay-making for income generation. Currently, >50 ha are planted with cvs. Mulato-II, Marandu and Basilisk to increase planting material in order to satisfy the high demand in the country.

Kenya. The Kenya Agricultural Research Institute (KARI) set up small-plot agronomic experiments in several KARI research stations throughout the country in order to compare the performance of cv. Mulato-II with other available grasses and to assess its agro-ecological adaptation (D. Njarui, pers. comm. 2011). At KARI-Kiboko Research Station, cv. Mulato-II was found superior to native range grasses such as buffel (Cenchrus ciliaris) and horsetail grass (Chloris roxburghiana) in both primary dry matter production and subsequent regrowth (Machogu 2013). It also had higher nutritive quality, especially in terms of high DM digestibility (65%) assessed in 12-week-old plants, whereas crude protein content (13.3%) was similar to that of the other grasses. While this trial was conducted with irrigation until 16 weeks after sowing, cv. Mulato-II in another rainfed trial at Kiboko was heavily infested by red spider mite and both biomass production and plant survival were hampered by drought.

Eritrea. Wolfe et al. (2008) evaluated cv. Mulato at two agricultural research stations in Eritrea, Halhale in the Central Highlands and Shambuko in the Western Lowlands, from 2006 to 2007 and found it was among the most promising grasses in Halhale.

Eastern Democratic Republic of the Congo (DRC)

Both cv. Mulato and Mulato-II were introduced to assess their agro-ecological adaptation in Sud-Kivu province of DRC. Small plots for agronomic evaluation were established at the INERA (Institut National pour l'Etude et la Recherche Agronomiques) Research Station in Mulungu and on farmers' fields in Kabare and Walungu 'groupements'. Cv. Mulato was also evaluated when planted on contour bunds for erosion control within CIALCA (Consortium for Improving Agriculture-based Livelihoods in Central Africa) (B.L. Maass, unpubl.). Unfortunately, the plants became so severely diseased that evaluation was disrupted and plots abandoned. Not only symptoms of fungal diseases (e.g., rust – probably caused by Uromyces setariae-italicae Yosh – and anthracnose) were found, but also of mites (H. Maraite 2010, pers. comm.). J. Linné (2010, pers. comm.) explained this undue susceptibility of hybrid Brachiaria as a re-encounter phenomenon induced by returning plants (hosts) selected under completely distinct biotic challenges back to the species' centers of origin and, consequently, center of diversity also of its diseases and pests.

Systems integration

Dairy production systems in Uganda. Cv.

Mulato was introduced as an alternative to Napier grass, the predominant forage for dairy cattle in zero-grazing systems (Kabirizi et al. 2013). After initial on-station and further participatory on-farm evaluation in Masaka district, incipient uptake of cv. Mulato took place (Mugerwa et al. 2012). Demand for cv. Mulato has been increasing since (Kabirizi et al. 2013). Mainly in smallholder dairy systems, cv. Mulato is being used for cut-and-carry together with legumes like Clitoria ternatea or Centrosema molle (Kabirizi et al. 2013). Cv. Mulato along with other grasses like B. brizantha cv. Toledo is now being promoted by NGOs such as 'Send a Cow' (Kato 2011). It is recommended to feed drought-tolerant cv. Mulato with a forage legume during the dry season, when Napier grass mono-crops are disadvantaged due to drought, Napier stunt disease and/or poor agronomic practices (Kabirizi et al. 2013). As no seed is available commercially, farmers, even with only small plots, sell vegetative planting material (splits) (B.L. Maass unpubl.). This, hence, creates small-scale agro-business opportunities, especially for women. In the more sub-humid area around Jinja, cv. Mulato also appears to be an ideal solution for grazing of calves due to its relatively high nutritive quality (R. Jones, pers. comm. 2014).

The push-pull-system in Kenya, Tanzania and Ethiopia

The largest uptake of hybrid Brachiaria cv. Mulato-II is currently taking place in eastern Africa, where the grass is used as a trap plant in the push-pull system that helps control maize stem borers and the parasitic weed, Striga hermonthica (Khan et al. 2014). The push-pull-system has been developed and promoted by the International Centre of Insect Physiology and Ecology (icipe) (Khan et al. 2014). This smart technology successfully harnesses agro-biodiversity. Initially, its components included Napier grass and Silverleaf desmodium (Desmodium uncinatum). However, on the systems's niche to semi-arid lands (500-700 mm rainfall p.a.), cv. Mulato-II has been identified as a new trap crop together with Greenleaf desmodium (D. intortum) as the intercrop; both are currently being disseminated. The two components are more drought-tolerant than the traditional ones, and their seed is commercially available. In addition, hybrid cv. Mulato-II Brachiaria is resistant to Napier stunt disease. About 15,000 smallholder farmers benefiting from the ADOPT project in Kenya, Tanzania and Ethiopia have already planted cv. Mulato-II (C. Midega, unpubl.). Farmers in Kenya claimed that their milk production has doubled due to the availability of the improved grass and Greenleaf desmodium. They prefer cv. Mulato-II over Napier grass for several reasons: it is highly palatable for livestock, easier to handle as cut-and-carry and for making hay to be used during the dry season. As the push-pull-system has been developed to control maize stem borer, thus far little attention has been paid to the possible importance of livestock production improvements for the uptake and further spread of the technology.

Conservation agriculture and dairy systems in Madagascar. In Madagascar, cv.

Mulato has been tested for soil structure improvement, high biomass production and carbon accumulation in the soil by its root system as a first step to prepare for direct seeding on compacted soils (conservation agriculture). However, the systems did not spread as they require herbicides for grass control, which are not easily accessible in Madagascar (O. Husson pers. comm. 2013). On the other hand, in dairy production systems in the highlands, specifically in the Vakinankaratra region, almost 20 ha were planted with cv. Mulato in 2011 (V.B. Rahetlah unpubl.). Owing to its better palatability and higher biomass yield as compared with other Brachiaria spp., cv. Mulato has been rapidly adopted by small-scale dairy farmers. It is mainly grown for green forage production under cut-and-carry systems during the warm and rainy season extending from November to April.

Research and development of new hybrid Brachiaria for Africa

Despite all the enthusiasm and demand in the region, Mulato-II seed is not yet available on the African market, except for experimental purposes. Therefore, Papalotla has requested varietal release from Kenyan authorities, possibly being granted later in 2014. A new research project led by the Biosciences eastern and central Africa (BecA)/ILRI-Hub that, among other outputs, focuses on integrating improved Brachiaria grasses into mixed smallholder crop-livestock systems, while considering climate-relevant effects on the environment (Djikeng et al. 2013), will most likely push further the adoption of hybrid Brachiaria in the region.

Outlook

Apparently, hybrid Brachiaria has a role to play in improving African animal agriculture. Yet, new pest and disease challenges have emerged that require further research attention. On the other hand, an array of diverse hybrids is still in the pipeline for release (Pizarro et al. 2013; E. Stern, pers. comm., 2013); some of these new materials may better address the specific biotic and abiotic challenges identified as well as the requirements for particular production systems in African locations. In order to maximize benefits for smallholder farmers and deploy the new hybrid Brachiaria cultivars effectively, the following research needs and opportunities have been identified:

(a) Researchable knowledge gaps (e.g., agronomy of system-integration, value for animal production in crop-livestock systems, socio-ecological niche – considering gender and economics, adoptability by smallholder farmers);

(b) Upcoming research needs (e.g., biotic challenges, such as red spider mite, sorghum shoot fly, fungal diseases; possible seed production on the continent); and

(c) Research and development opportunities (e.g., testing advanced hybrids under biotic and abiotic stress as well as in representative African production systems, fitting the right cultivars into different production systems and further develop their agronomy).

Brachiaria, so far neglected grasses on their continent of origin, have not only come home in the form of improved hybrids, but they have been very welcome by African farmers.

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7.3 Losses due to Napier Stunt Disease and the impact of promoting alternative forages in smallholder dairy systems in Uganda

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Introduction

In Uganda agriculture contributes up to nearly 20 percent of GDP, and accounts for 48 percent of exports. The livestock sub-sector contributes about 5.2% and 19% to total GDP and agricultural GDP, respectively. The dairy industry is estimated to contribute about 40 to 50% of the livestock GDP (MAAIF, 2011). This implies that the dairy industry contributes about 50% of the total output from the livestock sub-sector. It employs many people that are involved in various economic activities such as milk production, collection, transportation, processing, distribution and marketing as well as provision of inputs and support services (Dairy Development Authority - DDA, 2008). Sustainable agricultural development depends on appropriate, efficient and effective technologies and innovations. In addition, farmers adopt new technologies that are economically superior to the existing ones. Before changing from one production method to another, farmer consider many factors including agro-ecological requirements, availability of required additional production resources (labor, investible cash, skill, farmland and equipment), additional costs, and additional income resulting from the change. Besides they also consider the technology in respect of socio-cultural circumstances, goals, and the whole farming system compatibility. Farmers will therefore consider the implication of the proposed technological change on farm costs and incomes. They will seek to find answers to the following question. Will the extra income earned by changing to the new technology justify the extra cost? One of the tools in economics used to compare the economic benefits of technologies is farm budget analysis. A budget is a farm management method that is intended to assist researchers, extension workers, and farmers in the decision-making process. It is a hence a decision-support tool that quantifies and compares the effects of a proposed technologies farm profitability. Partial budget analysis shows the level of profitability of and helps to decide whether to adopt a new technology or not. A budget is a formal quantitative expression of plans on production inputs and output. Budgets indicate the type, quality, quantity and cost of production resources or inputs needed, and the type, quality, quantity and value of output or product obtained. An enterprise budget considers all income and costs of a specific enterprise to provide an estimate of its profit. According to Orodho, 2006 the major cattle feed are natural grass and planted fodder, mainly Napier grass (Pennisetum purpureum). The major constraining factors are: lack of adequate and quality feeds particularly in the dry season, animal genetics and disease challenges on livestock and on Napier grass which is the major livestock feed. The napier disease is much more severe and prevalent in poorly managed fields and farmers have noted that in well-weeded and heavily manured fields, disease severity is reduced.

Napier (elephant grass) was infested by a disease about 13 years ago. This disease was later confirmed to be Napier Stunt Disease (NSD) (Nielsen et. al., 2007). The disease was first observed on farmers' fields in Masaka district in 2000. This disease has decimated Napier fodder crop to the extent that in some cases farmers have lost up to 100 per cent economic biomass (Kabirii et al., 2007). Often the whole the stool is affected with NSD and this may lead to complete loss in yield and eventual death. Mubiru et al., 2011 observed that a common challenge that dairy farmers in Uganda face is low milk production. The current average yield is approximately 2400 kg per cow per lactation from cross-bred (Holstein Friesian S - East African Zebu) cows, which is only about 50% of their milk production potential. Milk production from dairy cattle is low in some cases ranging from 2-5 litres per cow per day (Mubiru et al., 2003).

The Livestock nutrition Program of NaLIRRI is currently addressing the constraint of NSD through a range of interventions. There has not been any assessment of the effects of NSD to small scale dairy keepers, non-cattle farmers selling Napier forages and temporal stability in small scale dairy feed resource availability. Besides, Brachiaria is being promoted to compensate for the lost biomass and incomes due to effects of NSD on Napier. A study was conducted to quantify the negative effects of NSD to dairy based livelihoods.

Methods

Study area and sampling procedure methods of data collection and analysis

The study was conducted in Masaka and Wakiso districts. Masaka district is bordered by Sembabule in the North West, Mpigi district in the North, Rakai district in the west and south and Kalangala District in the East. The District Headquarters is 120 km from Kampala. Masaka district has a population of 831,300 people with 420,000 females and 411,300 males. The population of is basically rural, with 754,000 rural dwellers and 77,300 urban dwellers. The major economic activity in Masaka District is agriculture with major crops being bananas, pineapples, and tomatoes), cash crops and coffee cotton integrated with livestock notably dairy and multipurpose local cattle, goats, pigs and chickens. The district lies in the Lake Victoria crescent agro-ecological zone and has a mix of peri-urban and rural settings with both densely and sparsely populated sub-zones. Dairy production ranges from extensive communal grazing of composite village herd and tethering dominated by local zebu cattle, perimeter fenced farm with a mix of low grade crosses and local breeds to semi-intensive and intensive (paddock fenced and stall fed) systems rearing mostly high grade crosses and exotic dairy breeds (Nanyeenya, 2008). Wakiso district lies in the Greater Kampala peri-urban zone. The effects of NSD was assesd in Masaka district where households sampled were drawn from Kitenga, Bukulula, Lusango and Kabonera. In Wakiso district, the study was conducted to document and evaluate challenges and benefits of adoption and integration of brachiaria in the small holder systems households covered were located in Buso, Namulonge and Kiwenda

Study respondents were selected purposive and snowball sampling procedures. All farmers selected intensively managed their cattle through stall feeding and semi-intensive management systems. All project intervention farmers (10 each for NSD tolerant clones and Brachiaria seed multiplication) were selected. Each of these named two other farmers to whom they have disseminated the planting materials given to them. In addition five dairy keepers in each of the study areas were identified and interviewed. In total 35 households were covered per district. Data were collected using semi-formal and formal approaches in each of the two sites based on formal survey techniques using direct interviews supported by standard questionnaires and Systematic Client Consultation (SCC) using check-lists. Data were analysed using enterprise and partial budgeting techniques. One of the most basic and important production decisions is choosing the combination of products or enterprises to produce. An enterprise is defined as a single crop or livestock commodity that actually produces a marketable product. An enterprise budget is a listing of all estimated income and expenses associated with a specific enterprise to provide an estimate of its profitability. The effects of integration of Brachiaria forage seed production into existing farming systems were examined using enterprise budgets. The effects of NSD on dairy enterprise farm performance through resource re-allocation and cash flow changes were assessed using financial analysis based on partial budgeting techniques.

This low yield can be attributed to poor cattle nutrition resulting from inadequate feeding. With improved feeding dairy yields for direct beneficiary and secondary beneficiary households registered 10.6 and 5.9 litres/cow/day, respectively (Kabirizi et al., 2013).

Results and discussion

Findings of the study on effects of promoting Brachiaria forage seed multiplication and NSD on dairy resource allocation and cash flow due to adjustments in dairy feed management in the pre and post Napier Stunt Disease (NSD) periods are discussed in this section. Data on enterprise budgets on Brachiaria Mulato (Table 7.3.1) indicates that dairy farmers who received Brachiaria mulato for multiplication and integrating it into livestock feed have on average established 0.75 acres, sell up to 230 bags of splits of planting materials to other farmers in a year and fetch net profits of about Uganda shillings 3.4 million (USD 1360) per acre per annum.

Table 7.3.1: Enterprise budgets on Brachiaria Mulato for cattle and non-cattle households

	Gross income	Cattle household	Non-cattle household
1	Area (acres)	1	1
2A	Bags of splits sold season1 (Number)	135	135
2B	Bags of splits sold Season2 (Number)	90	90
2C	Annual sales (Bags)	230	260
3	Price (Shillings/Bag)	20000	20000
4	Sales revenue (Shillings) (2 x 3)	4600000	5200000
	Variable Input costs (Shillings/acre)		
5A	Bush clearing (Shillings/Acre)	100000	100000
5B	Land preparation labour (Shillings/Acre)	120000	120000
6A	Quantity of planting material (Bags)	8	8
6B	Price of planting materials (Shillings/Bag)	20000	20000
6C	Cost of planting materials (Shillings/Acre)	160000	160000
6D	Planting and manure application labour (shillings/Acre)	50000	50000
7A	Weed control labour (shillings/Acre)	160000	160000
8A	Manure - 2 truck loads per annum (Shilllings/Acre)	0	80000
8B	Seasonal manure application labour (Shillings/Acre)	80000	80000
9	Harvesting, packing and loading labor (shillings/Acre)	460000	520000
	Total variable input costs (Shillings/Acre)	**1130000**	**1270000**
	Net profit (Shillings/Acre)	**3,470,000**	**3,930,000**

Non-cattle households whose fields regenerate faster given that they are not frequently cut to feed cattle registered net profits of shillings 3.93 million (USD 1572) per acre per annum.

Farmers have indicated that they have been able to use proceeds of Brachiaria income through buying household assets like chairs, investing in other farm enterprises like vegetable production, maize and sweet potato growing by especially hiring labour, improved promptness in settling school fees and others stated that they can now buy building materials in bulk to invest in construction of rental housing units.

Findings on effects of NSD on dairy farm resource allocation and cash flow are presented in Table 7.3.2. The disease led to reduction in area under Napier by about 40 per cent. This concurs with Kabirirzi et al., 2007 who noted that Napier Stunt Disease (NSD) occurred in 97 per cent of farmers' fields causing stunting, curling/twisting of leaf tips leading to up 50 per cent reduction in biomass yield. Contrary to Orodho, 2006 who stated that many smallholders have lost up to 100 percent of their Napier crop and are forced to de-stock or sell off their entire herd because of lack of sufficient feeds farmers in the study area retained their herd sizes (4.6 heads of cattle). They, however, struggled to make up for the lost biomass due to NSD by stepping up feed supplementation resulting into an increase in cost of supplements per day by 200 per cent. Time taken to fetch feeds was also greater than before by 43 per cent. As noted y Orodho, 2006, the disease is much more severe and prevalent in poorly managed fields and farmers have noted that in well-weeded and heavily manured fields, disease severity is reduced. Similarly farmers in the study area raised the quantities of manure applied per acre by one tone (1000 Kilograms). This changed the cost of manure application by shillings 34,400 per acre per annum. These corrective adjustments notwithstanding, milk yields per cow per day dropped about twenty per cent. The net financial effect of reduction in milk incomes and added cost resulted in a negative net financial effect of about shillings 1,500,000. This implies that the disease led to a financial drain equivalent to 54 per cent of the gross revenues from milk. This amount of money can settle two school fees terms of a child going to elite primary or secondary school or tuition for a university student for one semester (half of the year).

Table 7.3.2: Financial analysis of effects of Napier Stunt Disease on resource use and cash flow

Enterprise Resources and Cost Items	Quantity/ Value	Change (%)	Added income + Reduced Costs	Reduced revenue + Added Costs
Napier area (Acres)	1.80	38.00	N/A	N/A
Napier Post NSD (Acres)	1.11			
Cattle herd size (Number)	4.60	0		
Cattle Post NSD (Number)	4.60			
Milking cows (Number)	2.40	0		
Cows Post (Number)	2.40			
Milk/cow/day (Litres/day)	13.95	(18.00)	0	596,800
Milk/cow/day Post NSD (Litres/day)	11.46			
Cost of feed Supplements (shillings/day)	1,500.00	193.00	0	870,000
Cost of feed Supplements Post NSD (shillings/ day)	4,400.00			
Forage Collection Labour (Person-hours/day)	1.29	43.00		0
Forage Collection. Labour Post NSD (Person-hours/day)	1.84			
Manure Application Cost (Shillings/Per Annum)	3600	956.00	0	34,400
Manure Application Cost Post NSD (Shillings/ Per Annum)	38,000			
Net Financial Effect (Shillings Per Annum)	**(1,501,200)**	**80000**		

Summary, Conclusions and Recommendations

From the findings of the study it can be concluded that:

a) Both cattle households and non-cattle households were able to obtain reasonable profits from Brachiaria forage seed sales. They have also variously benefited by improving human capital, welfare, farm enterprise diversification and other long-term commercial investments
b) Farmers have adjusted to NSD effects but in financial terms have not fully compensated for the negative effects of NSD

It is recommended that:

a) Brachiaria propagation model explores manure application regimes since the crop is challenged by frequent cutting and splitting
b) Distribution of NSD tolerant clones should be accelerated so that farmers regain the original Napier acres and biomass to stabilize dairy revenues and reduce on the high cash outflows.

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7.4 Production characteristics of smallholder dairy farming in the Lake Victoria agro-ecological zone, Uganda

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Introduction

Smallholder dairy farming system constitutes an important source of livelihoods to the majority of mixed crop-livestock farmers involved in agricultural production in Uganda (Kabirizi et al., 2006). While, smallholder dairy farmers make a shift towards market-oriented dairy production, they are faced with persistent challenges of low productivity, coupled with limited labour inputs. This practice has condemned smallholder dairy farmers to subsistence production, resulting to low income, low saving and low investment in the dairy sector, triggering vicious cycle of low inputs, low productivity, low technology applications and environmental degradation, which translate into abject poverty (Muia et al., 2011). Uganda's slow growth in the dairy sector is evidenced by declining production yields lower than the potential production estimated growth of about 70% (MAAIF, 2010) considering that over 85% of dairy farmers are smallholders. The annual Gross domestic product (GDP) growth rate of agriculture in year 2012/13 was 1.4% and unstable (MFPED, 2013), yet population growth is estimated at 3.2 percent per annum and appears to be on the rise (UBOS, 2012). Therefore, it was important, to understand production characteristics of smallholder dairy farming so as to identify their opportunities and strength, and build on their threats and weakness to benchmark future research processes aimed at extracting famers out of abject poverty and extreme hunger.

Dairy production has become increasingly intensive to cope with nutritional needs of increasing human population and declining per capita land holding (Lukuyu et al., 2011). This has led to intensification of smallholder dairy farming adopting stall-feeding (also known as "cut and carry") where one to three heads of cattle are fed indoors instead of in-situ grazing (Tibayungwa et al., 2010). Smallholder dairy farming has become an important source of milk and has created employment for many resource poor households in Uganda (Kabirizi et al., 2006), partly due to Uganda's national development plan (NDP) policy whose objective is to eradicate poverty through agricultural transformation (MAAIF, 2010). Smallholder dairy farming, usually 1 or 2 heads of cattle, has the highest economic returns compared to other cattle management systems (MAAIF, 2010). However, low productive performance reduces its profitability (Kabi et al., 2013). For example, annual average milk yield per cow per lactation year of 305 days in developed countries is in excess of 8000 kg, while on smallholder dairy farm in Uganda it is less than 2000 kg per cow per lactation year [9]. Such low milk productivity is to a large extent a result of feed scarcity that leads to poor nutrition (Kabi et al., 2013). Smallholder dairy farming is based on stall feeding as major feeding system, because of its efficiency compared to other feeding systems. However, little information is currently available on production characteristics of smallholder dairy farming in Lake Victoria Agro-ecological Zone (LVZ), in Uganda. Moreover, production characteristics of smallholder dairy farming influence decisions on technology dissemination for future profitability. Since interaction between production and management revolve mostly around the supply of nutrients and energy through dairy feeds, there is need to characterize smallholder dairy farming system in order to predict their performance and benchmark strategic research innovations to address declining smallholder dairy farmer productivity. However, although several studies based on farm characteristics have been conducted among smallholder dairy farmers; little success has been achieved in extricating them out of the persistent extreme hunger and poverty. The objective of this study was to characterize smallholder dairy farming system from farmers' point of view so that together with scientists the farmers inform the process of identifying various intervening strategies to develop dynamic optimization interventions aimed at increasing milk productivity based on the most pressing challenges and un exploited resource endowments peculiar to each region.

Materials and Methods

Description of the Study Area

Three districts namely Buikwe (0°18'4.32 N and 33°3'6.63 E), Jinja (0°25'28 N and 33°12'15 E) and Mayuge (0°27'35 N and 33°28'49 E) (Figure 7.4.1) were purposively selected for the study. The mean daily temperature ranged between
16 - 28 °C, 18 - 28 °C and 17 - 27°C for Buikwe, Jinja and Mayuge Districts, respectively. The mean annual rainfall ranged between 1279 to 1544 mm, 1200 to 1500 mm and 1100 to 1500 mm for Jinja, Mayuge and Buikwe, respectively. The three districts are located in Lake Victoria Agro-ecological Zone (LVZ).

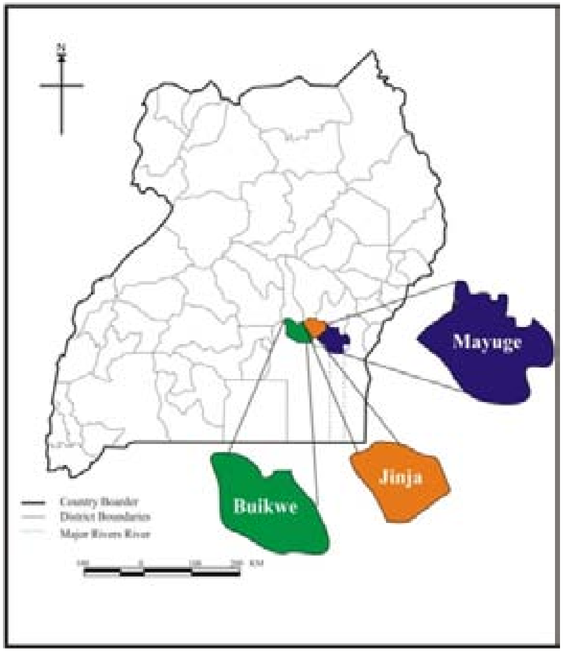

Figure 7.4.1: Map of Uganda showing the study locations of Buikwe, Jinja and Mayuge districts

The districts experience bimodal rainfall pattern typical often tropics, characterized by two rainy seasons (March to May and September to November), with two dry spells (December to February and June to August). The high rainfall puts the region in one of those ecological zones with the highest potential for crop cultivation, pasture production and intensive livestock, signifying a huge possibility to integrate crop and smallholder dairy farming for efficient natural resource exploitation and management. According to the Uganda Population and Housing Census (2002), the estimated mean population density was 256, 66, and 92.55 people per square kilometre for Buikwe, Jinja and Mayuge, respectively [5]. Agriculture is the main economic activity, but has of late suffered from seasonal unpredictable seasons characterized with unprecedented extremes of weather such as floods and severe droughts that lead to crop failure and increased feed scarcity. The mean agricultural area is 529, 601.1 and 603.3 km2 for Buikwe, Jinja and Mayuge districts, respectively.

Sampling Procedure, Sample Size, Data Collection and Analysis

Three districts were purposively selected based on the reported intensity of smallholder dairy farms (MAAIF, 2010). A three stage stratified multi-stage cluster sampling procedure was done; the first stage involved considering each of the districts as a homogenous group stratum (Domain of analysis). The second stage involved simple random sampling of three sub-counties per district in consultations with the district extension staff and sub-county extension officers. All the smallholder dairy farmers in the sampled sub-county were considered. Selection of households was also by simple random.

Sampling sample size was estimated using the following formula (Israel, 2009)

$$n = \frac{z^2_{\alpha/2}}{e^2} p(1-p)$$

where n = Sample size, $Z_{\alpha/2}$= Confidence interval at 95% (Standard value of 1.96) p = 10% of proportion of smallholder dairy farmers in LVZ, Uganda (UBOS, 2012) and e = desired levels of precision at 5%.

The chosen sample required then 14 respondents in each study site which was a sub-county totaling to 42 respondents per district 81 men and 45 women participated. Altogether, 81 men and 45 women participated in the three districts. Data was obtained using structured and semi- structured questionnaires administered by way of one-on-one direct interviews. Focus group discussions (one per sub-county) were also held to corroborate the information gathered in direct interviews. The questionnaires and focus group discussions were intended to capture information on production characteristics on smallholder dairy farms. The data captured was on household demographics, highest education level of household head, major sources of income into household, herd size, general challenges and available feed resources, labour activities and challenges in milk marketing. In order to establish differences among farmers' ranking of the different variables, farmers' responses were pooled and subjected to nonparametric statistics analysis (Kruskal – Wallis one-way analysis of variance) (XLSTAT., 2013). Variables were ranked by farmers using a scale of 1 to 5 with five being the most important factor. The computed mean of ranks were compared using multiple pair-wise comparisons to establish if there were significant differences in variables (Dunn , 1964). XLSTAT (2013) was used to generate summary statistics (frequencies, percentages and means) for the variables and later tabulated. Means of ranks of variables were analyzed using Chi square and were considered different at $P<0.05$.

Results

Household Demographics

Household demographics led into understanding of farming decisions, choice and levels of adoption of agricultural technologies in smallholder dairy farming system (Njarui et al., 2011). Across the household stratification, the majority of smallholder households in Lake Victoria Agro-ecological Zone (LVZ) were headed by males (Table 7.4.1). Household head is that person in the household who takes the overall social and economic decisions, assigns responsibilities, allocate resources and shoulders all the challenges and threats in the household. Besides, a household is defined as a group of persons who live and have meals together (UBOS, 2012).

Table 7.4.1: Household demographic profile of the smallholder dairy farmers in Lake Victoria agro-ecological zone, Uganda

Household characteristics	Buikwe (n = 42)	Jinja (n= 42)	Mayuge (n=42)
Female headed, %	28.57	66.67	30.95
Male headed, %	71.43	33.33	69.05
Average age of household head (years) Mean± SD			
51 ± 9	51 ± 9		
48 ± 11	48 ± 11		
50 ± 9	50 ± 9		
Average household size (persons) Mean± SD	6 ± 2	5 ± 1	6 ± 3
Dairy cattle farming experience (years) Mean± SD	10 ± 8	12 ± 8	11 ± 7

The proportion of the female-headed households was higher in Jinja than in Mayuge and Buikwe districts. The age range of household heads was between 37 to 60 years indicating socially active middle aged strong household heads with high energy levels of ambitions, expectations and high ability to take risks on investment for increased productivity. There was big range of variation in farming experience ranging between 2 to 20 years. The more years a household had in dairy farming, the more experienced and skilled it was in managing dairy cattle for improved productivity. Typically, household members comprised of husband, wife and children (Table 7.4.1). The household membership ranged from 4 to 9 members which directly impact on labour input availability in smallholder dairy farming system.

Education Level

The education level of the household heads in smallholder dairy farming system was relatively high in the study districts with majority having attained primary seven and above (Figure 7.4.2).

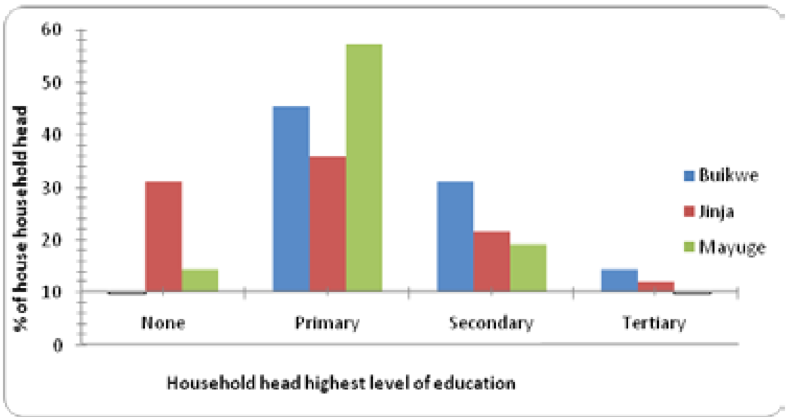

Figure 7.4,2: The highest level of education of the household heads in the smallholder dairy farming system in Lake Victoria Agro-ecological Zone, Uganda

Source of Income of Household Heads

There were variations in major sources of income of household heads between the three districts. The highest percentages of household heads in Jinja district were full time farmers (68.24%) compared with Buikwe (35.73%) and Mayuge (45%) where over 52.9% of household's heads were engaged in other businesses and employment apart from farming as indicated as in Figure 7.4.3.

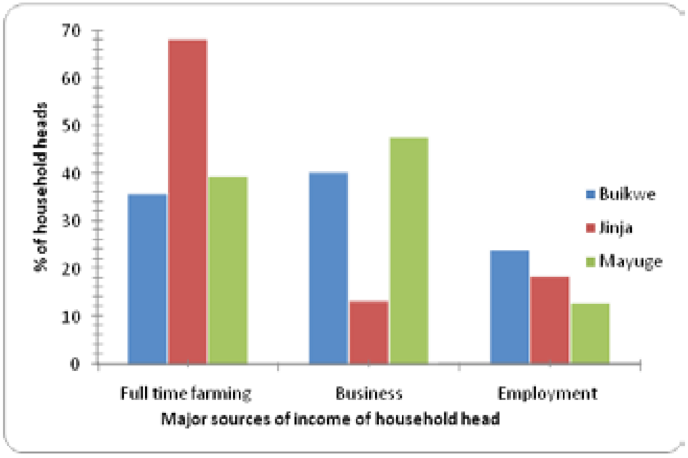

Figure 7.4.3: The major sources of income of household heads of smallholder dairy farmers in Lake Victoria Agro-ecological Zone, Uganda

Herd size and structure on smallholder dairy farms

Smallholder dairy households in the districts of Buikwe had a relatively larger dairy herd size (4.29 ± 0.86) compared to Jinja and Mayuge districts with herd size (3.12 ± 1.45 and 2.43 ± 1.12), respectively (Table 7.4.2). Cows constituted the highest proportion (48.3%) of the herd in Buikwe followed by heifers (22.34%). Smallholder dairy farmers in LVZ kept bulls for breeding purposes because artificial insemination services were reported to be unreliable.

Table 7.4.2: Mean ± SD dairy herd structure among smallholder dairy farmers in Lake Victoria agro-ecological zone, Uganda

Heard structure	Mean number			
	Buikwe	Jinja	Mayuge	SEM
Mature Bulls	1± 0.00	1 ± 0.00	1 ± 0.00	0.00
Cows	2.05 ± 0.44	1.14 ± 0.35	2.14 ±0.01	0.67
Heifer	1.02 ± 0.16	1.00 ± 0.00	1.00 ± 0.00	0.11
Male calves	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	0.00
Female calves	1.15 ± 0.37	1.00 ± 0.00	1.00 ±.0.00	0.29

Farmers ranking on challenges in smallholder dairy farming system

The farmers' ranking of the challenges facing smallholder dairy farming system in LVZ is as presented in Table 7.4.3. Chi square analysis showed that challenges in smallholder dairy farming system are highly significant p<0.0001 in all the districts. Feed scarcity which was highly pronounced during the dry season was unanimously ranked as the major challenge in all the three districts by farmers as one of the biggest challenge to productivity in smallholder dairy farming system in LVZ, Uganda.

Table 7.4.3: Smallholder dairy farmers ranking of challenges in Lake Victoria Agro-ecological Zone

District	Variable	Sum of ranks	Mean ranks	Rankings	(Chi^2, df =4 , p = 0.001)
Buikwe	Feed scarcity	2817.00	93.9^{c}	1	47.62
	Lack of basic knowledge	2304.00	76.8^{bc}	2	
	Livestock health	2037.00	70.24^{bc}	3	
	Limited Labour	1052.50	47.84^{ab}	4	
	Limited land	567.50	27.02^{a}	5	
Jinja	Feed scarcity	1587.50	72.16^{b}	1	46.14
	Livestock health	1217.50	55.34^{b}	2	
	Limited land	1173.50	53.34^{b}	3	
	Limited Labour	372.50	24.83^{a}	4	
	Lack of basic knowledge	305.00	20.33^{a}	5	
Mayuge	Feed scarcity	2659.00	91.69^{c}	1	45.56
	Livestock health	2114.00	72.89^{bc}	2	
	Lack of basic knowledge	1929.50	68.91^{bc}	3	
	Limited Labour	1019.50	46.34^{ab}	4	
	Limited land	534.00	26.70^{a}	5	

The current feeding regimes of dairy cattle in smallholder dairy farming system in LVZ is highly dependent on natural pastures and elephant grass as fodder only and alone they cannot lend themselves as good dairy cattle feed for balanced nutrition of high milk producing dairy cattle.

Farmers Ranking on Challenges in Smallholder Dairy Farming System

The farmers' ranking of the challenges facing smallholder dairy farming system in LVZ is presented in Table 7.4.4. Chi square analysis showed that mean ranks of challenges faced within smallholder dairy farming system significantly varied ($p<0.0001$) in all the districts. Feed scarcity which was highly pronounced during the dry season invariably topped the challenge rank and it was unanimously ranked as the major challenge in all the three districts by farmers as one of the biggest challenge to productivity in smallholder dairy farming system in LVZ, Uganda.

The current feeding regimes of dairy cattle in smallholder dairy farming system in LVZ is highly dependent on natural pastures and elephant grass as fodder. However, feeding elephant grass and natural pastures without supplementation cannot lend itself into a good dairy cattle feeding practice. Natural pastures and elephant grass if fed as sole feed resource would never meet the nutrition requirements of high milk producing dairy cattle.

Farmers Ranking on Feed Resource Utilization in Smallholder Dairy Farming System

Chi-square test showed that there was a significant difference ($p = 0.0001$) among farmers' ranking on availability of different feed resources in LVZ. The significant differences in farmers' ranking on levels of availability of feed resources were maintained among the districts (Table 7.4.4).

Table 7.4.4: Smallholder dairy farmers ranking of feed resources utilization in Lake Victoria agro-ecological zone

District	Feed resources	Sum of ranks	Mean of ranks	Ranking	(Chi^2, df=4 p-value)
Buikwe	Natural pastures	4865.5	121.6c	1	28.28, $p < 0.0001$
	Crop residues	4797.0	119.9c	2	
	Legumes	4102.5	105.2bc	3	
	Fodder pastures	3235.5	83.0ab	4	
	Agro-industrial by-products	2700.5	67.5a	5	
Jinja	Natural pastures	2603.0	76.6a	1	9.53, $p = 0.049$
	Agro-industrial by-products	2700.5	67.5a	2	
	Crop residues	1350.0	64.8a	3	
	Fodder pastures	1343.5	58.4a	4	
	Legumes	1264.	50.6a	5	
Mayuge	Natural pastures	4643.0	129.0b	1	47.76, $p < 0.0001$
	Crop residues	4133.0	114.8b	2	
	Agro-industrial by-products	2741.0	76.1a	3	
	Fodder pastures	2458.0	68.3a	4	
	Legumes	2315.0	64.3a	5	

Farmers' ranking on utilization of natural pastures was ranked highest in all the districts of Buikwe, Jinja and Mayuge with mean rank of 121.6, 76.6 and 129.0, respectively. In Jinja district, smallholder farmers ranked agro-industrial by-products as immediate alternative (mean ranks = 67.5). Farmers ranked utilization of crop residues as a second alternative in Mayuge and Buikwe (Mean rank = 114.8, 119.9) respectively. The farmers reported that utilization of natural pastures is limited to wet seasons. It was further identified that milk fluctuations in wet season and dry season in smallholder dairy farming system was because of high dependence on natural pastures that depend on natural rains/ seasons. Other feed resources utilized were fodder pastures and legumes. The high cost of commercial feeds affected its utilization which was attributed to limited investment by entrepreneurs in value addition to the abundant agro industrial by-products. The findings are in line with [6] who identified poor livestock nutrition, lack of basic knowledge as well as unfair balance of trade in smallholder farms as the important challenges that require urgent attention.

Availability of Labour in Smallholder Dairy Farming

The activities performed in the smallholder dairy cattle farming system in LVZ, Uganda are shown in Table 7.4.5. Most of these are performed daily, indicating that smallholder dairy farming is labour intensive system. There were no distinct age and sex division of labour, but all gender contributed to all farm activities. However, there were disparity in level of labour contribution between men, women and children for activities related to dairy production. In Buikwe and Mayuge on average, men contributed more labour (41.4 and 40.9%, respectively) in the dairy unit than women (22.1 and 24.1%, respectively). Women's labour activities were highest in shade cleaning than in any other activity while men's highest labour activities were in chopping and feeding, milking, marketing of milk and spraying against ticks as indicated in Table 7.4.5.

Table 7.4. 5: Labour activities in smallholder dairy farming system of Lake Victoria Agro-ecological Zone, Uganda

Activity	Number of individuals performing the activity %											
	Buikwe				Jinja				Mayuge			
	W	H	C	HR	W	H	C	HR	W	H	C	HR
Garden preparation and crop planting	52	21	10	17	63	9	7	21	69	5	8	18
Harvesting and transportation of feed	11	41	14	34	16	23	8	53	19	25	1	55
Chopping and feeding	8	54	7	31	8	38	4	50	5	35	6	64
Water collection and watering animals	47	12	13	28	18	9	6	67	22	26	0	52
Shed cleaning	48	10	10	32	42	8	4	46	51	5	4	40
Milking	2	66	14	18	5	34	5	56	9	77	2	12
Marketing	2	66	14	18	5	34	5	56	9	77	2	12
Spraying the animals	7	61	14	18	5	34	5	56	9	77	2	12
Average	**22.1**	**41.4**	**12**	**24.5**	**20.2**	**23.6**	**5.5**	**50.6**	**24.1**	**40.9**	**3.1**	**33.1**

In general, women tended to contribute highest to activities that did not directly involve money transactions while men mainly concentrated on tasks that immediately generated income. Irrespective of whether dealing with more pastures urban or rural districts, milking and marketing of milk was preserved for men while cleaning the shed was an activity for women. In Jinja, labour activities to the dairy units were carried out mainly on hired labour.

Challenges of Milk Marketing in Smallholder Dairy Farming System

Chi-square test showed how farmers ranked the challenges associated with raw milk marketing in LVZ in the three districts (Table 7.4.6). Poor price was the top most challenge identified by the farmers while unstable price of milk was ranked the second major challenge in all the districts all the districts (Table 7.4.6). Limited value addition to the highly perishable milk rendered it rather difficult to fetch reasonable prices despite its high local demand at the farms. Instability in milk price proves the high dependence on natural pastures as source of nutrients, which was dependent on weather situation. Generally, during the wet season, there was improved feed availability leading to increased milk output per household that would result into reduced milk prices, while in the dry season milk output was low resulting in increased prices.

Table 7.4.6: Smallholder dairy farmer's rankings of challenges on milk marketing in Lake Victoria agro-ecological zone, Uganda

District	Variables	Sum of ranks	Mean of ranks	Ranking	(Chi^2 , df=4, p-value)
Buikwe	Poor price	1633.50	71.02c	1	32.79, P = 0.0001
	Fluctuation in price	1296.50	56.37bc	2	
	Perishable product	1165.50	52.98bc	3	
	Delayed payments	634.50	37.32ab	4	
	Long distances to market	320.00	21.33a	5	
Jinja	Poor price	579.50	41.39b	1	17.52, P = 0.002
	Fluctuation in price	498.50	35.61ab	2	
	Long distance to market	412.50	31.73ab	3	
	Perishable product	187.00	18.7a	4	
	Delayed payments	152.50	16.94a	5	
Mayuge	Poor price	1269.00	63.45c	1	33.12, P = 0.0001
	Fluctuation in price	966.00	48.3bc	2	
	Perishable product	902.00	47.47bc	3	
	Long distances to market	473.50	31.56ab	4	
	Delayed payments	217.50	16.73a	5	

Discussion

Demographic Characteristics of the Households

The possible explanation of proportion of higher female households heads in Jinja district than in other districts of Buikwe, Mayuge was because, Non-Governmental Organizations (NGO), "Heifer Project International", which operated in the region prior to the study targeted women for economic empowerment and those who had been widowed by HIV/AIDS for receipt of in calf heifers, hence a relatively high proportion of women household heads who owned dairy cattle. This is supported by the fact that the average age of household head in Jinja was lower compared to Buikwe and Mayuge. Average household members in Jinja were also lower than those in Buikwe and Mayuge respectively. Typically, household members comprised of husband, wife and children. The size of household members could influence labour availability in dairy farming with Jinja having less labour available to perform dairy activities and relied most on hired labour. Availability of labour in any production system has a significant influence on productivity and since smallholder dairy farming system is labour intensive (Njarui et al., 2011) labour costs and availability had fundamental influence on productivity.

Buikwe district had more farmers who had finished tertiary institutions of learning, suggesting that adoption levels in Buikwe for a new innovation can be high compared to other districts. [15] noted that raising in education levels is proportional to level of adoption of agricultural technologies which is consistent with the general belief that adoption levels are positively correlated with levels of education. This is possibly because education influences the ability of farmers to interpret the technical recommendations that may require some level of education. Furthermore, [16] noted that literate farmers can comprehend the benefits from extension information and they are aware of the consequences of the prevailing challenges if they are not addressed in time.

Majority of the farmers in Buikwe and Mayuge had other main sources of income, while smallholder dairy farmers in Jinja relied on dairy farming as their main source of income. This is consistent with (Njarui et al., 2011) who made similar observation where high number of female-headed households in Masaka district in Uganda, who received animals from NGO (send a cow), had no other alternatives form of employment and household income. However, smallholder dairy farming in LVZ seems to be unstable venture due to low investment levels unreliable inputs and lack of infrastructural development such as milk collection centers and coolers to preserve milk which is not immediately consumed. Thus farmers seek other alternative livelihood complimentary means for their livelihoods that sometimes become competitive, deny smallholder dairy farming an opportunity for further knowledge and capital investment.

Challenges in Smallholder Dairy Farming System

While increased animal productivity has been identified as one of the options for increasing incomes, household nutrition and livelihood of the rural households (MAAIF, 2010) feed scarcity was unanimously identified by the farmers as one of the biggest challenge to increased milk productivity in LVZ. The consequence of feed scarcity to smallholder dairy farming system is poor milk yield, distortion of the estrus cycles, poor body condition and long calving intervals (Kaunda, 2011). Farmers therefore miss opportunities on proceeds from milk sales and offspring as a result long calving interval (Lukuyu et al., 2011). The generally high cost of commercial supplementary feeds irrespective of seasons in LVZ, despite the abundance of agro-industrial by-products points to limited investment of both knowledge and capital in value addition. This is in agreement with earlier observation by (Mubiru et al., 2011) who observed that low milk yield in Uganda is attributed to poor feeding methods resulting from not meeting the right nutritional requirement of dairy cattle. Similarly, limited value addition to highly perishable milk renders it rather difficult to fetch reasonable prices despite its local demand right at the farm. These results are consistent with earlier findings (Njarui et al., 2011) which indicated that poor milk price is a major challenge to increased dairy productivity in peri-urban areas of East and Central Africa.

Labour Activities in Smallholder Dairy Farming

Most activities were performed daily, implying that dairy farming is a labour intensive enterprise. There were no distinct age and sex division of labour, but all gender contributed to smallholder dairy activities. However, there were disparities in level of labour contribution between men, women and children. In Buikwe and Mayuge districts, on average, men contributed more labour in the dairy unit than women, but in Jinja, men contributed marginally more labour than women. Women contributed labour highly in shed cleaning than in any other activity while men contributed highest in milking, marketing milk and spraying against ticks. Possibly, cultural inclinations in majorly patriarchal societies in the study area where men are seen as household bread winners explains why men were responsible for those activities involving cash transactions in the dairy enterprise. Similarly, all decision concerning labour activities of the enterprise were unilaterally made by the heads of households the majority of whom were men. The contribution of children to running of dairy unit was insignificant, less than 7% on average of total labour activities. Notably, children did not participate in cutting forages, feeding and watering of the animals. The low contribution of children was primarily because they attended school during week days and they were only available during week-ends and holidays.

Nonetheless, the family labour was not sufficient to run the dairy unit and significant labour was sourced from outside particularly in Jinja. In Jinja, overall hired labour contributed more than half of the total labour required in running of the dairy enterprises. This implies that external labour is important for the success of dairy farming in the LVZ given the low levels of mechanization. This scenario was also reported by Njarui et al., 2011 who found out that hired employees contributed about 50% of the entire labour requirement of the dairy unit in the rural areas of semi-arid Kenya.

Conclusions and Recommendations

The conclusions drawn from this study are that lack of knowledge to make timely decisions on available feed resources, limited value addition to highly perishable milk and lack of basic equipment to reduce on hard work are major outstanding challenges pulling down dairy productivity. The efficiency of production and marketing of milk should be improved in order to enhance smallholder dairy production in LVZ, Uganda. Therefore milk productivity can be enhanced through appropriate engagement with the farmer to generate sustainable option to improve nutrient supply throughout the year. Highly appreciated and utilized crop residues and agro-industrial by-products should be identified, limitation to utilization evaluated and supplementary dairy cattle ration based on highly abundant and agro-industrial by-product and crop residue be formulated. Appropriate on-farm feed conservation practices that include biological processing of highly fibrous and lignified crop residues, hay and silage making be promoted on farm. Furthermore, it is necessary to conduct on-farm strategic studies in LVZ, Uganda to upgrade and enhance utilization of crop residues and agro-industrial by-products identified by this study as alternative dairy cattle feeding strategy to meet nutrient requirement during the dry seasons.

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7.5 Prioritization of agro-industrial by-products for improved productivity on smallholder dairy farms in the Lake Victoria Crescent, Uganda

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Introduction

Shortages and fluctuating quality and quantity of animal feed resources impose major constraints to productivity on smallholder dairy farm in Uganda. However, from the production and processing of plants for human food production, agro-industrial by-products are generated and are potentially suitable for the feeding of dairy cattle (Kabi et al., 2013), Lukuyu et al., (2011) reported that agro-industrial by-products play an important role on smallholder dairy farms in Sub-Saharan Africa for supply of metabolisable energy (ME) and crude protein (CP) which are key components in feeding dairy cattle for optimum productivity.

Smallholder dairy farming, where 1 to 5 head of cattle are reared on less than 0.5 to 5 acres of land, is an integral part of livestock production systems that provides food, manure for crop production, income and employment (Kabirizi et al., 2006)). In Uganda, development strategy and investment plan (DSIP) clearly recognize the role of smallholder dairy farmer in economic growth and poverty reduction (MAAIF, 2010). Under the Eastern Africa Agricultural Productivity Project (EAAPP) there has been a deliberate effort aimed at increasing smallholder dairy productivity. However, smallholder dairy farming system in Uganda often fails to attain maximum production limit of their potential, because of inability to obtain adequate required amounts of ME and CP (Mubiru et al., 2007). It is documented that smallholder dairy farmers in Uganda provide only 59% and 36% of the required ME and CP, respectively (Mubiru et al., 2011). According to (Mugerwa et al., 2012), Uganda has the potential to produce enough agro-industrial by-products for dairy cattle feeding, especially in Lake Victoria Agro-ecological Zone (LVZ) to provide adequate nutrition to match the present trend. Therefore, exploring the potential to prioritize agro-industrial by-products will lead to economically feasible as well as socially acceptable feed management strategies for improved sustainable productivity of smallholder dairy farm.

Despite the potential of agro-industrial by-products, their utilization in smallholder dairy farming system is limited. Therefore understanding utilization, spatial and temporal variability, and limitation to utilization will give an insight on prioritizing agro-industrial by-products. This will build coherent principles required to develop appropriate feeding strategies for sustainable productivity on smallholder dairy farms. The objective of the study was to establish use, variability and limitations to utilization of agro-industrial by-products in smallholder dairy farming system.

Materials and Methods

Description of the Study Area

The study was conducted in the Lake Victoria Agro-ecological Zone (LVZ) of Uganda which hosts the majority of smallholder dairy farmers (MAAIF, 2010). Three districts namely Buikwe (0018'4.32 N and 3303'6.63 E), Jinja (0025'28 N and 33012'15 E) and Mayuge (0027'35 N and 33028'49 E) were selected for the study based on the intensity of smallholder dairy farms (Figure 7.5.1).

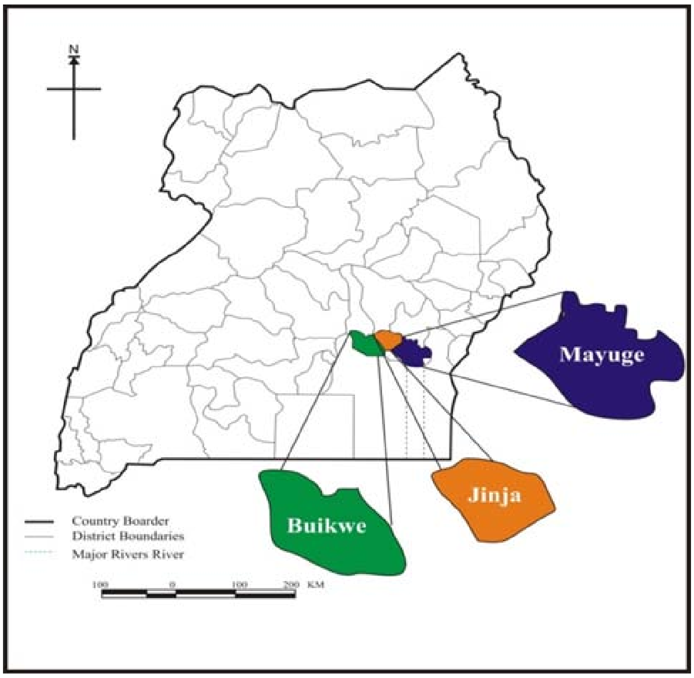

Figure 7.5.1: Map of Uganda showing the location of Buikwe, Jinja and Mayuge districts

The mean daily temperature ranged between 16-28°C, 18-28°C and 17-27°C for Buikwe, Jinja and Mayuge Districts respectively. The mean annual rainfall ranged between 1279 to 1544 mm, 1200 to 1500 mm and 1100 to 1500 mm for Jinja, Mayuge and Buikwe, respectively. The districts experienced tropical climate bimodal rainfall pattern characterized by two rainy seasons (March to May and September to November) with dry spells (December to February and June to August). According to the Population and Housing Census of 2002, the estimated mean population density was 256, 66, and 92.55 people's km^{-2} for Buikwe, Jinja and Mayuge, respectively (UBOS, 2012). Agriculture is the main economic activity in the zone, and the level of agricultural productivity at farm level greatly influences household's social- economic status.

Dairy cattle are mainly raised under intensive and semi-intensive smallholder management systems with the majority of farmers keeping between 1 to 5 head of cattle under stall feeding. Mean agricultural area is 529, 601.1 and 603.3 km^2 for districts of Buikwe, Jinja and Mayuge respectively.

Sampling Procedure, Sample Size, Data Collection and Analysis

A purposive multi-stage sampling design was employed in this study. In the first stage, the country was stratified into ten (10) strata (Agro-ecological Zones) on the basis of geographical demarcations. In the second stage, one out of the ten agro-ecological zones was purposively selected. In the third stage, three administrative districts were randomly selected as domain of analysis from the agro-ecological zone. In the fourth stage, three sub-counties per district were randomly selected, in the fifth stage three parishes per sub-county were randomly selected and a list of smallholder dairy farmers was developed per parish from respective extension officers in these three administrative districts. Finally, 7% of the farmers were randomly selected, 126 smallholder dairy households were interviewed across the agro-ecological zone. Primary data were collected through structured and semi- structured questionnaires administered by way of one-on-one direct interviews. Focus group discussions (one per sub-county) were also held to corroborate the information gathered in direct interviews. Secondary data were collected from document reviews at the district headquarters.

In order to establish differences among farmers' ranking on utilization, variability and limitations to utilization of agro-industrial by-products, farmers' ranking were pooled and subjected to nonparametric statistics analysis (Kruskal–Wallis one-way analysis of variance) using [9]. Using multiple pair-wise comparisons, the computed mean of ranks were used to establish if there were significant differences in utilization levels, variability, availability and limitations to utilization of agro-industrial by-products (Dunn, 1964), (XLSTAT, 2013) was used to generate descriptive statistics for the variables.

Results

Utilization of Agro-industrial By-products

Farmers supplement their animals with various types of agro-industrial products (Table 7.5.1). Four agro-industrial by-products were identified and ranked based on their utilization by farmers using a scale of 1 to 4 with four being the most utilized agro-industrial by-product and l the least utilized. Chi-square test at $p < 0.01$, df = 3 showed a significant differences among farmers' ranking on utilization of agro-industrial by-products.

Table 7.5.1: Smallholder dairy farmers' rankings of agro-industrial by-products utilization in LVZ, Uganda

District	Agro-industrial Bi-products	Sum of ranks	Mean of ranks	Ranking	Chi²
Buikwe	Cotton seed cake	1264.00	37.18ª	4	42.64
	Maize bran	3800.00	88.37ᵇ	3	
	Brewers spent grains	4031.00	93.74ᵇ	2	
	Molasses	4271.00	99.33ᵇ	1	
Jinja	Cotton seed cake	537.00	29.83ª	4	29.50
	Maize bran	1587.00	48.09ª	3	
	Molasses	2305.50	69.86ᵇ	2	
	Brewers spent grains	2473.50	74.95ᵇ	1	
Mayuge	Cotton seed cake	2250.50	66.19ª	4	13.33
	Maize bran	3502.00	77.82ᵃᵇ	3	
	Brewers spent grains	3933.50	89.40ᵃᵇ	2	
	Molasses	4849.00	103.17ᵇ	1	

[ab] means in the same row and same district without common letter are significantly different $p<0.05$

Factors Enhancing Utilization of Agro-industrial By-products in LVZ, Uganda

Factors enhancing utilization of agro-industrial by-products in LVZ were ranked by farmers and analyzed. Chi-square test at p<0.01, df = 4 showed significant differences among the farmers' rankings (Table 7.5.2).

Table 7.5.2: Farmers' rankings of factors that enhance use of agro-industrial by-products unprocessed

District	Agro-industrial Bi-products	Sum of ranks	Mean of ranks	Ranking	Chi²
Buikwe	Expensive supplementary feeds	2817.00	93.9^{c}	1	47.64
	Land shortage	2304.00	76.8b^{c}	2	
	Lack of basic equipment	2037.00	70.24^{bc}	3	
	Marketing infrastructure	1052.50	47.84^{ab}	4	
	Expensive labour	567.50	27.02^{a}	5	
Jinja	Land shortage for fodder production	1587.50	72.16^{b}	1	46.14
	Expensive supplementary feeds	1217.50	55.34^{b}	2	
	Expensive labour	1173.50	53.34^{b}	3	
	Marketing infrastructure	372.50	24.83^{a}	4	
	Lack of basic equipment	305.00	20.33^{c}	5	
Mayuge	Marketing infrastructure	2659.00	91.69^{bc}	1	45.56
	Expensive supplementary feeds	2114.50	72.89^{bc}	2	
	Land shortage	1929.50	68.91^{bc}	3	
	Lack of basic equipment	1019.00	46.34^{ab}	4	
	Expensive labour	534.00	26.70^{a}	5	

^{ab} means in the same row and same district without common letter are significantly different p<0.05

Spatial and Temporal Variability on Availability of Agro-industrial By-products

The variability of agro-industrial by-products were ranked by farmers basing on their memory of past experience. There were significant difference (p>0.05) in variability of agro-industrial by-products generally in all the seasons throughout the year across LVZ, in Uganda (Table 7.4.3).
Smallholder Dairy Farmers' Rankings of Limitations to Utilization of Agro-industrial By-products in LVZ, Uganda

Limiting factors to utilization of agro-industrial by-products were identified and ranked by smallholder dairy farmers as presented in Table 7.5.4. Five limiting factors were identified and ranked using a scale of 1 to 5, with 5 being the most limiting factor affecting utilization of agro-industrial by-product and 1 the least limiting factor. Chi-square test showed a significant difference at p<0.01, df = 4 among farmers rankings across the LVZ.

Table 7.5.3. Farmers ranking of spatial and temporal variability on availability of agro-industrial by-products in LVZ

District	Season	Variability	Mean Rank	P-value	df
Buikwe	1st rain season (March to May	Low	21.70	0.81	1
		Moderate	20.00		
Jinja		Low	21.27	0.79	1
		Moderate	23.20		
Mayuge		Low	21.34	0.62	1
		Moderate	22.70		
Buikwe	2nd rain season (September to November)	Low	21.90	1.18	1
		Moderate	19.50		
Jinja		Low	21.8	0.67	1
		Moderate	20.00		
Mayuge		Low	21.5	0.43	1
		Moderate	21.5		
Buikwe	1st rain season (June to August)	Low	11.00		
		Moderate	25.50	4.88	2
Jinja		High	22.06		
		Low	12.50		2
		Moderate	26.08	4.02	
Mayuge		High	21.77		
		Low	11.00		
		Moderate	26.50	6.59	1
		High	21.88		
Buikwe	2nd rain season (Dec to Feb)	Low	15.20	2.34	1
		High	22.35		
Jinja		Low	16.70	1.38	1
		High	22.15		
Mayuge		Low	18.90	1.2	1
		High	21.85		

Table 7.5.4. Smallholder dairy farmers' rankings of limitation to utilizing of Agro-industrial by-products

District	Limitations	Sum of ranks	Mean of ranks	Ranking	Chi-square
Buikwe	High input cost	6504.50	151.27[c]	1	53.04
	Inadequate knowledge	5609.00	130.44[b]	2	
	Limited knowledge to preserve	4337.50	100.87[b]	3	
	Poor market infrastructures	3191.50	77.84[a]	4	
	Processing and storage	3148.50	73.22[a]	5	
Jinja	High input cost	3623.00	109.79[b]	1	34.78
	Inadequate knowledge on usability	3356.00	101.70[b]	2	
	Limited knowledge to preserve	2586.50	80.83[ab]	3	
	Poor market infrastructures	2277.00	69.00[a]	4	
	Processing and storage	1687.50	51.14[a]	5	
Mayuge	High input cost	9175.00	183.50[d]	1	82.80
	Inadequate knowledge on usability	7725.00	154.50[c]	2	
	Limited knowledge to preserve	6375.00	127.50[b]	3	
	Processing and storage	4475.00	89.50[ab]	4	
	Poor market infrastructures	3625.00	72.50[b]	5	

Methods practiced by smallholder dairy farmers to store, process and preserve agro-industrial by-products

Table 7.5.5 shows the different methods used by the farmers to process and store agro-industrial by-products.

Table 7.5.5. Methods used by the farmers to store, process and preserve agro-industrial by-products in LVZ, Uganda

	% of households undertaking the practice on				
	Methods	BS	M	MB	CSC
Storage	Home heaps	53			
	Pits	23.4			
	None	12			
Processing	Additives to other feedstuff	15	61.1	100	100
Presentation	Drying	21.2			
	Mult-nutrient block		2.4		

BS = Brewers spent grain, M = Molasses, MB = Maize bran, CSC = Cotton seed cake

While 23.4% of the farmers' stored brewers spent grains in ground pits, 21% preserved it by drying and 12% used it directly. It was also observed that 61.1 % of the farmers mixed molasses with fodder especially in dry season to improve dry matter intake, while 2.4% used it in home-made multi-nutrient block. Maize bran and cotton seed cake were utilized as additive to the basal feed.

Discussion

Utilization of Agro-industrial By-products

The possible explanation for significant utilization of agro-industrial by-products in the study area was because of geographic comparative advantage that made most of agricultural processing industries such sugar factories, maize milling, brewery and oil manufacturing factories to be situated in this area. For this reason, smallholder dairy farmers in the study area have access to most of the agro-industrial by products. Use of agro-industrial by-products in LVZ is still limited to only four by-products implying that there could be some other factors limiting their integration. On the other hand, there is limited literature on utilization of agro-industrial by-products by farmers in smallholder dairy farming system in the zone in particular and generally in Uganda, unlike in other developing countries (Mugerwa et al., 2012). The current dairy cattle feeding regimen that heavily depends on elephant grass as the major source of nutrients to dairy cattle confirms earlier studies by (Kabirizi et al., 2006), which indicated that elephant grass is the most dominant and more frequently used source of energy in Uganda. Such poor supplementary regime does not lend itself into good husbandry for highly yielding dairy cattle, which probably explains the low productivity in smallholder dairy farming system in LVZ, of Uganda. Although molasses was ranked protein, it was not surprising to note that smallholder farmer whose animals depend mostly on natural pasture were supplemented with molasses, brewers spent grain, dairy meal and home-made concentrates to augment the protein and energy deficient pastures. Limited use of agro-industrial by-products to make home-made concentrates despite its high affordability by farmers was probably because the farmers had limited expertise to formulate the concentrates suggesting a need for more farmers' training. The findings imply that in Mayuge district farmers urgently require immediate solutions on how to process homemade concentrates for dairy cattle from agro-industrial by-products than any other district. number one agro-industrial by-product utilized by smallholder dairy farmer in the study area, it was reported to face stiff competition from alternative use in other cottage and commercial industries like ethanol production, local brew production and thermal power generation (Kabi et al., 2013). The potential of brewers spent grain to provide economical viable feed supplement to dairy cattle in the study area remains credible since there was no significant difference between molasses and brewers spent grain across all districts (Table 7.5.1).

Factors Enhancing Utilization of Agro-industrial By-products in LVZ, Uganda

Most of the smallholder dairy farmers in the area of study own between 0.5 to 5 acres of land which limits them in forage production. As such, the available forage is usually deficient to meet the nutritional requirements of their animals paving way for high levels of supplementation. The smallholder farmers largely keep cross-breed animals whose response to supplementation with high value protein is significant compared to local breeds as earlier reported (Dhiman et al., 2003). Given the fact that natural pastures are usually deficient in protein, it was not surprising to note that smallholder dairy farmer whose animals depend mostly on natural pastures and homemade concentrates to augment the protein and energy deficient pastures. Limited use of agro-industrial by-products to make homemade concentrates despite its affordability by farmers was probably because the farmers had limited expertise to formulate the concentrates suggesting a need for more farmers training. The funding imply that in Mayuge District farmers urgently required solution on how to process homemade concentrates for dairy cattle from agro-industrial by-products than any other district.

Spatial and temporal variability of agro-industrial by-products

The spatial and temporal variability of agro-industrial by-products in area of study was not significant and indicated low levels of variability in utilization. Farmers in LVZ ranked utilization of agro-industrial by-products as high in the dry seasons and slightly low in wet season. In a related study, similar relationship between utilization levels and season was earlier reported by farmers in Tanzanian western rangeland zone, Morogoro peri-urban area (Mlay et al., 2005). This is consistent with (Ngongoni et al., 2006), who stated that peak agro-industrial by-product utilization occurs during dry season. (Preston and Leng, 1987) noted that periods of intense utilization of agro-industrial by-products reflect the dynamics of dairy cattle nutrient requirements. During the dry season, forages are low in essential nutrients such as nitrogen, energy, minerals and vitamins required for optimal rumen microbial growth (Mlay et al., 2005). Thus it is very important to supplement with agro-industrial by-products for supply of deficient nutrients in poor quality forage during the dry period.

During focus group discussions farmers reveled that supplementing dairy cattle during dry season improves productivity in terms of milk yield and calving interval. This suggests that supplementing during dry season meets the high physiological nutrient demands for lactating animals hence improving on their productivity.

Limitation to utilization of agro-industrial by-products in LVZ, Uganda

The generally high cost of inputs ranked as the main limitation across all the districts (Table 7.5.1) irrespective of season was attributed to scarcity of supplementary feeds due to limited knowledge by farmers in value addition to the abundant agro industrial by-products. Similarly, poor marketing infrastructures that limited value addition to the highly perishable milk were a bottle neck to farmers to fetch reasonable prices. Therefore, in agreement with earlier observation [2], inadequate knowledge usability, limited knowledge on preservation, unstable supply, inadequate processing and storage of agro-industrial by-products were identified as very important limitations that need urgent attention if challenges that limit dairy cattle productivity are to be eliminated. Furthermore, lack of infrastructural development such as milk coolers in the area to preserve milk which is not immediately consumed locally especially during the wet season coupled with lack of equipment to reduce on drudgery of labour was reported to negatively impact on smallholder dairy productivity. It was evident in the study that although to some extent farmers were aware of the nutritive attributes of agro-industrial by-products to dairy cattle, they did not fully exploit the resource.

Storage, Processing and Preservation of Agro-industrial By-products

Based on storage, preservation and processing skills, farmers identified three methods of storage, two methods of preservation and two methods of processing, which were remarkably consistent with scientific methods. Such knowledge is worth documenting, promoted and where possible improved on to facilitates communication between farmers, extension staff and scientists on agro-industrial by-product utilization. The quantity and time period during which they are available, storage properties, cost of transport, preparation, and preservation are determinants for their utilization (Lentes et al., 2010b). In view of the reported shortages of conventional feeds for dairy cattle, there is a need to develop technologies that are already known to farmers, using more social economic efficient scientific strategies to obtained protein and energy supplements for improved productivity.

Conclusions

It was evident in the study that farmers are aware of the importance of agro-industrial by-products in dairy cattle feeding. Although a number of factors were fronted to explain variations in dairy cattle productivity, majority of smallholder dairy farmers attributed the challenges to social-economic deterioration associated with inadequate knowledge to processes, preserve and store agro-industrial by-products. Utilization of agro-industrial by-products was high during dry periods when natural pastures and forages are low. Sustainable agro-industrial by-products management strategies on smallholder dairy farm should not only target dry season, but also focus on ensuring sustainable nutrient supply for optimum productivity. Prioritizing agro-industrial by-products management strategies that enhance sustainable nutrient supply will help meet physiological nutrient demands by productive animals and thus mitigate productivity surges. It is also necessary to conduct scientific experimental investigations to establish appropriate economic inclusion levels of agro-industrial by-products. Such information would assist to guide management decisions in an attempt to maintain viable productivity equilibrium between nutrient supply and other farm input components. The study has also provided some basic information about farmers' knowledge of the utilization and limitations of agro-industrial by-products that could aid the development and promotion of sustainable and socially acceptable feeding strategies for smallholder dairy farming system. Smallholder dairy farmers demonstrated knowledge of the importance, limitation, spatial and temporal distribution of agro-industrial by-products. The study revealed that efforts aimed at prioritizing integration of agro-industrial by-products into dairy cattle feeds in LVZ should focus on technologies of processing, preservation and storage.

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7.6 Prioritization of crop residues for improving productivity on smallholder dairy farming households in the Lake Victoria Crescent, Uganda

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Introduction

Because of its contribution to the socio-economic development of rural Uganda in both food security and in- come generation, especially, among women and other disadvantaged groups, smallholder dairy production sys- tem has received considerable support from the Government of Uganda as well as non-government organizations (Kabirizi et al., 2006). Moreover, by functioning as a store of wealth (Winrock International, 1992) and supplying manure for crop production (Kabi et al., 2007), dairy cattle fit very well in integrated crop-livestock systems. In Uganda, dairy cattle play a key role in the nutrition, of most households with per capita milk consumption of about 58 litres (MAAIF, 2010) against FAO requirement of 200 litres per person per year (FAO, 2012). While annual average milk yield per cow per lactation per year of 305 days in developed countries can go above 8000 kg, less than 2000 kg is obtainable from pure dairy breeds, 1000 from cross breeds and 500 kg from indigenous cows in Uganda (Bahiigwa et al., 2005). These statistics are obviously distressing in light of the rapidly growing human population at a rate of 3.2% annually (UBOS, 2012). In Mugerwa (2012) it is singled out that feed scarcity leads to poor nutrition which is a key constraint holding down production efficiency and health of the dairy cow on smallholder dairy farms in Lake Victoria Agro-ecological Zone (LVZ). Poor nutrition of dairy cattle is exaggerated by drought induced feed scarcity attributed partly to change in climate and demographics. As human population increases demand for milk also increases, crop production expands, availability of land for forage production decreases contributing towards dairy cattle feed scarcity. With projected increase in demand for milk, coupled with declining land size for forage production due to demographic pressure, it seems inevitable for farmers to embrace alternative feed resources. Utilization of crop residues therefore seems a logical alternative to address the escalating levels of feed scarcity among smallholder dairy farming systems (Lentes et al., 2010). Efficient utilization of crop residues however faces a number of intriguing challenges that include low levels of metabolized energy and crude protein (Tesfaye et al., 2007) seasonal variability (Tsopito et al., 2004), bulky (Walli et al., 2008) and poor keeping qualities (Anandan et al., 2010). These challenges should be acknowledged for appropriate technological innovations that prioritize crop residues as alternative feed to supply nutrients to dairy cattle for improved productivity on smallholder farm.

Crop residues have been used as livestock feeds since time immemorial and are readily available feed re- sources (Njarui et al., 2011), however their nutritional value is poor and well documented (Tesfaye et al., 2007) (Tsopito et al., 2003). Considerable research efforts have been devoted into improving their nutritional value through crop management and breeding, physical, biological and chemical treatments as well as supplementation with high protein oil cakes, green fodder, and tree leaves (Mugerwa et al., 2012) (Preston et al., 1987). However, on-farm implementations of these strategic innovations seem unsatisfactory. Further- more, in Uganda there is scanty of information on crop residue utilization, temporal and spatial variability as well as limitations associated with utilization on smallholder dairy farms unlike in other developing countries. Which make a basis in identifying opportunities, to priorities feeds from crop residues for improved nutrition that translate into enhanced productivity on smallholder dairy farming household. Thus this survey was designed to assess crop residues variability, limitations and opportunities in LVZ for future research on developing appropriate dairy feeding systems that utilize crop residues. These will in long run secure smallholder dairy farming from demographic pressure and substance farming to improved productivity and sustainable farming system.

Materials and Methods

Description of the Study Area

The study was conducted in the Lake Victoria Agro-ecological Zone of Uganda which hosts the majority of smallholder dairy farmers. Three districts namely Buikwe (0˚18′4″N and 33˚3′6″E), Jinja (0˚25′28″N and 33˚12′15″E) and Mayuge (0˚27′35″N and 33˚28′49″E) were selected for the study based on the intensity of smallholder dairy farms (Figure 7.6.1). The mean daily temperature ranges between 16˚C - 28˚C, 18˚C - 28˚C and 17˚C - 27˚C for Buikwe, Jinja and Mayuge Districts. The mean annual rainfall ranges between 1279 to 1544 mm, 1200 to 1500 mm and 1100 to 1500 mm for Jinja, Mayuge and Buikwe respectively. The districts experience a tropical climate bimodal rainfall pattern characterized by two rainy seasons (March to May and September to November) with dry spells (December to February and June to August). According to the Population and Housing census (2002), the estimated mean population density was 256, 658 and 92.55 per person km-2 for Buikwe, Jinja and Mayuge respectively. Agriculture is the main economic activity, prolonged droughts that lead to crop failure and increased feed scarcity is the main constraints to agricultural production.

Dairy cattle are mainly raised under intensive and semi-intensive smallholder management systems with majority of farmers keeping between 1 to 5 head of cattle under stall feeding with negligible grazing and tethering. The mean agricultural area is 529, 601.1 and 603.3 km2 for districts of Buikwe, Jinja and Mayuge respectively.

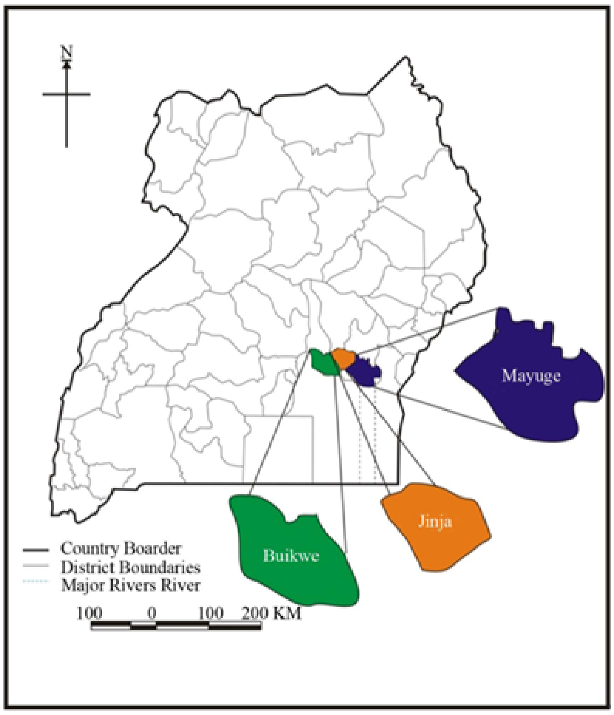

Figure 7.6.1. Map of Uganda showing the location of Buikwe, Jinja and Mayuge districts.

Sampling Procedure, Sample Size, Data Collection and Analysis

The study was conducted in three districts (Buikwe, Mayuge and Jinja) which were purposively selected based on the intensity of smallholder dairy farms. Three sub-counties were randomly selected from each district. After consultations with the district extension staff and sub-county extension officers and following all procedures of systematic random sampling selection, fourteen respondents were selected from each sub-county totaling to forty two respondents per district. Data was obtained using pre-tested structured and semi-structured questionnaires administered by way of one-on-one direct interviews. Focus group discussions (one per sub-county) were held to corroborate the information gathered in direct interviews. The questionnaires and focus group discussions were intended to capture information on availability, variability and limitations to utilize crop residues on smallholder dairy farms.

In order to establish if there were statistical significance among farmers' ranking of crop residues utilization, variability and limitations in utilization of crop residues, farmers' responses were pooled and subjected to non- parametric statistics analysis (Kruskal-Wallis one-way analysis of variance) using [16]. Five crop residues were ranked by farmers using a scale of 1 to 5 with five being the most important crop residue. Also, five limiting factors were ranked by farmers using a scale of 1 to 5, with 5 being the most important limitation in utilization of crop residue. The computed sum of ranks and mean of ranks were compared using multiple pair-wise comparisons to establish if there were significant differences in utilization levels and limitations to utilization of crop residues. [16] was used to generate summary statistics (frequencies, percentages and means) for the variables and later tabulated.

Results

Farmers' Ranking on Utilization of Crop Residues

Kruskal-Wallis test showed that there were significant differences (p = 0.0001) maintained in all the districts among farmers' ranking of the different crop residues (Table 7.6.1).

Table 7.6.1. Farmers ranking of crop residues.

District	Crop residue	Sum of ranks	Mean ranks	Chi², p-value, df = 4
Mayuge	Sugar cane tops	2647.00	64.56^{a}	X^2= 54.40, p = 0.0001
	G.nut haulms	3465.50	85.52^{ab}	
	Banana peels	3954.50	96.45^{ab}	
	Sweet potato vines	4810.00	117.32^{bc}	
	Maize stover	6238.00	152.15^{c}	
Jinja	G.nut haulm	2790.00	69.75^{a}	X^2 = 25.83, p = 0.0001
	Sugar cane tops	3468.00	86.7^{ab}	
	Banana peels	4069.00	101.72^{bc}	
	Sweet potato vines	4866.00	121.65^{abc}	
	Maize stover	3616.00	122.67^{bc}	
Buikwe	Sugar cane tops	4020.00	80.37^{a}	X^2=54.71, p=0.0001
	Banana peels	3616.00	89.33^{ab}	
	G.nut haulms	4608.00	102.4^{ab}	
	Sweet potato vines	5599.00	124.42^{b}	
	Maize stover	7581.5	168.48^{c}	

^{ab}Means in the same row and same district without common letter are significantly different (p< 0.05).

Farmers' ranking on utilization of maize stover was highest throughout the zone, in Buikwe, Jinja and Mayuge with mean ranks of 168.48, 122.67 and 152.15 respectively. Farmers ranked maize stover (mean of ranks = 152.15, 122.67 and 168.48) and sweet potato vines (mean of ranks = 117.32, 121.65 and 124.42) as the most important crop residue throughout Mayuge, Jinja and Buikwe districts respectively. Sugar cane tops (mean of ranks = 64.56 and 80.37) were ranked as the least important crop residue in Buikwe and Mayuge districts while in Jinja ground nuts haulms (mean of ranks = 69.75) was ranked as the least important crop residue. In Mayuge district, ground nut haulms (mean of ranks = 84.52) were ranked second least important crop residue while in Jinja it was sugar cane tops (mean of ranks = 86.7) and in Buikwe it was banana peels (mean of ranks = 89.33).

Farmers' Ranking on Spatial and Temporal Variability of Crop Residues

Spatial and temporal variability of crop residues in the study area were assessed on monthly basis by asking the respondents to classify abundance of crop residues as highest, moderate or lowest. The orders were then converted to scores in such ways that score 3 was given to the highest in abundance, score 2 moderate and score 1 lowest. Then the percentage score for each crop residue was calculated as its total weighted score divided by the overall total scores. Calculated accordingly, the percent score for variability of crop residues at given point in time by respondents are given in Figure 7.6.2 (UBOS, 2012), characterizes seasons based on amount of rain fall received, prevailing humidity and temperature. LVZ has two dry seasons (December to February and June to August) and two wet seasons (March to May and September to November) in a year. Generally farmers score indicated that quantities of crop residues vary throughout the year. The highest in abundance was reported to occur towards the beginning of dry season and least abundant levels were reported to be at the end of dry season. Maize stover was scored highest in abundance in first season, reduces slightly in second season then attains peak abundance in third season and reduces progressively in fourth season throughout the zone. The abundance levels of sweet potato vines were scored highest in first season reduces in second season, increases progressively to attain its peak abundance in third season, in fourth season it moves down then starts increasing again towards the end of the season.

It was noted that most frequently utilized crop residues are highest in abundance in third season and lowest in fourth season. Maize stovers were highest in abundance in Jinja district in first season, while the rest of the districts hit their peak abundance in third season. Ground nuts haulms were moderately abundant in fourth season in Jinja district while in the rest of the districts it was lowest in fourth season.

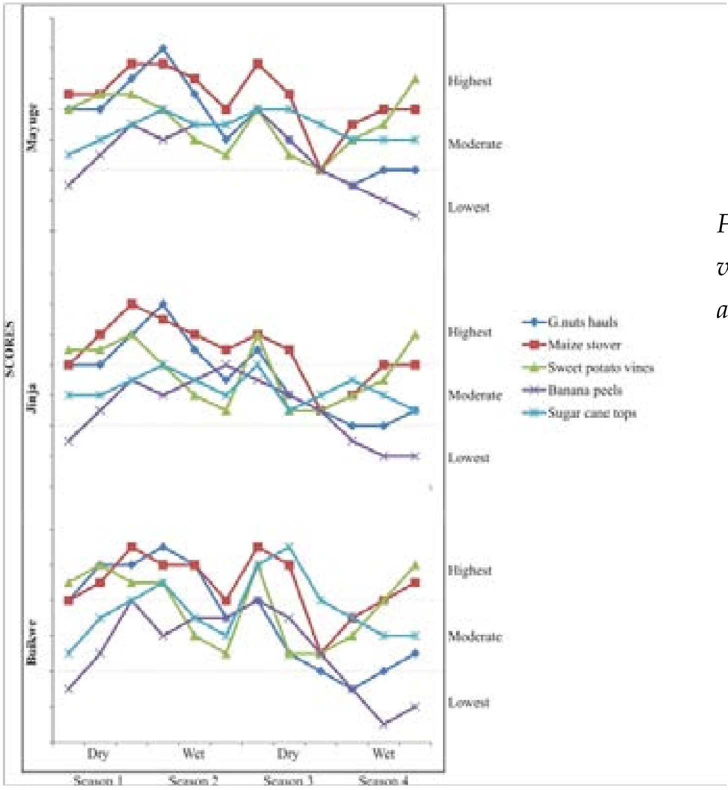

Figure 7.6.2. Spatial and temporal variability of crop residues in the study areas

3.3. Methods Applied by Farmers to Store, Process and Preserve Crop Residues

Table 2 shows different methods used by the farmers to store, process and preserve crop residues. It was depicted that storage, processing and preservation had positive effect on improving crop residues intake by the dairy cattle. Percentage of the respondents using different methods of storage, processing and preservation are shown in Table 7.6.2. The majority of the farmers 52.7% stored their maize stover by home heaps while 7.6% did not use any particular storage facilities. Physical processing (chopping) of maize stover, ground nuts haulms and sweet potato vines practiced by 71.2%, 60.4% and 88.3% of the respondents respectively was the most common technology applied. Farmers sprayed crop residues with additives that included molasses, salt, brewer's spent grain and yeast to improve on dry matter intake. The major preservation method of ground nuts haulms, sweet potato vines and banana peels was by drying represented by 3.6%, 27.9% and 44.1% respectively.

Table 7.6.2. Methods applied by farmers to store, process and preserve crop residues

Practice	Percentage score of the farmers undertaking the method					
	Method	MS	GNH	SPV	SCT	BP
Storage	Field heap	22.3	24.1	2		
	Home heaps	52.7	36.3	45.2		38.5
	Communal shade	17.4		27.7		
	None		7.6		25.1	
Processing	Physical processing	71.2	60.4	88.3		
	Spraying with additives*	81.1	21.6	2.7	5.8	27
Preservation	None	7.2	38.8	24.3	3.6	32.4
	Drying		3.6	27.9		44.1
	Multi-nutrient block	2.4		2.4		

MS = maize stover, GNH = ground nuts haulms, SPV = sweet potato vines, SCT = sugar cane tops, BP = banana peels, *With salt, molasses, and brewer's grain/yeast.

Farmers' Rankings of Limitations to Utilization of Crop Residues

The ranking of farmers on limitation to utilization of crop residues in smallholder dairy cattle feeds and feeding system are presented in Table 7.6.3. Kruskal-Wallis test revealed a high significant difference among the farmers ranking. Buikwe district ranked lack of knowledge to preserve crop residue (mean of ranks = 114.32) as the major limitation in utilization of crop residues. While in Jinja and Mayuge district lack of knowledge to process crop residues (mean rank = 88.29, 121.24) was ranked as the major limitation to utilization. Other limiting factors ranked in descending order of importance were: limited land, transportation of crop residues from the field and limited labour.

Table 7.6.3: Farmers ranking of limitation to utilization of crop residues

Practice	Percentage score of the farmers undertaking the method			
District	**Limitation**	**Sum of ranks**	**Mean of ranks**	**(Chi², df, p-value)**
Mayuge	Limited labour	1748.50	52.98[a]	$X^2 = 58.67$, df = 4, p = 0.0001
	Limited land	1829.50	55.44[a]	
	Transportation (Bulky)	2268.00	84[ab]	
	Lack of knowledge to preserve	4583.00	111.78[bc]	
	Lack of knowledge to process	4971.00	121.24[c]	
Jinja	Limited labour	1572.50	58.24[a]	$X^2 = 12.84$, df = 4, p = 0.012
	Limited land	1639.00	63.04[ab]	
	Transportation (Bulky)	1458.50	66.30[ab]	
	Lack of knowledge to preserve	2764.50	83.77[ab]	
	Lack of knowledge to process	3443.50	88.29[b]	
Buikwe	Transportation (Bulky)	1858.00	59.94[a]	df = 4, p = 0.0001 $X^2 = 33.0$
	Limited labour	2301.00	67.68[a]	
	Limited land	3262.50	95.96[ab]	
	Lack of knowledge to process	4910.50	111.60[b]	
	Lack of knowledge to preserve	4688.00	114.34[b]	

[a]Means in the same row and same district without common letter are different at $p < 0.05$.

Discussion

Crop residues are fibrous parts of crops that remain after those edible to human beings have been removed. Through their digestive adaptations, primarily based on the degradation of fibrous materials by microbes in the rumen (Preston et al., 1987), ruminant animals have the unique capacity to utilize these otherwise useless by-products. This indicates that in dairy cattle feeding system, crop residues can replace roughages in rations, reducing the competition on cereals between human beings, monogastic and ruminant animals. Crop residues are readily available in LVZ, cheap feed resource because the grain which is the main marketable product takes care of the production costs.

The major crop residues available in the study areas were established as maize stover, sweet potato vines, sugar cane tops, ground nuts haulms and banana peels. Maize stover was ranked a major crop residue available and utilizable in smallholder dairy farming system in LVZ of Uganda, the study area. It was also established that with increased crop failures due to prolonged drought, as has become more frequent even in the LVZ large acreages of maize crops would be available for conversion into feed for smallholder dairy farms. Uganda currently ranks with the highest potential of maize production for export among the countries in the East, Central and Southern African region where maize is the staple food (Okaboi et al., 2011). If this potential is exploited, the massive quantities of maize stover generated will be a major feed resource for smallholder dairy farmers. Furthermore, rankings of spatial and temporal variability of crop residues indicate that first season (December to February) was the main harvest period, which explained the abundance of the crop residues in second season (March to May). This is in line with studies by (Tsopito et al., 2013) who noted that variations in availability of crop residues as major factors constraining their utilization. Furthermore, suggesting that interventions to enhance utilization of crop residues in LVZ should prioritize maize stover. However, its nutritive value is low (Njarui et al., 2011) (Akinfemi et al., 2009), research should be directed towards enhancing its crude protein content, improving its digestibility and reduction on its crude fibre.

While there are prospects to improve the nutritive value of crop residues in LVZ through supplementation, simple treatment, processing and preservation methods, maize stover and sweet potato vain were fed without much attention to improve their nutritive values. The only method undertaken by number of respondents (71.2% maize stover and 88.3% sweet potato vain) was physical processing (Chopping). Feeding crop residues when they are unprocessed or untreated limits their intake (Lukuyu et al., 2011). Integrating crop residues with forage legumes improves rumen microbial degradation of crop residues by supplying nitrogen to the rumen microbes which increases digestibility and intake of poor quality feed (Smith et al., 1993). Nitrogen supplementation in the rumen environment deficient of nitrogen leads to increased dry matter digestibility and voluntary feed intake (Mlay et al., 2005). Furthermore, feeding small amounts of naturally occurring high protein supplement such as brewers spent grain also improves the nutritive value of crop residues (NRC, 2001). Biological treatment of maize stover utilizing mushroom fungi through fermentation, is another alternative to convert maize straw into high nutritive value dairy cattle feed (Akinfemi et al., 2009).

Maintaining access to sufficient quality and quantity of nutrition is vital for milk production in the dairy cattle (Lukuyu et al., 2011). Although crop residues are important feed resources they are low in nutritive value (Tsopito, et al., 2003) and poor storage methods (Table 7.6.2) practiced by farmers predisposes them to rain and sunlight resulting into further deterioration in quality (Njarui et al., 2011). Majority of the farmers (92.4%) interviewed stored maize stovers for future use in dairy cattle feeding. Although the majority of the farmers understood very well the importance of storage and tried to practice it but it was established that large proportion was left in the field for the animals to graze in situ hence resulting into inefficient utilization. Besides, where the crop residues were stored, during feeding, it was thrown in the cattle boma. This resulted into trampling and wastage. It was further observed that crop residues especially maize stovers are left to stand in the field post-harvest where they lose leaves prior to being harvested for storage. Even following harvesting and stacking they tend to be stored outdoors in home heaps as reported by 52.7% of the respondents resulting into further nutrient losses through leaching. These findings are consistent with earlier studies that mentioned low nutritive value of crop residues (Tsopito et al., 2003) and poor handling of maize stovers (Akinfemi et al., 2009). Therefore, in order to improve utilization of maize stover, the challenges on handling during harvesting, process and storage should be addressed. This is vital in enhancing maize stover utilization and improving its intake and nutritive value for improved smallholder dairy farm productivity.

Results of this study further reveals that inadequate knowledge to process and preserve crop residues was major limitations in utilization of crop residues. Other limitations in descending order included; difficulty in transportation (bulkiness), seasonal variability, labour and storage facilitates. Similar findings were reported by (Anandan et al., 2010) who cited lack of knowledge and capital, (Dejene et al., 2009) high labour cost, (Ngongoni et al., 2006) low nutritive value and (Walli et al., 2009) difficulty in transportation because crop residues are bulky. All these limitation directly influence the stability of the nutritive values of crop residues and hence there utilization. Earlier research interventions for promoting smallholder dairy cattle productivity focused on fodder agronomy and seed production (Mugerwa et al., 2012). However, with increased effects of climate change and reducing household land holdings, emphasis must be shifted to utilization crop residues. But nutritional deficiencies of crop residues make them unable to support maintenance and production requirements of a milking dairy cows (Mugerwa et al., 1987), pointing to the need for evaluation of strategic processing and supplementation with locally available ingredients as a viable research interventions (Mubiru et al., 2007). This calls for research innovations to improve on processing, preservation and storage of crop residues, which should be appealing to smallholder dairy cattle farmers for sustainable productivity.

Conclusion and Recommendations

Maize stover and sweet potato vines were the major crop residues utilized in the study area. They were not utilized at the optimum period thus compromising on their quality and variability. Lack of knowledge, poor quality and transportation were the major limitations. Improving productivity in dairy cattle production system in LVZ should therefore target qualitative improvement of nutritive value of maize stover. Research thrust should be directed towards nutritive value improvement techniques both on station and on farm to justify the economic feasibility. Biological processing of maize stovers with mushroom fungi may provide a feasible research notion for improved utilization of maize stover in order to improved smallholder dairy cattle productivity.

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7.7 Effect of supplementing lactating crossbred animals with Bentonite as a mineral supplement on milk production

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Introduction

Aflatoxins (AF) are a group of closely related, biological active mycotoxins (Mishra and Daradhiyar, 1991) that are highly toxic and carcinogenic fungal metabolites produced mainly by Aspergillus flavus and Aspergillus parasiticus. Almost any feed or grain for livestock and poultry is able to support fungal growth and AF formation. AF B1, B2, G1, G2 and M1 are the most common forms but AFB1 is considered to be the most toxic (Nilipour, 2002). They reduce growth and feed efficiency, and cause liver and kidney damage (Bintvihok, 2002). They also cause immuno-suppression and changes in relative organs weight (Kubena et al., 1993), increased mortality (Huff et al., 1988) and enhanced susceptibility to infectious diseases (Chang and Hamilton, 1991). According to the World Health Organization and the Food and Drug Administration Department of the US, the recommended maximum limit of aflatoxin in foods for humans, poultry and young pigs is 20 ppb, but levels as high as 1000 ppb have been reported in Uganda's grain and animal feeds (Kaaya, 2005). The major way of dealing with aflatoxin contaminated grain has been condemning them to animal feeds, but animals are squarely affected by aflatoxins with reduced growth, egg and milk yield and animals also pass on aflatoxins to their products and affect humans.

Numerous strategies, such as physical separation, thermal inactivation, irradiation, microbial degradation and treatment with a variety of chemicals have been used for the detoxification or inactivation of mycotoxin-contaminated feedstuff. One strategy is to bind the aflatoxin molecule to a compound that cannot be absorbed from the animal's digestive tract. The bound aflatoxins are then excreted in the faeces (Bintvihok, 2002). Bentonites have this capacity and have been utilized in many countries to bind aflatoxins. Bentonites are highly colloidal and plastic clay materials composed largely, but not exclusively, of montmorillonite (a species of dioctahedral smectite) without reference to a particular origin. The properties of bentonites can vary considerably depending on geological origin and any post-extraction modification, and their individual characteristics have a marked bearing on their economic use.

The discovery on Calcium Bentonite (CB) in Uganda coupled with the extra-ordinarily high level contamination of animal feeds with aflatoxins heightened the impetus to harness the clay in detoxification of aflatoxin infested feeds. Also, the Ugandan CB is rich in inorganic minerals containing 1.25, 1.35, 123.5, 35 and 0.2 ppm of Copper, Zinc, Iron, Manganse and Cromium respectively. It also contains 0.11, 0.18, 0.013, 0.015 and 0.02% nitrogen, Phosphorus, Sodium, Potassium and Calcium. Studies were therefore conducted to gain an understanding of the general effect of CB on animal productivity as well as to set the ground for more focused studies intended at harnessing the clay materials in animal nutrition. This paper presents preliminary findings of short but scientifically well designed studies on the role of CB as a detoxifier of afltoxins as a mineral supplement in lactating crossbred cattle.

Materials and Methods

The experiment was conducted in Jinja District with Jinja dairy farmers group. Twelve crossbred lactating cows were blocked into three groups on the basis of stage of lactation, initial body weight and the parity. Cows in their first, second or third lactations were used for the trial. Three experimental treatments including (1) Supplementation with concentrates containing bentonites, (2) Supplementation with concentrates containing commercial mineral premix and (3) Supplementation with concentrates containing neither premix nor bentonite (control) were allocated to the three groups of animals. The quantity of the supplement per animal per day was 500 grams. The quantity and costs of ingredients used in formulation of concentrates are presented in Table 7.7.1. The cows were feed on a Napier basal diet that met their dry matter intake. A 14 day adaptation period was allowed before data collection and then milk yields were recorded for the subsequent 7 days. The milk yield from the individual animals were collected and recorded daily twice a day at 08:00 hrs and at 16:00 hrs. Animals were dewormed at the start of the experiment, sprayed and had constant access to clean drinking water.

Table 7.7.1: Amount and cost of ingredients used in formulation of concentrates

Ingredient	CP (%)	Inclusion level (kg)	Unit cost (Ushs)	Cost of concentrate with no bentonite/ premix	Cost of Bentonite concentrate	Cost of premix concentrate
Maize stover	6	20	50	1,000	1,000	1,000
Maize bran	10	20	500	10,000	10,000	10,000
Molasses	5	30	330	9,900	9,900	9,900
Cotton seed	45.2	10	1400	14,000	14,000	14,000
Calliandra hay	28.3	15	300	4,500	4,500	4,500
Bentonite	-	5	1000		5,000	
Premix	-	1	5000			5,000
Cassava flour	-	4	1500			6,000
Total cost	39,400	44,400	50,400			

Results and Discussion

During the 7 days of data collection on milk production, highest milk yields were recorded from groups fed concentrates containing CB (Figure 7.7.1). Considering the price of a litre of milk to be Ushs 1000, for every shs 197 used in control supplements, Ushs 500 were received in return. Where concentrates containing bentonite were used, Ushs 2000 was obtained for every Ushs 222 while Ushs 1200 was obtained for every Ushs 252 used in premix concentrates. Bentonite clays have binding properties, and when used, there is no need for use of other binders like cement and cassava flour. This therefore reduces the cost of bentonite concentrates as compared to premix based concentrates and thus increases the returns per unit cost.

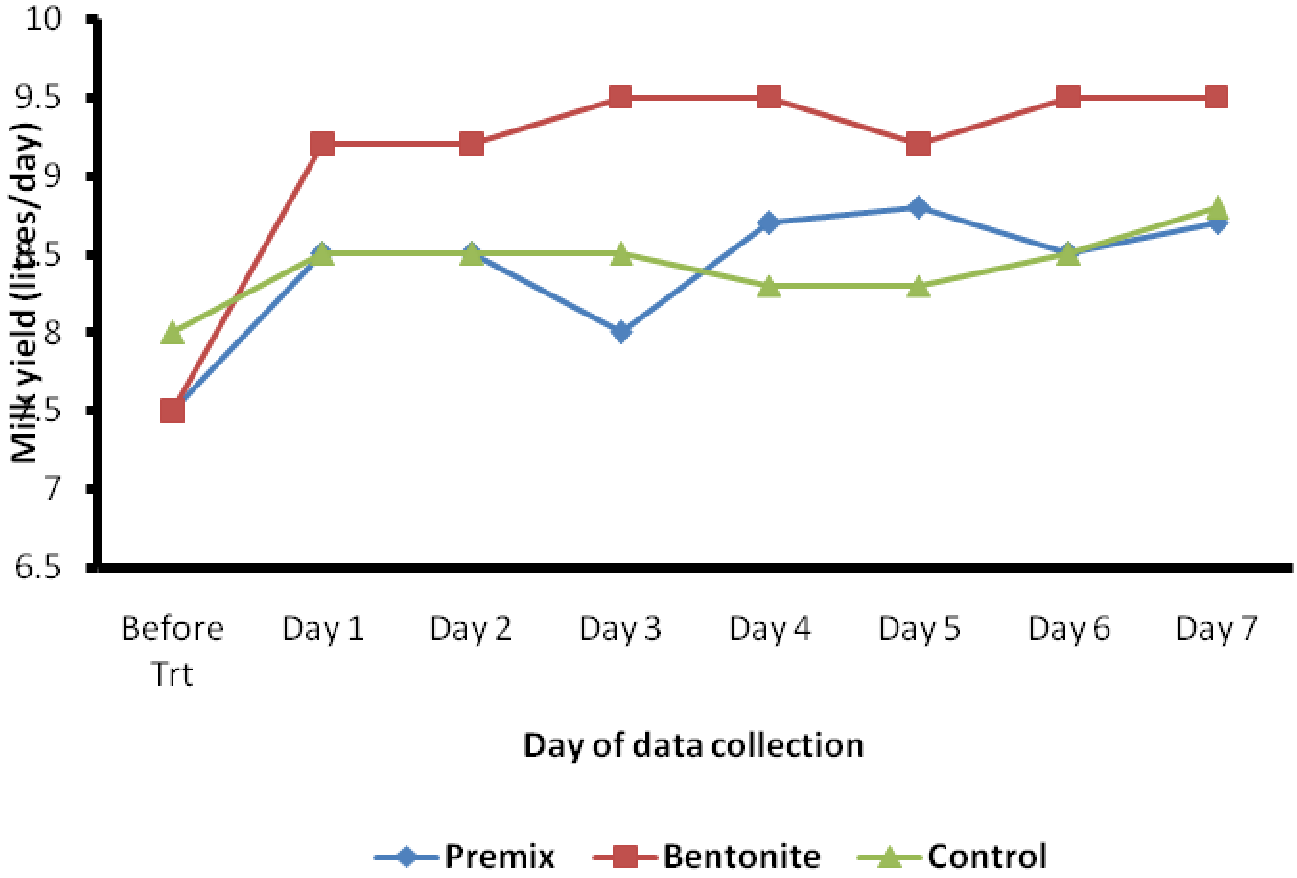

Figure 7.7.5: Variations in milk yield during the treatment

Because of its expanding properties, bentonite reduces the rate of feed passage through the animal's digestive system. The increased retention rate of digesta hence increases the amount of nutrients absorbed into the animal's body and contribute to increased milk yield as compared to other concentrates where rate of digesta flow is not altered. The aflatoxin and mycotoxin absorbing properties of bentonite also help in reducing the negative impacts of aflatoxin on feed utilization, growth and milk yield of animals. As such, bentonite supplemented cows gave more milk than their counterparts. Also note: Bentonite acts as pH regulators in the rumen, as they control pH, they enable animals to increase dry matter intake.

Conclusion

It seems logical to conclude that CB has a potential to supply the required nutrients to lactating animals to sustain high levels of milk production at even a much lower cost. It is recommended that more studies are required to establish the appropriate levels of inclusion in lactating animals' feed and where possible develop a mineral premix for various animals including goats and sheep.

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7.8 Multiplication of Brachiaria hybrid cv. Mulato 1 planting materials for livestock productivity enhancement (Short communication)

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Introduction

Brachiaria is a perennial grass native to East and Central Africa. A number of studies have shown that the species is of high nutritive value (Frederiksen and Kategile, 1980) and therefore has the potential to revolutionize grassland farming and animal production. This potential however, remains largely unexploited by smallholder farming communities. This is because of the planting materials are scarce which impedes there accessibility by the farming communities. As such, wider adoption of Brachiaria as forage in the farming is limited and the positive impacts it brings to livestock improvement and productivity is therefore felt by developed livestock farmers who have the purchasing power and smallholders are left out as they cannot afford the cost of the planting materials. In Uganda, availing improved pasture planting materials to smallholder farming communities has been a daunting challenge mostly for the pasture species with very low seed viability like Brachiaria ssp. As such, there multiplication has been mainly through getting Brachiaria stools, cutting it into smaller pieces and planting them in multiplication gardens. At maturity, these are then dug out from the garden and put into sacks for the farmers to multiply at their farms. Despite having worked for quite long in improving pasture production and there animal production, this has been quite challenging practice. As there has been slow progress in terms of availing planting materials to the farmers mostly due to the high operational costs in terms labor for opening the multiplication area and its eventual maintenance. Mugerwa et al. (2012) stated that efforts aimed at integration of introduced forages into smallholder diary systems need to focus on high yielding forages as well as insuring availability of adequate sources of planting materials. This can only be realized through innovative multiplication path ways. In an attempt to realize this goal, multiplication of Brachiaria splits under nursery was thought of and through this innovative approach, we have managed to raise thousands of seedlings as illustrated below.

Procedure

Top loam soils, cow dung and sand are mixed in ratio of 10:5:3 wheel barrows respectively. The mixture is then potted in polythene bags, Brachiaria cuttings with viable roots and buds are then cut and put in the potted media under nursery shade (one small cutting per pot). These are then watered twice in a day (morning and evening). Sprouting of the cutting starts within 3 weeks and in 10 weeks time they are ready for planting in the main field.

Advantages of multiplication under nursery

Thousands of Brachiaria splits can be raise in small space as shown in plates above and therefore many farmers can be availed with the planting material in a short interval Management of the splits under nursery is easy as compared to direct planting in the field. Less labor is required to raise these seedlings under shade compared to raising them directly in the field.

Conclusion

Multiplication of improved Brachiaria splits under nursery comes at a point of rampant outcry for improved pasture seed by livestock stock farmers. It is envisaged to bridge this gap and hence an important step to revolutionize grassland farming and animal production not only in Uganda but globally.

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