EFFECT OF INTERGRATING FORAGE LEGUMES IN SMALLHOLDER DAIRY FARMING SYSTEMS ON FEED AVAILABILITY AND ANIMAL PERFORMANCE

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DECLARATION

I declare that the work presented in this Thesis is original and that it has not been submitted for a degree to any other University

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DEDICATION

This work is dedicated to:

Our late father, Eria Serwadda Kabirizi for his struggle to educate us. I am very proud of his great effort and achievements that he accomplished in life. He was strong, compassionate, a great Dad and a friend to all of us and my late sister, Barbara Kabirizi Kintu whose spiritual, material and financial support enabled me to push on even under very hard conditions. May God rest their souls in eternal peace.

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ABSTRACT

The potential for incorporating forage legumes in intensive smallholder crop/livestock farming systems was assessed in a study conducted in Masaka district, Uganda from 2002-2004. The first part of the study consisted of a diagnostic survey to characterize the production system and together with farmers identify appropriate technologies to improve feed production and animal productivity. This was followed by (i) a trial to evaluate the effects of intercropping lablab with maize or forage legumes (*Centrosema pubescens*, *Macroptilium atropurpureun* and *Desmodium introtum*) with elephant grass (*Pennisetum purpureum*) on grain yield and fodder production, (ii) a feeding trial to determine the response and profitability of lactating crossbred cows fed forages from an intercrop of maize or elephant grass with forage legumes supplemented with legume hay and a homemade concentrate and (iii) a participatory technology evaluation survey to assess the benefits and constraints from improved forage technologies to the production system. The feeding trial, consisted of 4 dietary treatments in which a homemade concentrate (HMC) was supplemented to the basal diets of: elephant grass/legume fodder (EGL) and lablab hay (LH) [Treatment 1]; EGL + LH + calliandra leaf hay (CLH) [Treatment 2]; and elephant grass fodder fed together with maize/lablab stover (EGML) + CLH [Treatment 3]. A fourth treatment was elephant grass fodder served as a control [Treatment 4].

Diagnostic survey showed that about 70% of the respondents were women. Age at first calving, calving interval and lactation length averaged 26, 15 and 8 months, respectively. Elephant grass was the predominant fodder grass planted by over 98 % of the respondents while legumes (herbaceous and fodder trees) were used by less than 10%. Elephant grass fodder occupied less than 35% of the total farm area. Estimated fodder DM yields were 4,171; 4,945 and 5,722 kg/ha/yr in urban, peri-urban and rural areas, respectively There was a marked decline of about 53% in total DM intake during the dry season with resultant protein and energy deficits estimated at 940 g/cow/day and 35.5 MJ/cow/day, respectively compared to a deficit of 190 g/cow/day and a surplus of 35.0 MJ/cow/day, respectively in the wet season. This resulted in a decline in milk yield during the dry season of about 44 percent. Land shortage, high cost of seed and field maintenance, were major reasons for not planting leguminous forages. Based on total scores of the diagnostic survey and

results from previous on-station trials, elephant grass/legume mixtures, maize/lablab intercrop, lablab hay and calliandra leaf hay technologies were selected for on-farm trials/demonstrations to improve feed availability and overall animal productivity.

Intercropping elephant grass with forage legumes (EGL) increased ($p<0.05$) elephant grass plant growth (79 cm) and total fodder DM yields (12,211 kg/ha/yr) by 12 and 22 percent, respectively when compared to the monocrops. Legumes contributed about 12% of total DM yield. Mean fodder DM yield of 6,488 kg/ha/yr observed in EGL during the wet season was 13% higher ($p<0.05$) than the DM yield observed during the dry season (5,722 kg/ha/yr). The results showed no differences ($p>0.05$) in mean DM yields of legumes during the dry and wet seasons (677 and 780 kg/ha, respectively). Elephant grass/legume intercropping significantly ($p<0.05$) increased CP and CP yield (CPY); *In* vitro organic matter digestibility (IVOMD) and Ca content but lowered ($p>0.05$) the NDF content of elephant grass fodder. The contribution of forage legumes to total CPY was 26%. Total CPY of the intercrops was higher ($p<0.05$) during the wet season than during the dry season. Fodder DM, grain yields, and cob size were increased ($p<0.05$) by 26, 7 and 6%, respectively when maize was intercropped with lablab compared to monocrops (4,373 kg/ha/yr; 2,912 kg/ha/yr; 134 g respectively). Total fodder and grain yields in ML (5,165 kg/ha) decreased by about 11 and 8%, respectively in the second rains when compared with yields during the first rains (5,806 kg/ha). On average, the CP content of ML (8.4%) was 1.9 times higher ($p>0.05$) in intercrops when compared to the monocrops (4.0% CP). Maize/lablab intercropping reduced ($p<0.05$) OM, DM and NDF but increased ($p<0.05$) P; Ca; IVOMD and ME compared to maize monocrop. The study showed that the quantity and quality of elephant grass fodder produced from 0.405 ha, recommended to farmers by projects that supplied the animals, was not sufficient to supply about 4,941 kg DM and 4,392 kg CP required for a mature lactating cow of about 450 kg liveweight for a full year. The minimum acreage required per mature cow was estimated to be i) 0.9 ha of EGL, ii) 0.405 ha of EGL plus 0.4 ha/year of ML or iii) 0.405 ha of pure stand of EG plus 0.4 ha/year of ML.

Total DM, CP, ME, P and Ca intake increased ($p<0.05$) with supplementation. Average daily weight gain and mean daily milk yield were higher ($p<0.05$) in supplemented cows (Treatments 1, 2 and 3) than in unsupplemented cows

(Treatment 4). Mean digestible CP and OMD of the feeds were higher ($p<0.05$) in supplemented than in unsupplemented cows. Digestible crude protein (DCP) and OMD of the feeds were higher ($p>0.05$) during the wet season (9.3% and 63.6%, respectively) than during the dry season (9.0% and 63.2%, respectively). Initial BW of the study animals did not differ ($p<0.05$). Overall, supplemented cows had higher ($p<0.05$) BW and better body condition than unsupplemented cows. Unsupplemented cows lost ($p<0.05$) an average of 183.3 g/cow/day between calving to 8 weeks postpartum compared to 139.6 g/cow/day in supplemented cows. Body condition changes followed a pattern similar to that in BW. Overall, unsupplemented cows lost body condition of 0.5 (of scale of 0-9). Cows that were offered EGML basal diet produced about 13% more milk than cows on EGL diets. Mean milk yield per cow (10.2 lts/cow/day) was 13% higher ($p<0.05$) during the rain season than during the dry season (8.4 litres/cow/day). Calves born to supplemented cows had higher ($p<0.05$) birth and weaning weight than unsupplemented cows. Calves born to cows on EGML diet had higher ($p<0.05$) average daily gain than those on other EGL basal diets. Calving to first oestrus was reduced from about 50 days to 41 days in cows fed on EGL and EGML diets. Calving to conception interval was 79 days in supplemented cows and shorter ($p<0.05$) than 101.4 days observed in unsupplemented cows. Average number of services/conception per cow did not differ ($p>0.05$) among the supplemented cows but was twice ($p<0.05$) in unsupplemented cows. The return to investment per Ushs 1,000 spent was Ushs 422, 479 and 1,324 on Treatments 1, 2 and 3, respectively. Cost of weeding forages accounted for over 30% of the total cost of production. Revenue from milk yield accounted for about 95% of the total farm income on EGL and EGML forages. Sale of maize grain increased total farm income by about 25%.

In the post trials evaluation survey, majority of farmers identified improvement in: feed availability, food security, milk yield and income as the major benefits from forage legume interventions. However, high cost of forage legume seed and labour and initial slow growth of legumes in EGL, land shortage and low DM yields of forage legumes in EGL were major factors that would constrain wider adoption of the forage legume technologies.

Major lessons learned were: (i) identification, testing and evaluation of forage technologies with resource poor smallholder dairy farmers is a big challenge but rewarding. It requires a lot of patience and commitment from all stakeholders and it requires institutional support. (ii) A more holistic approach addressing several farmers' constraints simultaneously is expected to give better results than isolated Interventions.

The study therefore showed that in order to cope with a shortage of feeds during the dry season, EGML forages supplemented with 1 kg/cow/day of CLH and 4 kg/cow/day of HMC were superior to EGL basal forages. This was associated with a total DMI, milk yield, ADG, a calving to conception interval and a return to investment of 12.1 kg/cow/day, 10.8 litres/cow/day, 247.5 g/day, 78 days and Ushs 1,324, respectively. More research is however needed on simple labour saving technologies for harvesting, drying and conserving maize/lablab stover and lablab hay. Total DM, CP, ME, P and Ca intake increased ($p<0.05$) with supplementation.

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ACCRNOMYS

°C:	Degrees centigrade
ADF:	Acid Detergent Fibre
ADG:	Average daily gain
ADL:	Acid Detergent Lignin
AGDP:	Annual Gross Domestic Product
AI:	Artificial Insemination
Anon:	Anonymous
AOAC:	Association of Official Analytical Chemists
ARC:	Agricultural Research Council
ARTP:	Agricultural Research and Training Programme
BCS:	Body condition score
BW:	Body weight
$BW^{0.75}$	Metabolic body weight
Ca:	Calcium
CLH:	Calliandra leaf hay
CP:	Crude Protein
CPY:	Crude protein yield
cv:	cultivar
d.a.g:	days after germination
DANIDA:	Danish International Development Agency
DAP:	Diammonium phosphate
DATIC:	District Agricultural Training and Information Centre
DCP:	Digestible Crude Protein
DM:	Dry matter
DMI:	Dry matter intake
DOM:	Digestible organic matter
EG:	Elephant grass
FAO:	Food and Agriculture Organization
FCM:	Fat Corrected Milk
FSR:	Farming Systems Research
GDP:	Gross Domestic Product
ha:	Hectare

IMC:	Homemade concentrate
/OMD:	*In vitro* organic matter digestibility
/OMD:	*In vitro* Organic Matter Digestibility
:	Potassium
W4:	Kawanda 4
H:	Lablab hay
SRP:	Livestock Systems Research Programme
AAIF:	Ministry of Agricultural, Animal Industry and Fisheries
AK:	Makerere University
E:	Metabolisable Energy
FPED:	Ministry of Finance, Planning and Economic Development
J:	Mega Joules
L:	Maize stover/lablab residues
PMPS:	Meat Production Master Plan Study
S:	Maize stover
:	Nitrogen
AARI:	Namulonge Agriculture and Animal Production Programme
ARO:	National Agricultural Research Organization
DF:	Neutral Detergent Fibre
GOs:	Non Government Organisations
H_3:	Ammonia
RC:	Nutrient Requirements of dairy Cattle
:	Phosphorus
EAP:	Poverty Eradication Action Plan
MA:	Plan for Modernisation of Agriculture
RA:	Participatory Rural Appraisal
RCBD:	Randomized Complete Block Design
AS:	Statistical Analytical Systems
hs:	Shillings
PSS:	Statistical Package for the Social Sciences
SA:	Sub-Saharan Africa
TDMI:	Total dry matter intake

CHAPTER 1

. GENERAL BACKGROUND

.1. Introduction

ivestock are major component of the economies, contributing 10-40% of the Gross Domestic Product (GDP) in Sub-Saharan Africa (SSA) (Ndikumana and Kamidi, 2004). It has been estimated by World Bank that about 10% of the population of SSA are primarily dependent on livestock, while another 58% depend on crop production Winrock International, 1992). In smallholder systems, which dominate tropical agriculture, livestock are important because they provide direct cash income, they are capital assets, they produce manure for use as fertilizer and fuel, and they may be a source of power for transport and cultivation (de Leeuw *et al.*, 1998; Walshe *et al.*, 1998; Tangka *et al.,* 2000). Nevertheless, the production of milk for human food is often the primary reason for keeping livestock, whether by pastoralists to meet their subsistence needs in arid and semi-arid regions or by peri-urban smallholder farmers as a source of income from milk sales (de Leeuw *et al.*, 1998).

In SSA, livestock products provide 17-18% of human dietary protein and contribute to at least 25% of the agricultural gross domestic product or 8% of GDP (Winrock International, 1992). The annual growth rate of production through 2020 is projected to be 2.7% for meat, and 3.2% for milk in developing countries (Ndikumana and Kamid, 2004). Rapid population growth, income growth and urbanisation will fuel a strong increase in demand for meat and milk in the developing world. It is projected that the population of SSA will increase by about 3.1 percent and is expected to reach 675 million people and almost double by the year 2025 (Winrock International, 1992), resulting in an increasing scarcity of land and labour and higher land prices. This will lead to increased intensification of agriculture, as growing competition between crops and livestock farmers leads to evolution of mixed crop/livestock systems (Kurwijila *et al.,* 1995; Walshe *et al.*, 1998; Ebong *et al.,* 2001). Integration of livestock with crops results in improvements of 50% to over 100% in farm productivity and incomes compared to smallholders who only raise subsistence crops (Saka *et al.,* 1994; FAO, 2001). The two major crop/livestock production systems in Africa are identified as commercial and traditional systems (Kabushenga, 2002; Nakiganda, 2004). The commercial systems vary from intensive to semi-intensive enterprises (Nakiganda, 2004).

A number of constraints affecting smallholder crop/livestock production systems in the tropics have been reviewed and these include socio-economic, technological, institutional and financial constraints (Saka *et al.*, 1994; Kurwijila *et al.*, 1995; FAO, 2001; Rangnekar and Thorpe, 2001; Ndikumana and Kamidi, 2004). The major technical constraints are availability and quantity of feed, reproductive inefficiency, poor breeds, breeding programmes and policies, and health and diseases (Saka *et al.*, 1994; Roothaert *et al.*, 2003). The introduction of high producing animals of large frame size accentuates the nutritional deficiency problem particularly of lactating dairy cows and this could undermine reproductive functions, lactation and growth of the animals (Mpairwe, 1998). Thus, inadequate nutrition as a result of low quality and quantity of forages and use of unimproved practices has been identified as a major constraint in smallholder dairy production systems (Ndikumana and Kamidi, 2004). The projected increased demand for livestock and livestock products in the developing world calls for the development of a strong and dynamic research strategy to develop and disseminate technologies that will sustain the increased demand.

1.2. Role of animal agriculture sector in Uganda's economy

Uganda, one of the countries in SSA, lies astride the equator, between latitudes 4^0 12' North and 1^0 29' South and between longitudes 29^0 34' West and 35^0 0' East (MFPED, 2004). Total land area is approximately 197,100 sq. km of which about 62% is agricultural land and about 26% of the agricultural land is under pasture (FAO, 2004). More than two-thirds of the country lies between 1,000 to 2,500 meters above sea level. Rainfall varies from 500 mm in the pastoral areas in the North East to 2,000 mm per annum in the highland areas and along the shores of Lake Victoria with temperatures ranging from 15 to 30^0C. The country's human population has grown from 16.7 million in 1991 to 24.4 million in 2002 (Anon, 2005). Considering a 3.3% annual growth rate, the population now stands at 26.8 million and is expected to double in the next 21 years.

ganda is primarily an agrarian country with agriculture contributing about 40% of the ross Domestic Product (GDP) (Anon, 2005). Over 68.7% of the population depends n subsistence farming, up from 67.9% in 1991 (Anon, 2005). This increase is ttributed mainly to Poverty Eradication Action Plan (Anon, 2001). The agricultural ontribution to the GDP comes from smallholder rural subsistence farmers the ajority of whom are to a large extent dependant on agriculture (MFPED, 2004). The asic unit of production is the small-scale family holding with an average size of 0.5 to .8 ha in the South and 3.2 ha in the North (Nahdy, 2001).

nimal agriculture is one of the most important economic sub-sectors of Uganda's griculture and is currently among the most rapidly developing industries (MPMPS, 998). The livestock sector in Uganda contributes about 17% of the national griculture GDP in the form of milk and meat (Anon, 2004). The livestock population Uganda comprises of 6,100,000 cattle; 1,150,000 sheep; 6,852,000 goats; ,719,000 pigs and 33,000,000 chickens (FAO, 2004; Nakiganda, 2004). pproximately 4% of the cattle population are exotic and crossbred dairy cattle. Cattle opulation has continued to grow, at a rate of over 4% per annum, in response to ncreasing demand for milk and meat in the local market (Ebong *et al.,* 2001). Higher ates of growth are envisaged as Government pursues its policies of modernizing and ommercializing livestock agriculture (Anon, 2004).

.3. Justification of the research

n order to improve household nutrition, economies and food security among resource oor households in Uganda, Government and Non Government Organizations NGOs) have introduced intensive or stall-feeding dairy cattle production system ased on improved or exotic breeds and elephant grass (*Pennisetum purpureum*) as a ajor forage (Muwanga, 1994; Tumutegyereize *et al.,* 1999). This is in line with the ountry's Plan for Modernization of Agriculture (PMA) policy whose objective is to radicate poverty through agricultural transformation (Anon, 2005). Zero grazing dairy attle production has therefore become an important source of milk and has created mployment for many resource poor households. This had led to an increase in the emand for feed due to an increase in high genetic capacity of stall-fed dairy cattle reeds.

lthough the dairy enterprise is a major source of income contributing about 70% of ne total farm agricultural income (FAO, 2004), improved dairy cattle production is a unction of several management factors but poor nutritional status of cattle is onsidered the most challenging constraint to smallholder dairy farms in Uganda (abirizi, 1996). This is due to land shortage, low feed availability and unimproved ractices used by farmers in the utilization of available local feed resources (Mugisha *t al.*, 1999; LSRP, 2000; Kabirizi *et al.*, 2004). Part of the explanation relates to the naccessibility by farmers to appropriate forage technologies or technical information nd lack of appreciation of the extra nutritional requirements of the animals (LSRP, 000). Exposing farmers to new or improved resources and efficient practices for feed tilisation through research and/or extension interventions is acknowledged as one trategy for facilitating dairy cattle development in Uganda.

lephant grass (*Pennisetum purpureum*) fodder is recommended as a basal diet for tall-fed dairy cows because of its high biomass yield compared to other grasses Boonman, 1993; Anindo and Potter, 1994; Kabirizi, 1996). However, the low CP <12%) and high neutral detergent fibre (NDF) (>60%) of elephant grass fodder limit ntake, digestion and utilization by ruminants thereby leading to drastic reduction in nimal productivity (Samanya, 1996). Intercropping forage legumes with elephant rass improves the quality and quantity of elephant grass fodder and animal roductivity (Mwangi and Wambugu, 2003; Katuromunda, 2001; Mwangi, 2002; lubiru *et al.*, 2001; Kabirizi *et al.*, 2003) and there is a saving in inorganic nitrogen (N) eeded to obtain similar levels from pure stands (Saka *et al.*, 1994). The mixtures ould also reduce labour requirement and diminish pest and disease problems Preston, 2001). Little information, however, is currently available comparing the orage production, quality and animal performance from elephant/legume mixtures on mallholder dairy farms in Uganda.

laize is a staple food crop in Uganda and has become increasingly important as a ource of feed. Smallholder dairy farmers in Uganda grow an average of 0.4 ha of naize per household per year (Imanyoha *et al.*, 2000). Maize stover could therefore e an additional feed resource base for dairy cows especially during the dry season hen other feeds are in short supply. The low crude protein content (<5%) of maize tover is however a serious constraint to livestock nutrition (Crosse *et al.*, 1998;

Kassie *et al.*, 1999; Romney *et al.*, 2003). The integration of forage legumes such as *Lablab purpureus* (lablab) cv Rongai into cereal based cropping systems is a promising option for developing sustainable cropping systems (Mpairwe, 1998; Roothaert *et al.*, 2003). Mpairwe (1998) noted that the use of forages from cereal/forage legume intercropping systems as livestock feed is a new phenomenon and therefore, few studies have been undertaken to assess their potential in smallholder dairy production systems. He therefore recommended that the technology should be tested on-farm to determine the effects on milk production and reproductive efficiency, which could influence the success of a dairy enterprise.

Utilization of fodder trees such as *Calliandra calothyrsus* is one of the most effective means of improving both the supply and the quality of forage in smallholder livestock systems (Kaitho, 1997; Tuwei *et al.*, 2003). The promotion of fodder trees is based on their agronomic attributes which include fast growth, N fixation, high biomass production of foliage even during the dry season, tolerance to repeated lopping and soils with low pH and high quality fodder (Peterson *et al.*, 1998). For highly productive dairy cows that need some amount of by-pass protein, calliandra leaf meal has been reported to improve overall animal performance (Ebong *et al.*, 1999; Maasdrop *et al.*, 1999). In Uganda, however, no studies have been carried out on smallholder farms to evaluate the effects of supplementing a basal diet of elephant grass/legume mixtures or maize/lablab stover with calliandra leaf hay and/or lablab hay and a homemade concentrate on milk yield and reproductive performance of crossbred cows.

Supplementing lactating dairy cows offered low quality roughages with forage legumes such as *Lablab purpureus* cv Rongai and/or fodder trees and a concentrate improves rumen fermentation, fibre digestibility, forage intake, liveweight and milk yield (El-Tayeb and Takla, 1992; Kabirizi, 1996; Mpairwe, 1998; Hinderichsen *et al.*, 2004). Although commercial concentrates improve milk yield, smallholder dairy farmers in Uganda frequently complain that they are too expensive, not readily available and sometimes of sub-standard. Therefore, majority of farmers use homemade concentrates based on maize bran and cotton seed cake because the ingredients are readily availability and affordable (LSRP, 2000). However, the possibility that milk yield and farm profits could be improved through strategic supplementation of elephant grass/legume or maize/lablab forages with on-farm protein (lablab hay and calliandra leaf hay) and a homemade concentrate has not been assessed on-farm in Uganda.

The broad objective of this study was therefore carried out to investigate with farmers on-farm intercropping of forage legumes with elephant grass or maize on grain yield and fodder production. The study also evaluated profitability, feed utilization and response of smallholder crossbred dairy cows fed forages originating from maize or elephant grass/forage legume intercropping systems with on-farm generated protein (lablab hay and/or calliandra leaf hay) and energy (homemade concentrate) supplements.

1.4. Specific objectives of the study

The specific objectives of the study were:

1. To characterise intensive smallholder dairy production system and together with farmers identify forages and energy supplements that could be tested on-farm to improve animal productivity.
2. To determine the effects of intercropping maize/lablab or *P. purpureum* and forage legume on fodder and/or grain production in smallholder dairy farming systems.
3. To determine milk production, body condition, body weight and reproductive efficiency of crossbred dairy cows fed forages from elephant grass/legume (EGL) or maize/lablab (ML) intercrops supplemented with calliandra leaf hay (CLH) and/or lablab hay (LH) and a homemade concentrate (HMC).
4. To determine economic benefits of integrating forage legumes in intensive smallholder dairy farming systems.
5. To assess the benefits and constraints from improved forage technologies to the production system and household welfare and document lessons learned from working with resource poor smallholder dairy farmers.

1.5. Hypotheses

1. Inadequate protein and energy content of the diets and poor feed management limit smallholder dairy production systems and could be improved through participatory on-farm identification, testing and evaluation of forage/feed technologies.
2. Integrating forage legumes in cereal or elephant grass farming systems will increase the quantity and nutritive value of the feed resource base without reducing grain yield.
3. Feeding dairy cows forages from elephant grass or maize/forage legume intercropping systems supplemented with on-farm generated protein and energy sources will improve feed intake, body weight, body condition, milk yield and reproductive efficiency.
4. Integrating forage legumes into smallholder dairy production systems will increase farm profits.
5. Integrating forage legumes in smallholder dairy farming systems will result in negative (constraints) and positive (benefits) impacts that will influence adoption decisions and ability by farmers to increase animal productivity and farm profits.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Major feed resources in smallholder dairy farming systems and factors affecting their utilization

Over 70% of the population in SSA reside in rural areas and these primarily depend on agriculture for their livelihood (Saka *et al.,* 1994; Ndikumana and de Leeuw, 1996). Smallholder mixed dairy cattle production systems is a common practice in most countries of the SSA including Uganda (Walshe *et. al.*, 1998; LSRP, 2000). Land and labour are the major constraints of smallholders and as such factors are allocated to food crop production and only when available to forage crops (Getachew *et al.,* 1991).

Studies have indicated that the availability of livestock feeds in SSA is constrained by physical, biological and socio-economic factors (Okigbo, 1987; Haque, 1991; Omore *et al.*, 1999). Nutritional factors are the binding constraints to increasing milk production in smallholder dairy production systems in the tropics (Saka *et al.,* 1994; FAO, 2001; Ndikumana and Kamidi, 2004). The smallholders have limited resources available for feeding to their dairy cattle and often do not have the luxury of being able to select the basal diet. They therefore use whatever is available and at no or low cost (Leng, 1997). The basal diets for dairy cattle are low quality feeds, which are generally low in nutritive value. Leng (1990) defined low quality feeds as those forages with less than 55% digestible organic matter (DOM) and are deficient in true protein (less than 80 g/kg CP) and low insoluble sugars and starches (usually less than 100 g/kg). Inadequate amounts and poor quality feeds are therefore the major constraints to dairy cattle productivity in the tropics (Ndikumana and Kamidi, 2004). Ndikumana and de Leeuw (1996) identified roughages and concentrates as the major feed resources in smallholder dairy farming systems in SSA. Roughages consist of natural and planted pastures and crop residues.

2.2.1. Natural pastures

Natural pastures consist of grasses such as *P. purpureum*, *Panicum maximum*, *Hyperrhenia* spp., *Digitaria* spp, *Brachiaria, Imperata* spp., couch grass, grasses from swamps and *Setaria* spp; forage legumes such as *Desmodium uncinatum, D. intortum* and *Glycine* spp. (Boonman, 1993; Bogdan, 1977; Crowder and Chheda, 1982; Samanya, 1996; Kabirizi *et al.*, 2004). These are harvested from public land and their availability varies across seasons (Minson, 1982; Boonman, 1993; Anindo and Potter 1994 Samanya, 1996). Natural pastures in most of SSA are inadequately nutritious, even under optimal management and stocking rates (Boonman, 1993). Such pastures cannot sustain satisfactory levels of production and health of a dairy cow for most of the year (Skerman *et al.*, 1988; de Leeuw and Thorpe, 1999).

Grasses grow rapidly during the rains and set seed before the dry season (Ogwang, 1974). There is thus a rapid rise in lignin content and a consequent decline in digestibility (Crowder and Chheda, 1982). Associated with the rise in lignin is a drop in crude protein (CP) to less than 7% (Minson, 1982; Boonman, 1993), which is below the maintenance requirement of the ruminant animal (NRC, 2001). Consequently, ruminants gain body weight in the rains and lose it in the dry season. Cattle in the tropics have been found to lose 15-20% liveweight during the dry season if unsupplemented (Ndikumana and de Leeuw, 1996). The seasonal gain and loss in weight of animals results in poor growth pattern accompanied by low reproductive performance. Consequently, milk yields of stall-fed dairy cattle on natural pastures alone rarely exceed 3 to 4 kg per cow per day (Nsubuga, 1993). In many instances the animals have to rely heavily on crop by-products for survival until the next rainy season (Preston and Leng, 1987). In order to ensure milk yields substantially higher than those commonly reported in tropical countries, the use of high nutritive planted pastures is required (Boonman, 1993).

2.2.2. Planted pastures

If justified by the breed of the animal, milk price and rainfall pattern, the quantity and quality of feed available to dairy cattle can be improved substantially by planted forages such as fodder from trees, grasses and forage legumes (Boonman, 1993; Saka *et al.*, 1994; Samanya, 1996). The potential for pasture cultivation is determined y the agro-ecological zone, especially the amount and distribution of rainfall and, to a esser extent, by land tenure and land use rights. Where the rainfall is less than 400 nm/annum production of sown pastures may not be cost-effective (Boonman, 1993).

orage yields of planted pastures are governed by a number of factors including ainfall, soil fertility, fertilizer application, irrigation and the species involved (Ogwang, 974; Bogdan, 1977; Mtengeti *et al.,* 1992; Boonman, 1993). Under smallholder onditions in SSA, grass leys typically yield about 4 to 18 tons per ha of DM (Anindo nd Potter, 1994), forage legumes about 3 to 4 tons per ha (Bodgan, 1977; Skerman *t al.*, 1988) and fodder trees and shrubs about 5 to 10 tons per ha (Kang *et al.,* 1990; aussen, 1998).

he feeding value of cultivated forages is far superior to that of native pastures Skerman *et al.*, 1988; Humphreys, 1991; Boonman, 1993). Under good management, nd if provided to the animal in adequate quantities, planted pastures can sustain milk ields up to 8 to 10 kg per cow per day (Nsubuga, 1993; Samanya, 1996). Planted rasses are usually of relatively low digestibility and this accounts for the limited levels f milk produced when dairy cattle are fed such grasses (Bogdan, 1980; Boonman, 993). A larger proportion of the ingested and digested nutrients are used to meet naintenance requirements and very little is available for milk production. Improvement n liveweight and milk yield has been reported when dairy cows on planted pastures uch as elephant grass fodder are supplemented with a concentrate and/or forage egumes (Muinga *et al.,* 1992; Kabirizi, 1996). Although the concept of cultivated astures is not new, most farmers in the sub-region are unwilling to adopt it even if the ainfall is favourable. This is due to high establishment costs, unfavourable land use ights and non-competitive prices for livestock products in the face of cheap dairy mports (Gebremedhin *et al.,* 2003).

.2.3. Concentrates

Many tropical and sub-tropical countries are importing exotic breeds of dairy cattle or upgrading local types in an attempt to meet the local demand for milk and milk products. However, imported animals rarely achieve the levels of production that they show in their original habitats (Nsubuga, 1993). Energy has been identified as the nost limiting nutrient for milk production in smallholder dairy production systems Dindorkar *et al.*, 1982; Boodoo, 1991; Malossin *et al.*, 1995; Ferguson, 1996; Kabirizi *t al.*, 2000). Concentrate feeds are valued for their energy and protein levels and heir protein quality, which result in improved animal productivity (Boodoo *et al.*, 1990; /luinga *et al.*, 1993; Jingura *et al.*, 2001; Hayashida *et al.*, 2004).

mall quantities (1-4 kg/cow/day) of concentrates containing N lead to an increase in ne intake of low quality forages containing 1.0-1.2% N which in turn increases milk ield of dairy cows (Kellyaway and Porta, 1993). Muinga *et al.* (1993) obtained a esponse of 0.8 kg more milk per kg DM supplement when *Leucaena leucocephala* orage was used to supplement elephant grass fodder. When the cows were offered eucaena with maize bran, milk yield increased by 1.1 kg compared with leucaena only. Supplementing elephant grass fodder with lablab hay and a concentrate ncreased fat-corrected milk yield by about 5% when compared with elephant grass odder + lablab hay only diets (Kabirizi *et al.*, 2000). Similarly, the use of wheat bran and lablab hay as supplements to cows fed maize/lablab stover and oats/vetch hay diets improved milk yield (Mpairwe, 1998). However, Combellas and Martinez (1992) observed no differences in milk yields when low quality forages were supplemented vith either forage legumes or concentrates. They concluded that milk response to concentrate supplementation is not economical when their cost is considered. Ruiz 1983) observed that the key to significant increase in milk production is to ensure proper nutrition during the first two months of lactation when the cow has the greatest need for nutrients. It is therefore recommended that supplementation should start before parturition and concentrate feed levels should then be increased as the cow eaches lactation peak, and reduced afterwards (Ruiz, 1983). El Tayeb and Takla 1992) reported increased weight of heifers in the later stages of pregnancy, as a esult of an increase in concentrate feeding due to the increase in weight of cow and oetus.

Recently, interest among smallholder dairy farmers has been shown in the use of homemade concentrates for incorporation in diets for dairy cows (Kiruiro and Chemitei, 1993; Nkya *et al.*, 1998; LSRP, 2000; Jingura *et al.*, 2001). Jingura *et al.* 2001) reported no significant differences in milk yield between homemade and commercial concentrates. The daily average milk yield of 8.6 kg and 8.5 kg was ıchieved by animals offered the homemade and commercial concentrates, espectively with a 31% reduction in the cost of homemade concentrate feeding per tre of milk produced compared to the commercial brought-in concentrate. There is ttle doubt that increasing economic pressure will encourage the use of homemade oncentrates because commercial concentrates, as a supplement will no longer be ıffordable by most smallholder dairy farmers due to escalating costs and ınavailability.

:.2.4. Crop residues

Aixed crop/livestock production occurs virtually throughout the farming systems of the ropics and subtropics. Declining crop yield/unit area accompanied by progressively ncreasing requirement for food is forcing farmers to cultivate more land at the expense of grazing pasture and browses. The other aspect of this process is the ncrease in the production of crop residues. There is already a heavy reliance on the ıse of the by-products as feed during the long dry season immediately after harvest, and yet farmers still face a number of constraints on their efficient utilization (Kategile, 1981; Preston and Leng, 1987; Kassu, 1989; Romney *et al.*, 2003). Most crop esidues are low in protein and high in fibre content, which leads to their poor ıtilization by livestock (Steinbach, 1997).

t has been recognized that intake and utilization efficiency of crop residues are nfluenced by the rate of rumen fermentation (Van Soest, 1982) and the balance of ıutrients absorbed in the intestines (Kempton, 1982). Improvement in the nutritive value, removal of nutritional limitations to rumen fermentation, and a balanced supply of nutrients to host animals would result in an improvement in animal productivity (Preston and Leng, 1987). Preston (1986) suggested that the fermentable N content of a low quality diet should be raised to a minimum of 30 g/kg digestible organic matter. He further suggested that green forage is provided up to a minimum of about 0.7% of liveweight (20% the diet) and oilseed meal and cereal bran or an animal by product is given in amounts not to exceed 30% of the total dry matter. Positive responses on intake, liveweight gain and milk yield have been recorded when forage egumes or fodder trees and a concentrate are included in a diet based on crop residues (Kimambo *et al.*, 1992; Kassie *et al.*, 1999; Aregheore and Perera, 2004).

2.2.5. Agro-industrial by-products

The use of agro-industrial by products such as cotton seed cake, sunflower seed cake and brewer's grain, molasses and cereal milling by-products (maize and rice bran) as animal feed has been a common practice for decades in industrialized nations where millions of tons are produced each year (Bistanji *et al.*, 2000; El Hag, 1984).

The major problems facing the use of agro industrial by-products for animal feeding are their bulkiness and limited availability; high cost of transport and the general lack of understanding among livestock owners about the feeding value (Konimba, 1996). A number of studies have reported an improvement in animal productivity when fed low quality forages and supplemented with agro-industrial by-products (Chesworth *et al.*, 1989; Ogundola, 1989; Nkya *et al.*, 1998). Urea-molasses treatment increased crude protein content of maize stover four-fold compared with untreated stover (Munthali *et al.*, 1992). Supplementing urea-molasses treated stover with high levels of maize bran significantly increased liveweight gains of heifers (Munthali et al., 1992). Adebowale and Ademosun (1981) reported a 20% CP and 21 KJ/g gross energy in brewers dry grain. These values are higher than those of maize bran which are commonly used as energy sources in rations for livestock. An improvement in milk yield and reproductive efficiency has been reported when crossbred dairy cows fed low quality forages were supplemented with maize bran (Nkya *et al.*,1998; Mpairwe, 1998 Kabirizi *et al.*, 2004) or wheat bran (Mpairwe, 1998).

2.2.6. Conserved forages

The supply of nutrients from grasslands and harvested forages in the tropics is seasonal because of the rainfall pattern (Humphreys, 1991; Anindo and Potter, 1994). During the rain season, there is luxuriant growth of pastures and during the dry season, pasture is very scarce with resultant decline in animal performance. Hence the need to conserve forage to bridge the nutrient gap during periods of scarcity. Forage conservation in form of hay or silage allows for intensive dairy farming with a higher stocking rate than would otherwise be possible (Bareeba *et al.*, 1983; Muck, 1988; Titterton *et al.*, 2002). A number of factors affecting utilization of conserved forages in smallholder dairy production systems have been reviewed by Bareeba *et al.*

1983); Bareeba (1993), Kabirizi (1996); Titterton *et al.* (2002) and others. These include inadequate land to produce sufficient quantities, losses due to weather, lack of technical knowledge and skills, shortage of labour and capital. In addition, at the end of the rainy season, most crops are ready for harvest so fodder conservation competes with crop harvests for labour. Bareeba (1993) estimated total field losses during hay making ranging between 4 and 60% of the forage dry matter.

Hay from tropical grasses is not widely produced, because it is difficult to combine a good yield with satisfactory nutritive value. The protein content and digestibility of grasses decreases as the proportion of stem increases (Humphreys, 1991). Legume hay is attractive, but suffers the same risk of spoilage unless grown as special crops. Silage requires field curing and special fodder crops such as *Zea mays*, elephant grass fodder and *Sorghum* spp. A review of studies on the use of conserved forages has shown improvement in dairy cattle productivity (Muck, 1988; Bareeba, 1993, Kabirizi, 1996; Titterton *et al.* 2002; Kebread et al., 2005).

2.3. Methods used to improve feed resource availability in smallholder dairy farming systems

A number of possible methods that could be used by smallholder dairy farmers to ensure adequate year round feed supplies have been reviewed (Skerman *et al.*, 1988; Saka *et al.*, 1994; Kassie *et al.*, 1999). These include use of forage legumes (Skerman and Riveros, 1990; Katuromunda, 2001) and fodder trees (Kaitho, 1997; Peterson *et al.*, 1999) as protein supplements; intercropping grasses or cereal crops with forage legumes to prolong higher quality of feed into dry season (Ibrahim and t'Mannetje, 1998; Mpairwe, 1998; Romney *et al.*, 2003; Roothaert *et al.*, 2003), fodder conservation (Bareeba *et al.*, 1983; Kabirizi *et al.*, 2000) and, growing special fodder crops under intensive management in order to provide special pasture or cut-feed for the animals during shortage periods (Mtengeti *et al.*, 1992). Such crops could include Napier grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*); lablab (*Lablab purpureus*); Guatemala grass (*Tripscum laxum*) and various mixtures.

2.4. Role of forage legumes in crop/livestock farming systems

2.4.1. Forage legumes as a source of nitrogen for livestock

Nitrogen is the most limiting element in agricultural production and its deficiency reduces the productivity of crops, pastures and animals (Saka *et al.,* 1994). There are several potential sources of N to overcome this shortfall, namely mineralization of soil organic manure; artificial fertilizers; biological N fixation in legumes and organisms associated with tropical grasses (Nnadi and Haque, 1988). The role of forage legumes as the cheapest potential source of soil, crop and animal N in different farming systems in SSA include enhancement of high protein supply, increase crop productivity, fixing atmospheric N and maintaining the productivity of farmland (Skerman *et al.,* 1988; Mpairwe, 1998; Saka *et al.*, 1994; Katuromunda, 2001).

Biologically fixed N is transformed into leguminous protein and this may be consumed directly by animals in the forages to meet their protein requirements (Steele and Vallis, 1988). The excess is returned to the soil via animal manure and urine. Legumes produce most biologically fixed N and are therefore crucial in maintaining the N balance in nature (Nyatsanga and Pierre, 1973; Skerman and Riveros, 1990). Steele and Vallis (1988) estimated that there is an annual use of 35,000 mt of artificial fertilizer N on pastures, compared with 1.2 mt of N derived from biological N fixation. Very high yielding leguminous crops can add up to 500 kg of N to the soil per hectare per year although inputs of 100-300 kg N/ha/year from good quality legume-based pasture have also been reported (Steele and Vallis, 1988). The companion crop profits from legume-derived N either via release of N due to decay of subterranean parts of the plant and decomposition of the N-rich litter or via grazing animal especially from urine and dung (Skerman *et al.,* 1988).

2.4.2. Forage legumes as feed supplements to low quality forages

In smallholder dairy production systems where land is intensively cultivated for crop production for human use, animals are mainly dependent on crop residues and mature grasses particularly during the dry season. The feeding value of crop residues and mature grasses is inadequate to meet the nutritional requirements of the lactating dairy cows and this results in low animal productivity (Preston and Leng, 1987).

The effects of supplementing low quality forages with forage legumes on animal production have been extensively reviewed (Getachew *et al.*, 1994; Kabirizi, 1996; Saka *et al.*, 1994; Mpairwe, 1998; Kassie *et al.*, 1999; Katuromunda, 2001; Roothaert *et al.*, 2003). The beneficial effects of forage legume supplements include: increased metabolizable energy (ME) intake, increased availability of minerals and vitamins, improved rumen function and a laxative influence on the alimentary system. Forage legumes provide rumen degradable N and/or by-pass N, digestible energy and minerals when used as either supplements or sole feed (Norton and Poppi, 1995). They also contain proteins, minerals and vitamins essential for the growth of rumen microorganisms that degrade feedstuff prior to gastric and intestinal digestion by the host animal (Adu *et al.*, 1992; Mpairwe, 1998).

Significant differences in liveweight gains have been reported between heifers fed Napier grass supplemented with *D. intortum* and heifers fed on sole Napier grass (Mwangi and Wambugu, 2003). Mosi and Butterworth (1985) reported a 20% increase in feed intake of sheep with addition of 20-25% of *Trifolium tembense* hay to *Eragristis tef* straw. Kabirizi (1996) reported an improvement in elephant grass utilization; milk yield and fat corrected milk yield of lactating dairy cows supplemented with 2-3 kg/day of lablab hay. Milk production and composition from sub-tropical pastures is influenced by the legume species (Muinga *et al.*, 1992; Peterson *et al.*, 1998). Peterson *et al.* (1998) reported a 10% increase in butterfat content in milk from cows supplemented with calliandra foliage.

Reproductive performance and efficiency of dairy cows postpartum is largely dependent on the nutritional status of the cow (Butler and Smith, 1989). Poor feeding postpartum reduces luteal function and responsiveness of the ovaries to lutenizing hormone (Whisnant *et al.*, 1985). Cows fed a high energy diet after calving conceived earlier than those with lower energy intake (Hill *et al.*, 1970; Ferguson, 1996; Mpairwe, 1998). Feeding a high plane of nutrition to five anoestrus cows for 45 days resulted in 65% resuming cycling and 55% ovulating whereas the 20 cows kept on low plane diet neither recycled nor ovulated (Dindorkar *et al.*, 1982).

Inadequate nutrition is major cause of long calving intervals in the tropics (Mukasa-Mugerwa, 1989). A calving interval of 365 days is recommended for efficient production (Payne, 1989). Poor reproductive performance and calf losses could be reduced through appropriate management and proper feeding regimes (Mpairwe, 1998). The level of animal nutrition could be improved through use of improved pastures (Nsubuga, 1993); improved crop residues by intercropping forage legumes with cereals (Lupwayi *et al.* 1996); and by supplementing low quality diets with forage legumes (Makembi and Ndlovu, 1996).

A review by Saka *et al.* (1994) showed that under smallholder conditions, forage legumes might be better N supplements than non-protein N, oil seed cakes and other high energy and protein supplements due to high cost and limited availability of these conventional supplements. Therefore, the use of forage legumes as supplements to low quality forages can be an effective way of increasing milk production by smallholder dairy farmers.

2.5. Fodder trees and shrubs and their socio-economic significance in smallholder dairy farming systems

2.5.1. Role of fodder trees

The potential of tree foliage to produce considerable amounts of high protein biomass has led to the development of animal farming systems that integrate the use of tree foliage where low quality feed resources are used. Fodder trees have higher DM yields, better resistance to mismanagement and a capacity to retain high quality foliage under stress conditions compared to herbaceous forage legumes (Kang *et al.*, 1990; Kaitho, 1997; Leng, 1997; Raussen, 1998). Because of their deep-rooted nature, fodder trees are able to tap water and nutrient resources deep in the soil profile (Leng *et al.*, 1991). With proper management and propagation techniques, this fodder can be a viable feed resource to supplement income of smallholder farmers. In mixed farming systems, fodder trees and shrubs can have a stabilizing effect on prices as farmers have a longer holding capacity and are not forced into selling animals in periods of drought (Kaitho, 1997). Both fodder trees and shrubs also provide multiple benefits compared to forage legumes (Kang *et al.*, 1990). Fodder tree crops, establish easily and do not require extensive agronomic inputs. They constitute potentially valuable sources of supplementary feeds that subsistence and medium-scale livestock farmers in the tropics could use to improve livestock nutrition and productivity.

2.5.2. Nutritive value of fodder trees

The nutritive value of tree fodder varies with species, plant part, leaf age, season, soil type (Kaitho, 1997; Leng, 1997; Chamberin, 2001), the state of fodder, whether fresh, wilted or dry (Palmer *et al.*, 1995; Ebong *et al.*, 1999) and drying procedure (Peterson *et al.*, 1999). Dalzell (1996) reported that drying reduces extractable condensed tannins by 25% than obtained from freeze-dried samples. Where tree fodder after drying has been fed to goats on a basal diet of Napier grass, growth rate was stimulated when supplemented with protected soyabean meal (Ebong *et al.*, 1999).

During the dry season, forage usually has poor digestibility because dry old grass is rich in cellulose and lignin and poor in sugar and protein (Kaitho, 1997). Fodder trees and shrubs can provide protein and energy to keep rumen microbes active, increasing their ability to digest fibre, and thus enable livestock to make use of dry season pastures (Leng, 1997; Raussen, 1998). Crude protein contents of fodder trees is much higher than the values commonly given for grasses and forage legumes even at the best times of the year when the growth is vigorous (Kaitho and Kairuki, 1997; Leng *et al.*, 1991; Hinderichsen *et al.*, 2004). While the quality of grasses can fall well below the maintenance requirement (7%) during a long dry season, fodder trees will normally provide sufficient CP (Kang *et al.*, 1990). This therefore justifies their use in relatively small quantities in order to complement poorer quality pastures and crop residues (Kaitho, 1997).

Although fodder from trees and shrubs has been an important source of protein for grazing animals, in some cases, not only has their crude protein digestibility been observed to be low, but also several cases of livestock death have been associated with high tannin content of some foliages (Osuju, 1994; Dalzell, 1996; Maasdorp *et al.*, 1999). The most important property of tannins is their strong affinity for enzyme and feed protein which depends on the fodder tree species (Leng, 1997; Palmer *et al.*, 1995). Tannin content, therefore, potentially alters the use and value of tree foliages by ruminant livestock (Leng, 1997). Small quantities of tannins, however can have beneficial effect, possibly by decreasing rumen degradable protein and ammonia loss (Ebong *et al.*, 1999), and suppressing bloat (Maasdorp *et al.*, 1999). Low tannins in *Gliricidia* is believed to leave the protein so unprotected as to be completely degraded in the rumen (Leng, 1997).

2.5.3. Effect of fodder tree supplementation on animal production

There is extensive and diverse literature on the effects of fodder tree supplementation on the productivity of cattle, sheep and goats (Speedy *et al.*, 1991; Khalili and Varvikko, 1992; Shelton *et al.*, 1996). Fodder tree leaves particularly *Gliricidia sepium* (Mpairwe, 1994), leucaena (Otsyina *et al.*, 1995; Nherera *et al.*, 1998; Aregheore and Perera, 2004) and calliandra (Peterson *et al.*, 1999) have been used as supplements to a wide range of forages and crop residues. Leucaena supplements at a rate of 16% of DM have converted a weight loss to a significant weight gain in both sheep and cattle (Kimambo *et al.*, 1992; Muinga *et al.*, 1992). Muinga *et al.* (1992) reported an increase in DM intake and milk yield and a reduced liveweight loss in early lactation when crossbred cows were fed elephant grass fodder with graded levels of leucaena and a concentrate. Mpairwe (1994) and Kaitho (1997) recommended that, when used as supplements, the optimum dietary level of browses and shrubs should be about 30-50% of the ration on DM basis or 0.9 to 1.5 kg/100 kg BW.

2.5.4. *Calliandra calothyrsus* as a protein supplement to livestock

Calliandra calothyrsus (calliandra) is a fast growing tree/shrub reaching approximately 12 m in height at maturity. The leaves are suitable for forage and out-yield other shrub legumes, especially when grown on acid soil (Salawu *et. al.*, 1997). Annual DM yields of calliandra are in order of 7-47 t/ha of fodder (Tuwei *et al.*, 2003). Calliandra foliage contains 20-25% CP (Kaitho *et al.*, 1997; Salawu *et al.*, 1997; Nherera *et al.*, 1998; Peterson *et al.*, 1999).

Previous studies have shown an improvement in animal performance when supplemented with fresh foliage of calliandra (Palmer *et al.*, 1995; Salawu *et al.*, 1997;

Maasdrop *et al.,* 1999). Dairy heifers consuming an average daily amount of 3 kg of fresh tree fodder over a period of 10 months had an average daily weight gain of 0.55 kg, while exhibiting no apparent health problem (Peterson *et al.*, 1998). Whereas Palmer and Schlink (1992) and Palmer *et al.* (1995) reported that foliage of calliandra has higher value when fed as leaf meal, Kaitho (1997) observed that when calliandra leaf material was fed fresh to sheep, voluntary intake was higher than when fed dry. Ebong *et al.* (1999) observed an improvement in DM intake of elephant grass fodder, digestibility, growth and feed efficiency in goats fed a ration of 50:50 soya bean meal (SBM) to calliandra leaf meal (CLM) compared to goats on elephant grass fodder and pure SBM. The study showed that mixing fodder tree leaf meals in compound rations is an alternative way of using fodder trees in ruminant feeding.

2.6. Elephant grass (*Pennisetum purpureum* K. Schumach) fodder as a livestock feed

Elephant grass and its hybrids was introduced in East Africa as a suitable fodder crop in 1960s and has been increasingly associated with intensive and semi-intensive dairy production systems to meet the increasing demand for milk (Ogwang, 1974; Boonman, 1993). Average dry matter yield of unfertilised elephant grass during the wet season ranges from 3,210 to 5,343 kg/ha, and from 2,456 to 4,544 kg/ha for the dry season with a range of age of 42-63 days (Tilley, 1989; Boonman, 1993). The DM yields range from 27,300 to 37,100 kg/ha in regions with over 125 cm rainfall per year (Ogwang, 1974; Boonman, 1993). Dry matter yields of 17,710 and 23,926 kgs/ha have been obtained from elephant grass hybrids *KW4* and *P 99*, respectively (Ogwang, 1974). He further reported that the DM yields of the leaves ranges from 5,194 kg/ha for *KW4* to 7.715 kg/ha.

The stage of growth of a grass is the primary factor that affects it chemical composition and dry matter intake (Boonman, 1993; Anindo and Potter, 1994; Ogwang, 1974). Crude protein of elephant grass fodder declines with the maturation of the plants (Ogwang, 1974, Bogdan, 1977; Anindo and Potter, 1994). Woulters (1985) observed that 80% of the farms investigated in Kenya did not reach the target of 10% CP, while more than 40% had less than 7.5%. Yields of CP ranged from 403.6 to 487.1 kg/ha for 45 to 60 days cutting intervals, respectively. Samanya (1996) reported that at a height of 0.4 m, elephant grass fodder contained 20.5% DM, 9.8% CP, 29.7% NDF and 14% ash.

Supplementing dairy cows offered elephant grass fodder with forage legumes and/or concentrates improves dry matter intake, liveweight and milk production (Muinga *et al.*, 1992; Kabirizi *et al.* 2000; Katuromunda, 2001). Seiler *et al.* (1979) reported nitrate poisonings in cattle whose diet consisted solely of Napier grass grown under low soil fertility. Levels of nitrate averaged as high as 28.3 mg/g with some samples as high as 44 mg/g, which level in the same species from non-toxic areas was 3.9 mg/g.

2.6.1. Effects of intercropping *Pennisetum purpureum* with forage legumes on fodder dry matter yields

Several studies (Akinyemi and Onayinka, 1976; Mtengeti *et al.*, 1992; Njwe *et al.*, 1992; Shenu and Akinola, 1995; Ibrahim and t'Mannetje, 1998) have shown improved grass fodder DM yields when grasses are grown in mixture with forage legumes. The mixtures produced 22-154% higher total fodder DM yields than their respective unfertilised pure stand of grasses and were effective in controlling the weeds (Ezenwa and Aken'ova, 1998). However, other researchers (Mwangi and Wambugu, 2003; Bareeba, 2003) observed no significant differences in fodder DM yield when elephant grass was intercropped with forage legumes. The higher DM yields in intercrops was attributed to the additive effects of the legume DM rather than the effects on elephant grass performance and that the intercrops were possibly utilizing resources (soil, space) more efficiently (Mureithi and Thorpe, 1993; Mwangi, 2002). Mureithi and Thorpe (1993) observed that although total fodder DM yield was not affected by the legume species, the legume forage yields in the mixtures were significantly different. They further observed that the large differences in the legume cumulative DM yields were primary due to their varying ability to persist as companion crops with elephant grass. In an experiment to evaluate the effects of centro on growth rate and biomass yield of elephant grass fodder Mwangi (2002) and Mwangi and Wambugu (2003) reported that elephant grass tillers tended to suppress the growth of centro in the establishment phase by limiting the amount of light. Bogdan (1977) suggested that large and vigorous legumes capable of withstanding *P. purpureum* competition should be used for the purpose of intercropping with elephant grass.

2.6.2. Effects of intercropping elephant grass with forage legumes on chemical composition of fodder

Sustainable production of grass/legume mixtures depends on the amount of N fixed by the legume (Nitis, 1995; Shenu and Akinola, 1995; Ezenwa and Aken'ova, 1998; Ibrahim and t'Mannetje, 1998). The legumes have a higher nutritive value than the grasses, particularly in protein and mineral contents (Mureithi and Thorpe, 1993; Ezenwa and Aken'ova, 1998; Mwangi, 2002). Katuromunda *et al.* (2001) reported higher CP content from *Pennisetum*/legume mixtures than in sole *Pennisetum* fodder but the results did not show significant differences in calcium (Ca), phosphorus (P), organic matter (OM), ash *in* vitro organic matter digestibility (IVOMD) and NDF contents between the mixtures and sole elephant grass fodder. Higher cumulative yield, digestibility and N were obtained when *P. purpureum* was intercropped with *Macroptilium atropurpureum* (siratro) than when in pure stand (Touvin, 1989).

Skerman *et al.* (1988) observed that the increase in DM yields could be explained by the ability of the leguminous plant species to fix nitrogen, which is then available to the companion grasses. The legumes have been reported to transfer between 3 and 100 kg N/ha/yr to associated grasses in mixtures (Saka *et al.,* 1994; Ezenwa and Aken'ova, 1998; Ibrahim and t'Mannetje, 1998). Bogdan (1977) reported that about 11 percent of N fixed by the legume was transferred to *P. purpureum* during the 6 months of active growth. In the smallholder dairy farming systems in the humid tropics, the incorporation of forage legumes in the ecosystems can play an important role in maintaining soil N levels as well as improving animal productivity.

2.6.3. Effects of elephant grasses/legume mixtures on animal production

Large increases in liveweight gains have been recorded following introduction of legumes in elephant grass provided the soil is not grossly deficient in phosphorus (Ezenwa and Aken'ova, 1998; Mubiru *et al.,* 2001; Jones, 2003; Mwangi and Wambugu, 2003). Based on nutrition and agronomic data collected in Muguga, Kenya, Kaitho and Kairuki (1997) observed that intercropping forage legumes with elephant grass increased the carrying capacity from 8.2 to 9.8 heifers per hectare per year and total live-weight gain from 1,280 to 1,690 kg/ha/yr.

Mugisha *et al.* (1999) reported that because of better quality feeds, milk producers who intercropped forage legumes with elephant grass spent on average less than half on artificial insemination compared to sole elephant grass fodder. The above-cited cases demonstrate the potential role that elephant grass/legume mixtures can play in the livestock production system. This potential has, however, not been translated into tangible benefits on smallholder farms in Uganda, mainly due to poor adoption of the technology by smallholder farmers.

2.7. Effects of intercropping forage legumes with maize crop on maize stover and grain yield

The introduction of forage legumes in cereal-based cropping systems as a promising strategy for increasing crop and livestock productivity in SSA has been extensively reviewed (Abate *et al.*, 1992; Mwebaze, 1996; Mpairwe, 1998; Bosma *et al.*, 2003; Romney *et al.*, 2003). Data from intercropping experiments show that the grain and stover yields of the cereal in the mixture are less than the yields of the same crop grown alone, but that the total productivity per unit of land is usually greater for mixtures than for sole crops (Agboola and Fayemi, 1977; Katuromunda, 2001; Katuromunda *et al.*, 2001; Preston, 2001). Mwebaze (1996) reported a decline in grain yield of 11% when maize was intercropped with green leaf desmodium and a 7% decline with siratro intercrop as compared to sole maize. Similar trends have been observed in the mixtures of *Dolichos lablab* with maize and sorghum (Haque *et al.*, 1985; Mpairwe, 1998). Mpairwe (1998) reported 27% increase in stover yields but the grain yield decreased by 3.3% when lablab was intercropped with maize crop as compared to sole maize crop. In some cases, however, intercropping cereal crops with forage legumes has resulted in increased grain and stover yields (Sabiiti and Mugerwa, 1993). Although there may be reductions in grain yields when cereals crops are intercropped with forage legumes, total biomass productivity per unit land is usually greater for mixtures than for sole crops (Mwebaze, 1996; Mpairwe, 1998; Katuromunda, 2001; Romney *et. al.*, 2003).

The time of planting of the component crops in cereal/forage legume intercrops has great influence on fodder and grain yields and on the relative use of growth resources (Mohamed-Saleem, 1985; Singh and Rathi, 2003). Higher maize grain yields have been reported in the long rains than the short rains (Katuromunda, 2001). The general conclusion therefore is that although there may be reductions in grain yields when cereals crops are intercropped with forage legumes the total productivity per unit land is usually greater for mixtures than for sole crops (Lupwiny, 1996). Therefore, productivity of large amounts of high quality feed in the intercrops offsets the decreased cereal grain yield.

2.7.1. Effects of intercropping forage legumes with maize crop on chemical composition of maize stover

Cereal stovers are characterized by low levels of CP (<6%), minerals, vitamins, readily fermentable energy content and metabolizable energy (<7.5 MJ/kg DM) that limit their utilization by livestock (Mohamed-Saleem, 1988; Munthali *et al.*, 1992; Lupwanyi *et al.*, 1996). Previous studies have shown that intercropping cereals with forage legumes improves CP and total crude protein yields (CPY) (Nnadi and Haque, 1988; Saka *et al.*, 1994; Mpairwe, 1998). When *L. purpureus*, *Trifolium steucheri* and *Medicago polymorpha* were intercropped with maize, CPY of 619, 585 and 505 kg/ha, respectively were obtained compared with 269 kg/ha for pure maize (Nnadi and Haque, 1988). It has been observed that very high CP yields could be obtained from intercropping cereal crops with lablab due to N fixed by the legume (Nnadi and Haque, 1988; Mpairwe, 1998). Agboola and Fayemi (1977) reported that 45 kg N/ha of N was transferred from the legume to the maize in a cereal/legume intercrop. In an experiment at Debra Zeit, Ethiopia, Nnadi and Haque (1988) reported higher N content in grain from maize that was intercropped with vetch whereas lablab and clover showed no such effects. Saka *et al.* (1994) found no evidence that the presence of a legume has specific effects on the release of N from actively growing roots.

2.7.2. Effects of feeding cereal/forage legume stover on animal production

Improved DM intake, liveweight, body condition, milk yield and reproductive efficiency have been reported in dairy cows fed cereal/legume stover supplemented with forage legumes and concentrate (Islam *et al.*, 1995; Kawonga and Kulich, 1995; Crosse *et al.*, 1998; Diriba *et al.*, 2001) or/and fodder trees (Robertson, 1988; Kimambo *et al.*, 1992; Nherera *et al.*, 1998; Hinderichsen *et al.*, 2004). When crossbred cows were fed maize/lablab (ML) stover or oats/vetch (OV) with lablab hay and wheat bran supplements, there was an improvement in total DM intake by 21% (Mpairwe, 1998). Milk yield improved by 27% and postpartum anoestrus interval decreased by 34% with a calving to conception period interval of 80 days. The results also showed an improvement in rumen environment and total volatile fatty acids production which was reflected in the improved passage rates of particulate digesta and the rates of DM, OM, N and NDF degradation greater than 3% per hour. Addition of legume haulms to cereal crop residues increased total DM intake and/or digestibility of the feeds (Adu *et al.*, 1992).

The adoption of forage legume/cereal intercrop by smallholder dairy farmers will, therefore, depend on the demonstration of their productivity and subsequent positive impact on cereal and livestock production. Mpairwe (1998) recommended that for the cereal/forage legume intercropping technology to be fully integrated within the crop/livestock farming system, on-farm feeding trials should be carried out to assess the practicability and economic feasibility of utilizing the forages produced from cereal/ forage legume intercropping fed to the breeds of cows available with farmers and supplemented with on-farm available forage legumes and crop by-products.

2.8. Effects of supplementing low quality forages with concentrate and/or forage legumes on animal performance

The effects of forage legume and concentrate supplements on voluntary dry matter intake, milk production and milk composition and reproductive performance of crossbred dairy cows has been widely reviewed (Zerbini *et al.*, 1994; Malossin *et al.*, 1995; Kabirizi, 1996; Kassa and Tegegne, 1998; Jingura *et al.*, 2001; Katuromunda, 2001). Little *et al.* (1994) found that 0.5 to 1.0 kg of protein supplement (cottonseed or sesame cake) throughout the dry season improved the calving interval from about 420 to 360 days. Keady *et al.* (1999) observed that the impact of reduced feed intake is most often seen as a depression in milk and/or milk component yields as well as reductions in weight gain or increases in weight loss. Increasing the levels of concentrate feeding pre-calving increased days to first progesterone rise, the onset of cyclicity and reduced the number of services/conception (Keady *et al.*, 1999).

Milk production of crossbred cows increases when they are supplemented with concentrates and/or forage legumes (Kiwuwa *et al.,* 1983; Malossin *et al.*, 1995; Mpairwe, 1998; Kabirizi *et al.,* 2000). Pregnancy rates of cows supplemented with forage legumes and a concentrate in the wet season were about twice those of unsupplemented cows in the same season or those of cows supplemented and bred in the dry season (Ambrose *et al.,* 1984). Butterworth (1985) concluded that supplementation of breeding stock with forage legumes and concentrates lowered age at first calving, increased calving rate, shortened the interval between parturition and first oestrus and decreased mortality. The use of forage legumes and concentrates as supplements to dairy cattle offered low quality forages could therefore be an effective way of increasing milk production and overall productivity in smallholder production systems.

2.9. *Lablab purpureus* (lablab) as a fodder

Herbaceous forage legumes play an important role in improving animal productivity in temperate areas, a role that has yet to be clearly demonstrated for farmers in Uganda (Koume *et al.,* 1992; Kusekwa *et al.*, 1992; Boitumelo and Mahabile, 1992). On-station agronomic trials to examine various annual fodder legume species screened for drought resistance, ease of management, high DM yield and nutritive value in Uganda have shown that *Lablab purpureus* (lablab) cv Rongai is the most productive and the most easily established legume on smallholder dairy farms (Sabiiti, 1993; Kabirizi *et al.,* 2000). *Lablab purpureus*, previously classified as *Dolichos lablab,* is known in different parts of the world by different names (Jingura *et al.*, 2001; Hinderichsen.*et al.*, 2004).

Lablab plants can be drilled with maize at about 3-5 weeks after planting, when the maize is about 15 cm high (Mpairwe, 1998). Lablab has a long production season and can provide fodder and soil protection when many other herbaceous legumes have become desiccated (Kabirizi, 1996). Staying green during the dry season, lablab can provide up to 12 tones of DM/ha depending on rainfall, soil condition and time of seeding (Thomas and Dabas, 1982; Kabirizi, 1996). Average lablab DM yields from farmers' fields are about 1.5 t/ha (Boitumelo and Mahabile, 1992).

The crude protein content of lablab leaves ranges between 20 to 29% while that of the stems range between 8 and 16% and the whole plant 14-19% (Murphy and Colucci, 1999). With an average of 17% CP in the DM of about 6,000 kg/ha, lablab CP yield/unit area is therefore slightly above average when compared to other tropical legumes and has more protein than tropical grasses (Murphy and Colucci, 1999). The CP content and *in* vitro organic matter digestibility (IVOMD) of lablab plants decrease with maturity while the fibre fractions (ADF, NDF and ADL) follow an inverse pattern (Kabirizi *et al.*, 2000). Mean DM digestibility of lablab has been reported to be about 56%. Lablab therefore ranks well in DM digestibility compared to both tropical grasses and legumes (Mpairwe, 1998). Skerman *et al.* (1988) observed that lablab leaves do not contain tannins, thus they provide a rapidly fermentable source of protein with little by-pass protein potential.

Lablab can be fed as a good quality fresh foliage, hay or silage (Kabirizi, 1996; Murphy and Colucci, 1999). Lablab hay as a supplement to cattle on a poor quality basal diet increased rumen ammonia concentration, improved straw digestibility, increased particulate passage rate, decreased mean retention time and improved DM intake (Mpairwe, 1998; Hinderichsen *et al.*, 2004). Mean voluntary intake values indicate satisfactory palatability of lablab at vegetative stage of growth (Murphy and Colucci, 1999). After flowering, the leaf is the most valuable component of a lablab crop because of its higher CP content compared to that of the stem (Kabirizi *et al.*, 2000). These characteristics demonstrate the potential that lablab has in alleviating nutrient deficiencies in poor quality diets especially during the dry season.

Improved growth rates and milk yield have been reported in dairy cattle on low quality roughages supplemented with lablab hay and concentrate (Boitumelo and Mahabile, 1992; Mpairwe, 1998; Kabirizi *et al.*, 2000; Hinderichsen *et al.*, 2004) or with lablab hay, fodder tree hay and concentrate (Hinderichsen *et al.*, 2004). Maize stover diet supplemented with lablab resulted in better body weight changes of the does, higher kid birth weights, faster growth rates, more milk and shorter postpartum anoestrus periods as compared to traditional smallholder practices in which no supplementation was used (Makembe and Ndlovu, 1996). Kabirizi *et al.* (2000) recommended that for optimum milk yield, cross bred cows weighing about 450 kg liveweight on a basal diet of elephant grass fodder should be supplemented with 2-3 kg/cow/day of lablab hay and 4 kg/cow/day of concentrate. In Uganda, however, utilization of lablab hay as a dry season protein supplement to dairy cattle is a new technology that has not been tested on-farm. In light of the existing literature, feeding lablab hay, as a dry season supplement need to be encouraged and should form a basis for testing it as an on-farm feeding technology for zero grazing dairy farmers in Uganda.

2.10. Factors affecting adoption of forage legume technologies in smallholder crop/livestock farming systems

Numerous studies have been conducted to assess factors affecting adoption of forage crop technologies on smallholder crop/livestock farming systems (Nicholson *et al.*, 1992; Irungu *et al.*, 1998; Bosma *et al.*, 2003; Gebremedhin *et al.*, 2003; Mugisha, 2003; Muyeko *et al.*, 2003; Mwangi and Wambugu, 2003; Wanyama *et al.*, 2003). According to Wanyama *et al* (2003) and Peters and Lascano (2003), land and capital availability, farmer participation in on-farm trials, age and education of farmer and farmer experience are the major factors influencing adoption of forage technologies. However, Mwangi (2002) noted that availability of planting material and ease of propagation are the critical issues that need to be addressed before farmers would adopt the technologies. Moffat and Ngwira (2003) identified scarcity and high cost of forage seed, difficulties associated with forage establishment and maintenance, inaccessibility of forage research results by the end users and lack of appreciation of the value of forage by farmers as the major factors affecting adoption of forage technologies. Peters and Lascano (2003) recommended that participatory development and evaluation of forage legume technologies might be the key to improving adoption of forage legumes amongst smallholder farmers. Franzel *et al.* (2003) observed that successful dissemination of new technologies such as planting and use of fodder shrubs requires much more than the transfer of seed and knowledge. It rather involves building partnerships with a range of stakeholders and ensuring the appropriateness of the practice and farmers' interest in it. Success in disseminating the technologies also involves assisting local communities to mobilize resources, and ensuring effective participation of farmer groups in testing, disseminating, monitoring and evaluating the practice.

Although Government of Uganda and NGO have implemented forage development programmes in Uganda for over 30 years, there is no well-documented information relating to farmers' experiences (benefits and constraints) in the production and utilization of forage legumes in smallholder dairy farming systems. Mubiru *et al.* (2001) recommended that on-farm studies that incorporate experiences in the production and utilization of forage legume technologies should be carried out in Uganda as these largely influence technology adoption.

2.11. Farming Systems Research (FSR)

In SSA, rapid population growth has greatly exceeded the growth of food production over the last decades (IFPRI, 1996). Sustainable gains in agricultural productivity in SSA have proved elusive despite substantial investment in agricultural research (Jones, 1998). It is now well accepted that farmers should be involved in the identification and testing of agricultural technologies (Norman *et al.*, 1995; Kesseba, 1989; Velarde *et al.*, 2000; Peters and Lascano, 2003). The wider recognition of this practice and the need to take into account the socio-economic circumstances of the small-farm household, has led to the rationalization of the "Farming Systems Research" (FSR) or research with a farming system perspective (Heinrich *et al.*, 1997; Jagadish, 1998; Jones, 1998).

The farming systems approach suggests that in order to give adequate weight to farmers' goals and management strategies, adaptive research is best undertaken through on-farm, farmer-managed experiments (Norman *et al.*, 1995; Collinson, 1998). Both technical and socio-economic factors can then be taken into account and the experiments are used not only to evaluate technologies, but also to provide feedback to guide research workers at all levels in planning their future work (Norman *et al.*, 1995). Consequently, the use of FSR is often suggested as a tool for promoting technological change and technology transfer for smallholders (Singh *et al.*, 1995). It has sought to apply the power of scientific methods and knowledge to the solutions of the farmers' problems. Although Jagadish (1998) and Sebillote (1994) pointed out that there are methodological and institutional tensions in the pursuit of the solutions to farmers' problems through the FSR, it provides researchers an opportunity to evaluate roduction and utilization of forage technologies with farmers and getting feedback to uide further research.

.12. Nutrient Requirements of dairy cattle

lealthy rumen microbe populations are important to dairy cows (Leng, 1997). lourishing microbial populations can provide 50% to 80% of a dairy cow's daily rotein requirement and up to 80% of its energy requirements (Shaver *et al.*, 1995). he remainder of the cow's nutrients comes from the level of recommended daily utrients fed (NRC, 2001). In addition, research has shown that well-managed herds vith flourishing rumen microflora perform more consistently with smaller fluctuations in DMI, milk production and milk components (Shaver *et al.*, 1995). These cows cost-effectively maintain sustained levels of high production and performance. According to NRC (2001), the major nutrients for the growth and production of cattle are protein, energy, minerals and water although others such as vitamins are also important.

2.12.1. Protein

Intake of feeds with low organic matter digestibility is often depressed, due to a large physical fill in the rumen (Kaitho, 1997; Mlay, 2001; Waisswa *et al.* 2003). Protein supplementation for low-quality forages has been reported to increase microbial fermentation and increased rate of forage digestion and particulate passage (Zinn and Owens, 1986). Lack of rumen degradable protein occurs where rumen ammonia concentration falls below 5 mg NH_3-N per 100 ml (Waisswa *et al.*, 2003; Weisbjerge *et al.*, 2003). This results in impaired rumen fermentation. Requirements for degradable protein can be met from both normal feed protein and by supplying non-amino acid protein in sources like urea (Mlay, 2001). Essential amino acids are needed by high producing cows and must come either from dietary protein that escapes degradation or microbial protein produced during rumen fermentation and passed along to the small intestine (Curtis *et al.*, 1985; Kamatalit *et al.*, 1992). Additional undegradable protein fed during late gestation has improved body condition at calving in dairy and reduced days open compared to cows receiving a similar diet containing less protein (Van Saun and Sniffen, 1996). Topps (1994) recommended that protein-rich ingredients needed to be incorporated into the diet as substitutes for crop residues such as maize stover. By doing this, efficiency of rumen function would be increased and hence supply of nutrients (Orskov and Ryle, 1990).

2.12.2. Energy

Diets deficient in energy retard microbial protein fermentation, digestion and feed efficiency and therefore have a negative effect on growth and reproductive performance in cattle (Ovenell *et al.*, 1991; Marston *et al.*, 1993; Britt, 1998; Keady *et al.,* 1999). The more feed cows consume, the more energy they receive and the more milk they can produce (Keady *et al.,* 1999). By optimizing rumen fermentation or microbial activity at high DMI levels, cows maximize the level of nutrients retained from feed (Fergueson, 1996). The presence of the bacteria populations required to digest forages, fiber and starch helps make this possible.

Optimizing the rumen microbial population contributes to maximizing feed intake, fiber digestion and microbial synthesis for consistently high production levels (Marston *et al.*, 1993). It also increases volatile fatty acid (VFA) production for increased energy availability, decreases the risk of acidosis by reducing accumulation of organic acids and increases microbial protein reaching the small intestine by optimizing protein degradation in the rumen (Leng *et al.*, 1991).

A review by Ferguson (1996) and Ayahinde et al. (2005) shows that energy levels below maintenance requirements (95 MJ/kg DM) in the diet of pregnant cows increased maternal weight loss, and reduced low milk yield. Supplementation can positively or negatively affect forage digestion depending on the source of supplemental energy (starch or digestible fiber) and level of feeding (Martin and Hibberd, 1990; Pordomingo *et al.*, 1991). Grigsby *et al.* (1992) reported that for energy supplementation to be effective, rumen degradable protein requirements must be met. A comparative study of the value of nutrients supplied to cows in smallholder dairy farming systems in Kenya showed that there was a deficit of metabolisable energy (in supporting the desired level of output) of up to 15 MJ/day and a large deficit of effective rumen degradable protein of 235 g/day. The shortage or protein was considered to be much more critical than that of energy.

2.12.3 Water

Water is necessary for maintaining body fluids and proper ion balance; digesting, absorbing, and metabolizing nutrients; eliminating waste material and excess heat from the body; providing a fluid environment for the foetus; and transporting nutrients to and from body tissues (Murphy *et al.*, 1983; Beede, 1992). Dairy cattle get the water they need by drinking and consuming feed that contains water, as well as from metabolic water produced by the oxidation of organic nutrients (Pyne, 1990). The factors affecting water in cattle include: the amount of dry matter intake, the nature of feed, level of salt intake, air and water temperature, physiological stage of the animal, availability of water and the succulence of feed (Kebreab *et al.*, 2005). Water supply, if limited restricts voluntary feed intake and feed utilization of livestock depending on various factors and mechanisms (Laghans *et al.* 1995). NRC (2000) gave water requirements in terms of water required per kg dry matter ingested. For cattle, beyond the young calf stage, most estimates are within the range of 3-5 kg water per kg DM. For lactating cows giving 10 kg of milk per day and weighing 600 kg, an increased intake (from 78 to 105 kg per day is predicted when the temperature rises by about 10^0C. NRC (2001) recommended that water should be available all the time.

2.12.4 Minerals

Proper mineral nutrition and supplementation is essential to animal health and high levels of milk production (Durand and Komisarczuk, 1988; Morse et al., 1992). Forages contain mineral components which affect soil conditions and may therefore be low in essential nutrients such as calcium, phosphorus, sodium, chlorine, manganese, magnesium and sulphur as well as trace minerals such as cobalt, copper, selenium and zinc (Leng, 1997). The net effect of such deficiencies in the rumen is similar to a deficiency of nitrogen or ammonia, that is it lowers microbial cell yield per unit of carbohydrate digested and at times a lowered deficiency will be on microbial growth, thus the symptom that first arises in one of malnutrition or protein deficiency (Leng, 1990; McDowell et al. 1993; Leng, 1996).

In Uganda, however, no long-term participatory on-farm studies have been conducted to assess the effects of low magnitudes of CP, energy, minerals and water intake on body weight changes, body condition, milk yield and reproductive efficiency on smallholder dairy farms.

CHAPTER 3

3. GENERAL MATERIALS AND METHODS

A study was conducted in Masaka district, Uganda from 2002 to 2004 to assess the effect of incorporating forage legumes in intensive smallholder dairy farming systems on feed availability and animal performance. The first part of the study consisted of a diagnostic survey to characterize intensive dairy cattle production system and together with farmers identify forage legume technologies and energy supplements that could be tested on-farm to improve animal productivity. This was followed by two on-farm ials. The first trial evaluated the effects of intercropping maize with lablab or forage gumes (centro, siratro and green leaf desmodium) with elephant grass on grain and dder production. The second determined the response and profitability of crossbred vs fed forages from an intercrop of maize/lablab or elephant grass/forage legumes plemented with a legume hay and a homemade concentrate. At the end of the , a survey was conducted to identify benefits and constraints resulting from ration of forage legume technologies in the farming system.

cipatory research approach was applied during the implementation of the study which farmers were actively involved in all the stages of the research process om problem diagnosis and setting of the research agenda (identifying gies for on-farm studies), testing of selected forage technologies to ent of the technologies.

scription of study area

vas carried out in Masaka district, located between 0^0 15' and 0^0 43' South or and between 31^0 and 32^0 East longitude (Appendices 6.1 and 6.2). The of the district situated in the Lake Victoria Crescent area, is traditionally a , with the environmental conditions and climatic patterns highly exotic and cross breeds (Anon, 2004). The district has two rain seasons from March to May and the other from end of November to mid annual average rainfall is 800-1000 mm with 100-110 rainy days and nidity of 61.2%. Appendix 6.3 shows a 5-year total monthly rainfall ecorded from 1999-2003 at Kamenyamigo District Agricultural Training and nformation Center (DATIC). The average minimum and maximum temperature was 15.8^{0}C and 30.3^{0}C, respectively. The soil texture ranges from red laterite to sandy oam but is productive. The total geographical area of the district is about 4,560.4 sq. km out of which about 25% is under water and 20% under cultivation (Anon, 2004). In 2002, the district had a projected human population of about 0.9 millions with 49.5 and 50.5% male and female, respectively.

The major crops grown in the district in 2003 were bananas (79,800 ha), coffee (79,000 ha), maize (15,000 ha), cassava (18,000 ha) and sweet potatoes (15,000 ha), although other crops such as pineapples, yams and irish potatoes were found throughout the district (Anon, 2004). The district cattle population in 2003 was 102,486 heads constituted by 11,500 exotic or high-grade dairy breeds (Anon, 2004). Zero grazing dairy cattle production system is a major source of milk, income and employment for resource poor farmers especially women. The number of zero grazing units increased from 844 units in 2001 to 6000 units in 2003 (Anon, 2003). Inadequate supply of high quality animal feed all-year round is a major constraint limiting this sub-sector as earlier described by Anon (2003).

tudy 1: Production practices, constraints and future prospects of intensive dairy cattle production in Masaka district

1.1.1. Specific objectives

1. To identify feed resources used in intensive smallholder dairy production systems and their effects on dairy cattle productivity.
2. To identify with farmers forage legume technologies and energy supplements that could be tested on-farm to improve animal productivity.

3.1.1.2. Sampling procedure and data collection

Using information from the district extension staff and local leaders, a list of all sub-counties in urban, peri-urban and rural areas in the district was compiled. A quick reconnaissance survey was carried out to identify concentration of intensive dairy cattle milk producers in the three study areas. Three sub-counties (Masaka Municipality, Kalungu and Bukulula) representing urban, peri-urban and rural areas respectively and were accessible were randomly selected. A list of zero-grazers having 1-3 crossbred dairy cattle in each sub-county was compiled using information from the sub-county extension coordinators and local leaders. From each selected sub-county, 35 zero-grazers were randomly selected. Information on household characteristics, farm activities and facilities, land resource utilisation, forages and supplements used in feeding dairy cattle were collected from each household using a structured questionnaire (Appendix 6.4) supplemented by on-site observations. The questionnaire was pre-tested on 15 farmers (5 farmers per sub-county) in Masaka district after which it was revised to incorporate farmers' concerns in a participatory manner. A total of 105 farmers (35 from each sub-county) were interviewed. During the individual interviews, respondents were asked to indicate their interest in participating in on-farm trials to evaluate selected forage/feed technologies for increased feed resources availability leading to improved animal productivity.

In addition, Participatory Rural Appraisal (PRA) was used to involve many zero grazers, key informants and other stakeholders in the areas were held with 3 farmer groups each comprising of farmers who had benefited from in-calf heifer projects in

.1.2. Study 2: Effects of intercropping maize or *P. purpureum* with forage legumes on grain yield and fodder production

.1.2.1. Specific objectives

a) To determine the effect of intercropping forage legumes with maize or *P. purpureum* on maize grain and fodder dry matter (maize stover, *P. purpureum* and legume herbage) yield on smallholder dairy farms.
b) To evaluate the effect of intercropping forage legumes with maize or *P. purpureum* on chemical composition and *in vitro* dry matter digestibility of the fodder.

3.1.2.2. Study area

The study was conducted on 32 households selected from 4 villages (Butego; Kitenga, Kalungu and Buyikuuzi) in Bukulula sub-county of Masaka district (Appendices 6.1 and 6.2). Butego represented the urban areas where over 10% of the zero grazers depend entirely on purchase elephant grass. Eight households were selected from each village. Selection of the villages was based on the population of zero grazed crossbred dairy cows and on the number of farmers who expressed their interest in participating in on-farm research to test improved forage technologies for improved animal productivity (Study 1). Selection of the households was based on: i) willingness of the farm owner to participate in the study (Results of Study 1); ii) having a minimum of 0.5 ha of well established and managed elephant grass fodder field (iii) availability of land and labour to plant and manage the forage fields; iv) having one (8-12 weeks in-calf cow, parity=1) at the start of the trials and; iv) willingness of the farm owner to allow other farmers to visit the trials for purposes of monitoring and evaluation of the trials and to learn from participating farmers. All selected farmers were beneficiaries of Send-a cow Heifer Project. Two enumerators who were familiar with the study areas were recruited and trained to assist the farmers in data collection.

The Geographical Positioning System (GPS) was used to provide the geographical position (latitude and longitude) of the farms (Appendix 6.2). To establish the nutrient status of the soils, three replicate samples were taken from each of the 32 farms ɪefore (March 2002) and at the end of the study (September 2003) (Appendix 3.5). ᒥhe samples were taken from the plough layer (0-15 cm and 15-30 cm) on each site. ᒥhe samples were analysed for chemical properties [pH, Organic matter (OM), Nitrogen (N), Phosphorus (P) and Calcium (Ca)] using procedures described by Okalebo *et al.,* 2000).

3.1.2.3. Field experimental design

The experimental set-up was a Randomized Complete Block Design (RCBD) with two cropping systems (Table 3.1).

Table 3.1: Experimental treatments

Cropping system	Treatment
Elephant grass	Elephant grass/legume mixture
	Elephant grass monocrop
Maize	Maize/lablab intercrops (ML)
	Maize monocrop (Sole maize)

NB: the legumes in elephant grass/legume mixture were: *Centrosema pubescens* (centro), *Macroptilium atropurpureum* (siratro) and *Desmodium intortum* (green leaf desmodium).

Each of the cropping system had 2 treatments (monocrop and intercrop) replicated 8 times. Selection of the treatments (Table 1) depended on the farmers' choice of the technologies for on-farm trials to improve feed resource availability and dairy cattle performance (Appendix 6.6). More (16) farmers were selected for elephant grass compared to maize (8) because few farmers had sufficient land to plant maize (monocrop and intercrop) in addition to area already under elephant grass.

3.1.2.3.1. Production of elephant grass/legume mixtures (EGL) and sole elephant grass (sole EG)

At the beginning of the first rain season (March 2002), each of the 16 households selected to test elephant grass cropping system (elephant grass/forage legume intercrop and elephant grass monocrop) received seeds of *Desmodium intortum* (green leaf desmodium), *Macroptilium atropurpureum* (siratro) and *Centrocema pubescens* (centro) to sow into 0.5 ha of an already established elephant grass field. A seed rate of 3, 2 and 1 kg/ha of centro, siratro and desmodium respectively were used. The forage legumes were introduced where elephant grass fodder had been harvested and the ground dug to leave only the stools. At sowing time, the three forage legume seed species were thoroughly mixed together and sown between elephant grass rows (Appendix 6.7). Compost manure (1-2 ton/ha/season) was applied to the fodder fields to improve soil fertility and fodder DM yields (Mpairwe, 1998).

Sampling started 10 weeks after the germination of the forage legumes and continued every 45 days for 17 months. Sampling was done on 6 randomly selected households. Herbage biomass yield was estimated by cutting fodder at ground level from six randomly selected quadrate of 1 m x 1 m each. At each harvest, three elephant grass plants were randomly selected from each plot, their heights measured and recorded. Sampling was repeated in the centre, diagonal crossing, and edge of the field. Total (legumes + grass) forage yields per hectare were estimated by using an equation: $Y = R \times 10{,}000$ (where Y = the fresh weight yield in one hectare and R = yield in one square meter) (Nitis, 1995). Forage yields were estimated both in the dry and wet season.

The harvested material was weighed and then separated into elephant grass and forage legumes and the fresh weight recorded. Sub-samples of about 0.3 kg of each material (EGL, forage legumes and elephant grass fodder from intercrop) were taken and oven dried at 60^0C to constant weight. The dried samples were used for DM estimation and chemical analysis. For comparison, similar sampling (herbage biomass yield and chemical composition) was done on sole elephant grass where the legumes were not introduced.

3.1.2.3.2. Production of maize/lablab intercrop (ML) and sole maize

At the beginning of the first and second rains (March and September 2002, respectively), 8 households were selected to test maize cropping system (maize/lablab intercrop and maize monocrop). About 0.2 ha/season of maize/lablab intercrop (ML) and 0.2 ha/season of maize monocrop were established on each of the 16 households at the beginning of the first and second seasons of 2002 (Cropping systems 2 and 3). Maize (variety *Longe 1*) was planted at a spacing of 75 cm x 50 cm using 2 seeds per hill and a seed rate of 20 kg/ha as recommended (Imanyoha *et al.*, 2000) (Appendix 6.8). After the first weeding (about 3 weeks after the germination of maize seed), lablab (cv Rongai) seed was introduced into 0.2 ha of maize crop rows at spacing of 1m x 1m using 2 seeds per hill. Maize monocrop was planted using similar procedures described by Imanyoha *et al.* (2000).

Maize grain from the intercrop and monocrop was harvested at physiological maturity, 120 days after planting the maize seed (Imanyoha *et al.*, 2000). Maize/lablab stover (ML), cobs and grain yields were estimated on whole plant basis from six randomly selected plots of 1 m x 1 m each, sampled from each of the 6 randomly selected households. Total yield per hectare was estimated by using an equation: Y = R x 10,000 (where Y = the fresh weight yield in one hectare and R = yield in one square meter). The mean weight per cob, grain, lablab and stover yield from each plot was recorded. The ML plants and cobs from each plot were harvested, weighed and the material was separated into maize stover, lablab, cobs and grain fractions and each fraction weighed separately. After separating the dry cobs, the above ground plant material from the intercrop (stover and lablab) were preserved as animal feed, and stored on a well ventilated rack that was constructed below the roof of the cowshed. The grain and stover yield from each household was recorded. In all cases, the farmers did routine management of the fodder fields with regular supervision from the enumerators.

3.1.2.4. Monitoring and farmers' assessment of the technologies

Participatory techniques including group meetings, on-farm visits, and informal discussions were used to monitor and assess the performance of the technologies that were introduced on the farms and their contribution to household welfare. The meetings were held in the villages, where participating farmers came from. Field days were held to encourage interaction and collaborative learning between participating and non-participating farmers. Participatory evaluation was done using a check list (regrowth capacity, yield, resource-land, labour and capital required and drought resistance) and later during the feeding trials, the effect on animal productivity -milk yield and body weight and body condition) and overall farm profit. For purposes of monitoring the performance of the technologies, the farmers recorded in their record books all the data that was collected on their farms. Farmers scored 1-5 (1=poor and 5= very good) the contribution of the forage technologies to dairy cattle feeding and household welfare. Performance of animals accompanied by records on fodder production helped farmers to decide on what technology they would adopt.

3.1.2.5. Chemical analyses

Samples of about 0.3 kg of elephant grass/legume mixtures, elephant grass and legumes from the mixtures and forage legumes; stover, lablab and maize/lablab stover from intercrop and samples of stover from monocrop were randomly taken, weighed and oven dried at 60^0C to constant weight. The dried samples were used for DM estimation, chemical analysis and IVOMD. Similar analyses (DM yield and chemical composition) were done on samples taken from maize monocrop. All dried samples were weighed, ground, sieved through a 1 mm sieve and stored in airtight sample bottles. Samples were analysed for crude protein (CP) using Kjeldahl method as described by A.O.A.C. (2001). Crude protein yield (CPY) was calculated as the product of fodder DM yield and CP percentage. Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) were analysed using Van Soest and Robertson (1985) methods and IVOMD by the Tilley and Terry (1963) technique. Calcium (Ca) and Phosphorus (P) contents were determined using methods described by Okalebo *et al.* (1993). Metabolisable energy (ME) was estimated using a regression equation developed by Close and Menke (1986) where ME (MJ/kg DM) = 0.15*IVOMD; where IVOMD = *in vitro* organic matter digestibility (%). Chemical composition for elephant grass monocrop and intercrop was estimated during the wet and dry season while the chemical composition for maize monocrop and intercrop were estimated in the first and second seasons.

3.1.2.6. Statistical analyses

Data on maize grain and fodder DM yield and chemical components (CP, CPY; IVOMD; Ca; P and ME) of the fodder were subjected to analysis of variance for a Randomized Complete Block Design (RCBD) using SAS (Statistical Analytical Systems) (1999). The following statistical model was used in the data analysis:

$Y_{ijk} = \mu + C_i + S_j + HH_k + (CS)_{ij} + e_{ijk}$,

where Y_{ij} = fodder or grain yield or chemical composition for the k^{th} HH in the j^{th} season managed by the i^{th} cropping system;

μ = Overall mean;

C_i= Effect of i^{th} cropping system (C), 1-2 (monocrop; intercrop);

S_i=j^{th} Season [dry and wet];

HH_k = Effect of the k^{th} Household;

$(CS)_{ij}$ = the interaction between the i^{th} cropping system at j^{th} Season; e_{ijk} =Random error.

Comparisons of means were considered significantly different at ($p<0.05$) using the Least Significant Difference (LSD).

3.1.3. Study 3: The performance of crossbred cows fed forages from elephant grass/legume or maize/lablab intercropping systems and supplemented with legume hay and a homemade concentrate

3.1.3.1. Specific objectives

1. To determine milk production, body condition, body weight and reproductive efficiency of crossbred dairy cows fed forages from elephant grass/legume (EGL) or maize/lablab (ML) intercropping systems supplemented with calliandra leaf hay (CLH) and/or lablab hay (LH) and a homemade concentrate (HMC).
2. To determine the economic benefits of supplementing CLH and/or LH and a HMC to crossbred dairy cows fed forages from EGL or ML intercropping systems compared to sole elephant grass fodder.

3.1.3.2 Experimental design and treatments

Four dietary treatments (Table 3.2) were randomly allocated to 32 cows (one cow per household) in a Completely Randomized Design (CRD) with 8 replications. Each treatment was replicated 8 times. The trials were conducted in 4 villages with each village having 2 cows per treatment.

Table 3.2: Experimental treatments

Treatment	Basal forages	Supplements
1	EGL	LH + HMC
2	EGL	LH + CLH + HMC
3	EGML	CLH + HMC
4	Sole EG	None (farmers' practice)

EGL=elephant grass/legume mixture; EGML = elephant grass fed with maize stover/lablab; LH= lablab hay; CLH = calliandra leaf hay; HMC= homemade concentrate

Selection of the treatments/technologies was based on farmers' preference of the technologies during a feedback workshop (Appendix 3.6) and on previous on-station studies (Sabiiti and Mugerwa, 1990; Ebong *et al.,* 1999; Kabirizi, 1996; Mpairwe, 1998; Katuromunda, 2001). Treatments 1, 2 and 3 are referred to as "supplemented" while treatment 4 is referred to as "unsupplemented".

3.1.3.3. Production and management of basal forages and supplements

The basal forages [elephant grass/forage legume mixtures (EGL), elephant grass fodder fed together with maize/lablab stover (EGML) and sole elephant grass fodder (EG)] were produced as described in sections 3.1.2.3.1 and 3.1.2.3.2. the supplements [lablab hay (LH) and calliandra leaf hay (CLH)] were established in March 2002 as indicted in sections 3.1.3.3.1 and 3.1.3.3.2.

3.1.3.3.1. Production of lablab hay (LH)

In March 2002, each of the 16 households selected to test LH as a supplement (Treatments 1 and 2) was supplied with 4 kg of lablab seed to plant 0.25 ha of lablab fodder. Lablab seed was planted using a seed rate of 12 kg/ha and a spacing of 1 m x 1 m (Kabirizi, 1996). The farmers weeded the fields manually throughout the study period whenever necessary. Harvesting was done manually using hand shears. The plants were cut to about 30 cm above the ground level and above the branches to allow regrowth (Kabirizi *et al.*, 2000). Harvesting was done when 50% of the plants had flowered (Kabirizi, 1996). All the material was harvested on the same day. This was achieved by using a lay-on system where participating and other interested farmers worked in groups to solve the labour problem. The material was left in the fields for one day to reduce the moisture content and was later transferred to a drying area where it was left to dry for about 6 days. During drying time, the material was constantly turned using a rake to enhance drying. After drying, the hay was baled using wooden baling boxes of 75 cm x 50 cm x 40 cm each and the bales were tied with sisal strings (Appendix 6.9). The bales were stored on well-ventilated racks that were constructed below the roof of the cowsheds (Appendix 3.9f). Baling the material reduced the loss of leaves during storage and space required to store the hay.

amples of lablab hay were taken from 6 randomly selected households and analysed r DM yields and chemical composition using methods described in section 3.1.2.5.

1.3.3.2. Production of calliandra leaf hay (CLH)

the beginning of March 2002, each of the households selected to test CLH as a otein supplement was supplied with 500 calliandra seedlings. Raussens (1998) commended that in order to supplement one dairy cow with 6 kg of fresh fodder (1 g DM) every day over a lactation period of 10 months, a farmer needs 500 trees of alliandra. Calliandra seedlings (about 15 cm high) were purchased from the Forestry esources Research Institute (FORRI), Mukono district. The seedlings were planted t a spacing of 50 cm between plants as a single line hedge around the elephant rass fields. To improve the initial growth of the seedlings, about 2 hands-full of nanure was applied in the planting holes. Calliandra was first cut when the plants vere about 130 cm high, about 4 months after planting. The cutting was about 30 cm above ground to induce the tree to spread at the base. The harvested material (leaves and twigs) was collected and spread on mats or turpolines and dried in a shade. The eaf hay was stored in 100 kg-polythene bags (Appendix 6.10). Harvesting from these trees continued every 8-12 weeks depending on their regrowth which depended on the season.

Samples of calliandra leaf hay were taken from 6 randomly selected households and analysed for DM yields and chemical composition using methods described in section 3.1.2.5.

3.1.3.3.3 Formulation of a homemade concentrate (HMC)

Maize bran (MB) and cotton seed cake (CSC) were used as the main ingredients to formulate a homemade concentrate (HMC) that had about the same crude protein content (16% CP) as the commercial concentrates such as Nuvita Dairy Meal that were available on the market. Tables 3.3 and 3.4 show quantities, price and chemical composition of the ingredients that were used to make a HMC.

-ble 3.3: Proportions (kg/100 kg DM) and price/kg of the various components in the homemade concentrate

Ingredient	DM	CP (% DM)	Proportion in mixture (kg)	% CP contribution	Average price per kg	Total Cost (U Shs)
Maize bran	83.8	10.7	82.0	8.8	150	12,300
Cotton seed cake	93.6	45.2	17.0	7.7	300	5,100
Maclick Mineral powder	-	-	1.0	-	1700	1,700
Total	-	-	**100**	**16.5**	-	**19,100**

1 US $ = 1920 Ug. Shs

'he mineral powder was obtained from Welcome Cooper Uganda Limited and contained the following ninerals with the percentage contribution of each given in brackets: NaCl (27), Ca (18.51), P (11), Mg 3), Fe 90.5), Cu (0.10), Mn (0.4), Zn (0.5), S (0.4), Co (0.02), Se (0.00), Mo (0.002) and Ca: P ratio of 1.68:1.

Table 3.4: Chemical composition (%) of maize bran (MB), cotton seed cake (CSC) and homemade concentrate (HMC)

Components (% DM)	Type of ingredients			
	MB	CSC	HMC	#Commercial concentrate
Dry matter (%)	84.8	90.6	89.6	87.1
Organic matter	92.33	90.8	91.3	90.2
CP	8.8	45.2	16.5	16.0
IVOMD	66.1	67.1	65.7	67.2
Ash	7.2	7.4	6.9	7.1
Phosphorus	0.18	0.14	0.24	0.3
Calcium	0.19	0.3	0.47	0.5
Neutral Detergent Fibre	23.4	19.2	19	18.2
Acid Detergent Fibre	5.9	13.9	6.7	6.9
*Metabolizable Energy (MJ/kg DM)	9.9	10.1	9.8	10.1

ME was estimated using regression equations by Close and Menke (1986), ME= 0.15 *IVOMD;

Homemade concentrate = Maize bran (82%) + cotton seed cake (16%)

#The Commercial concentrate was "Nuvita", commonly used by smallholder dairy farmers

Treatment 1, the farmer harvested fresh EGL at a height of 80-100 cm (Nsubuga, 83), every morning; chopped the fodder into pieces of about 5 cm long using a hand ear. Chopped elephant grass/legume basal diet was offered to the animals *ad. itum*. The animals were supplemented with 3 kg/cow/day of chopped lablab hay abirizi, 1996). All animals were supplemented with 1 kg/cow/day of HMC before lving (Ruiz, 1983). This was intended to steam up the animals. The mixture of LH nd HMC was offered to the animals in the morning before EGL was offered. The uantity of HMC was increased to 4 kg/cow/day after calving. Half the mixture was ven during the morning milking time and the other half during the evening milking me.

Treatment 2, chopped EGL fodder was supplemented with 2 kg/cow/day of lablab ay (Kabirizi, 1996) and 1 kg/cow/day of CLH (Raussens, 1998). All animals were upplemented with 1 kg/cow/day of HMC before calving. The daily amount of HMC ffered was increased to 4 kg/cow/day when the cow calved. Half the amount of upplements was given during the morning milking time and the remaining amount vas given during the evening milking time.

n Treatment 3, ML and elephant grass fodder were chopped into pieces of about 5 cm long using a machete. Chopping was done before offering the fodder to the animals. Chopped ML was mixed with fresh EG forming the mixture (EGML), and offered *ad libitum*. The weights of ML and elephant grass fodder were recorded before hey were mixed. The cows were supplemented with a mixture of 1 kg/cow/day of HMC and 1 kg/cow/day of CLH before calving. The quantity of HMC was increased to 4 kg/cow/day after calving. Half the amount of the supplements was given during the morning milking time and remaining amount was given during the evening milking time.

For comparison, 8 households were selected where no intervention (farmer's practice) was introduced. This treatment (Treatment 4) constituted the sole elephant grass fodder (sole EG) as the control. In all treatments, animals had access to water and mineral blocks *ad libitum*. All feeds were weighed before they were offered to the animals and the weights recorded.

1.3.4 Experimental procedures and animal management

imals used in this study were crossbreeds (indigenous cows x Holstein-Friesians). ie exotic blood level of the animals was 83% (Send-a-cow Project Report, 2003). ecords from the farmers showed that the cows were 26-28 weeks in-calf at the start the feeding trials and had calved once. However, data collection started when the w had attained 28 weeks in-calf. The farmers carried out tick control by applying sing spot-on twice a week and other animal health routine management accinations, deworming, and disease control). The feeding trials lasted 10 months, ach cow covering 2 months prepartum and 8 months postpartum.

he calves were weighed at birth and thereafter once every month for 2 months. The alves were separated from the dams at birth and were kept in individual pens where ney were bucket-fed. Each calf received 2 litres of milk after every morning and 2 tres/calf evening milking time until weaning time, 2 months after calving. All the alves had free access to water.

.1.3.5. Data collection

Heart girths measurement, body condition score (BCS) and body weight (BW) of the cows were recorded by the enumerator in the presence of a farmer every fortnight. Heart girth was taken using a heart girth tape measure. This was converted to body weight (BW). Body condition score (BCS) was recorded using a scale of 1-9 (Nicholson and Butterworth, 1986). Each farmer was supplied with a 100-kg spring balance to weigh the daily quantities of feeds offered to the animals. Intake was estimated as quantities of all feeds offered minus quantities refused on DM basis. Samples of feeds offered were taken once every month for chemical composition using procedures described in Study 2. The farmers recorded total daily milk produced. The enumerator and the local veterinary staff assisted the farmer to observe the animal regularly for oestrus. At parturition, the calf body weight and sex were recorded. The farmer observed and recorded oestrus and conception dates, method of insemination (Artificial or Natural Service) and number of times the cow was inseminated/served before it conceived. Pregnancy was determined by rectal palpation two months after insemination by the local veterinary staff.

.3.6. Monitoring and farmers' assessment of the technologies

onitoring and farmers' assessment of the technologies were done using methods scribed in section 3.1.2.4.

.3.7. Economic analysis

ne costs per kilogramme of forage were estimated from their respective costs of oduction (land preparation, planting, weeding, harvesting, conserving). The current arket prices at the study time were used to compute the cost of inputs including eeds, ingredients used to make homemade concentrates and labour Appendices 11, 6.12 and 6.13 give estimated cost of production per kg of fodder, average uantities of fodder consumed per cow during the study period and prices used in in alculating the cost of producing fodder per kg, respectively in an already established airy unit. Income was derived from quantities of milk and maize grain produced and heir respective prices. No attempt was made to calculate the overall profitability of the dairy enterprises since data on fixed assets such as cost of the cows and cost of construction was not available.

The gross margin for each treatment/technology was calculated based on extra costs ncurred when they were incorporated in the production systems in relation to the ncome realized from sale of milk, maize grain, dressing percentage in weight during the study time and calves etc. Gross margin was used to provide a measure of competitiveness of a given treatment in terms of relative profitability. Gross margin = Total revenue - Variable costs (veterinary services, cost of feeds and labour). Extra cost and income of supplementing dairy cows as shown in the different treatments was calculated and compared to practice where there was no supplementation by control farmers. The ratio of extra income to extra cost was calculated to get return per extra shilling spent as cost due to treatment. Cost structure and revenue structure for each item was calculated as a percentage of the total cost or revenue.

1.3.8. **Statistical analyses**

ata were subjected to the analysis of variance (ANOVA) procedure for Randomized omplete Block Design using the procedure in SAS (Statistical Analysis Systems) 999). The model used in the analysis was:

$_{ijk} = \mu + T_i + S_j + C_k + (TS)_{ij} + \epsilon_{ijk}$, where:

$_{ijk}$ = Overall performance (k^{th} cow in the j^{th} season receiving the i^{th} Treatment);

= Overall mean; T_i = Effect of the i^{th} Treatment, i = 1, 2, 3, 4; S_j = the j^{th} Season, j = 2 (wet and dry); $(TS)_{ij}$ = Interaction between the i^{th} Treatment and j^{th} Season; ϵ_{ijk} = andom error.

omparisons of means were considered significantly ($p<0.05$) different using the east Significant difference (LSD).

3.4. Study 4: Farmers' experiences, constraints and opportunities in the production and utilization of forage legumes in smallholder dairy production systems

3.4.1.1. Specific objectives

1. To assess the benefits and constraints from improved forage technologies to the smallholder dairy production system and household welfare.
2. To document major lessons learnt from testing improved forage technologies with smallholder dairy farmers.

3.4.1.2. Identification of constraints and selection of possible interventions

Participatory on-farm evaluation of forage legumes technologies began at the end of 2001 with a baseline survey to identify forages and other feed resources used in smallholder dairy cattle feeding and constraints to their utilization (Study 1 and Appendix 6.14). During individual interviews and group meetings, farmers noted that feed shortages especially during the dry season was a major constraint to dairy cattle production. Farmers proposed on-farm trials to test forages that had been recommended on-station for dairy cattle feeding (Study 2 and 3 and Tables 3.1 and 3.2).

A 3-day feedback workshop was conducted to present results of the survey to the farmers. The workshop was conducted at Kamenyamigo DATIC where 9 improved forage technologies were being tested (Study 1). Using a scoring method, farmers selected 3 forage technologies for on-farm trials (Tables 3.1 and 3.2) to improve feed availability and animal productivity. Based on their willingness to participate in the study, 32 farmers were selected and were provided with seed to establish the forages (Study 2). Using data collected from the trials, farmers were able to evaluate the performance of the forages and their effects on animal performance. The trials also provided some seed to expand/adopt the species that were appreciated most.

.4.3. Monitoring and evaluation/farmers' perceptions of the technologies

thods used to monitor and evaluate the technologies were described in section .2.4 and Appendix 6.14. A feedback workshop was organized as part of the exit ategy to i) give a feedback on the results achieved by the farmers who participated he trials and the economic implications; ii) evaluate with farmers the key issues that de them succeed or fail during the study period and; iii) present results of their own alitative evaluation of the forage legume technologies to other farmers. The rkshop was also intended to identify indicators of positive and negative impacts enefits and constraints) that could affect adoption of the technologies that were sted during the workshop. The implementing farmers were facilitated to explain rage technology implementation and performance to 450 non-participating farmers. dicators of both positive and negative impacts of the technology intervention of rage improvement among the dairy farmers were documented. The data on idicators of the impact were disaggregated by gender to find out how many males nd females considered a particular impact of this technology intervention important.)ne hundred farmers (46 men and 54 women) participated in monitoring and valuation of the technologies.

.1.4.4. Statistical analyses

All data from the questionnaires were entered in SPSS computer format. The questionnaire data was analysed using SAS computer package. The bulk of statistical analysis hinged on descriptive statistics. Means, ranges, standard deviations, requencies and percentages were used to define the quantitative status of the data collected.

CHAPTER 4

RESULTS AND DISCUSSION

. Study 1: Production practices, constraints and future prospects of intensive smallholder dairy cattle production in Masaka district

.1.1. Household characteristics

Survey results indicated that about 71% of the households keeping stall-fed dairy cattle were female-headed and 29% were male-headed as shown in Figure 4.1. There were more female-headed households in the rural areas than in the urban and peri-urban areas. About 73% of the total income in female-headed households was derived from the dairy enterprise (Figure 4.2). The higher percentage of women keeping stall-fed cattle confirms previous studies (Samanya, 1996; Kabirizi and Orania, 1997; Mwebaze, 2000) that majority of dairy farmers in Uganda practicing stall-feeding are women. Many women are striving to improve household income by getting involved in income generating activities. According to Masaka district Report (2003), many widows especially from the rural areas have benefited from various Government and NGOs such as Heifer Project International.

The rural areas had the largest number (8-20) of people per household while the urban and peri-urban areas had 4-8 people per household. Gender, age, marital status and educational level of respondents are shown in Table 4.1. Majority of respondents in the study areas were aged between 46 and 60 years. In this sample, young men and women below the age of 20 years were never farm owners. The percentage of widows and married men and women was higher in urban and peri-urban areas than in the rural areas while the percent of single women and men was highest in rural areas. More than 25% of the respondents in each of the study areas had attained primary level of education. There were more women with primary level of education in rural than areas in urban and peri-urban areas than men.

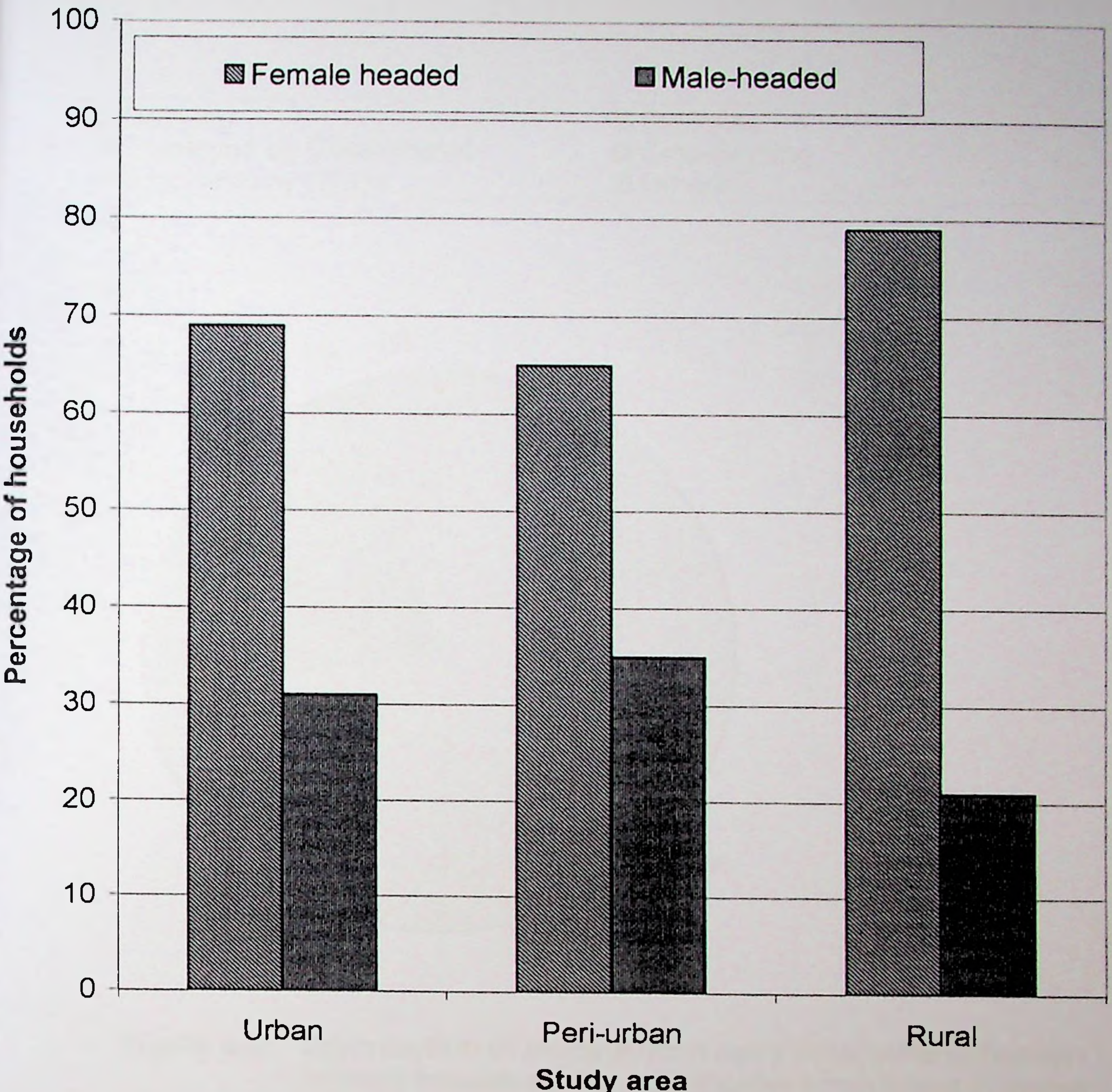


Figure 4.1: Household by gender

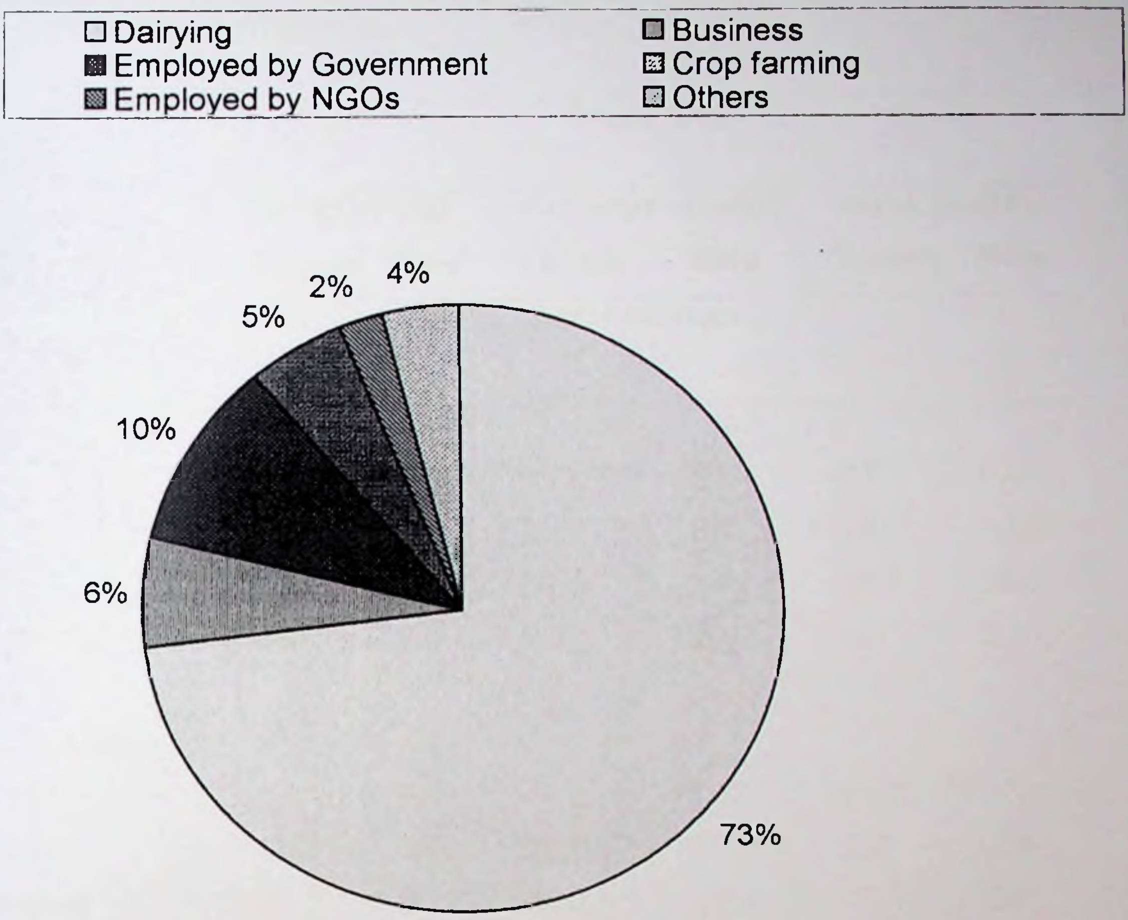


Figure 4.2: Contribution of income from dairy enterprise in female-headed households in smallholder production systems in Masaka district

ble 4.1: Gender, age, martial status and educational level of the respondents (%)

	Study area					
	Urban (n=35)		Peri-urban (n=35)		Rural (n=35)	
	Female	Male	Female	Male	Female	Male
haracteristics	Percentage					
ge (years)						
20	0.0	0.0	0.0	0.0	0.0	0.0
1-45	10.2	9.2	22.4	8.7	18.6	10.8
6-60	31.2	37.5	39.4	14.6	31.7	30.0
ver 60	9.1	3.0	9.9	5.0	0.0	2.9
larital status						
ingle	9.1	3.0	11.8	0.0	25.7	37.1
larried	18.2	15.3	11.8	0.0	2.9	2.9
Vidowed	21.2	33.2	38.2	29.4	17.1	5.0
)ivorced	0.0	0.0	6.4	2.4	3.0	6.3
ducational level						
None	12.1	9.1	11.8	0.0	1.3	2.9
Primary	34.4	37.2	28.2	29.4	44.8	38.0
Secondary	2.2	3.0	6.8	11.9	11.4	0.0
Post Secondary	3.0	0.0	1.9	0.0	0.0	1.6
Tertiary	0.0	0.0	10.0	0.0	0.0	0.0

one of the rural women and men had attained tertiary level of education but less an 10% of the women and men in the urban and peri-urban areas had attained icondary level of education. Overall, respondents in the rural areas were more lucated than those in the urban and peri-urban areas.

ne number and age of people of household members significantly contribute to bour availability and the efficiency of the dairy enterprise if many household embers are not very young children (less than 10 years old) or elderly people (over 0 years old). Information from farmers' meetings showed that the age bracket of the espondents could be associated with the Acquired Immune Deficiency Syndrome AIDS) epidemic that has claimed the lives of many youths in the age bracket of 20-40 ears in the district. However, migration of the youths to urban areas in search of mployment could also have contributed to fewer youths involved in farming activities. According to the District Extension Officer, the AIDS epidemic and the migration of the ouths to urban centres have had a negative impact on the overall performance of the dairy enterprise because most of the work is done by old women, most of whom are widows with many other responsibilities such as nursing orphans. Labour availability is positively associated with adoption of improved dairy cattle related activities such as fodder production (Mwangi, 2002). As the age of the households head increases, the probability of adoption of improved technologies decreases (Feder *et al.*, 1985; Nicholson *et al.*, 1999; Bosma *et al.*, 2003). Nicholson *et al.* (1999) estimated that a difference of 20 years would imply a decrease in the probability of adoption by more than 28%.

The higher percentage of widows in urban and peri-urban areas than in rural areas could be attributed to many widows who have migrated from the rural areas to urban and peri-urban areas in search of employment. The high percentage of respondents with primary level of education in the study areas could be due to the free Universal Primary Education (UPE) system that was introduced in Uganda in 1997. This system has attracted many farmers who would otherwise not have been able to get any education. These farmers are now able to participate in technology development and transfer processes. Previous studies (Bosma *et al.*, 2003; Peters and Lascano, 2003; Wanyama *et al.*, 2003) showed that the level of education has impact on ability of the farmer to participate in on-farm trials and adopt improved technologies. However, holson *et al.* (1999) observed that diverse types of households could adopt dairy le technologies. Age, sex, marital status and educational level are important in a ise that most NGOs in Uganda select beneficiaries of in-calf heifers on the basis of se factors.

e major sources and levels of income and transport availability of respondents in ensive smallholder dairy farmers are shown in Table 4.2. Farming was the major urce of income for majority of respondents in the three study areas. The percentage respondents with off-farm activities was higher in urban and peri-urban areas than rural areas. Generally, households from urban and peri-urban areas had a higher vel of income than the rural households. Majority of the respondents in peri-urban, rban and rural areas owned a bicycle but less than 3% of the respondents in urban nd peri-urban owned a vehicle or a motorcycle.

mployment off-farm has become an important source of income for urban and peri-urban households in part because of the development of small-scale industries. Majority of respondents with off-farm activities were employed by government, NGOs or self-employed. In addition to wages and salaries, some urban and peri-urban households operate small businesses such as kiosks. This importance of non-farm activities results in the intensification of dairy farming and the need to diversify household activities to reduce risk (Nicholson *et al.*, 1992). The source and level of income has implications on ability of a farmer to purchase inputs, plant and manage forage crops and manage the dairy cattle enterprise as a whole. Because of low income in rural areas, farmers could not purchase the various inputs required in forage production and/or pay for labour for the various activities. Increasing farm input prices are largely attributed to the declining ability of many farmers in Uganda to make tangible investments towards dairy improvement, particularly purchase of high quality concentrates and establishment of sufficient quantities of fodder. The results of this study agree with previous findings (Nicholson *et al.*, 1992; Gebremedhin *et al.*, 2003) that showed that lack of capital is one of the major factors limiting utilization of forage crops.

Table 4.2: Sources and level of income and transport availability in intensive smallholder dairy farmers in Masaka district

	Study area		
	Urban (n=35)	**Peri-urban (n=35)**	**Rural (n=35)**
Parameter	**Percentage of respondents**		
Source of income			
Farming	60	51	80
Off-farm	40	49	20
Income per month			
High (over US $ 100)	66	61	26
Medium (US $ 50-100)	22	25	36
Low (less than US $ 50)	12	14	38
Transport availability			
Motorcar	2.8	2.8	0
Motorcycle	5.7	11.4	0
Bicycle	94.3	97.1	58.0
Wheelbarrow	100.0	97.1	42.0

1 US $ = Ug. Shs 1700 (Source, Bank of Uganda rate, January, 2005)

Availability of transport in form of a vehicle, bicycle, a wheelbarrow etc. is an added advantage to the success of a dairy enterprise. Households that owned vehicles were not badly affected during the dry season since they could obtain fodder from as far as 25 km from the homesteads. Farmers with bicycles could not transport sufficient quantities of fodder because of limited quantities of forage a bicycle can carry that depends on the distance of the field from the household. Farmers estimated that a bicycle could transport 50-70 kgs of fresh elephant grass fodder. Because of unreliable means of transport and the long distance (2-10 km) from the households to the fodder fields, urban and peri-urban households could not transport manure to the fields, manage their fodder fields and transport sufficient quantities of fodder. However, over 90% of the respondents in the rural areas had their fodder fields established near the homesteads and this made transporting fodder and manure and managing the fodder fields easy. These farmers were able to provide their animals with sufficient quantities of fodder especially during the wet season when fodder was plenty. Another aspect of transport availability was the losses of fodder during transportation that depended on the mode of transport and the distance between the fodder fields and the feed stalls. While bicycles were more efficient for transporting harvested fodder over a long distance, wheelbarrows were better for short distances.

4.1.2. Land ownership, land size and utilization

Land tenure systems in Masaka district are shown in Table 4.3. Majority of the smallholder farmers owned land under the customary land tenure systems irrespective of whether they were in urban, peri-urban and rural area. A few farmers in the three study areas owned leasehold and freehold land tenure system. The percentage of respondents owning milo land was higher in the rural areas than in the urban and peri-urban areas.

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. 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 were sometimes conflicts among clan members.

Table 4.3: Land tenure systems on selected households in smallholder dairy production systems in Masaka District

	Study area		
	Urban (n=35)	Peri-urban (n=35)	Rural (n=35)
Land tenure system	**Percentage of respondents**		
Customary	81.8	70.6	71.4
Leasehold	9.1	8.8	2.9
Institutional	0.0	2.9	5.7
Freehold	3.0	14.8	2.9
Milo land	6.1	2.9	17.1

Under customary land tenure system, women are most discriminated against in the administration and dispute settlement of customary land. Women are said to be property just like land and therefore cannot own property because "property cannot own property" (Busingye, 2002). Even after planting the forages, there were times when clan leaders sold or gave away the land. This was 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.

Farmers in urban and peri-urban areas own small (0-1.5 ha) land holdings to support both fodder and food crop production. In rural areas, average land size was 2.5 ha (range =0.5-20 ha). Households could rent or borrow land from institutions such as schools and from neighbours to plant forages but fodder trees could not be planted on rented land because of the permanent nature of trees. Land availability and land tenure system have therefore remained the major obstacle limiting improved fodder production in smallholder resource poor households (Irungu *et al.*, 1998). However, Mugisha *et al.* (1999) observed that integration of forage legumes in farming system is more likely to be practiced by farmers who have less farmland than those with large areas.

Land utilization in intensive smallholder dairy production system of the urban, peri-urban and rural areas is shown in Figure 4.3. The biggest percentage of the farm ranging between 65-69% was allocated to food crops. However, a lower percentage ranging between 25-33% was allocated to elephant grass. Fallow, legumes and cash crops share of land was significantly small as shown in Figure 4.3.

Total acreage planted to forage legumes such as lablab (*Lablab purpureus*) was less than 0.1 ha per household in each of the study area. The number of planted fodder trees varied, with households in peri-urban areas having more trees (103.6 ± 28.7) than in rural areas (56.8 ± 14.9).

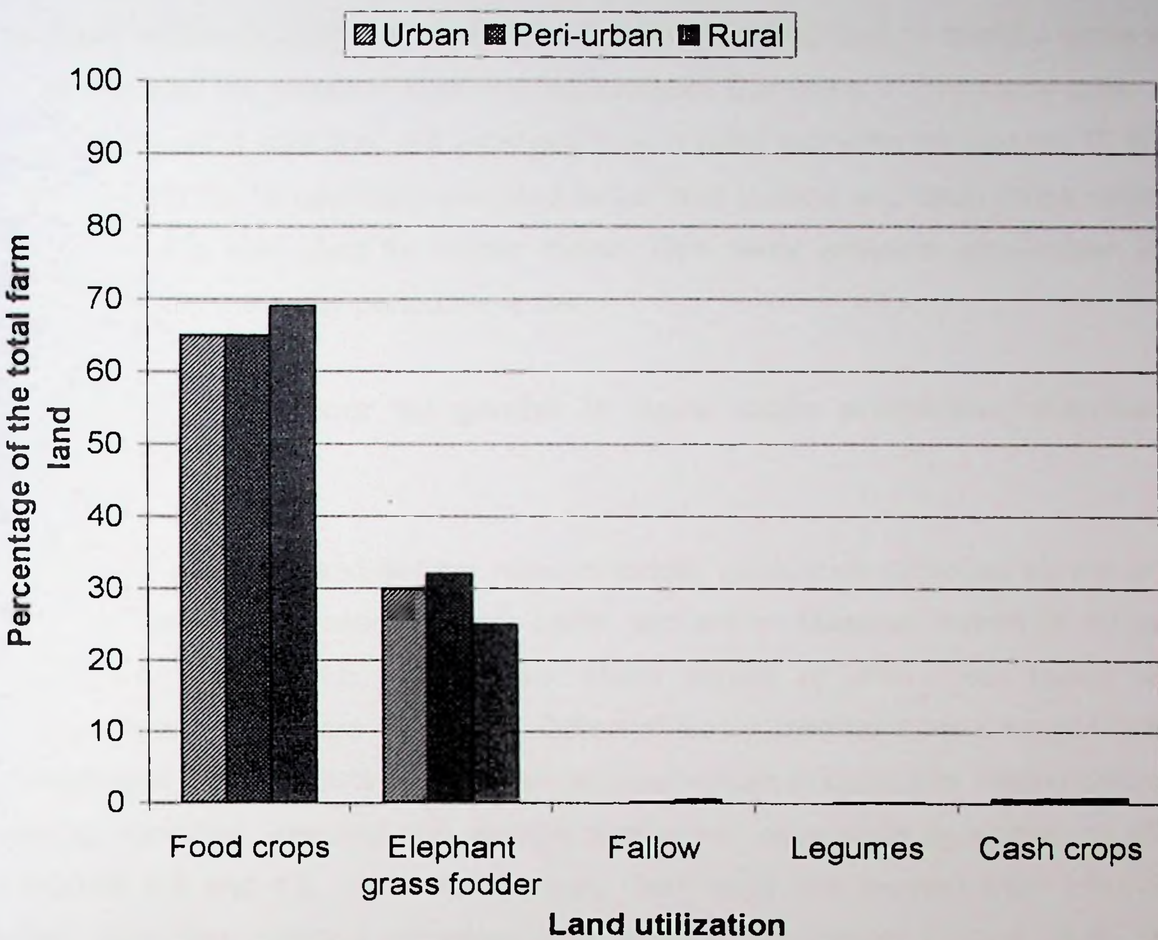


Figure 4.3: Land utilization in intensive smallholder dairy production systems of the urban, peri-urban and rural areas of Masaka district

About 5% of the farmers had received free calliandra seedlings from The District Soil Conservation Agro forestry Project.

The major factors households considered before allocating land to specific crops were soil fertility and the distance from the homestead. Dominant in the study area were free-draining sand soils that are generally low in plant nutrients particularly P, N and OM (Anon, 2003). Households allocated fertile land to food and cash crops while the less fertile land was used for fodder crops. This partly explains why fodder yields recorded during the study period were low.

4.1.3. Division of labour by gender in dairy cattle production activities in Masaka district

The division of labour and gender roles in fodder production activities by the urban, peri-urban and rural intensive dairy cattle farmers in Masaka district is shown in Figures 4.4, 4.5 and 4.6, respectively. Major source of labour was family labour although hired labour was also used. Different family members were responsible for different tasks. In over 50% of the urban and peri-urban households, fodder collection, planting, chopping, weeding and fertilizer application were done by women as shown in Figures 4.4 and 4.5. In the rural areas, men, boys and women were involved in fodder collection, planting chopping and fertilizer application in over 30% of the households as shown in Figure 4.6.

Overall, male involvement in all study areas was centred on monetary transactions and crisis situations demanding external assistance, such as calling for veterinary assistance or transporting of livestock. Since milk quantity is affected by fodder availability, many men were involved in fodder production. Hired labour was used at different levels. The amount paid was negotiable and depended on the type of work done. Farmers reported better management of the forage fields and the animals and therefore higher milk yields where hired labour was used as long as the labour was supervised.

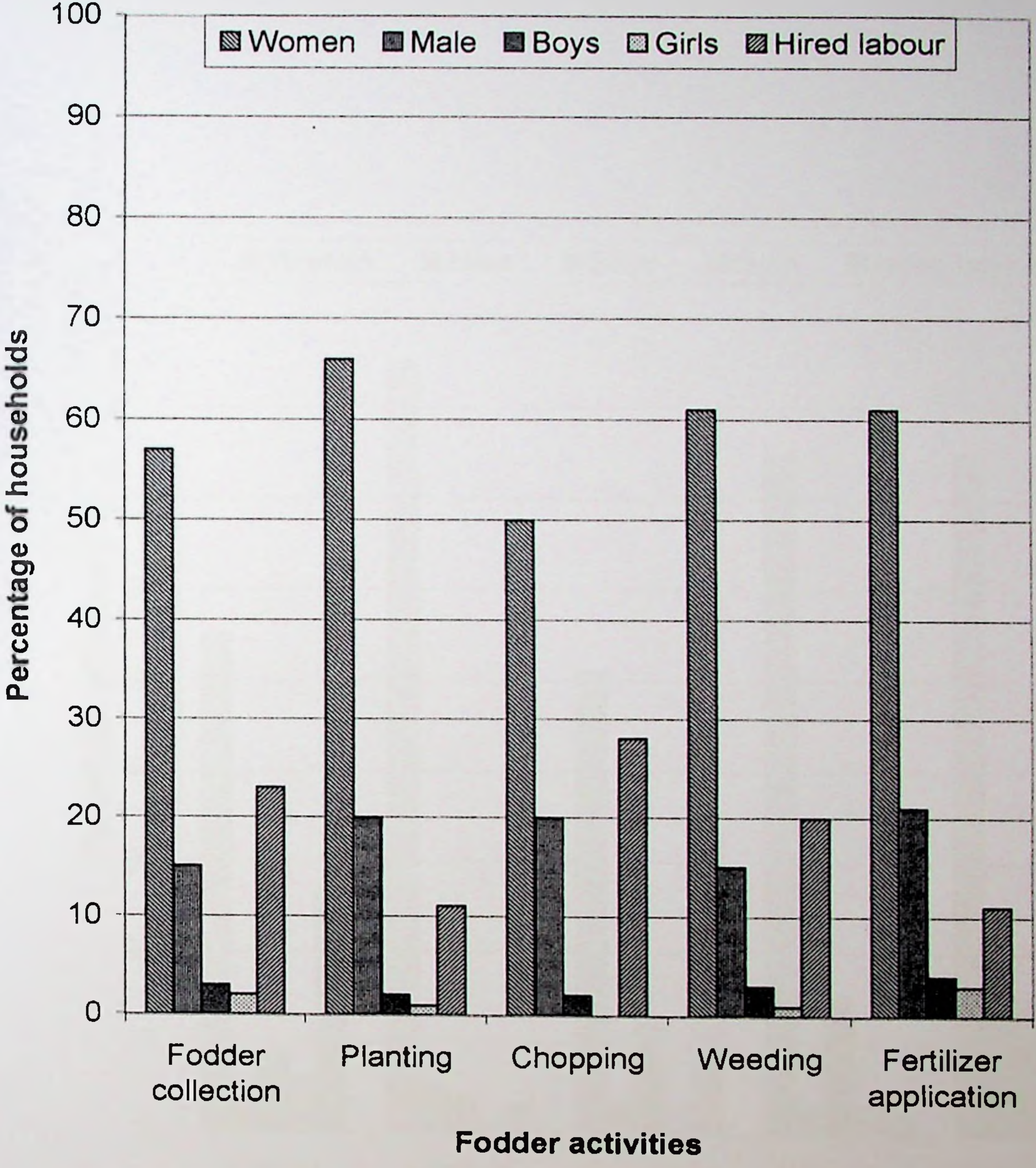


Figure 4.4: Division of labour in fodder production activities in urban areas of intensive smallholder dairy cattle production systems in Masaka district

Figure 4.5: **Division of labour in fodder production activities in peri-urban areas of intensive smallholder dairy cattle production systems in Masaka district**

Figure 4.6: Division of labour in fodder production activities in rural areas of intensive smallholder dairy cattle production systems in Masaka district

In urban and peri-urban areas, women reported that they were the key players in planting, weeding, manure/fertilizer application and milking because over 50% of the men had off-farm activities. Field observations showed that where women were the key players where no hired labour was used, management of the fodder fields was poor. The women could not produce sufficient quantities of fodder and overall management of the animals was poor because these women had to carry out other household activities. In urban and peri-urban areas, boys and girls below the age of 13 years were rarely involved in dairy cattle production activities especially fodder production. Efforts should therefore be made to involve this group in farming activities, because of scarce off-farm employment and the need for new generations of dairy farmers. This requires a change in attitude, because any jobs outside farming are valued high. Awareness creation, provision of credit and training programmes and sensitisation of parents, etc are options to consider. Previous studies (Irungu *et al.*, 1998; Nicholson *et al.*, 1992) reported a negative relationship between family labour and the decision to adopt Napier grass.

In rural areas, although women's major responsibility was to produce and prepare food for home consumption, they contributed about 20-40% of the labour in fodder production. The boys helped their fathers to plant, weed, collect and chop fodder, manure/fertilize the fields, clean the stalls, milk and sell dairy products but they had no control over the revenue. This means that more labour (men, boys, hired labour and women) was allocated to the dairy enterprise. The family was therefore able to produce sufficient quantities of fodder. However, the girls' contribution in fodder production was less than 5% of the total labour used on the farm because they had to help their mothers to prepare food for family members. Overall, management of the fodder fields and animal productivity was better in rural areas than in urban and peri-urban areas.

Information from farmer groups showed that labour is required throughout the year to prepare fields for planting and weeding food and forage crops. Farmers allocated labour, first to growing food crops and later to management of forage crops. Due to labour constraints and lack of capital, about 65% of the respondents in the study areas were not able to weed their forages regularly. This resulted in lower fodder DM yields of less than 10,000 kg/ha/year compared to 20,345 kg/ha/yr observed by

Ogwang (1974). Poor management of the fodder fields including irregular weeding possibly due to labour shortage explains the low fodder DM yields recorded on the farms. However, low soil fertility due to N deficiency cannot be ruled out as a cause of low fodder yields. Even though farmers got about 10-20 kg of fresh manure/cow/day, they were reluctant to return the manure to the fodder gardens. The use of manure in 50% of the households visited was therefore not felt as a priority possibly due to inadequate labour. Similar observations were made by Mubiru *et al.* (2000) and Ebong *et al.* (2001) who reported that inadequate application of manure to fodder fields due to labour constraints was one of the factors affecting fodder dry matter yields in smallholder dairy systems. Ogwang (1974) using elephant grass, Kawanda variety (KW_4) obtained a yield of 5,131 kg/ha without fertilizers, and 12,101 kg/ha with application of N fertilizers at a rate of 300 kg/ha. This underlines the importance of application of fertilizers in fodder production.

4.1.4. Livestock activities and herd structure

The herd structure distribution is shown in Table 4.4. Total number of dairy cattle kept was 295 with a range of 1-3 cattle per household. The rural areas had the highest number of animals. This was possibly because land was more available in rural areas to plant fodder and it was relatively cheaper than in urban and peri-urban areas. All animals kept were crossbreeds between the indigenous cows (Ankole, Zebu and Nganda) and Holstein-Friesians or Jerseys. The exotic blood level of the animals was 83%. Over 90% of the households did not keep bull calves under stall-feeding systems. They either sold off their bull calves, underfed them or killed them because they considered them unprofitable compared to female calves (future cows). In addition to milk, meat could be produced from dairy cattle (bull calves).

Production and reproduction parameters of the dairy cattle under urban, peri-urban and rural intensive smallholder production systems are shown in Table 4.5. The average number of cows milked every day did not differ between the urban, peri-urban and rural areas.

Table 4.4: Herd structure and distribution on selected households in smallholder dairy production systems in Masaka district

	Study area		
Herd structure	Urban (n=104)	Peri-urban (n=75)	Rural (n= 116)
Lactating cows	30	13	44
Dry cows	14	19	18
In-calf cows	13	9	7
Steers	1	9	2
Bulls	1	2	1
Heifers	13	8	4
In-calf heifers	14	10	14
Calves	18	5	26

Table 4.5: Production and reproduction parameters of crossbred dairy cattle under smallholder dairy production systems in Masaka district

Parameter	Study area			
	Urban	Peri-urban	Rural	Mean
Number of cows milked/day	1.6±1.4	1.2±0.5	1.5±1.6	1.4±1.2
Average lactation length (months)	8.7±5.1	8.4±2.8	10.3±3.9	9.1±3.9
Average milk yield/cow/day in wet season (lts)	10.8±5.2	11.5±4.8	10.0±5.1	10.8±5.1
Average milk yield/cow/day in dry season (lts)	6.0±2.0	6.5±3.0	5.4±2.4	6.0±2.5
Average milk offered to calf (lts/day)	2.9±1.7	3.6±1.7	3.3±1.1	3.3±1.5
Milk consumed at home (lts/day)	2.0±1.0	2.3±1.6	2.6±0.8	2.3±1.1
Milk sold (lts/day)	7.2±3.6	7.8±4.9	5.6±2.2	6.7±3.7
Price of milk (dry season) (Shs/lt)	420±88	373±93	378±50.0	390±78
Price of milk (wet season) (Shs/lt)	413±85	377±86	355±82.0	382±84.3
Age at first calving (months)	26.0±2.7	25.0±9.2	27.3±8.8	26.1±6.9
Calving interval (months)	12.6±4.6	10.9±4.8	13.0±3.4	12.2±4.3
Services per conception	1.5±0.3	1.4±0.5	2.1±0.7	1.7±0.5

Mean±SD: Mean±Standard deviation

The rural areas had higher mean lactation length than urban and peri-urban areas. Mean daily milk yield was higher during the wet season than in the dry season. Daily mean milk yield declined by about 40-50 percent during the dry season. Milk offered to the calves was higher in peri-urban and rural areas than in the urban areas. However, the average daily milk consumption was higher in the rural areas than in the urban and peri-urban areas. The price of milk was higher in urban than in peri-urban and rural areas. The price increased by about 1.3% during the dry season. Mean age at first service was lowest in rural areas (21.3 months) compared to 24 months in urban areas. Calving interval and number of services per conception were higher in rural than in urban and peri-urban areas.

The shorter lactation length observed in urban and peri-urban areas compared to rural areas was considered to be a true reflection of farmer circumstances, where poor nutrition affected milk yield and lactation length. Inability of farmers to detect heat, differences in feeds and management practices during the first lactation could have been responsible for these differences. Overall, mean length of lactation in the urban and peri-urban areas was shorter (7.5 months) than reported lactation length of 10 months in crossbred cows (Anon, 1996). Death or sale of calves due to inadequate fodder was one of the reasons for short lactations in urban and peri-urban areas as cattle often failed to let-down the milk unless stimulated by suckling.

In general, milk yields were lower than 20-25 litres/cow/day reported on improved farms (Samanya, 1996; Ebong *et al.,* 2002). Besides nutrition due to inadequate feeds and water shortage, poor genotypes of cows distributed by some projects could have contributed to very low milk yields in all study areas. Previous studies elsewhere have identified poor breeds, inadequate feeds and poor feed management practices as a major constraint to optimum milk production in this production system (Saka *et al.* 1994; Samanya, 1996; LSRP, 2000; Ebong *et* al, 2001; Mubiru *et al.*, 2001) in Uganda.

Quantity of milk consumed at home and sold depended on family size, amount of milk produced and sold per day and the availability of a market and price for milk. The price of milk depended on season and location of the household from the main trading center. The disposal of excess milk was either through customers who bought it from ne farmers' homes or sold outside e.g. at milk collection centers and schools, hotels. Although the study did not probe into the contribution of the dairy enterprise to the nutritional status of the farm families, household members looked healthy compared to families with no dairy cow. The fact that milk consumed at home ranged between 2-2.6 litres/day is indicative of constant supply of animal protein balanced in essential amino acids than in plant protein. Similar observations were made by Leegwater *et al.* (1991) and Nicholson *et al.* (1999) in a study in Kenya. The quantity of milk consumed per person was however below 0.5 litres of milk/person/day recommended by FAO (Anon, 1996). There is therefore a need to sensitize farmers on the benefits from milk consumption. The price of milk depended on the market infrastructure. The price was higher in urban and peri-urban areas due to higher demand.

This study showed prolonged calving intervals (CI) of over 15 months in about 40% of milking cows. This proportion is big and would contribute to reproductive wastage. Cows with CI of between 15-24 months would be dry for longer periods. Such cows would tax farmers through high veterinary cost and high cost of feeding without returns from milk and calf crop. Under such a situation, keeping cattle for milk production as the major target would not be economical. Apart from diseases, poor heat detection, poor quality semen and unskilled technician, poor nutrition is a major factor affecting conception. This also affects the programming of milk production on the farm. The age at first calving and calving interval were within the range reported by Shiferaw *et al.* (2003). There were considerable differences in calving intervals within the same breeds, suggesting differences in management, farmers' knowledge and skills in heat detection, silent heat incidences, fertility problems and competence of Artificial Inseminators. The major causes of infertility were difficulties in heat detection and high cost of Artificial Insemination (AI) services.

The number of services/conception observed in this study was consistent with earlier results obtained by LSRP (2000) and Ebong *et al.* (2001) in Masaka district. Efficient management of reproduction should be for a dairy cow to produce a calf annually. This can be achieved if the cow is served within 30-60 days postpartum, and the number of services per conception should not exceed two (Samanya, 1996). The high ratio of services/conception in rural areas was possibly because of the distance from the rural areas to the urban centres where the AI technicians were based.

4.1.5. Sources of feeds for dairy cattle in smallholder dairy production systems in Masaka district

The major sources of feeds offered to dairy cattle by the individual households are shown in Table 4.6. The feed sources used on individual households depended on location of the farm from the homestead, capital, land and labour availability. Majority of the households in urban and peri-urban areas depended on purchased fodder and crop residues especially during periods of feed shortages. Planted fodder accounted for less than 35% (Table 4.6) of the total feed used in all the study areas. None of the rural households purchased crop residues but a few farmers from the study areas obtained crops residues from the neighbours. More households from rural areas than urban and peri-urban areas used crops residues from their own farms. Less than 4% of the rural households used agro-industrial by-products compared to over 10% in urban and peri-urban areas.

Given the high cost of animal feed, elephant grass is recommended for planting for stall-fed dairy cows. The high number of urban farmers depending on purchased elephant grass fodder and crop residues was a result of small acreages of land and lack of knowledge and skills regarding the quantity of fodder the cow would require throughout the year. Purchased fodder, some of it harvested from public land or from neighbours' farms, whose animals had died, was bought in bundles enough to feed 1 cow for 1 day. The average cost of purchased fodder was Ug Shs 500 per bundle of about 30 kgs. The distance traveled in search of fodder and crop residues ranged between 0.5 and 3.0 km during the wet season, but increased to 20 km during the dry season. In rural areas, crop residues such as sweetpotato vines, cassava leaves and peels and banana peels were obtained from own farms because farmers had large acreages of planted food crops. Surplus fodder was produced during the wet season but was not conserved. Similar observations were made by Samanya (1996). Agro-industrial by-products were rarely used in rural areas because of lack of cash.

Table 4.6: Sources of feeds in smallholder dairy cattle production systems

	Study area		
	Urban (n=35)	Peri-urban (n=35)	Rural (n=35)
	Percentage of respondents		
Source of fodder			
Purchased fodder	65.7	54.3	19.3
Neighbour's land	2.0	10.2	8.0
Public land	10.0	3.1	4.2
Planted fodder	26.0	22.3	33.1
Purchased crop residues	77.1	91.1	0
Crop residues from neighbour	8.1	14.5	5.0
Crop residues from own farms	9.2	4.3	57.1
Agro-industrial by-products	11.4	13.1	3.3

4.1.6. Major forages used to feed dairy cattle in smallholder dairy production systems in Masaka district

The major forages and fodder crops fed to dairy cows in intensive smallholder dairy production systems are shown in Figure 4.7. Elephant grass was the major fodder crop fed to dairy cattle irrespective of the location. *Chloris gayana* and Setaria grasses were on the other hand not popular with the farmers. The farmers were not keen at growing leguminous fodder as exemplified by results in Figure 4.7. Less than 10% of the respondents in all study areas had integrated forage legumes in the farming systems. The major forage legume was *Lablab purpureus* cv Rongai. The major fodder tree species planted by farmers were *Calliandra calothyrsus* and *Sesbania seban*.

Elephant grass was the most popular forage fed to dairy cattle because of its long established qualities of good palatability, high biomass yield per unit area of land and availability of planting materials (Ogwang, 1974; Samanya, 1996). Dairy farmers are advised to plant about 0.405 ha of elephant grass per mature cow and her offspring and to cut it when it is 60-90 cm high. While the mean acreage was 0.57 ha in the wet season, it drastically declined by about 50% during the dry season. Seventeen percent of the farmers in urban and 14.2% in peri-urban areas had not planted elephant grass. These farmers depended on purchased fodder. Mean fodder DM yields per household in the wet season was 4,171 kg/ha/year. Farmers maintained the same acreage irrespective of the increase in number of animals and this resulted in inadequate fodder and low animal productivity.

It was also noted that during the wet season when there was plenty of fodder, elephant grass plants tended to overgrow to over 110 cm high. During the dry season, however, many farmers were harvesting the fodder even below a height of 45 cm. The cutting frequency was 12 and 8 weeks for the dry and wet seasons, respectively with average DM yields of 3,298 and 3,780 ha, respectively per cutting. Similar time intervals of harvesting elephant grass were earlier observed by Mubiru *et al.* (2001). Shortage of fodder during the dry season was also due to lack of fodder conservation on all households visited.

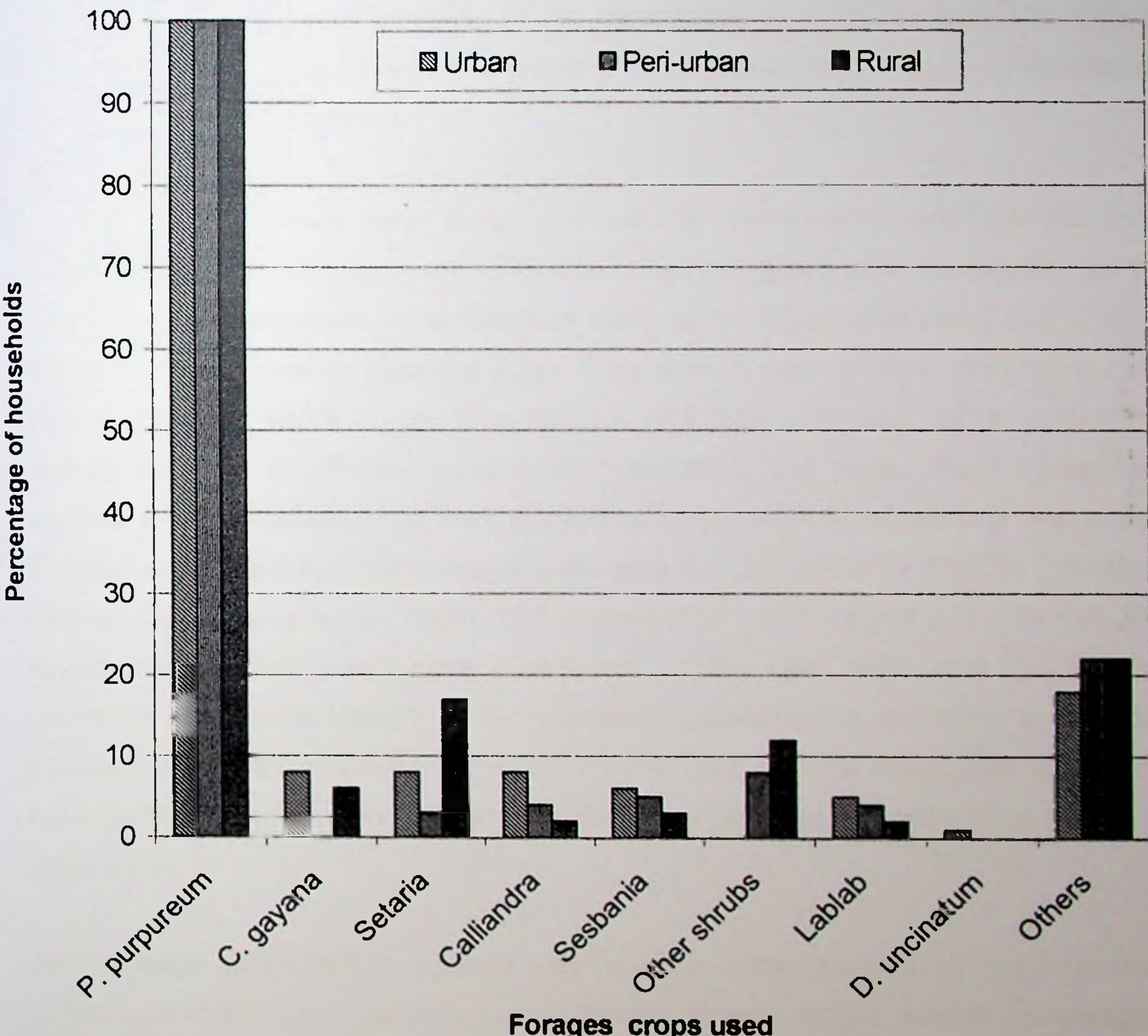


Figure 4.7: **Major forages and fodder crops in intensive smallholder dairy farming systems in Masaka district**

Although crop residues were abundant, they were not adequately utlized to feed the dairy cows. Despite the fact that over 76% of the visited households had a plot (0.1-0.5 ha) of maize crop, maize stover was not used as a feed resource. Farmers lacked knowledge and skills on proper utilization of maize stover as a feed resource.Maize stover was left to waste in the gardens. There is therefore a need to educate farmers on the optimum utilization of crop residues. *Chloris* and *setaria* were not popular among farmers probably because of the lower biomass yield compared to elephant grass, unavailability or high cost of planting material/seed and intensive management associated with the species.

The results of this study have shown that low milk yields could have been due to low acreage and poor management of planted elephant grass and inadequate feeding. Low DM yields observed on smallholder dairy farms could have been due to use of low yielding varieties of elephant grass compared to high yielding varieties such as *Hybrid P99* that yields up to 23 mt/ha/year of fodder (Ogwang, 1974) and/or poor management of the fodder fields and/or diseases and pests. Field observations showed that the varieties that were planted had become susceptible to a new stunting disease and a pest that had drastically reduced the DM yields by 20-60% (Kalule and Kabirizi, 2003; Alicai *et al.*, 2004). The disease was first identified by farmers in 2001. Another factor that could have contributed to low DM yields was the improper utilization of manure. Majority of the households preferred to use manure on banana plantations instead of the fodder fields. Farmers felt banana production was a more paying enterprise than fodder production because bananas are major food source and cash crops.

The acreage under forage legumes was very low in the wet and dry seasons due to scarcity of seed, poor regrowth during the dry season and/or lack of knowledge on their management and utilization. Although lablab forage is drought resistant, it could not persist during the dry season because of poor harvesting techniques during the wet season during which the stems were cut at less than 20 cm above ground level, thus hampering regrowth. A harvesting height of 30 cm above ground level and above the branches is recommended (Kabirizi, 1996). Mean acreage of planted lablab dropped from about 0.05 ha per household to 0.01 ha. Although legume tree fodder was found on 10% of the households in the wet season, it dropped to less than 5%

during the dry season. Low legume fodder production suggests low protein supply to the animals and this confirms why milk production and reproductive efficiency was below average (Table 4.5). The results agree with findings by Mugisha *et al.* (1999) who reported low milk yields and reproductive performance of crossbred cows on farms where leguminous fodder plants were not integrated in the farming systems.

Other feeds offered to dairy cattle were the leaves of indigenous fodder trees and shrubs such as *Ficus* and *Vernonia* species. All respondents used *Vernonia* spp. as a feed, medicine and to improve appetite in dairy cattle. The use of indigenous fodder trees and shrubs was higher in the dry season than in the wet season. Weeds were also fed to animals during the wet season.

4.1.7. Quantities of feeds offered to dairy cattle in smallholder dairy production systems in Masaka district

The quantities of major feeds offered to cattle during the dry and wet season on selected households are shown in Table 4.7. The major component of the diet was elephant grass fodder. Average total daily DM intake of elephant grass fodder was about 43% lower during the dry season when compared with the wet season. Elephant grass fodder constituted about 71% and 81% of the total diet during the dry and wet season, respectively. Forage legumes accounted for about 6 and 7% of the total diet during the dry and wet season, respectively. Crop residues constituted about 12% and 4% of the diet during the dry and wet season, respectively.

Although data on feed resources showed that there was a diversity of feed resources offered to the animals, the quantities in which they were offered especially during the dry season were not adequate to meet the nutritional needs of the cattle throughout the year. Humphrey (1991) and NRC (2001) recommended a DM intake of 3% of the animal's body weight. Total DM intake was 4 and 37 percent lower in the wet and dry season, respectively when compared with the recommended DM intake for a crossbred dairy cow weighing about 450 kg liveweight.

Table 4.7: Average quantities (kg. DM) of major feed resources offered to cattle (average 450 kg BW) by season on selected farms in Masaka district

	Dry season		Wet season	
	Mean	**Range**	**Mean**	**Range**
Feed resource				
Elephant grass fodder	6.0	4-8	10.5	8-14
Banana peels	0.25	0-5	0.0	0-0
Banana pseudo stems	0.25	0-0.5	0	0
Sweet potato vines	0.5	0-1	0.5	0-1
Forage legumes	0.5	0-1	1.0	0-2
Homemade concentrates	1.0	0-2	1.0	0-2
Total	**8.5**		**13.0**	

Although forage availability was not limiting during the wet season, the quality varied greatly as most of the grass was rapidly growing due to heavy rains (Mubiru *et al.*, 2000). The reduction in forage quality with maturity is an important consideration where the elephant grass is cut daily and fed to the animals, compared to the practice of harvesting at a certain stage of maturity and feeding from storage as silage and hay (Bareeba, 1983; Kabirizi, 1996). In the dry season, the observed decrease in forage intake was attributed to a decrease in the quantity and quality (CP and ME) of available forage on the farms due to poor regrowth resulting from the drought. This finding confirms observations by Nsubuga (1993) and Samanya (1996) that there is a seasonal variation in the quantity and quality of fodder on smallholder dairy farms in Uganda. Other factors that could have contributed to low DM intake were the small (<1 ha per mature animal) acreages of planted fodder and the wastage of fodder. Field observations showed that there was a lot of wastage of fodder from harvesting, transporting, chopping and feeding. The losses were attributed to poor construction and positioning of feed troughs which allowed fodder to spill over when the cow was feeding; harvesting overgrown fodder especially during the dry season and chopping long pieces (over 5 cm long) of grass which encouraged the animals to select the palatable leafy parts, leaving the drier and longer stemmy parts in the trough. Another factor was the tendency of farmers to leave large amounts of fodder in the troughs which initiated the fermentation process causing changes in taste and palatability. Low dry matter intake could also be due to low intake of forage legumes. Forage legumes provide rumen degradable N and/or by-pass N, digestible energy and minerals when used as supplements and result in improved dry matter intake (Norton and Poppi, 1995).

The average body weight of the cows kept by farmers was 450 kg liveweight. According to NRC (2001), a cow's intake should be about 14 kg DM (3% of its body weight). The calculated quantities of CP and metabolisable energy (ME) supplied and deficits and milk production potentials during the wet and dry seasons on selected households are shown in Figures 4.8 and 4.9. During the wet season, average CP and energy content of the feeds offered to dairy cattle on smallholder dairy farms in Masaka district are about 110 g/kg DM and 10 MJ/kg DM, respectively. However, during the dry season, average CP content of the feeds declined to about 80 g/kg DM and 7 MJ/kg DM, respectively (Mubiru *et al.*, 2001).

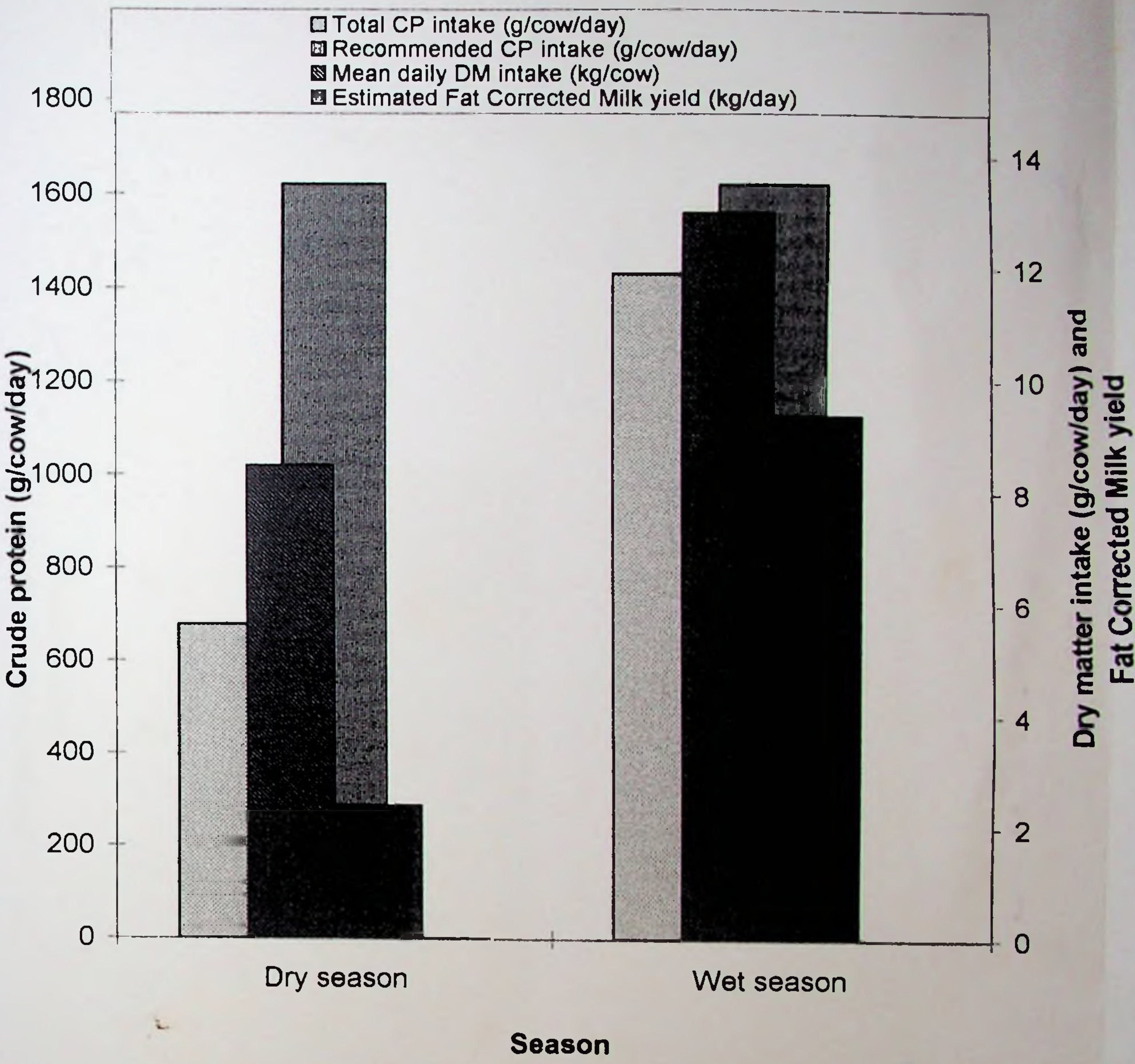


Figure 4.8: Calculated milk production potentials derived from total daily DM intake in relation to daily CP requirements for lactating dairy cows on selected households in Masaka district

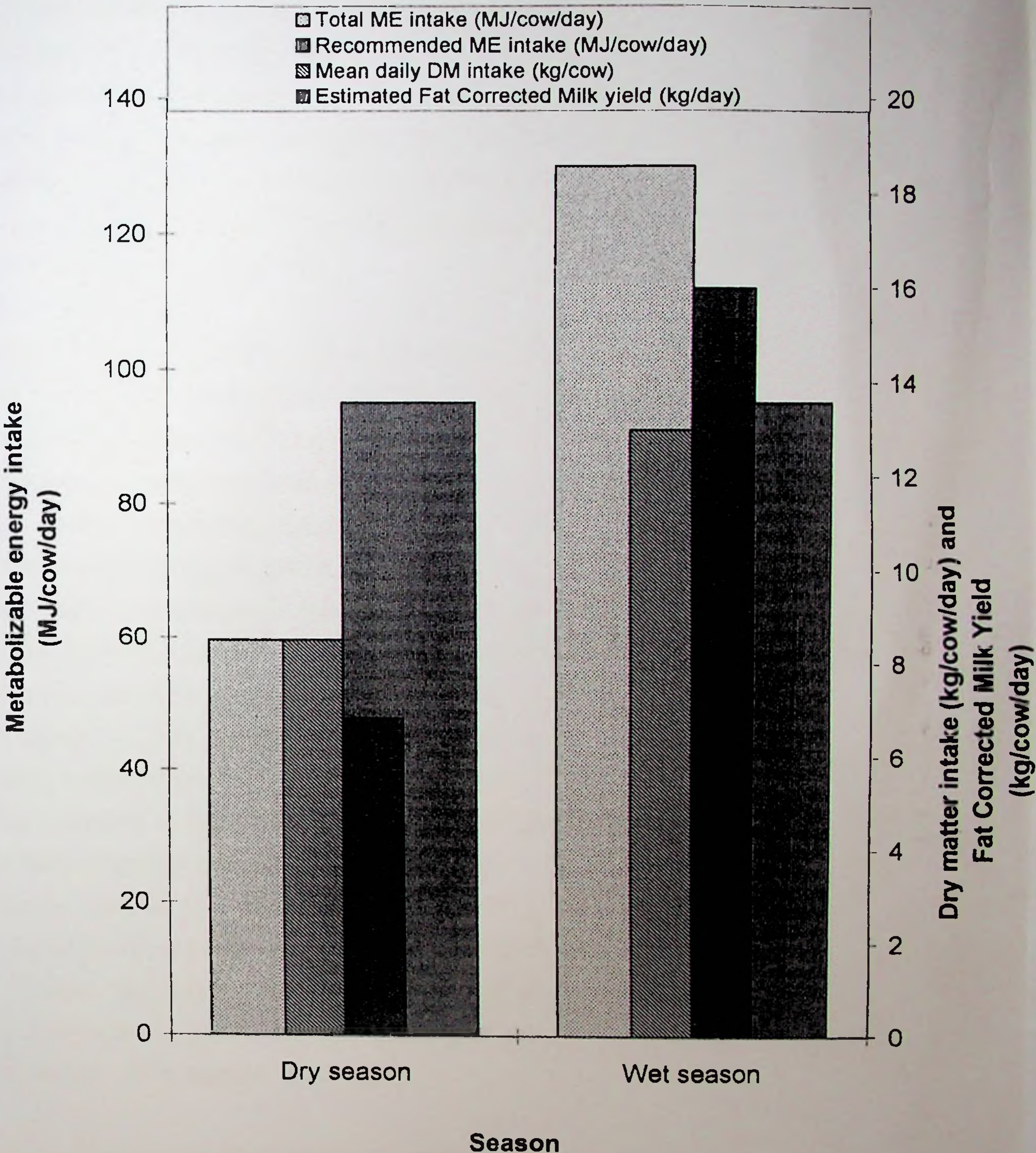


Figure 4.9: **Calculated milk production potentials derived from total daily DM intake in relation to daily ME requirements for lactating dairy cows on selected households in Masaka district**

The minimum daily requirement recommended for production and lactation is 1620 g/cow/day of CP and 95 MJ/cow/day (NRC, 2001). Considering a mean DM intake of 8.5 kg/cow/day during the dry season (Table 4.7), the CP supplied and deficits were 680 and 940 g cow/day, respectively (Figure 4.8). However, during the wet season, the mean daily DM intake was 13.0 kg/cow, therefore, mean CP supplied and deficits were 1,430 g/day and 190 g/day, respectively. Metabolizable energy supplied and deficits during the dry season were 59.5 and 35.5 MJ/cow/day, respectively. During the wet season, however, the energy supplied was about 130 with a surplus of about 35.0 MJ/cow/day (Figure 4.9).

According to NRC (2001), about 5.2 MJ and 78 g protein is required to produce 1 kg 4% Fat Corrected Milk (FCM) yield (Samanya, 1996; NRC, 2001). A-450 kg dairy cow requires a minimum of 700 g CP/day and 47 MJ/day for its growth. Therefore, the CP and energy intake in excess of the maintenance requirement (NRC, 2001) during the wet season generated about 9.4 and 9.2 FCM per day yield, respectively. Crude protein and energy intake during the dry season were below the minimum levels required for maintenance and production of dairy cattle due to low DM intake (Table 4.7) and low CP and ME content of the feeds. The results therefore showed that cows received sub-optimal amounts of CP and ME during the dry season and were unable to lactate to their genetic potential. Similar results were reported by (Mubiru *et al.*, 2000) in Masaka district. The calculated FCM values though very low were well within the expected range for low quality diets similar to those used on smallholder dairy farms in Uganda (Nsubuga, 1983; Mwebaze, 2000). However, based on CP and ME requirements as recommended by NRC (2001), it is evident that the forage intake met the maintenance requirements of the cows during the wet and dry season. A decrease in protein and energy intake decreases palatability and digestibility of the feeds with an increase in gut retention, resulting in an overall depression in fodder intake (Ogwang, 1974; Muinga *et al.* 1992).

4.1.8. Protein concentrate and mineral supplements

Percentages of households using protein concentrates and mineral supplements are shown in Table 4.8.

Table 4.8: Percentage of households using concentrate and mineral supplements in the study areas

	Study area		
	Urban (n=35)	Peri-urban (n=35)	Rural (n=35)
	Percentage of households		
Concentrates			
Homemade concentrates	50	57	49
Maize bran	28	24	35
Commercial dairy meal	5	9	0
Cotton seed cake	17	10	16
Minerals			
Locally formulated mineral blocks	77	72	78
Common salt	17	14	6
Rock salt	6	14	16

The major protein concentrate in urban, peri-urban and rural areas was the locally formulated homemade concentrate made out of maize bran and cotton seed cake. Commercial dairy concentrates composed mainly of maize bran, cotton seed cake and sunflower cake were purchased by less than 10% of the respondents in urban and peri-urban areas and were offered to milking cows only at a rate of 1-5 kg/cow/day. Over 70% of the respondents in each of the study areas used locally formulated mineral blocks comprising of a mixture of 1 kg mineral powder, 2 kg table salt and 1 kg high quality phosphorus powder used as a binder.

Maize bran and cotton seed cake were used to formulate homemade concentrates because they were cheaper and more readily available than commercial concentrates. Farmers reported that the homemade concentrate was cheaper than commercial concentrates and it improved milk yields. Farmers lacked the cash to buy commercial concentrates and some of the commercial concentrates were substandard and at times adulterated with sand and saw dust.

The low percentage of respondents using commercial supplements is an indication that inadequate energy is one of the factors limiting optimum milk production in smallholder dairy production systems in Uganda since concentrate supplements improve energy intake (Boodoo *et al.*, 1991). Due to high cost of commercial concentrates, over 20% of the farmers in urban, peri-urban and rural areas used maize bran as concentrate supplement. Mlay *et al.* (2001) observed that most farmers in Morogoro, Tanzania fed maize bran to milking cows during milking times with the main aim of distracting the animals so as to make them calm and easy to milk. Nkya *et al.* (1998) observed that maize bran has a high soluble carbohydrates and a low ADF which makes it a good supplement for the supply of energy.

However, its CP content is less than 10% and could not meet the protein requirement of high milk yielding cows (Mubiru *et al.*, 2000). Maize bran cannot therefore be recommended as a sole supplement unless the forage intake includes a high percentage of legumes or other potential N rich sources. There is therefore a need to train farmers in formulation of balanced homemade concentrates based on maize bran and cotton seed cake which are locally available and affordable and to evaluate its response to dairy cow productivity.

Locally formulated mineral blocks were used by majority of respondents in all study areas and comprised of a mixture of 1 kg mineral powder, 2 kg table salt and 1 kg high quality phosphorus powder used as a binder. Forage legumes are major sources of minerals such as phosphorus, calcium and sulphur but these were not widely used in adequate quantities (Table 4.7). Mineral deficiency is therefore often widespread in tropical forages and at times digestibility and intake of forages is low (Durand and Komisarczuk, 1988). Therefore mineral supplementation is essential for ruminant production in the tropics.

Field observations however showed no mineral deficiencies in dairy cattle on farms where locally formulated mineral blocks were being used. Therefore, the use of locally mineral supplements should be encouraged as a way of improving mineral intake in dairy cattle. The type of mineral block was cheaper (Ug. shs 2,300 per block) compared to the imported blocks (Ug. shs 3,500-4,000). There is however a need for more studies to validate this observation.

4.1.9. Water availability

Major sources of water are shown in Table 4.9. The major source of water for respondents in urban and peri-urban areas was tap water while rural households got water from the communal boreholes. The distance travelled to the source of water in the study areas in urban and peri-urban areas was 0-2 km. However, the distance travelled was longer for households in the rural areas. Information from farmer groups showed that all farmers watered their animals but the frequency depended on the water source and the season.

Water shortage and the long distance travelled in search of water during the dry season were major constraints in the rural areas and this resulted in low milk yields. It is therefore imperative to introduce strategic management technologies that would help farmers improve water availability for humans and livestock.

Table 4.9: Major sources of water and distance traveled to the source of water in smallholder dairy production systems in Masaka district

	Study area		
	Urban (n=35)	Peri-uban (n=35)	Rural (n-35)
Source of water			
Tap water	97	67	3
Rain catchments	3	29	16
Rivers	0	0	2
Communal borehole	0	4	79
Average distance (km) travelled in search of water			
0-2	92	88	12
3-5	8	12	83
Over 5	0	0	5

4.1.10. Constraints to utilization of forage legumes in smallholder dairy farming systems in Masaka district

Major constraints to utilization of forage legumes in smallholder dairy farming systems are shown in Table 4.10. Majority of the respondents in all study areas cited high cost of forage legume seeds and lack of planting material as major factors that limited the utilization of forage legumes. Lack of technical knowledge as a constraint to fodder production was more prevalent in rural areas than in urban and peri-urban areas.

High cost of forage legume seed and/or lack of planting materials were attributed to low demand of forage seed. The major sources of planting material/seed were: government and NGOs projects, own farms and neighbours. *Desmodium uncinatum* (silver leaf desmodium) was growing naturally in all the areas visited and could be established using cuttings or splits but none of the farmers was aware that the legume could be fed to cattle to improve overall productivity. Respondents living in swampy areas with poor soils found it very difficult to plant forage crops because of poor establishment.

Based on constraints to fodder production, high cost/lack of planting materials and lack of technical knowledge on forage management and utilization appeared to be the major areas of interventions. Previous adoption studies (Nicholson *et al.,* 1999; Mwangi, 2002; Gebremedhin *et al.,* 2003) identified lack of forage seed/planting materials and lack of inadequate knowledge on fodder utilization as major factors affecting adoption of forage technologies. There is therefore a need to train farmers in small-scale forage seed production and on-farm and on-station trials/demonstrations on seed production and forage utilization should be set-up. Interested farmers should also be facilitated with credit to purchase inputs (fertilizers, seed etc) required for small-scale pasture seed production.

Table 4.10: Major constraints to utilization of forages in smallholder dairy farming systems in Masaka district

	Study area		
	Urban (n=35)	Peri-urban (n=35)	Rural (n=35)
	Percentage of the respondents		
Constraint			
High cost/Lack of planting materials/seed	77.1	100.0	94.3
High cost of maintenance	39.0	67.0	80.0
Land shortage	51.0	17.0	11.0
Lack of technical knowledge	77.1	57.1	85.6
Legumes "kill" elephant grass plants	45.0	51.0	30.0

4.1.11: Seasonal feed availability and mechanisms for coping with feed shortages

All households experienced feed shortages during the dry season and over 70% of the visited households experienced feed shortages throughout the year. Most affected households were those located in urban and peri-urban areas where land is a major constraint as exemplified by the percentage of farmers who bought fodder as a way of coping with the shortage (Table 4.11).

A number of strategies were used to overcome feed shortages during the dry season as shown in Table 4.11. More households in urban and peri-urban areas depended on purchased fodder and crop residues than in rural areas. The percentage of households depending on crop residues from own farm was highest in rural areas, and lowest in urban areas. Less than 10% of the households in peri-urban and rural areas tethered animals during the dry season. There were more farmers in urban that reduced the quantity of feed than in rural areas.

The high percentage of households in urban and peri-urban areas depending on purchased fodder and crop residues during periods of feed shortages was due to small acreages of planted elephant grass; poorly managed elephant grass fields and lack of knowledge in fodder management, utilization and fodder conservation technologies. During the dry season, the regrowth was very poor and it required 10-14 weeks to cut the fodder. Therefore a larger area of fodder was harvested than in the wet season. This partly explains the drastic decrease in acreage of elephant grass in the dry season. Farmers reported that due to small acreages of planted elephant grass, they could not produce surplus fodder to conserve. In rural areas, the percentage of households depending on purchased fodder was less than 5% because majority of the households had sufficient land for fodder and food production. Because of large acreages of planted bananas and sweetpotatoes, many farmers depended on sweetpotato vines and banana based crop residues (banana peels, banana pseudostems and banana flowers) to supplement elephant grass fodder during the dry season. A few households in the rural and peri-urban areas tethered their animals on public land and fallow land. None of the farmers in urban areas tethered animals on public land because it was prohibited by the Municipality.

Table 4.11: **Coping mechanisms used by households to overcome feed shortages (percentage of farmers under the study)**

	Study area		
	Urban (n=35)	**Peri-urban (n=35)**	**Rural (n=35)**
Coping mechanism			
Purchase fodder and crop residues	75.0	65.0	4.0
Reduce quantity of feed	17.0	10.0	4.4
Tether animal on public land	0.0	11.0	16.6
Use crop residues from own farm	8.0	14.0	75.1

A lot of research has been done in Uganda on hay and silage making (Bareeba, 1983; Kabirizi, 1996), but farmers have not adopted this knowledge. A number of factors affecting fodder conservation were mentioned during group meetings and individual interviews. These included: inadequate fodder, lack of knowledge and skills on fodder conservation technologies and lack of labour. For those with surplus fodder, available labour saving technologies such as the forage choppers were too costly for economic investment by individual households. Previous studies (Bareeba, 1983 and Kabirizi, 1996) carried out in Uganda showed that in order to stabilize the supply of fodder throughout the year and ensure adequate nutrition for livestock, there is a need to conserve the excess fodder that occur during the wet season. This also facilitates intensive smallholder dairy farming with a higher stocking rate than otherwise would be possible.

A number of strategies to improve feed availability and animal productivity in smallholder dairy cattle production systems were proposed. These included: on-farm trials, demonstration fields and/or cross visits proposed by 87, 78 and 56 percent of the respondents. During a feedback workshop at Kamenyamigo DATIC (Study 1), maize/lablab intercrop (ML); elephant grass/legume mixtures (EGL); lablab and calliandra forage technologies were selected for on-farm trials to improve feed resource availability and animal productivity (Appendix 6.6). Majority (87%) of the farmers were willing to contribute to labour for land preparation, planting, weeding and harvesting towards implementation of the trials. However, none of the farmers was willing to pay for seed or meet the full cost.

In conclusion, smallholder dairy cattle production system is a multi-purpose system producing milk and serving as capital asset. It comprises of small crop-livestock farms (0.5-2ha) where women contribute greatly to labour availability for the dairy activities especially to forage production. However, animal performance is constrained by a number of factors. The major ones being the level of dairy cattle feeding due to inadequate use of forage legumes technologies; sub-standard or/and high cost of commercial concentrates or unbalanced homemade concentrates resulting in protein and energy deficits. It was suggested that this could be addressed through on-farm testing/demonstration of improved forage and feed management systems based on integration of forage legume technologies. Utilization of forage legume technologies that do not require a lot of land such as cereal crop/forage legume intercrops; elephant grass/legume mixtures and/or fodder trees are most appropriate under smallholder production condition.

4.2. Study 2: Effects of intercropping maize or *P. purpureum* with forage legumes on maize grain yield and fodder production

4.2.1. Elephant grass fodder DM yield with and without forage legumes

Although field observations showed that the initial growth of forage legumes in elephant grass fields was slow, siratro and desmodium established well but centro performed very poorly in all the fields. This was probably due to elephant grass tillers that could have suppressed its growth in the establishment phase by limiting the amount of light. The shedding effect of elephant grass possibly hindered the growth of centro in the mixture. This is in agreement with earlier reports by Mtengeti *et al.* (1998) where shedding effect of elephant grass plants hindered the growth of the legumes in the mixture. Siratro and desmodium survived because of their ability to tolerate shading as indicated by Mureithi and Thorpe (1993).

Results of the effects of elephant grass/forage legume intercropping on fodder dry matter (DM) yields are shown in Table 4.12. The height of elephant grass plants; total (elephant grass + legumes) fodder (EGL) DM yields and DM yield of elephant grass fodder at all harvests were higher ($p<0.05$) in intercrops than in monocrops. Intercropping increased total DM yield by about 23%. Mean percentage of the legumes in the mixtures was 12%. Desmodium contributed about 61% of the total DM yield of the legumes in the intercrops while siratro and centro contributed 30% and 9%, respectively.

The higher growth rate of elephant grass plants and higher total fodder DM yields in intercrops compared to monocrops could be attributed to the presence of forage legumes that improved growth of elephant grass plants. The senescence, leaf fall, death and decomposition of forage legumes either from old tissues that died naturally, or from tissues of any age killed by drought have been reported to improve soil N (Skerman and Riveros, 1990; Mtengeti *et al.*, 1992; Saka et al., 1994). The forage legumes also acted as a cover crop, controlled weeds and conserved soil moisture.

Table 4.12: The least square means and SEM for fodder DM yields of elephant grass with and without forage legumes

	Cropping system		
	Monocrop	Intercrop	SEM
Parameter			
Plant height (cm)	79±2[b]	88±2[a]	0.93
Dry matter yield (kg/ha/yr)			
Elephant grass	10,024±215[b]	10,753±259[a]	112.01
Desmodium	-	892±36	-
Siratro	-	430±24	-
Centro	-	136±9	-
Total DM yield of legumes	-	1,458±58	-
Total DM Yield	10,024±215[b]	12,211±304[a]	224.46
Percentage of legumes	-	12±0.4	
Percentage change in DM Yield	-	23±0.8	

(Mean ±SEM)= Standard Error of the Mean

[ab]Least square means within a row followed by superscripts differ ($p<0.05$)

However, improved total fodder DM yields in the intercrops could also have been due to additive and complementary effect of legumes and elephant grass that raised the productivity per unit of land. The forage legumes provided soil cover reducing water loss from soil by evaporation and minimizing the effects of weeds in the intercrops. Mohamed-Saleem (1986) observed that the intercrops reduce labour requirements for weeding.

The low percentage of forage legumes in the mixtures could have been due to the shedding effects of the legumes by elephant grass plants. The legumes were introduced into already established elephant grass which had formed extensive rooting system that could have out-competed the legume seedlings. Previous studies by Lascano (1994) showed that forage legumes are rare in the tropics due to lack of robustness in the legumes to withstand competition from companion crops. The high percentage of desmodium in the intercrops was expected since it showed quicker germination and establishment than centro and siratro. It is also an indication that desmodium persisted during the dry and wet seasons and competed effectively for light, soil moisture and nutrients with elephant grass plants. These are characteristics that are very essential for a productive companion forage legume planted with elephant grass. On the contrary, Katuromunda (2001) observed that siratro was the most compatible legume with *P. purpureum* when compared with desmodium and centro. He further observed that on a number of sites, desmodium failed to germinate completely, especially where it was intercropped with already established *P. purpureum*.

Mean fodder DM yields of the intercrops were higher ($p<0.05$) during the wet season (6,488$\pm$224.5 kg/ha) than during the dry season (5,722$\pm$224.5 kg/ha). However, the results showed no significant ($p>0.05$) differences in total fodder DM yield and proportion of forage legumes in the intercrops between the dry season (677$\pm$82.6 kg/ha and 5.7%, respectively) and wet season (780$\pm$82.6 kg/ha and 6.6%, respectively). Mean fodder DM yields reported in this study were about 40% lower than the yields (20,491 kg/ha) reported by Mubiru *et al.* (2001) in Masaka district.

The lower DM yields reported in this study could have been due to the long drought during the establishment phase, competition between elephant grass and the forage legumes; differences in level of management (such as cutting height and manure application), soil fertility and/or other agronomic practices related to the specific site/farm. All these factors have been reported to affect the amount of nutrients, particularly N and moisture nutrients available for optimum plant growth (Boonman, 1993).

The changes in mean monthly fodder DM of the monocrops and intercrops and forage legumes, relative humidity and the rainfall pattern during the study period are shown in Figure 4.10. It was evident that the amount of elephant grass and legumes available at any particular time and site was a function of rainfall and other management and environmental factors. There was a decline in total fodder DM yields from January to May 2003 as a result of poor regrowth of the legumes and the grass due to low soil moisture. Under cutting regime, Bareeba (2003) attributed the decline in legume composition to the removal of most of the active vegetative buds leading to poor regeneration.

It is recommended that animals should be given an opportunity to reject the lower quality material (such as stems) offered, so that the ratio of utilization (feed consumed/feed offered) may be quite low if milk production is to be maintained (Humphreys, 1991 and Methu *et. al.*, 2001). Humphreys (1991) recommended a ratio of utilization of 0.45. Forage allowance is further modified by the size of the animal and the daily intake as a fraction of body weight (%BW) according to NRC (2001). Humphreys (1991) therefore recommended that:

$$\text{Desirable forage allowance} = \frac{\text{Intake as a fraction of body weight}}{\text{Desired ratio of utilization}}$$

Average liveweight of the animals kept on smallholder dairy farms is about 470 kg. Therefore, the recommended DM intake was about 14.1 kg DM/day with a daily forage allowance of about 31 kg DM per day. Presently, projects that distribute in-calf heifers recommend establishment of about 0.405 ha of EGL mixtures for every mature cow and its offspring.

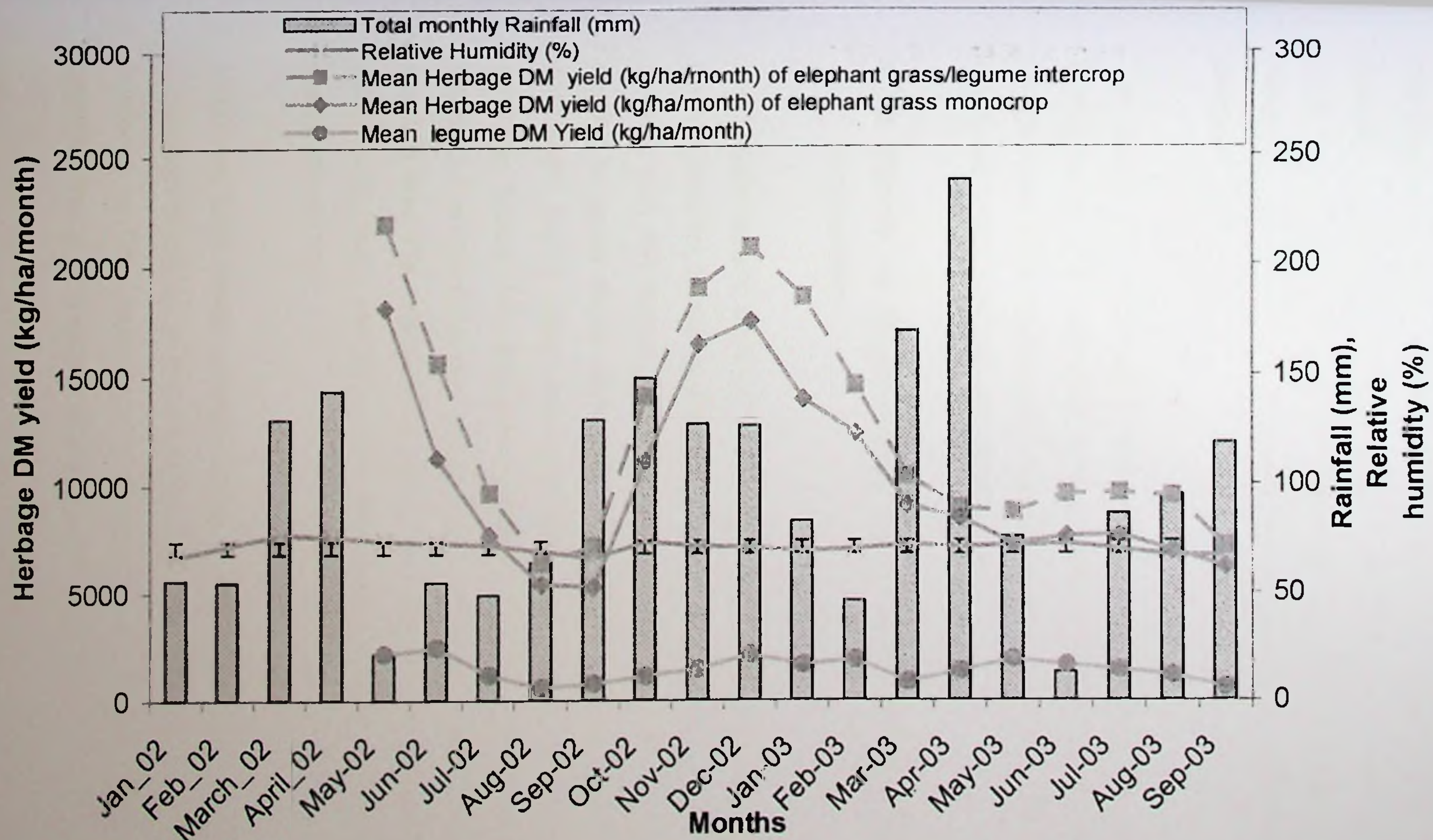


Figure 4.10: Changes in mean herbage DM yield, total monthly rainfall and relative humidity on smallholder dairy farms in Masaka district during the period of May 2002 to September 2003

Total fodder DM yield was about 12,210 kg/ha/yr of EGL and 10,024 kg/ha/yr of elephant grass monocrop (Table 4.12). The fodder DM yield from a recommended acreage of 0.405 ha of intercrop and monocrop is therefore about 4,945 and 4,059.7 kg/ha/yr, respectively. This quantity of fodder would support one mature cow for about 160±4.2 and 131±3.4 days, respectively. The results therefore show that although intercropping elephant grass with forage legumes improves total fodder DM yields, the quantity of fodder available from 0.405 ha is not sufficient to support a mature lactating dairy cow throughout the year. The minimum acreage required to support a mature cow for a year is about 0.9 ha of EGL or 1.1 ha of pure stand of well managed elephant grass.

The results of this study therefore show that production of large amounts of good quality forage per unit area is an important pasture parameter because intercropped forages can allow higher carrying capacities compared with the monocrops and hence improved production per animal per year.

4.2.2. Effects of intercropping maize with lablab on grain yield and fodder production

Field observations showed that during the first month after introducing lablab seed into the maize crop, lablab plants grew slowly competing with weeds between maize rows, but not with the maize plants. When the maize plants began to tussle, lablab vines started to grow more vigorously and obtained their greatest development a month before the maize cobs were harvested. The effects of intercropping maize with lablab on mean fodder DM and grain yields are presented in Table 4.13. The proportion of lablab in the intercrop was about 24%. Cob size and grain yield increased ($p<0.05$) by about 6 and 7%, respectively when compared with the monocrops. Total fodder DM yields and mean weight of the cobs were higher ($p<0.05$) in the intercrops than in maize monocrop.

Improved total fodder (maize stover + lablab) DM yields could be attributed to higher proportion of lablab in the intercrop and efficient utilization of water resources and soil nutrients in ML intercrops. It could also be due to less competition between the growing maize and lablab plants and the weeds.

Table 4.13: Effect of intercropping maize with lablab on grain and fodder DM yields

	Cropping system		
	Intercrop	Monocrop	SEM
Parameter			
Lablab fodder DM yield (kg/ha/yr)	1321	-	-
Stover DM yield (kg/ha/yr)	4166 ± 200	4373 ± 190	200.6
Total fodder DM yield (kg/ha/yr)	5486 ± 261^{a}	4373 ± 190^{b}	174.7
Mean weight of cobs (g/cob)	142 ± 4^{a}	134 ± 4^{b}	4.2
Grain yield (kg/ha/yr)	3115 ± 198	2912 ± 188	136.1

SEM=Standard Error of the Mean

^{ab}Least square means within a row followed by superscripts differ ($p<0.05$)

Two months after introducing lablab into the maize crop, lablab plants provided a soil cover, thus reducing water loss from the soil by evaporation. Because of their spreading habits, lablab plants controlled the weeds that could have competed with maize and lablab plants for soil nutrients and moisture. Lablab leaf senescence improved soil organic matter and improved total fodder DM yield. The high proportion of lablab reported in this study could be attributed to its ability to withstand drought compared to maize plants. Because of its deep-rooted nature (Thomas and Dabas 1982), lablab plants were able to tap water and nutrient resources deep in the soil profile. Therefore, higher total fodder DM yield in intercrops was not only due to higher total (lablab + maize) plant population densities but also to yield advantages that accrued basically from a lower competition and edaphic space in monocrops. Results of improved fodder DM yield obtained in this study were consistent with those of Sabiiti and Mugerwa (1993), Mpairwe (1998), Katuromunda (2001) and Roothaert et al. (2003) who showed that intercropping cereals with forage legumes improves total fodder DM yields by 7-25%.

The relatively lower ($p>0.05$) DM yield of maize stover in intercrops compared to monocrops could be due to the smothering effects of lablab vines on the maize stalks during the third month after planting the maize seed. During that period, lablab vines grew vigorously twining around the maize stalks and this could have lowered the yield of the maize stover.

Maize grain yields improved ($p<0.05$) by 7% as a result of intercropping lablab with maize. Results of enhanced grain yields (11 to 73%) from various cereal/legume intercrops have been reported by Kusekwa *et al.* (1992) and Katuromunda (2001). However, several studies by Nnadi and Haque (1990); Mwebaze (1996) and Mpairwe (1998) reported a depression of 7 to 24% in grain yield when cereals were simultaneously intercropped with forage legumes. The improved grain yields obtained in this study could have been due to late planting of lablab in the maize crop. Due to labour constraints, farmers staggered the planting dates (21 to 35 days) of lablab into the maize crop and this could have minimized interspecies competition for growth requirements and ensured full utilization of available growth factors in a growing season. Thus delaying the planting of lablab enabled the earlier sown maize to grow without competition.

In view of the results of this study, there is a need for more on-farm and on-station studies to determine the effects of staggering planting dates of different varieties of lablab and maize in a maize/lablab intercrop on total fodder DM and grain yield in different ecological zones in Uganda.

Seasonal effects of intercropping maize with lablab on maize grain and fodder DM yields are presented in Table 4.14. Total fodder DM and grain yields in intercrops decreased ($p<0.05$) during the second season (short rains) by about 11% and 8%, respectively when compared to the first season (long rains). Mean weight of cobs from both intercrops and monocrops however increased by 8 and 6, respectively.

Grain and total fodder DM yields in the intercrops were lower in the second season than in the first season due to lower soil moisture during the second season compared to the first season (Appendix 3.3). The decline in grain and fodder DM yields in the second season was attributed to the regrowths of lablab plants left in the fields after harvesting the forage during the first season. The regrowths were cut back when the maize seed started germinating during the second season. This could have resulted in competition for nutrients between the germinating maize seed and lablab plants resulting in lower fodder and grain yields during the second season. However, Katuromunda (2001) observed that the differences in grain yields between the long (4.04 t/ha) and short (3.83 t/ha) rains were attributed to timely rain season.

Lower fodder DM and grain yields in the second season could also have been due to nutrient mining by the crops in the first season since farmers used the same fields for the second season without applying fertilisers. Previous studies by Ofori and Stem (1986) showed that even though intercropping usually included a legume, applied N may still confer some benefits to the system, because the cereal component depend heavily on N for maximum yield although fertilizers required in the intercrops should be lower than in sole cereal stands. Therefore, the positive DM yields with intercrops obtained in this study indicated that although the legumes in mixtures may have provided some of the required nutrients, fertilization was still needed in the intercrops.

Table 4.14: Effects of season on grain and fodder DM yields of maize monocrop and maize/lablab intercrop

Parameter	Seasons		SEM
	First season (Long rains)	Second season (Short rains)	
DM Yield of lablab DM yields (kg/ha)	1444 ± 94	1199 ± 154	91.5
Stover DM yield from intercrop (kg/ha)	4363 ± 286	3967 ± 280	200.0
Total fodder DM yield in intercrop (kg/ha)	5806 ± 324^{a}	5165 ± 414^{b}	260.8
Total stover DM yield in monocrop (kg/ha)	4575 ± 239	4172 ± 295	190.0
Grain yield (kg/ha) in intercrop	3245 ± 234^{a}	2986 ± 325^{b}	198.1
Grain yield (kg/ha) in monocrop	2979 ± 208	2846 ± 320	188.0
Mean weight per cob (g) from intercrop	138 ± 6	146 ± 6	4.1
Mean weight per cob (g) from monocrop	128 ± 5	139 ± 6	3.9

SEM=Standard Error of the Mean

^{ab}Least square means within a row followed by superscripts differ ($p<0.05$)

Mean DM yield of ML was 5485.8 kg ha/year (Table 4.13). Therefore, the quantity of ML produced from 0.4 ha/yr is about 2,194.3 kg DM. This quantity of fodder could support a mature cow producing about 13 litres/day at a rate of about 9 kg DM/day for about 247 days (about 8.4 months). Therefore, if a farmer establishes 0.4 ha/yr of ML in addition to either 0.405 ha of EGL or 0.405 ha of well managed sole stand of elephant grass, there will be sufficient fodder to feed a lactating dairy cow for about 412 and 382 days, respectively.

4.2.3. Chemical composition and *in vitro* dry matter digestibility of elephant grass with and without legumes

The effect of intercropping elephant grass with forage legumes on chemical composition and *in vitro* DM digestibility is shown in Table 4.15. Elephant grass/legume intercropping increased ($p<0.05$) crude protein (CP) and CP yield (CPY), IVOMD, Ca and P but lowered ($p<0.05$) NDF content of EGL forages. Intercropping elephant grass with forage legumes had no effect on DM, OM and ME content of EGL forages.

The higher CP content and CP yields obtained in the intercrops could be attributed to benefits that the associated grass obtained from forage legumes which had higher CP than the grasses (Table 4.15). However, Mwangi (2001) reported no significant differences in CPY of *P. purpureum* grown alone or mixed with legumes. He noted that lack of significant differences might have been due to a reflection of late harvest of forages, at the stage of seeding, when reserves of N in roots, stems and leaves have been mobilized for seed production. It is recommended that harvesting earlier, especially before flowering may provide a more meaningful assessment of the effects of legume mixtures on grass and legume N content.

Forage legumes contributed about 26% more to total CP yields in the intercrops than they did to the total DM yield (Table 4.15). A minimum of 1600 g CP and 95 MJ per day are recommended for the growth and production of animals similar to those used (about 470 kg liveweight) on smallholder dairy farms in Uganda (NRC, 2001).

Table 4.15: Effects of intercropping elephant grass with forage legumes on chemical composition and *in vitro* dry matter digestibility of fodder

	Cropping system		
	Monocrop	**Intercrop**	**SEM**
Chemical composition (% DM)			
Dry Matter content	18.9 ± 0.2	18.5 ± 0.2	0.14
Crude Protein	7.4 ± 1^{b}	8.4 ± 0.1^{a}	0.06
Crude Protein Yield (kg/ha/yr)	809.0 ± 33^{b}	1163.3 ± 55^{a}	35.9
Organic Matter	90.2 ± 0.2	90.6 ± 0.2	0.14
Neutral Detergent Fibre	65.7 ± 0.3^{a}	63.1 ± 0.1^{b}	0.21
In vitro OMD	60.1 ± 0.1^{b}	62.0 ± 0.1^{a}	0.09
Calcium	0.23 ± 0.0^{b}	0.33 ± 0.0^{a}	0.01
Phosphorus	0.22 ± 0.0^{b}	0.25 ± 0.0^{a}	0.01
#Metabolisable energy (MJ/kg DM)	9.2 ± 0.01	9.4 ± 0.0	0.01

SEM=Standard Error of the Mean

#Calculated ME = 0.15*IVOMD (Close and Menke, 1986)

[ab]Least square means within a row followed by different superscripts differ ($p<0.05$)

With a fodder DM yield of 12,211 kg/ha (Table 4.12) and a CPY of 1163.3 kg/ha/yr (Table 4.15) of EGL, the CPY of about 471 kg produced from 0.405 ha of EGL (Table 4.15) would support a lactating cow for about 278 days (NRC, 2001). Total ME of 4,649 MJ produced from 0.405 ha of EGL (Table 4.15) would support the same animal at a rate of 95 MJ/day for about 49 days. Therefore, forages from EGL intercropping systems should be supplemented with other sources of protein and energy to meet the nutritional requirements of lactating dairy cows.

Intercropping elephant grass with legumes reduced ($p<0.05$) NDF content by 4% when compared to the monocrop. This indicated an improvement in the quality of fodder from elephant grass/legume mixtures, which was a result of the presence of the legumes with low NDF. Mean IVOMD increased ($p<0.05$) by about 2% in intercrops because of the presence of forage legumes that had higher CP and IVOMD and a lower NDF than elephant grass fodder (Kabirizi et al., 2000). With a lower NDF content compared to the monocrop (Table 4.15), the IVOMD of EGL forages were expected to be high. Improvement in IVOMD would result in improved DM intake.

Although Ca and P contents of EGL improved, Ca and P contents in the fodder from both monocrops and intercrops were lower than the minimum requirements (0.48% P and 0.34%r Ca on DM basis) in the rations of dairy cows (NRC, 2001). This was probably due to a 36% decline in soil P (Appendix 3.5). Results of soil sample analysis (Appendix 3.5) showed that the legumes in EGL extracted a lot of P and Ca that were not replaced through top dressing. Tropical forage legumes are very efficient at extracting Ca and P from low Ca and P soils (Haque *et al.*, 1991). The low Ca and P contents in EGL could also be due to low legume content in the mixtures Top dressing with fertilizers rich in Ca and P would therefore promote forage legumes and elephant grass growth in the mixture and hence promote total fodder DM yields.

In conclusion, the results of this study have shown that forage legumes have the potential for improving total fodder DM yield per unit of land and the nutritive value of the forages. This will in turn be expected to improve dairy cattle nutrition and thus increases milk yield and household income.

4.2.4. Effects of intercropping *Lablab purpureus* with maize on chemical composition on maize/lablab stover

Results on the effect of intercropping maize with lablab on chemical composition and *in vitro* OMD of fodder are presented in Table 4.16. Intercropping maize with lablab increased ($p<0.05$) CP content and total CPY from maize/lablab intercrop, as compared to maize monocrop. On average, the CP content was 1.9 times higher in intercrops when compared to the monocrops. Maize/lablab intercropping reduced ($p<0.05$) OM, DM and NDF but increased ($p<0.05$) P; Ca; IVOMD and ME compared to maize monocrop.

The improvement in CP in the intercrops could be attributed to higher proportion (24%) of lablab that improved total CP content in the intercrop. While CP content of lablab was 18.6% that of maize stover was only 4% (Table 4.16). Improvement in the quality and quantity of ML is therefore the key factor to increasing the nutritional value of maize stover for the dairy cow during the dry season. Although CP content of ML was above the minimum level (7% CP) recommended for moderate growth (NRC, 2001), it was lower than reported by Mpairwe (1998) in ML (8.6% CP). The differences in the results of the trials could be attributed to chemical fertilizers (100 kg/ha of diammonium phosphate, DAP) he applied at planting time and 50 kg/ha of urea applied as top dress, six weeks after planting or to the maize variety. Phosphorus is an important nutrient in the successful establishment of forage legumes (Satter and Wu, 2000) and its deficiency affects N fixation in legumes through its effects on nodule development and nodule fixation and plant growth (Haque *et. al.* 1985) and hence increases N or CP content and P concentration uptake by the plant (Skerman and Riveros, 1990).

Although intercropping lablab with maize improved fodder DM yields, the CPY and ME from the intercrops were not adequate to meet the nutritional requirements of crossbred lactating dairy cattle (Table 4.16). Based on the findings of this study, it is recommended that dairy cattle fed on forages from maize/lablab intercropping systems must be supplemented with other sources of protein and energy to meet the nutritional requirements of lactating cows.

Table 4.16: Effects of maize/lablab intercropping on chemical composition on fodder

Parameter (% DM basis)	MS from monocrop	ML stover	SEM
Organic Matter	90.8±0.2	90.5±0.2	0.20
Dry matter	49.8±2.3	49.2±1	1.83
CP	4.0±0.1[b]	7.7±0.1[a]	0.22
CPY (kg/ha/year)	180.0±8[b]	432.0±20[a]	36.84
Ash	9.2±0.33	9.3±0.1	0.43
NDF	62.5[a]	60.8±2[b]	1.46
Ca	0.33[b]	0.39± 0.1[a]	0.02
P	0.44 [b]	0.50±0.0[a]	0.02
IVOMD	55.2±1[b]	58.8±2[a]	0.87
#ME (MJ/kg DM)	8.6±0.1[b]	9.0±1[a]	0.13

Calculated ME = 0.15*IVOMD (Close and Menke, 1986);

MS=Maize stover; ML= Maize/lablab stover

[ab]Least square means within a row followed by different superscripts differ ($p<0.05$)

The high IVOMD content in intercrops could have been due to the presence of lablab, which had lower NDF content (<60%) than maize stover. Singh and Oosting (1992) categorized feeds with NDF contents ranging between 45 and 65% as medium quality feeds and those with NDF below 45% as high quality feeds. Therefore, the feeds obtained from maize/lablab intercrop and maize monocrop were of medium quality.

The higher Ca and P contents in the intercrops were attributed to presence of lablab legume which had higher Ca and P contents compared to maize stover (Table 4.16). Tropical forage legumes generally contain high concentrations of most nutritionally valuable minerals (Elliot. and McMeniman, 1987; Elliot, 1996). However, nutritional requirements may not always be met, since availability for absorption and function varies with each element (Norton and Poppi, 1995). The Ca and P content of ML were lower than the estimated requirements (0.48%) but the P content was higher than the minimum (0.34%) required for a lactating dairy cow. The low Ca values observed in the ML forages could be attributed to decline (5.6%) in soil Ca level observed in the soil samples (Appendix 4.6).

Results of this study supported the hypothesis that integrating forage legumes in cereal or elephant grass cropping systems will increase the quantity and nutritive value of the feed resource base without reducing the grain yield. The low fodder DM yields of legumes in elephant grass/legume intercrops is however a major constraint to the adoption of the technology as a dry season feed resource. Maize/lablab intercropping is of particular importance to resource poor crop/livestock farmers for it would improve the quality and quantity of fodder to fill the feed gap during the dry season while improving maize grain yield from the same piece of land. Improving forage DM yields and or forage quality without adversely affecting grain yield is an attractive option for intensive smallholder mixed crop/livestock systems. Improved feed supply from the intercrops would have a positive effect on the carrying capacity and hence increase milk yield, growth rate and reproductive performance of the animals.

Although EGL and ML technologies improved fodder production and therefore carrying capacity, the observed fodder DM, CP and ME yields produced were not adequate to support a lactating dairy cow for a full year. Thus feeds from EGL and ML intercropping systems when fed alone may not be able to support very high levels of production. Supplementing EGL or ML forages with forage legumes or fodder trees such as lablab and/or *Calliandra calothyrsus* and a concentrate and improving overall management of the forages using recommended management practices (such as use of improved varieties and manure/or inorganic fertilizers; proper harvesting height) are possible methods of improving the forage quality and quantity.

4.3. Study 3: The performance of crossbred cows fed forages from elephant grass/legume or maize/lablab intercropping systems and supplemented with legume hay and homemade concentrate

4.3.1. Quantities of residues harvested

Average quantities of lablab hay (LH), calliandra leaf hay (CLH) and maize/lablab stover (ML) conserved and stored per household were 406±78.1, 310±55.4 and 1,350±284 kg DM, respectively. The quantities of material conserved and stored depended on established acreage, labour and capital availability, the distance and the means used to transport the residues from the fields to the homesteads. Participating and other interested farmers worked in groups to solve the labour shortage. The members of the group nearest to the field trials helped the farm owner to plant, weed, harvest, transport and conserve the forages. Lablab herbage was harvested three times a year from the same field after which the ratoon crop was removed.

4.3.2. Chemical composition of basal forages and supplements

The chemical composition and *in* vitro dry matter digestibility of the feeds are given in Table 4.17. Sole EG had the lowest DM content among the basal forages. Calliandra leaf hay, HMC and LH had higher CP and slightly lower NDF than EGL, EG and ML forages. Among the forage supplements, the CP content of CLH was about 42% higher than that of LH. Lablab hay had higher NDF and ADF content than CLH.

Neutral detergent fibre (NDF) was highest in sole EG fodder and lowest in HMC. Calliandra leaf hay had the highest mineral concentrations among the supplements. Metabolizable energy and ODM were highest in HMC, intermediate in EGL and lowest in sole EG. The ADL varied (36.2-38.7%) between the basal forages but was lowest in HMC among the supplements. Dry matter and CP values for sole EG obtained in this study compared closely with those reported for elephant grass fodder variety *KW 4* by Ogwang (1976) in Uganda. Crude protein content of sole EG was lower than 11-16%, the minimum level required for maintenance and production of dairy cattle (NRC, 2001).

Table 4.17: Chemical composition (% DM) of the basal forages and supplements

	Basal forages			Supplements		
	EGL	EG	ML	CLH	HMC	LH
Parameter						
Dry matter	14.0	14.5	90.0	78.9	89.6	83.3
Organic matter	91.4	91.9	91.0	90.0	91.3	88.2
Neutral detergent fibre	61.8	64.8	61.1	51.2	19.0	54.8
Acid detergent lignin	36.7	36.8	38.2	43.1	6.7	39.7
Crude protein	9.7	7.2	6.2	22.5	16.7	15.8
In vitro OMD	63.7	58.1	62.9	60.1	77.7	59.7
#ME (MJ/kg DM)	9.6	8.7	9.2	9.0	11.7	9.0
Phosphorus	0.26	0.21	0.51	0.46	0.24	0.47
Calcium	0.26	0.25	0.37	1.65	0.47	0.46

EGL= Elephant grass/legume mixture; EG = Sole elephant grass fodder;

ML= Maize/lablab stover; LH = Lablab hay; CLH = Calliandra leaf hay; HMC= Homemade concentrate;

#Calculated ME = 0.15*IVOMD% (Close and Menke, 1986)

Although the legume content in EGL reported by Katuromunda (2001) was 7%, mean CP content of sole EG and EGL were higher (10% and 14.3% CP) than reported in this study (Table 4.17). This could be attributed to differences in elephant grass fodder varieties used in both studies. Majority of farmers use *Kawanda 4* that was distributed by the Projects that distribute the animals while Katuromunda (2001) used improved elephant grass variety. The low mean CP content of ML reported in this study could be due to leaf shattering of lablab that was occurred during drying and baling on a few households. On the other hand, although CP content of ML and EGL was improved through intercropping, the CP content was still below the minimum (10-16% CP) level required for effective microbial activity in the rumen for growth and lactation of dairy cattle (Crowder and Chedda, 1982; NRC, 2001). The results of this study are in line with findings by Mpairwe (1998) and Katuromunda (2001) who reported that forages from ML and EGL are deficient in CP and energy and should therefore not be used as sole feed. The high concentrations of CP and mineral in CLH, HMC and LH make them suitable supplements when low quality forages such as EGL and ML are fed to dairy cattle.

The lower NDF, ADF and ADL content and higher OMD values in EGL and ML forages than sole EG was attributed to the presence of the forage legumes that had lower NDF contents with higher CP and OMD values. In the tropics, lactating dairy cows need a diet of about 16% CP and 55% OMD for maintenance and production (NRC, 2001). This means that EGL, EGML and EG forages are capable of supporting maintenance requirements for dairy cattle.

The low Ca and P content in EGL forages could be due to low legume content (12%) in the mixture (Table 4.12) and/or low soil Ca and P content in the study area which were below the critical minimum level (5.2 mg/100g) (Soil sample analysis report, 2002), for crop production (Appendix 6.5). The legumes could also have extracted a lot of Ca and P that were not replaced by farmers because of low levels of fertilizers applied to the fodder fields. Tropical legumes have been reported to be very efficient at extracting P and Ca from low P and Ca soils (Haque *et al.*, 1985). Calcium and P content of sole EG and EGL forages were below the levels of 0.35% Ca and 0.3% P, respectively recommended by NRC (2001) for growth and production of dairy cattle.

The high Ca and P content in ML, CLH and LH supplements were due to lablab and calliandra legumes that are high in mineral contents (Leng, 1997; Makembe and Ndlovu, 1996). Previous studies (LSRP, 2000) have shown that smallholder dairy farmers rarely provide concentrates and mineral supplements to their animals because of lack of capital. Therefore, the adoption of EGL and ML forages together with CLH and LH supplements will provide Ca and P minerals, which are the two most limiting minerals in dairy cattle nutrition.

Results of Table 4.17 shows that ME in sole EG was below the minimum (95 MJ/day DM) levels recommended for growth and production of dairy cattle by NRC (2001). However, ME for HMC was higher than the minimum required for maintenance and production of lactating cows. This was expected since the homemade concentrate had high energy and protein levels (Table 4.17), which result in improved animal productivity.

The chemical composition of the forage supplements (CLH and LH) was higher than the basal forages. A potential forage legume to be used as a supplement to enhance the quality of poor quality roughages and crop residues such as EGL and ML should have a high protein content to supply readily fermentable protein. There would be an added advantage if the legume contains other critical nutrients such as minerals, vitamins and other compounds which enhance the rumen ecosystem (Leng *et al.*, 1991). From the present study CLH has a great potential to enhance the nutritive value of low N pastures and poor quality crop residues because it contains satisfactory levels of protein and minerals (Table 4.17) (Ebong *et al.*, 1999). In addition, to their perennial nature, fodder trees have high herbage DM yields and could be harvested and fed to livestock at any time of the year to increase the efficiency of utilization of the basal diets.

4.3.3. Dry matter and crude protein intake by crossbred dairy cows

Mean dry matter intake (DMI) and CP intake of the basal diets and supplements offered to the animals are shown in Table 4.18. Mean DMI and total CP intake were higher ($p<0.05$) in supplemented than in unsupplemented animals. Mean DMI of elephant grass fodder was 52% lower ($p<0.05$) in cows that were offered EGML diets than those that were offered sole EG (unsupplemented). Differences ($p<0.05$) in total dry matter intake (TDMI), DMI as a percentage of body weight (% BW) and DMI as metabolic body weight (DMI $BW^{0.75}$) were observed between supplemented and unsupplemented animals. Total DMI and CP intake were highest ($p<0.05$) in cows that were offered EGML basal diet with CLH and HMC supplements. Supplementing EGL basal diet with CLH in addition to LH and HMC improved TDMI by 7.4% compared to when the diet was supplemented with only LH and HMC. Total DMI as percentage of BW in supplemented and unsupplemented cows was lower than 3% recommended by NRC (2001).

The increased total DM intake with supplementation could be due to several reasons. It could be attributed to increased CP intake that was deficient in unsupplemented diet and as a consequence improved N supply in the rumen since the consumed supplemented diets contained high levels of CP (15.8-22.5% CP). This led to increased amount of amino acids that were absorbed from the diets. Increased DMI of low quality feeds attributed to addition of a legume hay and a concentrate has been reported by Osuju *et al.* (1995), Heldt *et al.* (1999); Aregheore and Perera (2004) and Hinderichsen *et al.* (2004). However, the above results deviate from those of Boitumela and Mahabile (1992) who reported no differences in DMI of elephant grass fed lactating cows, supplemented with legume hay and a concentrate. The lower DMI of elephant grass fodder in cows that were offered EGML basal diets compared with sole EG could be attributed to preference of ML forages and the supplements by animals. The supplements fed together with ML forages had higher CP content than sole EG (Table 4.17).

Table 4.18: Mean dry matter and crude protein intake of basal forages and supplements by crossbred dairy cows

	Treatments					
Parameter	EGL+LH + HMC	EGL+LH+CLH +HMC	EGML+CLH +HMC	Sole EG	SEM	Significance level
Dry Matter Intake (DMI) (kg/cow/day)						
Elephant grass/legume mixtures	6.7	6.6	-	-	0.04	
Lablab hay	1.3	0.8	-	-	0.01	
Homemade concentrate	3.1	3.1	3.2	-	0.02	
Calliandra leaf hay	-	0.9	0.9	-	0.01	
Maize/lablab stover	-	-	3.5	-	0.02	
Elephant grass fodder	-	-	4.6	7.0	0.04	
Total DMI	11.1^{c}	11.3^{b}	12.0^{a}	7.0^{d}	0.03	***
Total DMI (% Body weight)	2.4^{c}	2.4^{b}	2.6^{a}	1.9^{d}	0.01	***
Total DMI (g/kg $BW^{0.75}$)	111.3^{c}	111.8^{b}	120.5^{a}	83.2^{d}	0.36	***
Crude Protein Intake (g/cow/day)						
Elephant grass/legume mixtures	613.9	604.9	-	-	3.68	
Lablab hay	207.6	116.5	-	-	1.77	
Homemade concentrate	521.1	521.1	520.1	-	3.15	
Calliandra leaf hay	-	200.0	200.0	-	1.17	
Maize/lablab stover	-	-	215.5	-	1.20	
Sole elephant grass fodder	-	-	332.8	502.5	2.65	
Total Crude protein intake (g/cow/day)	1343^{b}	1443^{a}	1269^{c}	503^{d}	29.60	***

EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder; ^{abcd} Least square means within a row followed by different superscripts differ ($p<0.05$); SEM = Standard Error of the mean

Initially the cows tended to reject ML but after they got used to it, they ate it readily and there was a dramatic increase in both DM intake and overall animal performance.

Total DMI and CP intake were improved by 1.5 and 7.4 percent, respectively when cows offered EGL basal diet were supplemented with CLH, HMC and LH compared to HMC + LH only. Kaitho (1997) urged that drying calliandra foliage increases the DM content and amount of protein bypassing the rumen as well as decreasing the content of anti-nutritional factors. Previous studies by Kamatalit *et al.* (1992) and Ebong *et al.* (1999) showed that proteins in calliandra foliage have a well-balanced amino acid profile that are protected from degradation in the rumen, particularly when the foliage is dry. Improved amino acid profile results in improved dry matter and protein intake, growth and feed efficiency. The results therefore indicate that additional supplementation with CLH is beneficial to dairy cows especially where farmers do not have enough land and labour to produce sufficient quantities of lablab hay.

The lower DMI of sole EG compared to EGL diet (Table 4.12) could be attributed to coarseness and lower CP content especially when fed at maturity. The nutritive value and the physical characteristics of the sward have been reported to influence DMI (Parga *et al.*, 2000). The low CP levels of elephant grass fodder (Table 4.17) could not provide enough N that would stimulate microbial activity, which would in turn lead to higher rate of digesta breakdown and passage. According to NRC (2001), unsupplemented cows required a minimum intake of about 1680 g/cow/day of CP for their growth and lactation. Total CP intake was only 502.5 g/cow/day, resulting in a deficit of about 1177.5 g/cow/day. Supplemented cows received sufficient CP for their growth and production (Table 4.18). Differences in DMI between cows that were fed on EGL and sole EG fodder could have been due to the differences in soil fertility, soil moisture content and management practices on the study fields. These factors have been reported to influence fodder yield and quality and therefore DMI (Allen, 1996).

4.3.4. Metabolizable energy and mineral intake by crossbred dairy cows

The effect of supplementing with CLH, LH and HMC on metabolizable energy (ME) and mineral intake by crossbred cows fed EGL or EGML diets is shown in Table 4.19. Total ME intake (MEI) was higher ($p<0.05$) in supplemented than in unsupplemented cows. The highest MEI among the supplemented diets was obtained in cows that were offered EGML basal diets with HMC and CLH supplements. Total ME intake from elephant grass fodder was about 34% lower in EGML basal diets than in sole EG diet. The MEI of unsupplemented cows was only 60.7 MJ/cow/day. Mineral (P and Ca) intake was higher ($p<0.05$) in supplemented than in unsupplemented cows. Among the supplemented diets, Ca and P intake were highest in cows fed on EGML + CLH + HMC diet.

Higher ME intake in supplemented diets could be attributed to the supplements, particularly HMC which were high in ME (Table 4.17). Supplementation with HMC resulted in MEI of about 36 MJ/cow compared to less than 15 MJ/cow for LH and CLH. According to NRC (2001), the minimum ME requirement for maintenance for lactating and pregnant cows weighing about 450 kg and producing 8-12 litres of milk of 4.7% butter fat content per day was 95 MJ/cow/day. This means that all supplemented cows received sufficient energy for their maintenance and production. However, ME in unsupplemented diets was inadequate and resulted in a deficit of about 34 MJ per/cow/day,

The low ME content of sole EG (Table 4.17) partly explains the low total DMI in unsupplemented diet compared to supplemented diets. The results of this trial shown that energy deficits lead to reduction in DMI, loss in body weight and body condition, reduced milk yield and may affect reproductive efficiency (Britt, 1998; Keady *et al.*, 1999). The results of this trial also confirm results obtained in trial 1 that energy deficit in sole elephant grass diets limit DMI and overall animal production.

The differences in Ca and P intake between supplemented and unsupplemented cows could be attributed to higher Ca and P contents in the supplements (Table 4.17) compared to the basal forages.

Table 4.19: Metabolizable energy and mineral intake by crossbred dairy cows

Parameter	Treatments					
	EGL+LH+HMC	EGL+LH+CLH+HMC	EGML+CLH+HMC	EG	SEM	Significance level
ME intake (MJ/cow/day)						
Elephant grass/legume mixtures	64.3	63.1	-	-	0.38	
Lablab hay	12.0	6.7	-	-	0.10	
Homemade concentrate	36.3	36.5	36.4	-	0.22	
Calliandra leaf hay	-	8.0	8.0	-	0.05	
Maize/lablab stover	-	-	32.7	-	0.18	
Sole elephant grass	-	-	40.2	60.7	0.32	
Total ME intake (MJ/cow/day)	112.6^{c}	114.3^{b}	116.3^{a}	60.7^{d}	0.30	***
Phosphorus intake (g/cow/day)						
Elephant grass/legume mixtures	17.4	17.1	-	-	0.10	
Lablab hay	6.3	3.5	-	-	0.05	
Homemade concentrate	7.5	7.5	7.5	-	0.05	
Calliandra leaf hay	-	4.1	4.1	-	0.02	
Maize/lablab stover	-	-	15.3	-		
Sole elephant grass	-	-	9.7	14.7	0.08	
Total P intake (g/cow/day)	31.1^{c}	32.3^{b}	36.6^{a}	14.7^{d}	0.12	***
Calcium intake (g/cow/day)						
Elephant grass/legume mixtures	16.7	16.4	-	-	0.10	
Lablab hay	22.0	12.3	-	-	0.19	
Homemade concentrate	14.7	14.7	14.6	-	0.09	
Calliandra leaf hay	-	2.8	2.9	-	0.02	
Maize/lablab stover	-	-	34.8	-	0.01	
Sole elephant grass	-	-	11.6	17.5	0.09	
Total Ca intake (g/cow/day)	54.3^{b}	46.2^{c}	63.7^{a}	17.5^{d}	0.25	***

EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder; CLH = Calliandra leaf hay; ML = Maize/lablab stover; SEM = Standard Error of the mean

^{abcd}Least square means within a row followed by different superscripts differ ($p<0.05$); SEM = Standard Error of the mean

Calcium and P intake in unsupplemented cows were below (38-50 g/cow/day P) and (120-150 g/cow/day Ca) the minimum requirement for moderate levels of production (NRC, 2001).Phosphorus deficiency in the rumen reduces microbial growth efficiency and in some cases the digestibility and intake of forages (Durand and Komisarezuk, 1988). However, all cows were supplemented with homemade mineral blocks which were high in Ca and P content that could have provided the mineral requirements since no cases of disorders related to mineral deficiencies were reported during study period.

The value of forage legume hay and HMC as supplements depends mainly on their capacity to provide the nutrients (CP, ME and minerals) that are deficient in the basal diet. This includes their ability to provide the essential nutrients to the rumen microbial population and/or critical nutrients to meet the host animal's requirements thus increasing the efficiency of feed utilization. Thus, EGL and EGML diets alone supplied deficient diets, which responded to supplementation with forage legume hay and a HMC.

4.3.5 Seasonal effects on digestible crude protein and organic matter digestibility of the feeds

Results of the effect of supplementing dairy cows on digestible crude protein (DCP) and organic matter digestibility (OMD) of the feeds during the wet and dry seasons are shown in Table 4.20 and Figures 4.11 and 4.12. Mean DCP and OMD values of all the treatments were higher ($p<0.05$) during the wet season than during the dry season. The values increased with increasing amount of rainfall period reaching highest level in April 2003, at the peak of the rain season (Figures 4.11 and 4.12). Digestible crude protein and OMD values of the feeds decreased from May 2003 to end of the study. The lowest DCP values were obtained in July 2003, at the peak of the dry season. Digestible crude protein and ODM of the feeds were highest in EGL + LH + CLH + HMC diets, intermediate in EGML + CLH +HMC diets and lowest in sole EG diets.

Table 4.20: **Effect of supplements on percentage digestible crude protein (DCP) and organic matter digestibility (ODM) of feeds during the wet and dry season**

	Season		
Parameter	Dry season	Wet season	SEM
Digestible crude protein (%)			
T 1	9.3^{b}	9.9^{a}	0.35
T 2	9.4^{b}	10.2^{a}	0.35
T 3	8.8^{b}	9.4^{a}	0.35
T 4	8.0^{b}	8.4^{a}	0.35
SEM	0.18	0.45	
Organic matter digestibility (%)			
T 1	61.3^{b}	62.6^{a}	0.63
T 2	62.1^{b}	63.6^{a}	0.63
T 3	61.8^{b}	62.9^{a}	0.63
T 4	58.8^{b}	60.0^{a}	0.63
SEM	0.18	0.45	

T1= EGL + LH + HMC; T 2 = EGL + LH + CLH + HMC; T 3 = EG + ML + CLH + HMC; T 4 + Sole EG
EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover;
LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder
SEM = Standard Error of the Mean
^{abcd}Least square means within a row followed by different superscripts differ ($p<0.05$)

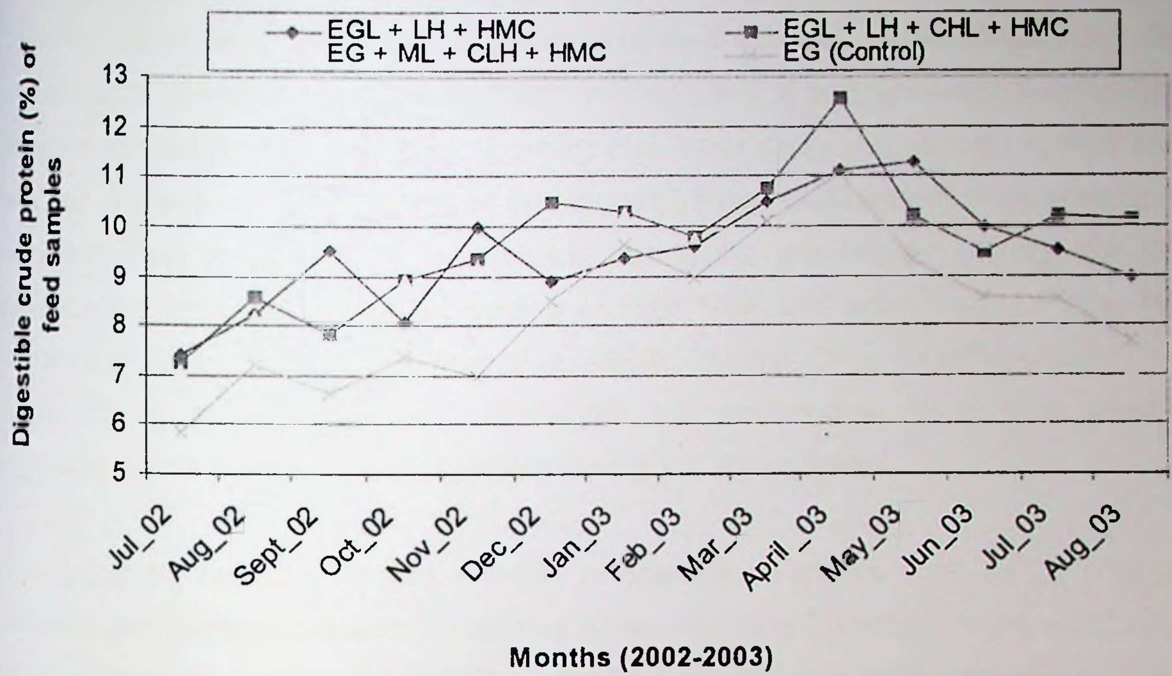


Figure 4.11: Effect of season on digestible crude protein content of the feeds

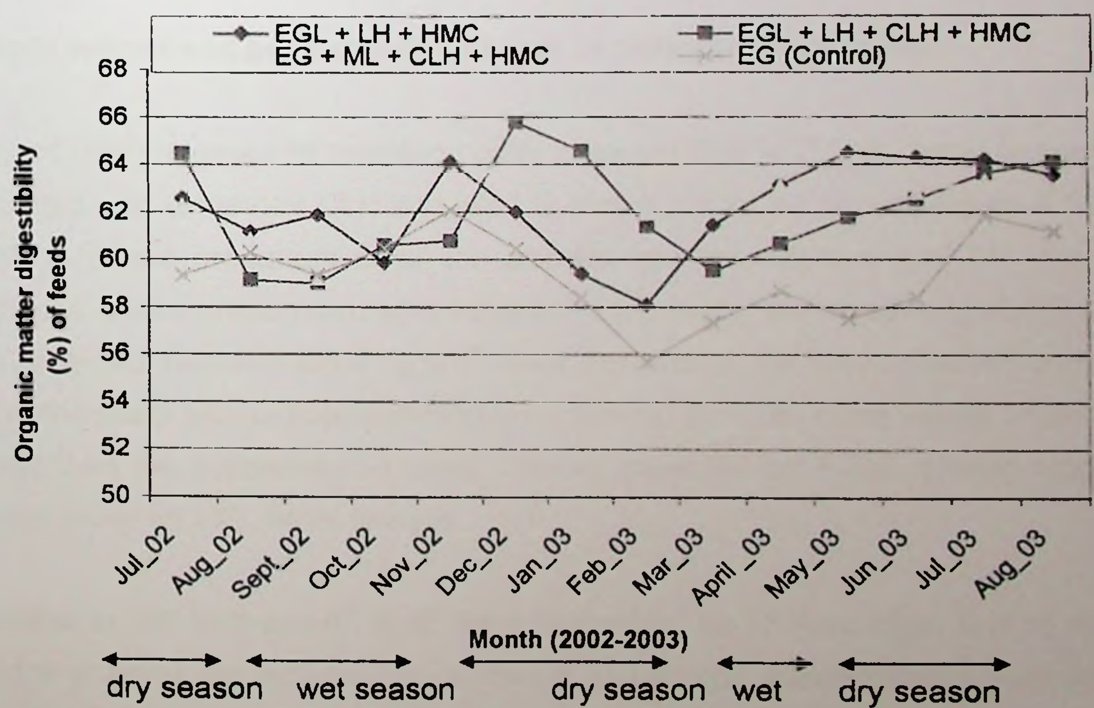


Figure 4.12: Effect of season on organic matter digestibility of feeds

The higher DCP and OMD values of the feeds during the wet season than the dry pseason could have been due to better quality of elephant grass fodder and the supplements. Driedger and Loerch (1999) reported that N supplementation to mature steers improved the OMD by 5%. It could also have been due to high rainfall that resulted in plenty of succulent fodder and higher CP and OMD values than overgrown elephant grass fodder that was available during the dry season. During the dry season, the forages are mature leading to high NDF and lignin, low CP and ME contents and overall low OMD (Nkya *et al.,* 1998). The low CP and OMD values of the feeds during the dry season underscore the importance of N and energy supplementation to dairy cattle especially during the dry season.

During the dry season, forages are low in essential nutrients such as N, energy, minerals and vitamins required for optimal rumen microbial growth (Preston and Leng, 1984). This partly explains the low OMD and DCP of the feeds collected during the dry season. Romney and Gill (2000) reported that the most important factor influencing production response of an animal is the total quantity of the absorbed nutrients, which are in turn determined by intake, and digestibility of the ingested feed.

4.3.6. Body weight and body condition score of crossbred dairy cows

Body weight (BW) changes of crossbred dairy cows fed EGL or EGML basal forages supplemented with LH and/or CLH and HMC is shown in Table 4.21 and Figure 4.13. Initial BW, 8 weeks prepartum of all the animals was not different ($p>0.05$). Four weeks (8 to 4 weeks prepartum), after initiation of the study, an increase ($p<0.05$) in BW was observed. Between the 4^{th} and 8^{th} week postpartum, the trend reversed until the end of the study with unsupplemented cows loosing ($p<0.05$) more weight (-183.3 g/cow/day) than the supplemented cows. Overall, cows fed on EGML gained more weight than those on EGL basal forages.

The increase in BW between 8^{th} to 4^{th} week prepartum could have been due to the effect of the growing foetus in addition to the CP and energy requirements of animals being met. Kabirizi et al., (2000) reported that cows supplemented with lablab forage had significantly higher body weight gains than the non-supplemented cows.

Table 4.21: Effects of supplementing EGL or EGML forages with a legume hay and a homemade concentrate on body weight of crossbred dairy cows

	Treatments					
	EGL+LH +HMC	EGL+LH +CLH+HMC	EGML+CLH +HMC	EG	SEM	Significance level
Parameter						
Mean body weight (BW) (kg/cow)						
Initial BW at 8 wks prepartum	465.5	468.6	469.8	468.5	2.00	ns
BW (at calving)	438.6	439.1	457.3	435.8	2.11	ns
BW at 8 wks postpartum	428.4^{b}	430.9^{b}	450.6^{a}	424.8^{b}	2.49	*
Final BW (at 30 wks postpartum)	459.5^{b}	459.0^{b}	487.8^{a}	444.1^{c}	3.30	**
BW change (BWC)-calving to 8 wks postpartum	-10.25^{ba}	-8.25^{ba}	-6.6^{a}	-11.0^{b}	0.70	ns
BWC Calving to 30 wks postpartum	20.9^{ba}	19.9^{b}	30.5^{a}	8.4^{c}	2.14	*
BWC 8 wks prepartum 30 wks postpartum (g/day)	31.1^{a}	28.1^{ba}	37.1^{a}	19.4^{b}	1.89	**
ADG calving to 8 wks postpartum (g/day)	-170.8^{ba}	-137.5^{ba}	-110.4^{a}	-183.3^{b}	11.73	ns

EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG =sole elephant grass fodder; BWC= Body weight change; ADG= Average daily gain; BW= Body weight
^{abcd}= Least square means within a row with different superscripts differ: * =p<0.05;** =p<0.01, ***= p<0.01; ns = not significant;
SEM = Standard Error of the mean

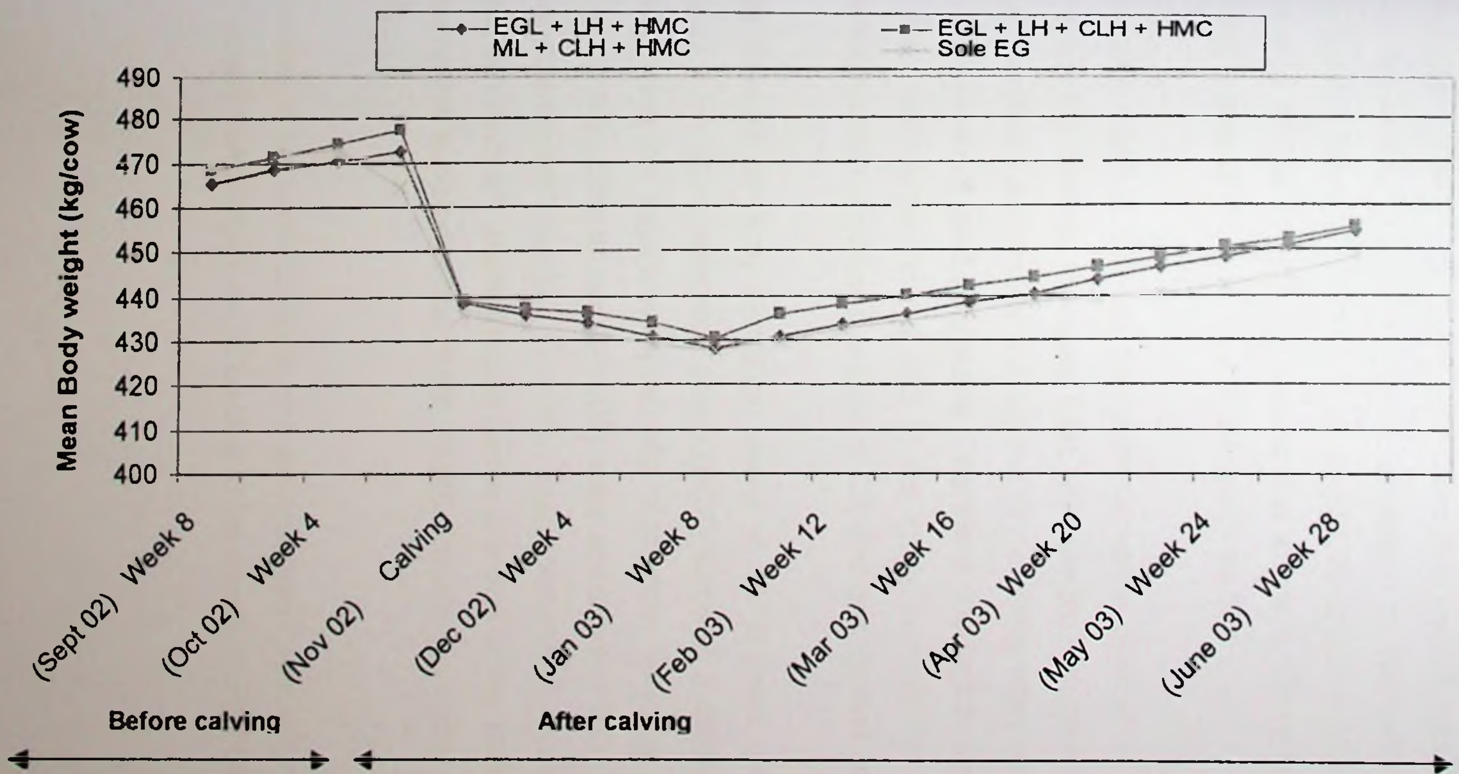


Figure 4.13: Effects of supplementing with a legume hay and homemade concentrate on body weight changes of crossbred cows

The loss in BW in supplemented animals during the first 8 weeks postpartum could be a result of increases in milk yields (Figure 4.15), resulting from improved feeds. Therefore, CP and ME intake could have been utilized for milk production instead of increased body weight. Similar results have been reported by Muinga *et al.* (1992). Later in the lactation period (8 to 28 weeks postpartum) when milk yields decreased (Figure 4.17), the increased CP and ME intake resulted into fat deposition and body weight gain. The lower BW gain in cows that were fed EGL basal forages compared to cows fed EGML forages could be attributed to fluctuation in feed supply. During the dry season, there was a shortage of EGL forages on all farms. There was therefore a tendency for farmers to underfeed the animals. Cows fed on EGML forages had a steady supply of ML throughout the study period.

The main effect of offering the animals with supplements was to improve feed quality and quantity thereby increase DMI, milk yields, reduce body weight loss and improve body condition especially during the dry season when smallholder dairy cows suffer most because of feed shortages. Therefore, the higher average daily gain (ADG) from 8^{th}week postpartum to the end of the study in cows fed on EGML forages could be associated with increased supply of CP and energy and adequate feeds.

The changes in body condition score of the animals are shown in Table 4.22 and Figure 4.14. Body condition score (BCS) followed a pattern similar to changes in BW. There were no significant ($p>0.05$) differences in initial BCS between the animals. After calving, differences ($p<0.05$) were observed in BCS between supplemented and unsupplemented cows. Overall, unsupplemented cows lost ($p<0.05$) more body condition from 8^{th} week postpartum to the end of the study than supplemented cows. Among the supplemented diets, EGML resulted in better body condition compared to EGL.

The loss in body condition in unsupplemented cows between 8 weeks prepartum and 28 weeks postpartum could be due to low levels of total DMI, CP and ME intake

Table 4.22: Effects of supplementing with a legume hay and homemade concentrate on body condition of crossbred dairy cows

	Treatments					
Parameter	EGL+LH +HMC	EGL+LH+ CLH+HMC	EGML+CLH +HMC	EG	SEM	Significance level
Body Condition score						
Initial BCS (8 weeks prepartum)	4.7	4.9	4.9	4.7	0.05	ns
BCS (day 0 after calving time)	4.6^{ba}	4.8^{a}	4.9^{a}	4.3^{b}	0.07	*
BCS (8 wks postpartum)	4.5^{bc}	4.6^{ba}	4.9^{a}	4.0^{c}	0.08	**
BCS (30 wks postpartum)	5.0^{a}	5.3^{a}	5.4^{a}	4.1^{b}	0.13	*
Change in BCS (8 wks prepartum to calving)	-0.1^{ba}	-0.1^{ba}	0.0^{a}	-0.3^{b}	0.05	*
Change in BCS (calving to 8 wks postpartum)	-0.2^{a}	-0.3^{a}	0.0^{a}	-0.2^{a}	0.07	ns
Change in BCS (8 wks prepartum to 30 wks postpartum)	0.3^{a}	0.3^{a}	0.6^{a}	-0.5^{b}	0.11	*

EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder; BCS= Body condition score;
^{abcd} = Within row, means with different superscripts are significantly different: * =p<0.05;** =p<0.01; ***= p<0.01; ns = not significant; SEM = Standard Error of the mean

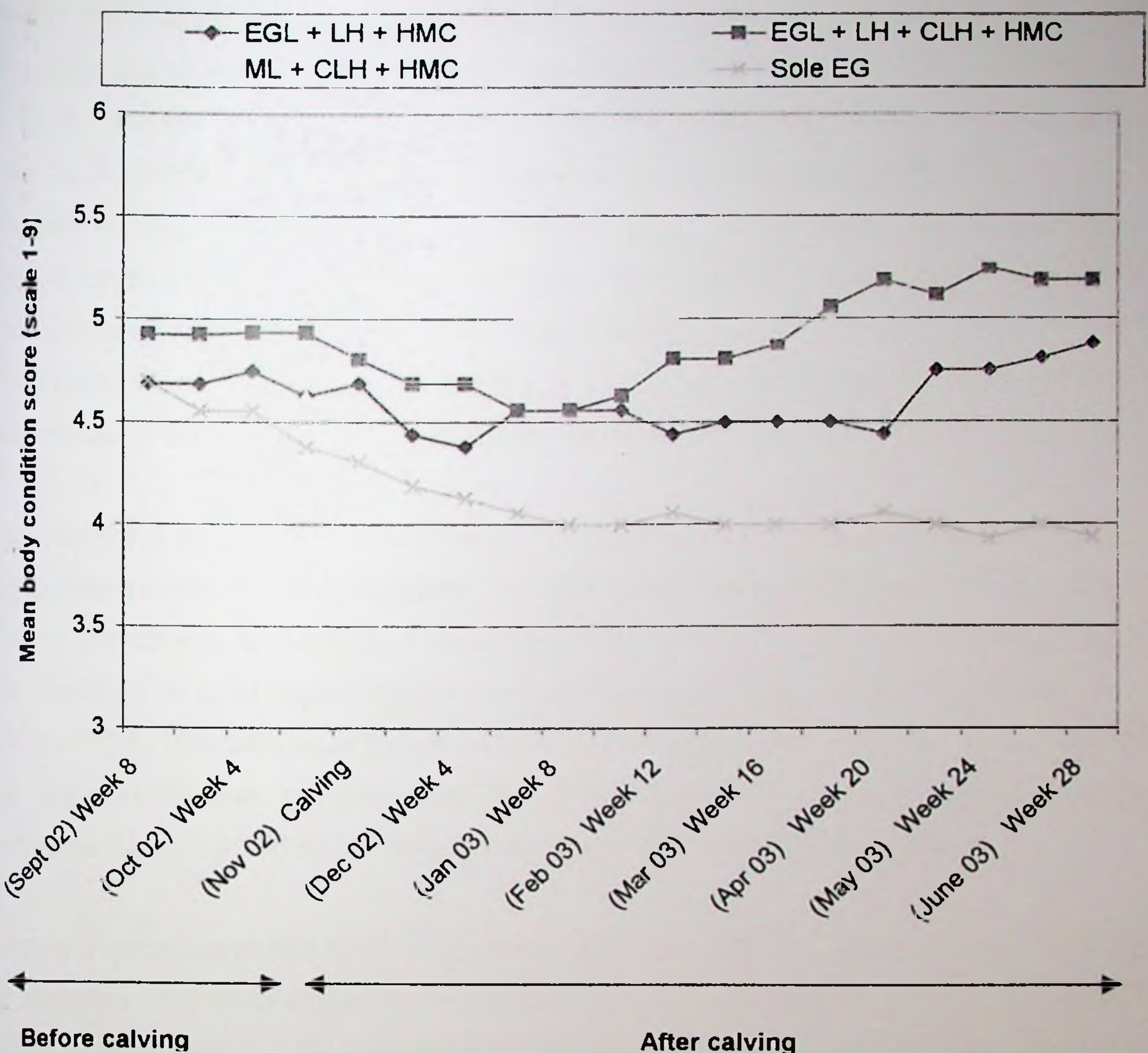


Figure 4.14: Effects of supplementing crossbred cows with a legume hay and homemade concentrate on body condition of crossbred dairy cows

(Tables 4.18 and 4.19) and to inadequate supply of feeds especially during the dry season. Similarly, the loss in body condition of animals that were fed on EGL diets was partly due to low DMI at the time of calving. Most of the cows calved at the peak of the dry season (November) when the legume content and total fodder DM yields were low (Figure 4.10) compared to cows fed on EGML forages. Although there was a shortage of elephant grass fodder during the dry season, cows that were offered EGML forages benefited from ML stover that was abundantly available throughout the study period. Findings from this study have confirmed previous results that showed that feeding cows at high levels (quantity and quality) before calving results in better body condition and BW at calving and after calving (Keady *et al.*, 1999).

It is during this period between 8 weeks prepartum and 10 weeks postpartum when cows undergo tremendous metabolic changes, e.g. shifting from pregnant to lactating state to prioritise milk production and prepare to conceive again and that breeding is often initiated at 8-10 weeks postpartum. All these activities have negative effect on BW and BCS. The pattern of growth and nutrient intake observed in this study indicate that supplementation of EGL and ML basal diets with forage legumes and a concentrate has a positive impact on daily weight gains and body condition.

In many tropical countries such as Uganda, there are regular feed shortages and long dry seasons, therefore under such conditions substance feeding, mainly poor quality elephant grass fodder and crop by-products results in reduced live weight and body condition and low productivity of livestock. Therefore, during periods of feed shortage, forages from shrubs and especially trees and homemade concentrates have great value as they supply dietary nitrogen, energy, minerals and vitamins.

4.3.7. Milk yield of crossbred dairy cows

The effect of supplementing with a legume hay and homemade concentrate on mean daily milk yield of crossbred cows fed EGL or EGML basal forages is shown in Figure 4.15 and Table 4.23. Supplemented cows produced higher ($p<0.05$) milk yield than unsupplemented cows. Overall, mean daily milk yield during the wet season (10.4 litres/cow/day) was about 24% higher ($P<0.05$) than during the dry season (8.4 ± 0.05 litres/cow/day). Among the supplemented diets, EGML + CLH + HMC produced higher ($p<0.05$) milk yield during the wet and dry season than EGL. Supplementing EGL diet with CLH, LH and HMC yielded ($p<0.05$) about 7% more milk than cows fed on EGL + LH + HMC.

The observed improvement in milk yields in supplemented diets confirms findings from the survey (Study 1) shows that lower productivity of unsupplemented cows is due to low magnitudes of CP and ME in the basal diets. It also indicates that supplementation with legume hay and a concentrate before and after calving improved milk production.

Milk yield in supplemented cows increased and peaked at 8-12 weeks postpartum after which it started decreasing thus displaying a normal lactation curve. Mean daily maximum milk yield for supplemented cows was 16 litres/cow/day compared to milk yield of 25 litres/day reported for crossbred cows (Samanya, 1996) on well managed zero grazing units in Uganda. The differences in mean yield between the two trials could be attributed to differences in genetic potential of the individual cows and/or environmental factors such as management, feed and water supply on the different households. Similar observations were made by Leaver (1985) and El Said *et al.* (2001).

The superior milk yield recorded in cows that were offered EGML compared to EGL basal diets was due to extra CP, ME and mineral intake (Tables 4.18 and 4.19) and adequate feed supply throughout the study period, which enabled the cow to meet the increased nutrient requirements of lactation. Purwantara *et al.* (2001) observed that environmental factors, including season, nutrition and reproduction affect 70% of milk production in dairy cattle.

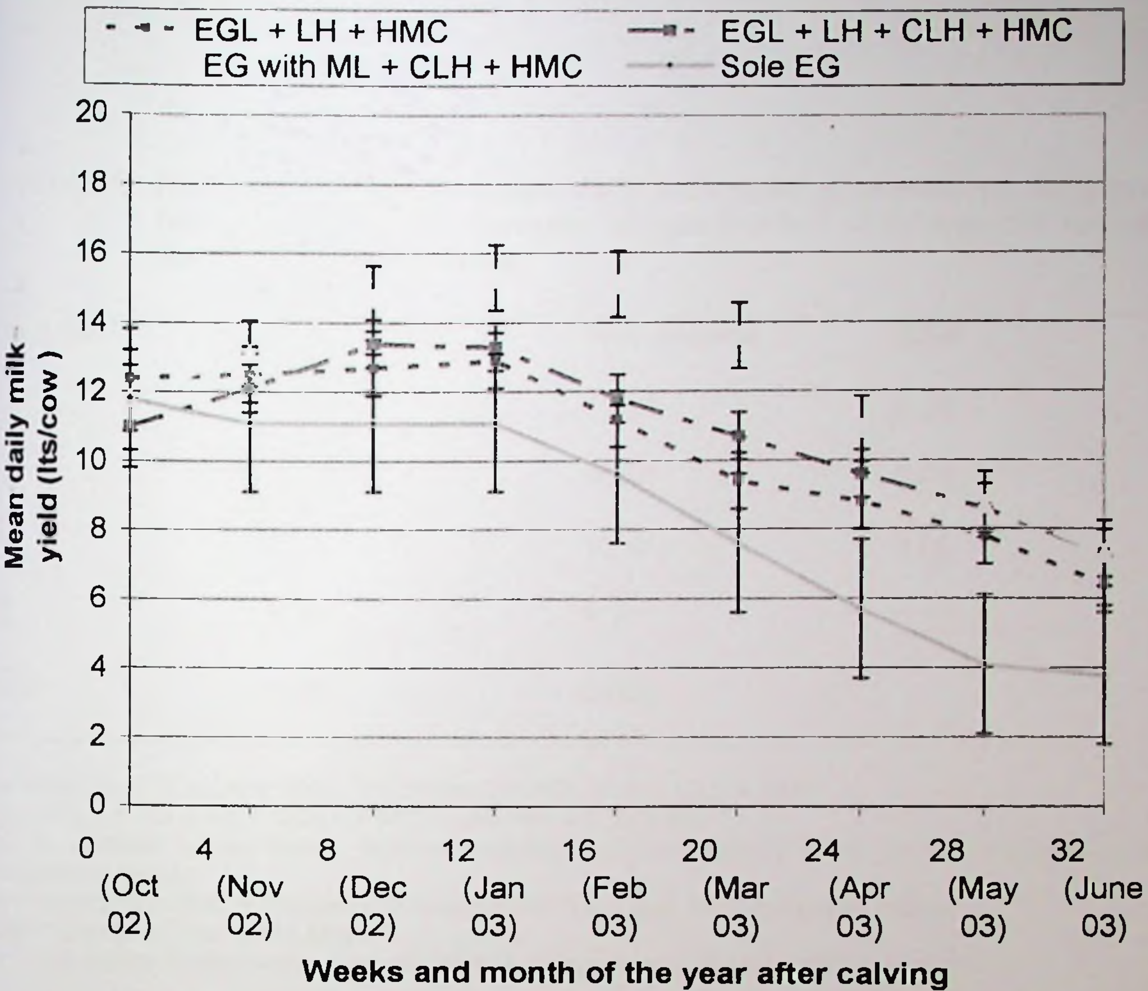


Figure 4.15: **Lactation curves for crossbred cows fed EGL or EGML forages supplemented with CLH and/or LH and a HMC (Mean+SEM)**

Table 4.23: **Effect of season on mean daily milk yield of crossbred dairy cows fed EGL or EGML forages supplemented with legume hay and homemade concentrate**

Treatment	Dry season	Wet season	SEM
T1	8.4^{b}	10.2^{a}	0.03
T2	8.9^{b}	10.9^{a}	0.05
T3	9.7^{b}	12.8^{a}	0.07
T4	6.5^{b}	7.7^{a}	0.02
SEM	0.05	0.05	

Treatment 1= EGL + LH + HMC; Treatment 2 = EGL + LH + CLH + HMC;
Treatment 3 = EG + ML + CLH + HMC; Treatment 4 + Sole EG
EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover;
LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder
SEM = Standard Error of the Mean
^{abcd}Least square means within a row followed by different superscripts differ ($p<0.05$)

The higher milk yield in cows offered EGML compared to cows that were offered EGL basal forages means that for a smallholder dairy farmer with limited land for food and fodder production, integration of lablab in maize cropping system is one way of improving feed quality and quantity and therefore improve milk yield during the dry season.

Additional supplementation of EGL + LH + HMC diet with CLH produced about 22% more milk than when the EGL diet was supplemented with only LH and HMC. Calliandra leaf hay had a higher CP content compared to LH (Table 4.17) and this improved DMI, milk yield and overall performance. The protein value of a feed for ruminants depends not only on its ability to supply rumen microbes with degradable protein, but also on its ability to supply the animal with digestible rumen undegradable protein (Waisswa *et al.*, 2003).Both requirements are important, but the requirement for rumen degradable feed protein is essential for rumen fermentation and therefore for digestion, microbial protein synthesis and production of short chain fatty acids. Therefore, lack of rumen degradable protein can also severely impair feed intake and overall animal productivity (Konimba, 1996). Jingura *et. al.* (2001) reported a significant contribution of the legume hay to nutrient supply to dairy cows. He observed that the 3 kg/day of lablab hay offered per day supplied about 182 g of rumen degradable protein (RDP), 224 g of rumen undegradable protein (UDP) and 26 MJ of ME per day, which contributed significantly to rumen microbial growth and, in turn to milk production.

Milk yields, body weight and body condition response to supplementation with CLH and/or LH and HMC were most evident during the dry season. The results showed that during normal growing seasons, there seemed little advantage in supplementation because of plenty of elephant grass fodder and other feed resources that were available. In view of the results of this study and the labour and land required to produce and conserve LH and CLH on smallholder dairy farmers, it is recommended that strategic supplementation be done during the wet season so that more conserved fodder is saved for the dry season. This would save on resources i.e. land, capital and labour which are the major constraints to fodder conservation in smallholder dairy production systems. It would also attract smallholder dairy farmers to adopt fodder conservation technology. Similar observations were made by Gimbi *et al* (2003) who recommended that the level of energy supplementation should be higher during dry than rain season.

Unsupplemented cows had the lowest mean daily milk yield throughout the entire lactation period (Figure 4.15). This could be attributed to low intake of CP and ME observed in this diet (Tables 4.18 and 4.19) and inadequate feed supply especially during the dry season. According to NRC (2001), the cow breed used in this study, based on mean body weight and milk production, required about 47 MJ/cow/day for their maintenance. The amount provided by the unsupplemented diets was approximately 60.7 MJ/cow/day (Table 4.19), which implies a difference of only 13.7 MJ/cow/day over its maintenance requirements. Lactating cows similar to those used in this study require about 78 g CP and 5.2 MJ per day to produce 1 kg of 4.0% Fat Corrected Milk (FCM). Thus, the ME in excess of maintenance for unsupplemented cows was insufficient and generated only 2.6 kg FCM per day. The cows therefore, received sub-optimal amounts of ME and were unable to lactate to their genetic potential. The FCM values of the unsupplemented diets though very low, were well within the range reported by Anon (2003) in Uganda. Because unsupplemented animals lost more weight and body condition between calving and 8 weeks postpartum (Tables 4.21 and 4.22 and Figures 4.13 and 4.14), it is reasonable to conclude that milk production was in part at the expense of the animal's body weight. These results are in agreement with observations made by Zerbini *et al.* (1994) and Hayirli *et al.* (2002) that inadequate feeding result in high rates of body weight loss and decreased milk production.

This study has shown that on-farm production of high quality forages and concentrates are possibilities for smallholder dairy farmers to improve animal productivity and farm profits. Use of forages from maize/lablab or elephant grass/legume intercropping systems increases feed production, thus ensuring year-round feed supply particularly so in smallholder dairy production systems. Feed quality (protein, energy, vitamins and minerals) is enhanced especially by the forage legume component and a concentrate with a consequent increase in livestock productivity.

4.3.8. Reproductive performance of crossbred dairy cows

4.3.8.1. Performance of calves

The effects of supplementing with CLH and/or LH and a HMC on growth rate of the calves are summarised in Table 4.24. Birth and weaning weights and average daily weight gain (ADG) of calves were higher ($p<0.05$) in supplemented than unsupplemented cows. Overall, calves from cows fed on EGML + CLH + HMC diets had higher ($p<0.05$) birth and weaning weights and average daily gain (ADG) than calves of cows fed on EGL basal forages.

The higher birth and weaning weight of calves from supplemented cows compared to unsupplemented cows could be attributed to higher DM intake (TDMI, protein, minerals and energy) that catered for both the dam and the growth of the foetus. Previous studies (Carstens *et al.*, 1987) showed that the protein-restricted cows were found to have lower BCS at calving and produced less colostrum volume, produced weaker calves, had reduced thermogenic capacity and took longer to come on heat than cows fed adequate protein.

Table 4.24: Effects of supplementing with a legume hay and homemade concentrate on reproductive performance of crossbred dairy cows

	Treatments				
Performance of calves	**EGL+LH+ HMC**	**EGL+LH+CL H +HMC**	**EGML+CLH +HMC**	**EG**	**SEM**
Birth weight of calves (kg)	30.4^{b}	30.5^{b}	33.6^{a}	29.4^{b}	0.45
Range	(27-36)	(28-33)	(30-36)	(27-33)	
Weight at weaning (2mths)	50.1^{b}	49.3^{b}	55.0^{a}	49.4^{b}	0.58
Range	(48-53)	(47-52)	(50-59.5)	(47.5-54.0)	
ADG of calves (g/calf/day)	329.2^{b}	315.6^{b}	366.4^{a}	342.7^{ba}	5.55
Reproductive performance of cows					
1^{st} oestrus (days)	50.4^{ba}	54.3^{a}	40.5^{b}	61.0^{a}	2.52
Range	(42-60)	(43-65)	(22-60)	(30-90)	
2^{nd} oestrus (days)	70.3^{ba}	72.0^{ba}	63.9^{b}	79.1^{a}	2.02
Range	(62-108)	(51-78)	(53-85)	(60-109)	
Days from calving to conception	79.3^{b}	73.0^{b}	77.5^{b}	101.4^{a}	3.28
Range	(60-95)	(51-85)	(60-96)	(66-136)	
Number of inseminations	1.6^{b}	1.5^{b}	1.1^{b}	2.3^{a}	0.13
Range	(1-2)	(1-2)	(1-2)	(1-4)	

EGL = elephant grass/ forage legume mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder

^{abcd} = Least square means within a row with different superscripts differ ($p<0.05$)

SEM = Standard Error of the mean

Other factors that could have contributed to differences in ADG and weaning weight of calves were the daily amount of milk given to the calf.

In smallholder dairy systems in Masaka district, farmers feed the calves according to the level of milk produced by the cow. During the wet season when there is plenty of milk, calves are offered 3-6 litres/day. However, during the dry season when the quantity of milk decreases due to feed shortage and the price of milk increases because of higher demand, the amount of milk given to the calves is reduced to 1-3 litres/day. The low quantity of milk offered to calves results in lower body weight. Other reasons for the differences in ADG are the different feed management systems, differences in breeds and size of animals. Many smallholders practice artificial rearing where calves are bucket fed. In comparing pre-weaning management rearing systems for smallholder farmers in developing countries, Preston and Leng (1987) reported that the restricted suckling rearing system improves performance of pre-weaned calves, and hence is more viable than artificial rearing. Pre-weaning management therefore remains critical in smallholder dairy production systems in Uganda because the calves are commonly underfed, graze poor quality pastures, receive poor management, and small amount of supplements or none at all. The growth of calves on low quality feeds is therefore retarded and overall productivity is low. Previous studies (Akayenzu *et al.,* 1994; Lyima *et al.*2003) have shown that the provision of supplements is necessary for good calf growth particularly where there is deliberate milk savings or there is inadequate milk supply for calves

4.3.8.2 Performance of cows

The results of the effect of supplementing with LH and/or CLH and HMC on reproductive performance of crossbred dairy cows fed EGL or EGML basal forages are shown in Table 4.24. Differences ($p<0.05$) in reproductive performance of crossbred dairy cows were observed as a result of feeding cows on EGL or EGML diets supplemented with CLH and/or LH and HMC. Interval from calving to first oestrus and second oestrus was shorter ($p<0.05$) in supplemented than unsupplemented cows. Average number of services/conception was higher ($p<0.05$) in unsupplemented than supplemented cows. The interval between calving to conception was shorter (73-78 days) in supplemented cows compared to unsupplemented cows (101 days). Significant differences ($p<0.05$) were observed in intervals between calving to first and second oestrus, calving to conception and average number of services/conception within supplemented cows.

In the present study, the longer interval between calving and observation of first postpartum visual oestrus in unsupplemented cows indicate sub-optimal reproductive performance. In dairy cattle, interval from parturition to first observed oestrus varies from 30 to 76 days (Gimbi *et al.*, 2003). Sub-optimal reproductive performance in unsupplemented cows could be partly due to low CP, energy and mineral intake (Tables 4.18 and 4.19) that resulted in loss in body weight and body condition during the first 8 weeks after calving (Tables 4.21 and 4.22 and Figure 4.13 and 4.14). Previous studies (Hafez 1987; Canfield and Butler, 1991; Lalman *et al.*, 1997; Lynch *et al.*, 1997) have shown that CP and energy balance intake play a major role in the initiation of ovulatory ovarian cycles in postpartum dairy cattle. Butterworth (1985); Lanyasunya *et al.* (2001) and Gimbi *et al.* (2003) concluded that supplementation of breeding stock lowered age at first calving, increased calving rate, shortened the interval between parturition and first oestrus, decreased mortality and improved farm profits. Restricting CP intake in pregnant beef heifers has been shown to increase postpartum interval to first oestrus, first service, and conception and decreased the number of animals that showed oestrus and conceived (Randel, 1990). Because of inadequate energy and CP intake, unsupplemented cows took longer to commence cyclic ovarian activity than well-fed supplemented cows. Similarly decreased calving to conception intervals in supplemented cows was attributed to higher CP and energy intake as shown in Tables 4.18 and 4.19. Diets similar to sole EG fodder where ME intake during the prepartum period is low result in poor body condition at calving, prolonged postpartum anoestrus, and a decrease in the percentage of cows exhibiting oestrus during the breeding season. The provision of protein, mineral and energy supplements is therefore a prerequisite for a successful management to good reproductive performance of dairy cows.

In addition to nutrition, there are a number of constraints that affect reproductive efficiency in many smallholder dairy production systems in Uganda. The major deficiencies are poor heat detection, mating of cows at a wrong time and the tendency of farmers to assume that a cow will become pregnant once it is inseminated or served with a bull. They therefore neglect to look for returns to service and find out many months later that the cow is not pregnant, by which time valuable production time has been lost.

This study has shown that appropriate use of forages from elephant grass or maize intercropping systems with forage legumes supplemented with homemade concentrates will result in improved performance of crossbred dairy cows in smallholder dairy systems. Farmers can therefore improve food security and alleviate feed shortages through appropriate and efficient use of home produced feed resources and concentrates. Results of this study have shown the importance of supplementing with a legume hay and homemade concentrate on body weight, body condition, milk yield and reproductive efficiency of dairy cattle fed low quality forages.

4.3.9. Economic analysis

A simple economic analysis carried out on the effect of supplementing dairy cows fed EGL or EGML basal forages with a legume hay and a homemade concentrate on animal performance is shown in Table 4.25. It was assumed that the cost of all other inputs such as the structures, pangas, buckets etc were the same on all the farms. These costs were therefore not considered in the calculations. Appendix 6.11 shows details of estimated cost of producing forages used during the study period. Appendices 6.12 and 6.13 show average quantities of fodder consumed per cow during the study period (360 days) and prices used in the calculations, respectively. Table 4.25 shows additional costs and returns (Ushs/cow/lactation) due to treatment during the study period (October 2002 to June 2003). The cost of weeding EGL and EGML forages accounted for about 40% of the total cost compared to about 30% for a pure stand of elephant grass fodder. Average cost of veterinary services and AI or use of a bull were higher in unsupplemented cows than cows on EGL or EGML forages. Sale of milk contributed over 90% of the household income when EGL were incorporated in the farming systems compared to about 70% for EGML forages. However, sale of maize grain improved household income by about 25% when ML forages were integrated in the farming systems. The ratio of extra income/extra cost was higher for EGML than EGL forages. Veterinary and AI costs were higher in unsupplemented diets when compared with supplemented diets.

Table 4.25: Additional costs and returns (Ushs/cow/lactation) due to supplementation during the study period (360 days)

Parameter	EGL+ LH+ HMC	% of total cost or revenue structure	EGL+LH+ CLH+HMC	% of total cost or revenue structure	EGM+ CLH+ HMC	% of total cost or revenue structure	Sole EG	% of total cost or revenue structure
Cost of production and inputs								
Land preparation	100,000	4.4	100,000	4.2	100,000	4.2	100,000	6.9
Cost of inputs (seed)	82,000	3.6	132,000	5.6	176,000	7.4	60,000	4.2
Planting and manure application	120,000	5.2	140,000	5.9	90,000	3.8	30,000	2.1
Weeding	920,000	40.1	920,000	39.0	720,000	30.3	600,000	41.6
Harvesting, drying and conservation	230,000	10.0	230,000	9.8	430,000	18.1	0	0.0
Feeding, milking, cleaning	360,000	15.7	360,000	15.3	360,000	15.2	360,000	25.0
Homemade concentrate	270,000	11.8	270,000	11.5	270,000	11.4	0	0.0
Veterinary services (Average)	165,000	7.2	171,000	7.3	180,000	7.6	193,000	13.4
Artificial Insemination/use of bull	45,000	2.0	33,000	1.4	48,000	2.0	99,000	6.9
Total cost of production	**2,292,000**		**2,356,000**		**2,374,000**		**1,442,000**	
Estimated revenue per farm								
Maize grain	0	0	0	0	600,000	24.8	0	0
Milk yield	1,462,400	95.0	1,549,000	95.7	1,722,800	71.3	1,133,200	95.9
Extra liveweight gained	77,750	5.0	70,250	4.3	92,750	3.8	48,500	4.1
Total income (Ushs)	**1,540,150**		**1,619,250**		**2,415,550**		**1,181,700**	
Extra cost due to treatment	850,000		914,000		932,000			
Extra income due to treatment	358,450		437,550		1,233,850			
Ratio of extra income/extra cost as cost due to treatment	0.42		0.48		1.32			
Return to investment per Ushs 1000 spent	422		479		1,324			

EG= elephant grass/legume mixture; EGML = Elephant grass fodder fed together with Maize/lablab stover; Sole EG = sole elephant grass fodder;
HMC = Homemade concentrate; LH = Lablab hay
Assumptions: labour for herding was the same and all farmers had the same equipments (spades, buckets, pangas) given by the project as part of the package

Weeding accounted for over 40% of the total cost of producing leguminous forages because of the high cost of inputs and labour. Farmers and/or hired labourers had to take extra care not to destroy the seedlings. The use of EGML with CLH and HMC supplements offered higher returns to investment compared to EGL with LH and/or CLH and HMC and was economically viable for feed availability and food security on smallholder dairy farms. Based on results of the study (Table 4.25), it can be concluded that any feed management system is only profitable and acceptable for wide scale adoption by farmers when the additional returns generated under that system are greater than additional cost involved. The economic benefits therefore justify the additional costs of forage legumes and homemade concentrates in intensive smallholder dairy farming systems.

Appropriate supplementation packages to any dairy enterprise must put into consideration the costs, acceptability and ease of adoption by the targeted farmers. At the start of the trials, very few farmers commonly used commercial concentrates because of the high cost and poor quality (Study 1). On-farm mixing of feed led to saving Ushs 110 per kg of homemade concentrate when compared to Ushs 300 per kg of commercial concentrates in addition to improved animal productivity and daily income. The study showed that, diets formulated from locally available protein and energy ingredients are cost-effective and have potential for use as replacement to the conventional dairy meal in maintaining a high milk production and improving farm profits in the dry season. Therefore, under smallholder dairy production systems where shortage of high quality forages and high cost or/and substandard commercial concentrates are major constraints, the use of EGML with CLH and HMC supplements is the cheapest way of ensuring year-round feed supply, improving overall animal performance, household food security and farm profits compared to EGL basal diets.

Tables 4.24 and 4.25 show that the cost of Ai and number of services per conception were lower in supplemented when compared to unsupplemented cows. This findings may be explained by the fact that supplemented cows received adequate protein and energy intake. This resulted in higher milk yield, better body condition, higher daily average weight gain and an improvement in reproductive performance. The cows were therefore able to come on heat and conceiver earlier than the unsupplemented cows.

The results of the feeding trials supported the hypotheses that feeding dairy cows forages from elephant grass or maize/forage legume intercropping systems supplemented with on-farm generated protein and energy sources improves feed intake, body weight, body condition, milk yield and reproductive efficiency and increases farm profits. Inadequate protein and energy intake during both prepartum and postpartum periods have been reported to result in a pregnancy rate of 32% compared with 74% in cows with higher protein and energy intake (Randel, 1990)

Although results of this study have demonstrated the value of lablab hay as a supplement to low quality forages, the resources (land, labour and capital) required to produce sufficient quantities of lablab hay to supplement a dairy cow throughout the 4-6 months of the dry season may be beyond the means of a resource poor smallholder dairy farmer. This study showed that supplementing with CLH and HMC resulted in higher milk yield and higher returns to investment compared to when the cows were supplemented with only LH and HMC. The cost per kilogramme of CLH was also lower (Ushs 150) compared to LH (Ushs 210). There is therefore a need to promote the use of fodder trees as these do not require a lot of land and labour to manage. Fodder tree leaf hay requires less labour than lablab hay. It was estimated that in order to produce sufficient quantities of lablab hay to last of a dry season of about 6 months in Masaka district, the farmer would require about over 1.3 ha to produce about 540 kg DM lablab hay compared to about 200 kg DM CLH from 600 calliandra trees.

4.4. Study 4: Farmers' experiences, constraints and opportunities in the production and utilization of forage legumes in smallholder dairy production systems and lessons learned

4.4.1. Positive impacts

A total of 100 farmers (54% women) participated in monitoring and evaluation of the forage technologies that were tested on 32 households (Table 4.26). The higher participation of women compared to 46% men can be explained by their dominant roles and responsibilities in smallholder dairy production. All farmers acknowledged problems related to feed shortage during the dry season. In general, women and men considered factors related directly to animals and household welfare to be more important than factors related to agronomic characteristics of the forages. About 90% of the farmers mentioned improved animal body condition and body weight during the dry season (Table 4.26). More women than men mentioned less burden of searching for feeds during the dry season due to improved quantity and quality of feeds. All women reported that they had benefited from increased availability of firewood as a result of integrating calliandra fodder trees in the farming systems. Intercropping lablab with food crops such as bananas and maize enabled about 69% of the farmers to utilize their land more efficiently and maximize returns from limited resources and stabilize income returns overtime. Both men and women reported increased milk yield and an improvement in maize grain yield as a result of integrating leguminous forages in crop/livestock farming systems. This in turn resulted in increased household income.

Improvement in feed supply (quality and quantity) resulted in better animal body condition and body weight. This in turn reduced incidences of animal diseases as mentioned by 51% of the farmers and lowered veterinary costs. Mugisha *et al.* (1999) reported fewer cases of diseases on farms that integrated forage legumes in crop/livestock systems in peri-urban areas of central Uganda.

able 4.26: **Benefits identified by dairy farmers as a result of incorporating forage legumes in farming systems**

Benefits	Percentage Men (n=46)	Percentage Women (n=54)	Overall (n=100)
mproved animal body condition and Weight during the dry season (CLH and ML)	87.0	92.6	90
Less burden of searching for legumes during the dry season (CLH)	54.3	92.6	70
Lablab is drought tolerant (LH)	87.0	85.2	84
Improved food and feed security (ML)	65.2	96.3	82
Improved quality of feed (ML)	76.1	75.9	76
Improved milk yield (CLH & ML)	71.7	72.2	72
Calliandra provides stakes and firewood (CLH)	47.8	100	76
Improved household nutrition	58.7	90.7	76
Group formation	43.5	92.6	70
Suppressed weeds (LH)	63.0	74.1	69
Maximum utilization of resources (ML)	43.5	90.7	69
Improved household income (ML)	87.0	37.0	60
Better feeding, lower cases of diseases (ML & CLH)	47.8	53.7	51
Improved milk quality (taste) (CLH)	52.2	40.7	46
Improved knowledge and skills	54.3	92.6	75
Better services from extension staff	32.6	55.6	45

The technology referred to is indicated in brackets: ML= maize/lablab intercrop; CLH = calliandra leaf hay; LH = Lablab hay

The dry season coincided with the time of the year when maize/lablab stover was harvested. The farmers therefore made use of the stover to fill the feed gap. The results agree with findings by Bosma *et al.* (2003) who reported improved quality and quantity of feeds in smallholder production systems due to introduction of improved forages.

Seventy percent of the farmers mentioned less burden of searching for feed during the dry season (Table 4.26). The higher percentage of women than men who mentioned less burden of searching for feed during the dry season shows the importance of identifying not only the group that participates in research but also the target group that is likely to benefit more by adopting a particular technology. Similar observations were made by Tangka *et al.* (2000) in Kenya. Results of study 1 and Kabirizi and Drania (1997) showed that women in Uganda are more involved in nearly all processes of dairy cattle and fodder production therefore, any positive contribution such as improved all-year-round feed availability from this participation in research is likely to benefit both the individual households and the entire community as well.

Improved supply of firewood was mentioned by more women than men (Table 4.26) because women and children (after school) were in charge of searching for firewood, food and fodder. Using fodder tree leaf hay as a feed and the dry stems as a source of fuel enabled the women and children to save time that would otherwise be used to search for firewood and/or feed to do other household tasks. Improved food security (milk and maize grain) as a result of intercropping maize with lablab was cited by more women than men because of their greater involvement in managing dairy cattle and ensuring household food security.

Sixty five percent of the farmers reported that intercropping lablab with maize maximized land utilization because land shortage is a major constraint in intensive smallholder dairy farming systems in Masaka district (Table 4.26). Men and women observed that they could not accommodate any flexibility in the present cropping system due to very small land holdings; therefore forage cultivation technologies had not been popular. However, where land was available, it was often unproductive and of low quality. The other issue related to land was insecure ownership since majority (about 91%) of the women had no land title (Table 4.26). Irungu *et al.* (1998) identified land owned as a factor affecting adoption of Napier grass in Kenya.

Sixty nine percent of the farmers reported that integrating forage legumes especially lablab with maize controlled weeds. More women than men cited weed control as a major benefit resulting from lablab/maize intercrop because women were fully responsible for production of food crop. This in turn reduced labour requirements for weeding. Although the initial establishment of lablab legume in maize crop was very poor, once established, lablab plants were fairly drought and shade tolerant. With their spreading habit, fast early growth, and ability to grow with little soil moisture; lablab plants were effective in smothering couch grass weeds and quickly provided an effective ground cover to protect the soil from erosion. Similar observations were reported by Murphy and Colucci (1999) and Kabirizi *et al.* (2000).

Improved household income as a result of selling more milk and maize due to improved forage technologies was cited by about 60% of the farmers (Table 4.26). The study recognizes male-female sharing of both domestic and productive work. Although women were involved in all activities connected with dairy cattle and fodder production including sale of milk and they provided labour throughout the year this was not reflected in decision-making regarding income (Table 4.26). In general, men made decisions on important household expenditures. According to men, increased farm household income from sale of milk, livestock and maize grain was invested in expenditures for the family, for example school fees, medical bills and purchasing agricultural inputs although the women did not agree with them.

More than three quarters of the milk produced was sold while the rest was used for home consumption. About seventy percent of the farmers reported that they were able to improve nutrition of the families and maintain a small cash income. The availability of milk for families substantially improved the family nutrition especially of the children although with increased milk production, about 7% of the farmers were faced with the problem of marketing the milk especially during the wet seasons when there was a lot of milk from other areas. A study by Leegwater *et al.* (1991) showed that the nutritional status of pre-school age children was better in National Dairy Development

Project (NDDP) households and among NDDP customers than among children from the general population.

Forty six percent of the farmers reported that calliandra leaf hay had marked positive effect on taste of milk, a factor that was highly valued by farmers. Although many buyers in Uganda do not offer higher price for milk quality in terms of taste, the demand for such milk was very high. Peterson *et al.* (1998) reported improved butter fat content and income from milk sales as a result of supplementing dairy cows with calliandra foliage in Kenya.

Participating farmers reported that their success in the trials attracted many other farmers from within and outside the district. During the study period, the number of farmers who adopted maize/lablab technology increased from 5 to 145 (Figure 4.16) but more important about 70& of the farmers reported that they were able to form groups (Table 4.26). The groups involved themselves in various economic activities such as crop and livestock production and drama as a means to raise their standard of living. Being together in groups helped them to combine their efforts in improving their economic activities. The groups also helped women to get recognition in the village and respect by their husbands.

According to 45% of the farmers, the attitude and approach of extension staff changed. In the past, the extension staff were only concerned with animal health, when the study began they became more interested in animal feeding and breeding. Extension services especially artificial insemination was more readily available and more reliable. Farmers received more training and were involved in workshops more often. Farmers mentioned that the study tours and workshops were a new experience for them and were highly appreciated. The tours and workshops helped them learn new forage technologies and to increase the efficiency on their farms. The participatory approach stimulated households to exchange knowledge on all aspects of crop and livestock farming. An adoption study conducted by Nicholson *et al.* (1999) showed that inability of farmers to participate in development project was important in their decision not to adopt grade or cross cattle, given that they had insufficient cash to buy an animal.

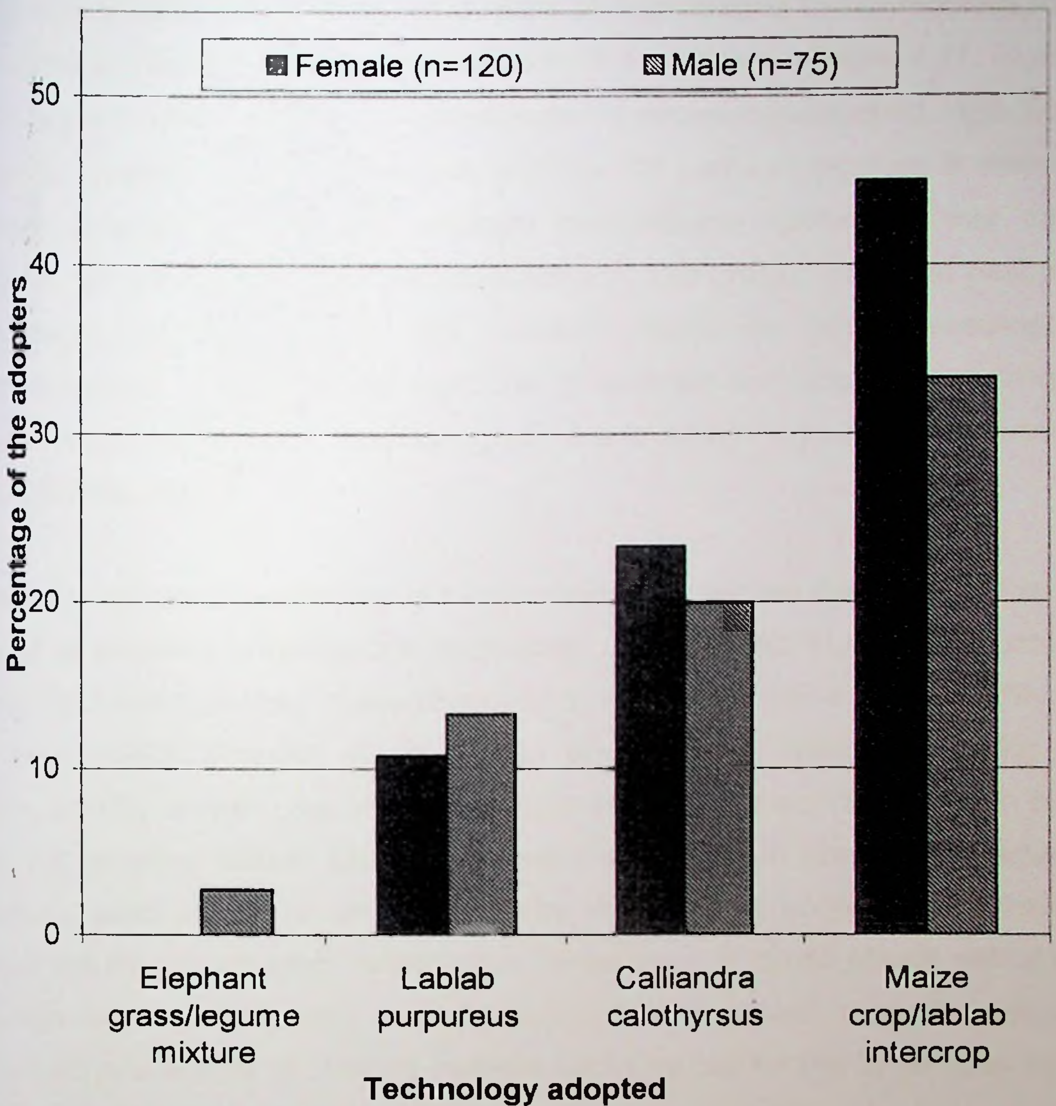


Figure 4.16: Percentage of adopters of the different technologies during the period of September 2002 to September 2003

4.4.2. Negative impacts

Negative impacts (constraints) as a result of incorporating forage legumes in farming systems as identified by smallholder farmers are shown in Table 4.27. Over 80% of the farmers cited high cost or unavailability of forage legume seed, high labour and capital demands, initial slow growth and low DM yields of legumes in mixtures as a major constraints to use of elephant grass/legume intercrop. Other constraints mentioned were damage of seedlings/plants by free grazing livestock; pest problems, especially termites; aphids and cutworm attack on young seedlings during establishment, low soil fertility, high cost of materials and labour to construct storage facilities and low yields of elephant grass due to elephant grass stunt disease (Kalule and Kabirizi, 2003).

High cost and/or unavailability of forage seed partly explain the recorded low adoption rates of elephant grass/legume technology (Figure 4.16). The main source of seed was the small quantities of seed supplied by the project. Several studies (Mureithi and Thorpe, 1993; Franzel *et al.,* 2003; Mwangi and Wambugu, 2003) reported unavailability or high cost of forage legume seed as a major reason given by farmers for not adopting Napier grass/forage legume mixtures in Kenya. In Uganda, forage legume seed supply is limited given the low demand; consequently, there is little incentive for private seed multiplication. Since there is limited private sector activity in forage seed multiplication and distribution, efforts geared towards facilitating and demand and supply of planting material will be crucial for the large-scale adoption of forage legume technologies.

Dairying is labour intensive, therefore, its economic rationale heavily depends on rural wage rates and the opportunity cost of family labour. The major source of labour was household members but hired labour was also available (Figures 44, 4.5 and 4.6). The most demanding activities were row planting, weeding, manure application, harvesting, transporting, chopping, drying and conserving forages. Planting siratro, centro and desmodium in rows and weeding legume seedlings required extra care and labour because the seeds are very small compared to seed of food crops the farmers were already used to.

Table 4.27: Constraints identified by smallholder dairy farmers as a result of incorporating forage legumes in farming systems

	Percentage Men (n=46)	Percentage Women (n=54)	Overall (n=100)
Constraints			
High cost /Unavailability of legume seed (EGL)	100.0	100.0	100
Lack of capital	100.0	100.0	100
High labour and capital demands (EGL & LH)	100.0	97.8	99
Lablab plants smoother banana plants (LH)	98.1	95.7	97
Initial slow growth of forage legumes in EGL mixtures (EGL)	96.3	93.5	95
Low yields of legumes in EGL mixture during the dry season	92.6	91.3	72
Elephant grass disease affects fodder yield and quality (EGL)	88.9	80.4	85
Need for/high cost of storage facilities (ML & LH)	90.7	73.9	83
Damage of legume seedlings/plants by pests and stray animals (EGL & LH)	64.8	47.8	57
Land shortage	61.1	41.3	52

The technology referred to is indicated in brackets: ML= maize/lablab intercrop; CLH = calliandra leaf hay; LH = Lablab hay; EGL = elephant grass/legume mixtures

It is also at this time when the same labour is required to plant or weed food crops. In most cases hired labour was used to weed the forage fields. In this case, hired labourers charged more money because of the extra care, time and labour used to avoid destroying the legume seedlings. In some cases, the seedlings were weeded out because hired labourers lacked skills and knowledge on legume management. Harvesting and transporting fodder from the fields, drying and chopping lablab foliage and maize/lablab stover was reported to be labour intensive. Similarly, in this study, all farmers reported that use of forage legume technologies resulted in changes in their cropping patterns. This led to hiring of more casual labourers or increased workloads for household members especially during harvesting and drying of fodder. Mugisha (2003) reported low adoption of knowledge and skills in rice production due to expensive and tedious practices especially row planting. Another study by Wandera *et al.* (1993) showed that high labour requirements, hairiness of Napier grass and rapid decline in soil fertility of grass plots were major constraints limiting production and use of fodders on smallholder farms in Kenya. CIAT (2003) observed that the use of forage legume technologies as cover crops required substantial area of land, some of it to be part of which is left under fallow, high labour for clearing and ploughing in the vegetation and patience in attaining results.

High capital requirements for establishing and managing fodder fields was a major constraint because farmers did not have enough capital to purchase the required inputs and later meet the labour costs for managing the forages. The main source of capital would be credit but farmers were not keen to apply for it because they did not want to risk their land being sold for defaulting. Access to credit plays a crucial role in the development and adoption of new technologies (Mureithi and Thorpe, 1993).

The initial slow growth of forage legumes in elephant grass/legume intercrop during establishment phase was cited by 95% of the farmers. This resulted in a quick invasion of weeds and created a requirement for more labour and money. The low DM yield of forage legumes in mixtures during the dry season discouraged 87% of the farmers because they could not have sufficient fodder for the animals. This partly explains the low adoption rates recorded during the study period (Figure 4.18). Similar results were reported in smallholder dairy farming systems in Kenya by Mwangi and Wambugu (2001) and Mwangi and Wambugu (2003).

Over 90% of the farmers who intercropped lablab with bananas reported a reduction in banana yields. Lablab plants competed heavily with banana plants for water and other nutrients. Results of the study showed that farmers were reluctant to adopt lablab hay because unlike calliandra tree, lablab required planting on an annual basis. The resources (land, labour and capital) required to produce sufficient quantities of lablab hay (540 kg) to supplement a dairy cow throughout the dry season (6 months) were also beyond the means of a resource poor farmer. The small fields earmarked for food and fodder production could not offer space to establish lablab in large quantities. Ninety-two percent of farmers did not have sufficient land for fodder and food crops. Farmers preferred calliandra leaf hay to lablab hay as a protein supplement since calliandra trees were easier to manage and require little land. Besides, there were other benefits associated with calliandra leaf hay as shown in Table 4.26. More research on the use of fodder tree leaf hay as a dry season supplement to dairy cattle therefore needs to be carried out in light of the results of this study.

4.4.3. Lessons learned

It was shown that farmers learned and tested maize/lablab intercropping, lablab hay, calliandra leaf hay and elephant grass/legume mixture forage technologies. On the other hand; extension staff, local leaders (policy makers) and researchers involved learned about the importance of facilitating the process of technology transfer. Farmers' indigenous knowledge and experience can be incorporated into the search for solutions. Farmers' capacity and expertise for conducting collaborative research is built up and becomes a valuable resource for future research programmes. Cross-visits and feedback workshops were found to be very effective in sustaining and keeping farmers' interest. These often served to broaden farmers' outlook and made them realize that there were things that they could do by themselves.

Understanding of farmers' production objectives and the constraints to achieving these objectives is critical in understanding and determining their information requirements. Once the technology options have been identified, farmers' criteria for accepting or rejecting a technology becomes crucial to its targeting and adaptation in new situations. Empowering farmers in experimenting with options provides faster feedback that improves research design in an iterative research cycle.

In conclusion, the key to adoption of forage technologies is to allow farmers study, identify the constraints versus the benefits associated with the technology, adapt and expand. The issues of seed availability, seed cost and low dry matter yield of forage legumes in EGL are major constraints to adoption of forage legume technology. There is a need for government and non-government organizations to support small-scale pasture seed scale production schemes to improve availability of seed. Activities related to increasing forage availability should be complemented with improvements of animal husbandry practices, i.e. nutrition, health and housing, the utilization of compost/manure and the marketing of livestock products. A more holistic approach addressing several farmer constraints simultaneously is expected to give better results than isolated Interventions.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The major constraint to intensive smallholder dairy cattle production is the availability of all-year-round forage supply. Elephant grass (*P. purpureum*) fodder is recommended as a basal diet for dairy cattle for stall-fed dairy cows because of its high biomass yield compared to other grasses. The major problem with elephant grass is, it matures early and becomes coarse and stemmy and the legume component is often missing in most production systems. Elephant grass therefore has low feeding value for a greater part of the year which tends to result in low milk yield and loss in weight, long calving intervals and some times death of the animals.

It was concluded from Study 1 that intensive smallholder dairy cattle production is playing a vital role in improving nutrition, food security and household income and creating employment. There was however seasonal feed shortages for optimum milk production, constraints that could be addressed through the development of improved feeding systems based on integration of forage legumes and energy supplements in the farming systems. Based on total scores and results from previous on-station trials, elephant grass/legume mixtures, maize/lablab intercrop, lablab hay and calliandra leaf hay technologies were selected for on-farm trials/demonstrations to improve feed availability and overall animal productivity.

Results of Study 2 showed that EGL and ML technologies are important to resource poor crop/livestock farmers for they would provide improved fodder production to fill the feed gap during the dry season while improving maize grain yield from the same piece of land. Improving forage DM yield and or forage quality without adversely affecting grain yield is an attractive option for smallholder mixed crop/livestock systems where livestock is inadequately fed and land to grow food and forage crops separately has remained a major constraint. Improved feed supply would have a positive effect on milk yield, growth and reproductive performance. The CP levels and energy levels in EGL mixtures and ML were less than the levels recommended for the growth and production of a lactating dairy cow (NRC, 2001). Thus feeds from EGL and ML intercropping systems when fed alone may not be able to support very high levels of production especially in lactating dairy cows. Legume enrichment, for example with lablab and/or calliandra leaf hay and a concentrate is a possible method of improving the forage quality. It was also observed that the quantity of fodder available at any particular time of the year from an area of about 0.405 ha of EGL is not sufficient to support a mature cow for a year. The minimum acreage recommended is either 0.405 ha of EGL plus 0.4ha/year of ML or 0.405 ha of sole EG plus 0.4 ha/year of ML.

Study 3 showed that feeding dairy cows on EGML + CLH + HMC led to higher TDMI, body weight, milk yield and reproductive efficiency of crossbred cows and improved farm profits compared to EGL basal diets. The most important contribution of EGML + CLH + HMC diets was not only the superior improvement in animal performance but also the improvement in feed supply. This type of feeding is therefore important for areas which experience long dry seasons during which elephant grass fodder is scarce. What remains to be addressed is to establish appropriate labour saving technologies that could minimize harvest losses and minimize manpower requirement, preserve nutritional qualities and ensure an acceptable final product for the animals.

Study 4 showed that fodder trees and shrubs should therefore be included in smallholder dairy farming systems. Research on management and use of fodder trees and shrubs in smallholder dairy farming systems is limited, although their potential is increasingly recognized. The most important problem that urgently requires solution is how to increase the availability of tree fodder to stall fed animals through improved management taking into considerations seasonal changes in plant productivity and the feed requirements of the animals. The study also showed that the legume component in EGL during the wet and dry season was only 12%. There is a need for more studies to evaluate the persistence of forage legume species in elephant grass/legume intercrops in different agro-ecological zones in Uganda.

Incorporating forage legumes in smallholder dairy farming systems could solve the problem of inadequate feeds during the dry season and improve dairy cattle performance, household food security and farm income and maximize utilization of available resources. Crossbred cows similar to those used in this study could be sustained throughout the year on forages from about 0.405 ha of improved and well managed pure stand of elephant grass and 0.4 ha/year of ML supplemented with 1 kg/cow/day of CLH and 4 kg/cow/day of HMC. The results of this study are very useful to the smallholder dairy farmers who are usually faced with problems of inadequate year-round feed supply that result in poor animal performance and low household income. This information is therefore useful for poverty alleviation if utilized by various government and NGOs involved in implementing poverty alleviation programmes for smallholder dairy farmers both within and outside Uganda. The results could also be used to generate data for use in modelling smallholder production systems to ensure year-round fodder supply using various crops and crop combination in various agro-ecological situations. For the technology to be fully integrated into the farming systems, simple and affordable labour technologies for harvesting, transporting, chopping, drying and storing fodder should be developed.

5.1. Areas for future research

The study has shown that EGL technology improves fodder production but the low DM yields of legumes in elephant grass/legume intercrops throughout the year and the high cost of the legume seed are major constraints to the adoption of the technology as a dry season feed resource. More studies should therefore be done on biomass productivity; nutritional quality and persistence of elephant grass/legume intercrops under different cutting intensities in different agro-ecological zones in Uganda. There is also a need for detailed studies on the profitability of forage legume technologies including an investment plan and gross margin analysis for 5 years.

Maize/lablab technology is of particular importance to resource poor crop/livestock farmers for it would provide improved fodder production to fill the feed gap during the dry season while improving maize grain yield from the same piece of land. However, the high labour required to harvest, transport, conserve and store the stover, calls for more research in simple labour saving technologies that are affordable by the small-scale farmer. Staggering planting dates of lablab into maize resulted into high maize grain yields than when lablab was planted at the same time with maize. In view of these results, there is a need for more studies to determine the optimum seed rate, spacing and staggering intervals of planting dates of lablab on grain; and fodder production.

5.2. REFERENCES

A.O.A.C. (Association of Official Analytical Chemists). 2001. Official Methods of Analysis 15th Edition, 2200 Wilson Boulevard, Arlington, Virginia 22201, USA.

Abate, T., Tekalign M. and Getinet, G. 1992. Integration of forage legumes into cereal cropping systems in Vertisols of the Ethiopian highlands. *Tropical Agriculture*, 59, 68-72.

Adebowale, E.A. and Ademosun, A.A. 1981. Studies on the utilization of brewers dried grain by sheep and goats. Growth studies. *Bulletin of Animal Health and Production in Africa,* 29, 365.

Adu, L.F., Fajemisin, B.A. and Adamu, A.M. 1992. The utilization of sorghum stover fed to sheep as influenced by urea or graded levels of lablab supplementation. In: Rey, B., Lebbie, S.H. and Reynolds (eds). *Small ruminant research and development in Africa.* Proceedings of the First Biannual Conference of the African Small Ruminant Research Network held in Nairobi, Kenya, 10-14 December 1990. ILCA (International Livestock Centre for Africa), Nairobi, Kenya. pp. 367-374

Agboola, A.A. and Fayemi A.A. 1977. Fixation and excretion of nitrogen by tropical legumes. *Agronomy Journal*, 66, 409-721.

Akayenzu, J.M., Linn, J.G., Otterby, D.E., Hassen, W.P. and Lohnson, D.G. 1994. Evaluation of a calf starter containing different amount of crude protein for growth of Holstein Friesian calves. *Journal of Dairy Science,* Vol. 77. pp. 1882-1889.

Akinyemi, A.A. and Onayinka, B.O. 1976. Grass/legume compatibility in the derived savanna regions of western Nigeria. *Nigerian Journal of Animal Production,*. 3,120-125.

Alicai, T., Kabirizi, J., Byenkya, S., Kayiwa, S. and Ebong, C. 2004. Assessment of the magnitude and farmers' management practices of the elephant grass stunting disorder in Masaka district. Survey Report, 2004. Namulonge Agricultural and Animal Production Research Institute, Uganda.

Allen, M. S. 1996. Physical constraints on voluntary intake of forages by ruminants. *Journal of Animal Science*, 74, 3063– 3075.

Ambrose, A.V., Oyedipe, E.O. and Buvanendran, E. 1984. Influence of management and season of breeding on pregnancy rates of zebu cattle in an artificial insemination programme. *Tropical Agriculture (Trinidad*), 64, 265-267.

Anindo, D.O. and Potter, H.L. 1994. Seasonal variation in productivity and nutritive value of Napier grass at Muguga, Kenya. *East. African Agriculture and Forestry Journal,* 59, 177-185.

Anon, 1996. The Uganda Dairy Sub-sector, A rapid appraisal, 1996. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).

Anon, 2001. Plan for Modernization of Agriculture, Eradicating Poverty in Uganda. Government Strategy and Operational Framework. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Entebbe and Ministry of Finance, Planning and Economic Development (MFPED), Kampala. August 2002.

Anon, 2003. Masaka District Local Council Annual Report, 2003.

Anon, 2004. Basic Agricultural Statistics 2004. Agricultural Planning Department. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).

Anon, 2005. Uganda Population and Housing Census Report. Uganda Bureau of Statistics. Ministry of Finance, Planning and Economic Development.

Aregheore, E.M. and Perera, D. 2004. Effects of *Erythrina variegata*, *Gliricidia sepium* and *Leucaena leucocephala* on dry matter intake and nutrient digestibility of maize stover, before and after spraying with molasses. *Animal Feed Science and Technology,* 111,191-201.

Ayatunde, A.A., Fernandez-Rivera, S. and McCrabb, G. (eds). 2005. *Coping with feed scarcity in smallholder livestock systems in developing countries.* Animal Sciences Group, Wageningen UR, Wageningen, The Netherlands, Univesity of Reading, Reading UK. ETH (Swiss Federal Institute of Technology), Zurich

Switzerland and ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 97-232.

Kebread, E., Smith, T.; Tanner, J. and Osuju, P. 2005. Review of under nutrition in smallholder ruminant production systems in the tropics. In: Ayatunde, A.A., Fernandez-Rivera, S. and McCrabb, G. (eds). *Coping with feed scarcity in smallholder livestock systems in developing countries.* Animal Sciences Group, Wageningen UR, Wageningen, The Netherlands, University of Reading, Reading, UK, ETH (Swiss Institute of Technology), Zurich, Switzerland, and ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 56.

Bareeba, F. 2003. Evaluation of forage legumes in association with *Panicum maximum* under grazing and cutting management systems. In, Proceedings of the 30th Scientific Conference of Tanzania Society for Animal Production, 4H Centre-Tanga, October 28th–30th, 2003. TSAP (Tanzania Society of Animal Production) Conference Series Vol. 30, (2003). pp. 228-235.

Bareeba, F.B. 1993. Forage conservation and utilization. In: Sabiiti, E.N., Bareeba, F.B. and Mwebaze, S. (eds) *Pasture and feeding systems for sustainable livestock production and environment.* Proceedings of the second Uganda Pasture Network (UPANE) workshop held at Makerere Universtiy, 14-16th December 1992. pp. 69-73.

Bareeba, F.B., Ingalls, J.A., McKirdy A. and H.R. Sharma. 1983. Apparent digestibility and nutritional value of urea or ammonia solution treated corn silage for lactating Holstein cows and mature sheep. *Canadian Journal of Animal Science,* 53, 871-879.

Beede, D.K. 1992. Water for Dairy Cattle. In: Large Dairy Herd Management. In:. H.H. Van horn and C.J. Wilcox (eds). American Dairy Science Association. Champaign, Ill. Dairy Practices Council. 1990. Guidelines for Potable Water on Dairy Farms 3rd rev. ed. Barre, Vt. McFarland, D.F. 2000. Feed area and water space design in dairy housing and equipment systems. NRAES-129. Ithaca, NY.

Bistanji, G., Hamadeh, S., Hajj Hassan, S., Tami, F. and Tannous, R. 2000. The potential of agro-industrial by-products as feeds for livestock in Lebanon. *Livestock Research for Rural Development,* 3, 56-59.

Bogdan, A.V. 1977. *Tropical pasture and fodder plants.* Longman Inc. New York.

Boitumelo, W.S. and Mahabile, W. 1992. Improving milk production in small-scale dairy farms in Botswana, Incorporating forage legumes in the farming systems. In: Stares J.E.S., Said, A.N. and Kategile J.A. (eds.). *The Complementarity of feed resources for animal production in Africa.* Proceedings of the Joint Feed Resources Networks Workshop held in Gaborone, Botswana, 4-8 March 1991. pp. 353-362.

Bonsi, M.L. 1995. The role of fodder trees in the utilization of roughage by sheep. PhD Thesis, Unversity of Science and Technology, Kumasi. pp. 275.

Boodoo, A.A. 1991. Milk production from tropical fodder and sugarcane residues, Case study, On-farm research in Mauritius. In: Speedy, A. and Sansoucy, R. (eds). *Feeding Dairy Cows in the Tropics.* FAO Animal Production and Health Paper No. 86, Rome, Italy, pp. 225-235.

Boodoo, A.A., Ramjee, R., Hulman, B., Dolberg, F. and Rowe, J.B. 1990. Effect of supplements of balanced concentrates and cottonseed cake on milk production in Mauritius villages *Livestock Research for Rural Development,* 2, 2-10.

Boonman, J.G. 1993. East African Grasses and Fodders, Their Ecology and Husbandry. Kluwer Academic Publishers. pp. 196.

Bosma, R.H., Ruathaet, R.L., Asis, P., Saguinhan, J., Binh, L.H., Yen, V.H. 2003. Economic and social benefits of new forage technologies in Mindanao, Phillipines and Tuyen Quang, Vietnam. CIAT (Centro Internacionale de Agricultural Tropical) Working Document No. 191.

Britt, J.H. 1998. Reproductive efficiency in dairy cattle as related to nutrition and the environment. Proceedings of "The dairy herd management" conference. The University of Georgia Cooperative Extension Service.

Busingye, H. 2002. Customary land tenure reform in Uganda, Lessons for South Africa. Paper presented during the International Symposium on communal tenure reform. Land reform in Africa, Lessons for South Africa. Johannesburg, from 12th to 13th August 2002. Programme for land and agrarian studies (PLAAS).

Butler, W.R. and Smith, R.D. 1989. Inter-relationships between energy balance and postpartum reproductive function in dairy cattle. *Journal of Dairy Science,* 72, 767-783.

Butterworth, M.H. 1985. *Beef cattle nutrition and tropical pastures.* Longman, London. pp. 267.

Canfield, R.W. and Butler, W.R. 1991. Energy balance, first ovulation and the effects of naloxone on LH secretion in early postpartum dairy cows. *Journal of Animal Science,* 69, 740-746.

Carstens, G.E., Johnson, D.E., Holland, M.D. 1987. Effects of prepartum protein nutrition and birth weight on basal metabolism in bovine neonates. *Journal of Animal Science,* 65,705.

Chamberin, J.S. 2001. *Calliandra calothyrsus,* an Agroforestry tree for the humid Tropics. OFI. Tropical Forestry Paper No. 40. Oxford Forestry Institute.

Chesworth, J.M., McKillop, D.F. and Spiggs, D.J. 1987. Combination of agro-industrial by products for use in dairy diets formulated by on-farm use of least cost ration system. In: Said, A.N. and Dzowela, B.H. (eds.). *Overcoming constraints to the efficient uitlization of agricultural by-products as animal feed.* Proceedings of the fourth Annual Workshop held at the Institute of Animal Research, Mankon Station, Bameda, Cameroon, 20-27 October 1987. ARNAB, Addis Ababa, Ethiopia. pp. 61-79.

CIAT (Centro Internacional de Agriculture Tropical). 2003. Farmers' evaluations and innovations with legume cover crops. Highlights CIAT in Africa. No. 6. March 2003.

Close, W. and Menke, K.H. 1986. Selected Topics in animal nutrition. A manual prepared for the 3rd Hohnheim Course in Animal Nutrition in Tropics and Sub-tropics. The Institute of Animal Nutrition, University of Hohenheim. 2nd edition. pp. 74-85.

Collinson, M. 1998. Issues of cost effectiveness with farming systems research as a stage in agricultural R & D. In: *Going beyond the farm boundary.* Proceedings of the 15th International Symposium on Rural Livelihoods, empowerment and the environment,. Association for Farming Systems Research-Extension (AFSRE), held from 29th November to 4th December 1998, Pretoria, South Africa. Vol. 2. pp. 599-605.

Combellas, J. and Martinez, N. 1992. Produccion de lenche y consumo en vacas alimentadas con forraje de corte (*Pennisetum purpureum* y concetrardo. Produccion *Animal Tropical*, 7, 60-64. (Abstract).

Crosse, S., Umunna, N. N., Osuji P O, Tegegne, H., Khalili, T. and Tedla, A. 1998. Comparative yield and nutritive value of forages from two cereal-legume based cropping systems. 2. Milk production and reproductive performance of crossbred dairy cows. *Tropical Agriculture (Trinidad)*, 75, 7-10.

Crowder, L.V. and Chedda, H. R. 1982. Tropical Grassland Husbandry. Longman, London and New York. pp. 308-384.

Dalzell, S. 1996. Sampling of condensed tannin analysis of *Leucaena* foliage. *Leucnet News* 2. pp. 5.

de Leeuw, P.N. and Thorpe, W. 1996. Low input cattle production systems in tropical Africa. An analysis of actual and potential cow-calf productivity. In, *All African Conference Handbook and Volume of Abstracts. South African Society of Animal Science*, Irene, South Africa. pp. 3.

Dindorkar, C,V., Muzaffar, S.J. and Kaikini, A.S. 1982. Note on the effect of feeding extra energy diets to anoestrus cattle. *Indian Journal of Animal Science,* 52, 1228-1229.

Diriba, A., Tessema Z., Sdmasu S., Demekashs, A. and Senait Y. 2001. Enhancing utilization of maize as food and feed in Ethiopia, Availability, limitations and opportunities for improvement. Second National Maize Workshop, 12-16 November, *2001* pp. 178-183.

Driedger, L.J. and Loerch, S.C.1999. The effect of protein concentration and source on nutrient digestibility by mature limit-fed-high concentrate diets. *Journal of Animal Science*, 77, 960-966.

Durand, M. and Komisarczuk, S. 1988. Influence of minerals on rumen microbiota. *Journal of Nutrition,* 118, 246-250.

Ebong, C., Byenkya, S.G. and Ndikumana, J. 1999. Effects of substituting Calliandra leaf meal for soya bean meal on intake, digestibility, growth and feed efficiency in goats. *Journal of Applied Animal Research,* 16,211-216.

Ebong, C., Ejobi, F., Isabirye, P. Kabasa D. and Kabirizi, J. 2001. Baseline survey of the Uganda cattle methane emissions in Uganda. Ministry of Water, Lands and Environment (Unpublished).

El Hag, M.G. 1984. Use of agro-industrial by-products and crop residues in the Sudan. In, Proceedings of FAO/ILCA Expert consultation from 5 to 9 March 1984. Addis Ababa, Ethiopia.

El Said, Z.M. O., Shalaby, A., Mohammed, A.M. 2001. Genetic and non-genetic factors affecting days open, number of services per conception and age at first calving, in a Herd cattle of Holstein Friesian cattle. *Pakistan Journal of Biological Sciences*, 4, 740-744.

Elliot, R. 1996. The use of green material to improve the nutritional status of animals fed low quality crop residues. In: R.M. Dixon (ed). *Ruminant Feeding Systems utilizing fibrous agricultural residues.* Camberra, ACT, Australia, pp. 49-67.

Elliot, R. and McMeniman, M.P. 1987. Supplementation of ruminant diets with forage legumes. In: Hacker, J.B. and Ternouth, J.H. (eds). *The nutrition of herbivores.* Academic Press, Sydney.

El-Tayeb, A.E. and Takla, A.G. 1992. Effect of addition of concentrates to Sudan grass (*Sorghum sudanense*) in the pre-calving period on performance of Holstein-Friesian heifers in Sudan. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds.). *The Complementarity of feed resources for animal production in Africa.* Proceedings of a Joint feed resources network workshop held in Gaborone, Botswana from 4 to 8 March, pp. 259-264.

Ezenwa, L. and Aken'ova, M.E., 1998. Performance of mixtures of selected grasses and adapted herbaceous legumes in southwest Nigeria. *Tropical Grasslands,* 32, 131-138.

FAO (Food and Agriculture Organization). 2001. Mixed crop/livestock farming, A review of traditional technologies based on literature and field experience. FAO Animal Production and Health Papers. 512,112-124.

FAO, 2004. FAOSTAT data. Food and Agriculture Organization, Rome. http.//faostat.external.fao.org/default.jsp (accessed June, 2004).

FAO (Food and Agriculture Organization). 2004. Livestock Information, Sector Analysis and Policy Branch. AGAL. November 2004.

Feder, G.R., Just, R.E. and Zilberman, D. 1985. Adoption of agricultural innovations in developing countries, A survey. *Economic Development and Cultural Change,* 33, 255-298.

Ferguson, J.G. 1996. Diet, production and reproduction in dairy cows. *Animal Feed Technology,* 59,173-184.

Franzel, S., Wambugu, C., Tuwei, P. and Karanja, G. 2003. The adoption and scaling up of the use of fodder shrubs in central Kenya. *Tropical Grasslands,* 37, 239-250.

Gebremedhin, B., Ahamed, M.M. and Ehui, S.K. 2003. Determinants of adoption of improved forage technologies in crop-livestock mixed systems, evidence from the highlands of Ethiopia. *Tropical Grasslands,* 37, 240-256.

Getachew, A., Zerbini, E. and Abate, T. 1991. Crop-livestock interactions and implications for animal traction research in the Ethiopian highlands. Paper presented at the Fourth National Livestock Improvement Conference, Addis Ababa, 13-15 November 1991. ILCA, Addis Ababa, Ethiopia.

Getachew, G., Said, A.N. and Sundtøl, F. 1994.The effect of forage legume supplementation on digestibility and body weight gain by sheep fed on a basal diet of maize stover. *Animal Feed Science and Technology,* 46, 97–108.

Gimbi, A.A., Kimambo, A.E., Kanuya, N.L., Mtenga, L.A. and Laswai, G.H. 2003. Seasonal variations on reproductive performance, mineral and body condition status of smallholder dairy cattle in Rungwe district, Tanzania. In, Proceedings of the 30th Scientific Conference, 4H Centre-Tanga, October 28th–30th, 2003. TSAP (Tanzania Society of Animal Production) Conference Series Vol. 30, (2003). pp.333-341.

Grigsby, K. N., M. S. Kerley, J. A. Paterson, and J. C. Weigel. 1992. Site and extent of nutrient digestion by steers fed a low-quality bromegrass hay diet with incremental levels of soybean hull substitution. *Journal of Animal. Science* 70, 1941–1949.

Grigsby, K. N., M. S. Kerley, J. A. Paterson, and J. C. Weigel. 1993. Combinations of starch and digestible fiber in supplements for steers consuming a low-quality bromegrass hay diet. *Journal of Animal. Science* 70,1941–1949.

Hafez, A.1987. Reproduction in farm animals. 5th ed. Lea and Febiger Philadelphia. pp. 400-420.

Haque, I. 1991. Soil-related constraints on the production of herbaceous and tree legumes in sub-Saharan Africa and their alleviation. In, *Soil constraints in sustainable plant production in the tropics*. Proceedings of the 24th International Symposium on tropical agriculture research, Kyoto, Japan, 14-16 August 1990.TARS no. 24,113-123.

Haque, I., Nnadi L.A. and Mohamed-Saleem, L.M. 1985. Forage Legume-cereal systems, improvement of soil fertility and agricultural production with special reference to sub-Saharan Africa. Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA (International Livestock Centre for Africa, Addis Ababa, Ethiopia, 16-19th September 1985. pp. 336.

Hayashida, M., Orden E., Cruz, E., Libertado, C., Cruz C. and Fujihara T. 2004. Effects of concentrate supplementation on blood mineral concentration of growing upgraded Philippine goats. *Animal Science Journal,* 75,139-144.

Hayirli, A., Grummer, R., Nordheim, E.V. and Crump, P.M. 2002. Animal and dietary factors affecting feed intake during the prefresh transition period in Holsteins. *Journal of Dairy Science,* 85, 3430-3443.

Heinrich, G.M., Russel, J.T. and Jones, R.B. 1997. Technology exchange policies and procedures, current approaches and proposals for the future from ICRISAT-Southern and Eastern Africa. Mimeo

Heldt, J.S., Cochran, R.C., Mathias, C. P., Woods, B.C., Olson, K.C., Tigemeyer, E.C., Nagaraja, T.G., Vanzant, E.S. and Johnson, D. E. 1999. Effects of level and source of carbohydrate and level of degradable intake protein on intake and digestion of low-quality tall-prairie hay by beef steers. *Journal of Animal Science,* 77, 2846-2854.

Hill, J.R., Lamond, D.R., Henricks, D.M., Dickey, J. F. and Niswender, G.D. 1970. The effects of under nutrition on ovarian function and fertility in beef heifers. *Biology of Reproduction,* 2:27-84.

Hindrichsen, I.K., Osuji, P.O., Odenyo, A.A., Madsen, J. and Hvelplund, T. 2001. Effects of supplementation with four multipurpose trees and *Lablab Purpureus* on rumen microbial population, rumen fermentation, digesta kinetics and microbial protein supply of sheep fed maize stover *ad libitum.* Proceedings of the 21st Annual Scientific Conference of Tanzanian Society of Animal Production (TSAP) held at Morogoro, Tanzania. pp. 315-317.

Hinderichsen, I. K., Osuji, P. O., Odenyo, A. A., Madsen, J. and Hvelplund, T. 2004. Effect of supplementation of maize stover with foliage of various tropical multipurpose trees and *Lablab purpureus* on intake, rumen fermentation, digesta kinetics and microbial protein supply of sheep. *Animal Feed Science and Technology,* 113,83-96.

Humphreys, L.R. 1991. *Tropical Pasture Utilization.* Cambridge University Press. Cambridge. UK.

Ibrahim, M.A. and t'Mannetje, L. 1998. Compatibility, persistence and productivity of grass-legume mixtures in the humid tropics of Costa Rica. 1. Dry matter yield, nitrogen and botanical composition. ILCA (International Livestock Research Center) 1991. ILCA Annual Report, 1991. Addis Ababa, pp. 79-83.

IFPRI (International Food Policy Research Institute). 1996. *Is there hope for food plenty in Africa?* International Food Policy Research Institute. Washington, D.C.

Imanyoha, J., Kyetere D., Bigirwa, G. and Kikafunda, J. 2000. Application for release of four maize varieties. Cereals Programme Annual Report. Namulonge Agricultural and Animal Production Research Institute, 2000.

Irungu, P., Mbogo, S., Staal, S., Thorpe, W. and Njuki, D. 1998. Factors influencing adoption of Napier grass in smallholder dairy production systems in Kenya. In: M/s Agronom Services Ltd (eds.). *Agricultural Research and Development for Sustainable Resource Management and Increased Production.* Proceedings of the 6th Biannual KARI (Kenya Agricultural Research Institute) Scientific Conference held at Nairobi, Kenya, from 9-11 November 1998. pp. 294-301.

Islam, M., Sarker, N.R and Islam, M.M. 1995. Effect of feeding legume with straw supplementation on milk production at Pabna milk shed area. *American Journal of Animal Science,* 8,107-111.

Jagadish, T. 1998. Working with farmer groups, Experiences, benefits and problems. In, *Going beyond the farm boundary.* Proceedings of the 15th International Symposium on Rural Livelihoods, empowerment and the environment, Association for Farming Systems Research-Extension (AFSRE), held from 29th November to 4th December 1998, Pretoria, South Africa. 2, 1284-1295.

Jingura, R. M., Sibanda, S. and Hamudikuwanda, T. 2001. Lactation performance of dairy cows given conserved grass forages and supplemented with lablab hay and two different concentrates in the dry season. Proceedings of Tanzanian Society of Animal Production. pp.191-204.

Jones, R. B. 1998. Technology exchange, the missing link in farming systems research and extension. In: *Going beyond the farm boundary.* Proceedings of the 15th International Symposium on Rural Livelihoods, empowerment and the environment, Association for Farming Systems Research-Extension (AFSRE), held from 29th November to 4th December 1998, Pretoria, South Africa. 2, 725-731.

ones, R. J. 2003. Effects of sown grasses and stocking rates on pasture and animal roduction from legume-based pastures in the seasonally dry tropics. *Tropical Grasslands*, 37,129-150.

Kabirizi, J. M. and Drania, A. 1997. The contribution of the Heifer Project for Women Farmers in Mpigi District (HPWF) to dairy development in Uganda. In: *Cattle Research Netetwork Newsletter. International Livestock* Research Institute, 5, 10-11.

Kabirizi, J. M., Bareeba, F. B., Sabiiti, E.N., Namagembe, A. and Kigongo, J. 2000. Effect of supplementing crossbred dairy cattle fed elephant grass based diet with lablab hay and a concentrate. *Uganda Journal of Agricultural Sciences*, 5, 9-16.

Kabirizi, J.M. 1996. Productivity and feeding value of *Lablab purpureus* cv. Rongai for lactating dairy cows fed elephant grass based diet. MSc Thesis. Makerere University.

Kabirizi, J.M., Mpairwe, D. and Mutetikka, D. 2003. Farmers' experiences in elephant grass/legume intercropping production system, A case study of Masaka district, Uganda. *Paper presented at the Tanzania Animal Production Society Annual Scientific Conference, 28th to 30th October 2003*. Tanga, Tanzania. pp. 200-218.

Kabirizi, J.M., Mpairwe, D. and Mutetikka, D. 2004. Testing forage legume technologies with farmers: A case study of Masaka district, Uganda. *Uganda Journal of Agricultural Sciences*, Vol. 9. No.3. September 2004. pp. 906-913.

Kabushenga, T.E. 2002. Development of an appropriate programme for the control of Contagious Bovine Pleuropneumonia in Uganda. PhD Thesis. University of Reading, U.K.

Kaitho, J.R. 1997. Nutritive value of browses as protein supplement(s) to poor quality roughages. PhD Thesis. Department of Animal Nutrition. University of Wahenengin, The Netherlands.

Kaitho, R.J. and Kairuki, J.N. 1997. Effects of *Desmodium, Sesbania* and *Calliandra* supplementation on growth of dairy heifers fed Napier grass basal diet. *American Journal of Animal Sciences*. 11, 680-684.

Kalule, T. and Kabirizi, J. 2003. Report on the assessment of elephant grass disorder on smallholder dairy farms in Masaka District, Uganda. Namulonge Agricultural and Animal Production Research Institute (Unpublished).

Kamatalit, P.I Tellere, E., Vanbelle, M., Collignon, G. and Foulon, M. 1992. *In situ* degradability of organic matter, crude protein and cell wall of various tree forages. *Animal Production Journal,* 55, 29-34.

Kang, B.T, Reynolds, L. and Atta-Krah, A.N. 1990. Alley Farming. *Advances in Agronomy, 43*, 315-359.

Kassa, T. and Tegegne, A. 1998. Factors affecting reproductive performance of zebu and crossbred cows under small-scale dairy farms. *Tropical Agriculture (Trinidad),* 75, 39-45.

Kassie, M., Jabbar., M.A., Kassa, B. and Mohamed-Saleem, M.A. 1999. Benefits of Integration of cereals and forage legumes with and without crossbred cows in mixed farms, *An ex ante* Analysis for Highland Ethiopia. *Journal of Sustainable Agriculture,* 14, 10-17.

Kassu, Y. 1989. Overcoming the constraints of nitrogen availability to improve crop residue utilization by ruminants in Burkina Faso. In: Said, A.N. and Dzowela, B.H. (eds). *Overcoming constraints to the efficient uitlization of agricultural by-products as animal feed.* Proceedings of the fourth Annual Workshop held at the Institute of Animal Research, Mankon Station, Bameda, Cameroon, from 20th to 27th October 1987. ARNAB, Addis Ababa, Ethiopia. pp. 80-104

Kategile, J.A. 1981. Agricultural by-products as livestock feeds, Tanzania's experience. In: *Crop residues and Agro-industrial by products in animal feeding*. Proceedings of the FAO/ILCA workshop, Dakar, Senegal, FAO Animal Production and Health Paper No 32, 101-106.

Katuromunda, S. 2001. Compatibility and Productivity of forage legumes with maize and elephant grass in peri-urban smallholder crop/livestock production systems. MSc Thesis. Makerere University pp 34-60.

Katuromunda, S., Sabiiti, E.N. and Bareeba, F.B. 2001. *Sustainable Pennisetum purpureum fodder production in the peri-urban smallholder crop/livestock production systems in Uganda.* In: Tenywa, J. S., Nampala, P, Tusiime, G. and Osiru, M. (eds.) *African Journal of Crop Science.* Conference Proceedings (Part 1). Lagos, from 22nd to 26th October 2001. 5, 559-564.

Kawonga, K. C. and Kulich J. 1995. The intercropping of maize with pasture legumes, In: Chisanga J.S., Kawonga, K.C., Maluza, T.F., Mwenya. J., Undi, M., Yambayamba, E.S.K. (eds). Proceedings of the 2nd Livestock and Pasture Research Planning Meeting, Ministry of Agriculture, Food and Fisheries, Research Branch, Lusaka, Zambia. 8-11 November 1995.

Keady, T.W.J., Mayne, C.S. and Fitzpatrick. D.A. 1999. *An examination of the effect of concentrate supplementation during late gestation on subsequent milk yield and composition of lactating dairy cattle.* Proceedings of the British Society of Animal Science held at the society's Annual Meetings at Scarborough in March 1999. pp. 21.

Kellyaway, R. and Porta, S. 1993. *Feeding concentrates, Supplements for dairy cows.* Dairy Research and Development Corporation. pp. 35-145.

Kempton, T.J. 1982. Role of feed supplements in the utilization of low protein roughage diets by sheep. *World Review of Animal Production,* 18 (2), 7-15.

Kesseba, A.M. 1989. *Technology systems for small farmers, Issues and options* Westview Press. Boulder, San Francisco, & London. pp.11-12.

Khalili, H. and Varvikko, T. 1992. Effect of replacement of concentrate mix with wilted sesbania (*Sesbania sesban*) forage on diet digestibility, rumen fermentation and milk production in Friesian x Zebu (Boran) crossbred cows fed low quality native hay. *Animal Feed Science and Technology,* 36, 275-266.

Kimambo, A.E., Makiwa, A.M., Shem, M.N. 1992. The use of *Leucaena leucocephala* supplementation to improve the utilization of maize stover by sheep. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). *The Complementarity of feed resources for animal production in Africa.* Proceedings of a Joint feed resource networks Workshop held in Gaborone, Botswana. 4-8 March, 1991. pp. 163-172.

Kiruiro, E.M. and Chemitei, V.C. 1993. The evaluation of different protein and energy supplements on milk production in pasture-grazed Friesian cattle. In: Ndikumana J. and de Leeuw P. (eds.). *Sustainable Feed Production and Utilisation for Smallholder Livestock Enterprises in Sub-Saharan Africa.* Proceedings of the Second African Feed Resources Network (AFRNET) Workshop held in Harare, Zimbabwe, 6 –10 December 1993. pp 50-54

Kiwuwa, G.H., Trail J.C.M., Yousef, M.K., Worku G., Anderson, F.M. and Durkin, J. W. 1983. Crossbred dairy cattle productivity in Arsi region, Ethiopia. ILCA (International Livestock Centre for Africa) Research Report. No. 11. pp. 29.

Koume, C., Hoefs, S., Powell, J M., Roxas D. and Renard, C. 1992. Mixture *Stylosanthes* effects on millet yields and animal production. In: Stares J E S., Said, A. N and Kategile J A. (eds). *The Complementarity of feed resources for animal production in Africa.* Proceedings of the Joint Feed Resources Networks Worship held in Gaborone, Botswana, from 4th to 8th March 1991. pp. 137-146.

Kurwijila, L.R., Henriksen, J. Aboud, A.O.O., and Kifaro, G. C. 1995. Strategies for market orientation of small scale milk producers and their organizations. Food and Agriculture Organization of the United Nations Rome Sokoine University of Agriculture.

Kusekwa, M.L., Bitende, S.N. and Ngowi, N. D. 1988. Productivity of oversown pastures in northern Tanzania. In: Dzowela, B.H., Said, A.N., Wendem-Agenehu, A., and Kategile, J.A. (eds.). *Utilization of Research Results on Forage and Agricultural By-product Materials as Animal Feed Resources in Africa.* PANESA/ARNAB (Pastures Network for Eastern and Southern African Research Network for Agricultural By-products). Proceedings of the First Joint workshop held in Lilongwe, Malawi, 5-9 December 1988. PANESA/ARNAB, Addis Ababa, Ethiopia. pp 833.

Lalman, D.L., Keisler, D.H., Williams, J.E.I., Scholljegerdes, E.J. and Mallet, D.M. 1997. Influence of postpartum weight and body condition change on duration of anestrus by undernourished suckled beef heifers. *Journal of Animal Science,* 75, 2003-2008.

Langhans, W., Rossi, R. and Scharrer, E. 1995. Relationship between feed and water intake in ruminants. In: van Engelhardt, W.; Leonhard-Merek, S., Breves, G. and Giesecke, D. (eds). *Ruminant physiology, digestion, metabolism, growth and reproduction. Proceedings of the VIII international symposium on ruminant physiology held at Willingen, Germany, from 10th to 14th September 1994.* Ferdinand Enke Verlag, D-70443 Stuttgart, Germany, pp. 199-216.

Lanyasunya, T.P., Mukisira, E.A., Lokwaleput, I.K. and Siamba, D.N. 2001. Factors limiting optimization of smallholder peri-urban dairy herd production in Kenya. *Livestock and Environment.* Proceedings of the 10th Conference of the Association of Institutions for Tropical Veterinary Medicine, Copenhagen, Denmark.

Lascano, C.E. 1994. Nutritive value and animal production of forage Arachis. In: P.C. Kerridgr and B. Hardy (eds). *Biology and agronomy of forage Arachis,* CIATI, Cali, Colombia. pp. 109-121.

Leaver, J.D. 1985. Milk production from grazed temperate grassland. *Journal of Dairy Research,* 52, 313-344.

Leegwater, P., Ngolo, J. and Horweg, J. 1991. *Dairy development and nutrition in Kilifi District, Kenya.* Report 35. Food and Nutrition Planning Unit, Ministry of Planning and National Development, Nairobi, Kenya, and Food and Nutrition Studies Programme, African Studies Centre, Leiden, The Netherlands.

Leng, R. A. 1990. Factors affecting utilization of "poor quality" forages by ruminants, particularly under tropical conditions. *Nutrition Research Review,* 3, 277-393.

Leng, R. A. 1997. Tree foliage in ruminat nutrition. FAO Animal Production and Health Paper 139. Food and Agriculture Orgamization of the United Nations Rome, 1997.

Leng, R.A., Bird, S.H., Klieve, A, Choo, B.S., Ball, F.M., Asefa, G.P., Brumby, V.D., Mudgal, U.B., Chaudhry, S.U., Haryono, A. and Hendratno, N. 1991. The potential for tree forage supplements to manipulate rumen protozoa to enhance protein to energy ratios in ruminants fed on poor quality forages. In: Speedy and Luc Pugliese. (eds.). *Legume trees and other fodder trees as protein sources for livestock.* Proceedings of the FAO Expert Consultation held at the Malaysian Agricultural

esearch and Development Institute (MARDI) in Kuala Lumpur, Malaysia, from 14th to
October 1991. pp. 71-82.

ttle, D.A., **Wassink, G.J., Agyemanga, K., Leperre, P., Janneh, L. and Badjie, B. 994.** Feed supplementation of lactating N'Dama cows under village husbandry. *opical Agriculture* (Trinidad), 71, 223-228.

SRP (Livestock Systems Research Programme) Report, 2000. District Diagnostic urvey Reports. Livestock Systems Research Programme (NARO/DANIDA/LSRP), ganda.

upwayi, N.Z., Abate, T. and Hailu, R. 1996. On-farm integration of forage legumes to cereal cropping systems in the Ethiopian Highlands. *African Crop Science ournal*, 4, 365-372.

yimo, H.L.N., Laswai, G.H., Mtenga, L.A., Kimambo, A.E., Mgheni, D.M. lvelplund, T. and Weisbejerg, M.R. 2003. Pre-weaning performance of crossbred dairy calves reared on locally prepared calf concentrates. In: Proceedings of the 30th Scientific Conference held at 4H Centre-Tanga, from 28th to 30th October, 2003. TSAP Tanzanian Society of Animal Production) Conference Series Vol. 30, (2003). pp. 321-332.

Lynch, J.M., Lamb, G.C., Miller, B.L., Brandt Jr., R.T., Cochran, R.C., and Minton, J.E. 1997. Influence of timing of gain on growth and reproductive performance of beef replacement heifers. *Journal Animal Science*, 75, 1715-1722.

Maasdrop, B.V., Muchenje, V. and Titterton, M. 1999. Palatability and effect on dairy cow milk yield of dried fodder from the forage trees *Acacia bolivia, Calliandra calothrysus and Leucaena leucocephola. Animal Feed Science and Technology*, 77, 49-59.

Makembe, N.E.T. and Ndlovu, L.R. 1996. *Dolichos lablab (Lablab purpureus* cv Rongai) as supplementary feed to maize stover for indigenous female goats in Zimbabwe. *Small Ruminant Research*, 21, 31-36.

ossin, F., Bovolenta, S., Piras, C. and Ventura, W. 1995. Effect of concentrate pplementation on herbage intake and milk yield of dairy cows grazing an alpine sture. *Livestock Production Science,* 43,119-128.

rston, T. T., K. S. Lusby, and R. P. Wettemann. 1993. The effects of energy and otein supplements on spring-calving cows. pp. 111–117 in Okla. Agric. *Experimental ation Bulletin*. P-933. Stillwater, OK.

artin, S. K., and C. A. Hibberd. 1990. Intake and digestibility of low-quality native ass hay by beef cows supplemented with graded levels of soybean hulls. *Journal of nimal Science* 68, 4319–4325.

IcCollum, F. T., and M. L. Galyean. 1985. Influence of cottonseed meal upplementation on voluntary intake, rumen fermentation and rate of passage of rairie hay in beef steers. *Journal of Animal Science*. 60, 570–577.

McDowell, L.R., J.H. Conrad, and F.G. Hembry. 1993. Minerals for grazing ruminants in tropical regions. Second edition. *Bulletin of the Center for Tropical Agriculture*. University of Florida. Gainesville, FL.

Mertens, D.R. 1994. Regulation of forage intake. In: Fahey, G.C.(ed). *Forage Quality, evaluation and Utilization,* Madison, WI. pp. 450–493.

Methu, J.N., Owen, E., Abate, A.L. and Tanner, J.C. 2001. Botanical and nutritional composition of maize stover, intakes and feed selection by dairy cattle. *Livestock Production Science,* 71, 87-96.

MFPED (Ministry of Finance, Planning and Economic Development). 2004. Population Census Report, 2004, Uganda.

Minson, D.J. 1982. Effects of chemical and physical and composition of herbage eaten upon intake. In: J.B. Hacker (eds). 1982. *Nutritional limits to animal production from Pastures*. Proceedings of International Symposium. held at St. Lucia, Queensland. Australia. from 24th to 28th August 1981. CAB, Famaham, Royal, U.K. pp. 89-110.

Mlay, P. N. S. 2001. Enhancement of smallholder dairy production under tropical conditions through supplementation to optimize roughage intake, digestibility and microbial protein synthesis. PhD Thesis. Department of Animal Science and Animal Health. The Royal Veterinary and Agricultural University, Copenhagen. pp. 154-158.

Moffat, K. and Ngwira, A. 2003. Forage demand and constraints to adoption of forage technologies by livestock keepers in Malawai. *Tropical Grasslands,* 37, 274-274.

Mohamed-Saleem, M.A. 1985. Effect of sowing time on grain and fodder production potential of sorghum undersown with stylo in the sub-humud zone of Nigeria. *Tropical Agriculture (Trinidad),* 62,151-153.

Morse, D., Head, H.H. Wilcox, C.D., Van Horn, H.H., Hissem, C.D. and Harris, B. 1992. Effects of concentration of dietary phosphorus on amount and route of excretion. *Journal of Dairy Science*. 75, 3039.

Mosi, A.K. and Butterworth, M.H. 1985. The voluntary intake and digestibility of combinations of cereal crop residues and legume hay for sheep. *Animal Feed Science and Technology,* 12, 241-251.

Mpairwe, D. 1994. Evaluation of *Gliricidia sepium* (Jacq.) Walp as a fodder Tree/Shrub for ruminant production. M.Sc. Thesis. Makerere University.

Mpairwe, D. 1998. Integration of forage legumes with cereal crops for improved grain yield, forage production and utilization for smallholder dairy production systems. Ph D. Thesis. Makerere University.

MPMPS (Meat Production Master Plan Study). 1998. Final Report. Ministry of Agriculture Animal Industry and Fisheries. The Government of Republic of Uganda.

Mtengeti, E.J., Urio, N.A. and Mlay, G.I. 1992. Intensive fodder gardens for increasing forage availability for smallholder dairy production in Hai District, Tanzania. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). 1992. *The Complementarity of feed resources for animal production in Africa*. Proceedings of a Joint feed resources network workshop held in Gaborone, Botswana 4-8 March, pp. 120-136.

Mubiru, S., Ebong, C., Rubaire-Akiiki, C., Kabirizi, J., Odur, A., Ndyanabo, J., Niels, W., Namagembe, A., Mayega, L., Nakatudde, P. and Luvumu, E 2001. Effect of forage legume on growth and biomass yield of elephant grass. Paper presented in NARO Scientific Workshop held at the International Conference Centre, Kampala, Uganda, from 2nd to 7th December 2001.

Mubiru, S., Ebong, C., Rubaire-Akiiki, C., Kabirizi, J.M,, Odur, A., Ndyanabo, J. Niels, W., Namagembe, A., Mayega, L., Nakatudde, P. and Luvumu, E. 2000. Strategic Utilization of Feed resources for Improved Productivity on Smallholder Dairy farms in Uganda. Paper presented at the Livestock Systems Research Programme (LSRP) Review Workshop held at The Sunset Hotel International, Jinja, from 12th to 13th December 2000.

Muck, R.E. 1988. Factors influencing silage quality and their implications for management. *Journal of Dairy Science,* 71, 2992-3002.

Mugisha, J. 2003. Technology adoption survey- 2003. Farmers' Organization Component (FOC). (Unpublished). Ministry of Agriculture, Animal Industry and Fisheries (MAIF), Uganda.

Mugisha, T.K., Ngategize P.K. and Sabiiti E.N. 1999. Determinants and impact of integration of forage legumes in crop/livestock systems in peri-urban areas of central Uganda. *African Crop Science Journal,* 7, 591-598.

Muinga, R.W., Thorpe. W. and Topps, J.H. 1993. Lactational performance of Jersey cows given Napier fodder (*Pennisetum purpureum*) with and without protein concentrates in the semi-humid tropics. *Tropical Animal Health and Production,* 25,118-128.

Muinga, R.W., Thorpe. W., Topps, J.H. and Mureithi, J.G. 1992. Responses to *Pennisetum purpureum* basal diet harvested at two different heights and fed with three levels of luecaena forage to cross bred dairy cows in the sub-humid tropics. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). *The Complementarity of feed resources for animal production in Africa.* Proceedings of a Joint feed resources network workshop held in Gaborone, Botswana 4-8 March, pp. 75-77.

Mukasa-Mugerwa, E. 1989. A review of reproductive performance of female *Bos indicus* (Zebu) cattle. ILCA Monograph No. 8. ILCA, Addis Ababa, Ethiopia.

Munthali, J.T.K., Jayasuriya, C.N. and Bhattachrya, A.N. 1992. Effects of urea diet of maize stover and supplementation with maize bran or urea-molasses block on the performance of growing steers and heifers. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds.). *The Complementarity of feed resources for animal production in* Africa. Proceedings of a Joint Feed Resources Network Workshop held in Gaborone, Botswana from 4th to 8th March, pp. 279-286.

Mureithi, J.G. and Thorpe, W. 1993. The effects of herbaceous legume intercropping and mulching on the productivity of Napier grass (*Pennisetum purpureum*) and total forage yield in coastal lowland Kenya. In: Ndikumana, J. and de Leeuw, P. (eds). *Sustainable feed production and utilization for smallholder livestock enterprises in Sub-Saharan Africa*. Proceedings of the Second African Feed Resources Network (AFRNET), Harare, Zimbabwe, from 6th to 19th December 1993. AFRNET (African Feed Resources Network), Nairobi, Kenya.

Murphy, A.M. and Colucci, P.E. 1999. A tropical forage solution to poor quality ruminant diet: A review of *Lablab purpureus. Livestock Research for Rural Development,* 11, 2-8.

Murphy, M.R., C.L. Davis and G.C. McCoy. 1983. Factors affecting water consumption by Holstein cows in early lactation. *Journal of Dairy Science*. 66,35.

Muwanga, J.W. 1994. An economic evaluation of zero grazing dairy production systems in Uganda, A case study in Mpigi and Mukono Districts. MSc. Thesis, Makerere University, Kampala.

Muyeko, F.N., Masinde, A.A.O., Cherutyot, D.T., Odongo, J., Ojowi, M. and Okeyo, R. 2003. Assessing factors influencing adoption of pastures and fodder amongst smallholder subsistence farmers in selected districts of West Kenya. *Tropical Grasslands,* 37, 219-226.

Mwangi, D.M. 2002. *Transfer of herbaceous legume technology to smallholder farms, The case of Desmodium intortum in Central Kenya*. In: Mwangi D.M. and Kairuki J. N.

(eds). Proceedings of APSK (Animal Production Society of Kenya), 2002. Annual Symposium held from 9th to 10th May 2002 at National Animal Husbandry Research Centre, Nairobi, Kenya. pp. 9-20.

Mwangi, D.M. and Wambugu, C. 2003. Adoption and scaling up of forage legumes, the case of *Desmodium* and *Calliandra calothyrsus* in central Kenya. *Tropical Grasslands,* 37, 227-238.

Mwebaze, S.M. 1996. Biomass production of maize (*Zea mays*) intercropped with selected forage legumes for food and feed in smallholder farming systems. MSc. Thesis, Makerere University, Kampala.

Mwebaze, S.M. 2000. Study of economic impact of agro-ecological work through stall-fed livestock in Uganda. Heifer International. Uganda case study. November 2000.

Nahdy S. 2001. Decentralization of services in Uganda, The formation of National Agricultural Advisory Services (NAADS). In: Rangnekar, D. and Thorpe, W. (eds). *Proceedings of a Smallholder dairy production and marketing—Opportunities and Constraints South–South workshop held at National Dairy Development Board (NDDB), Anand, India, from 13th to 16th March 2001.*

Nakiganda, A. N. 2004. Economic evaluation of smallholder dairy cattle feeding strategies in Masaka district, Uganda. PhD. Thesis. The University of Reading.
National Research Council. 2001. Nutrient Requirements of Dairy Cattle 7th rev. ed. Washington, D.C., National Academy Press.

Ndikumana, J. and de Leeuw, P.N. 1996. *Sustainable Feed Production and Utilization of Smallholder Livestock Enterprises in Sub-Saharan Africa.* Proceedings of the Second African Feed Resources Network (AFRNET), Harare, Zimbabwe, from 6th to 10th December 1993. AFRNET (African Feed Resources Network), Nairobi, Kenya. pp. 5-9.

Ndikumana, J. and Kamidi R. 2004. Challenges and opportunities for the livestock industry in East and Central Africa. *Paper presented during the Regional Conference on Animal Production, Nairobi, Kenya, from 15th to 18th March 2004.*

Ngwa, A.T. and Tawah, C.L. 1992. Effect of legume crop residues and concentrate supplementation on voluntary intake and potential value in and performance of kirdi sheep fed a basal diet of rice straw. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). *The Complementarity of Feed Resources for Animal Production in Africa.* Proceedings of a Joint feed resources network workshop held in Gaborone, Botswana 4-8 March, pp. 239-248.

Nherera, F.V., Ndlovu, L.R and Dzowela, B.H. 1998. Utilisation of *Leucaena diversifolia*, *Leucaena esculenta*, *Leucaena pallida* and *Calliandra calothyrsus* as nitrogen supplements for growing goats fed maize stover. *Animal Feed Science and Technology,* 74, 15 –28.

Nicholson, C.F., Thornton, P.K., Mohammed, L., Muinga, R. W., Mwamachi, D.M., Elbasha, E.H., Staal, S.J. and Thorpe, W. 1999. *Smallholder Dairy Technology in Coastal Kenya, An adoption and Impact study.* ILRI (International Livestock Research Institute).

Nicholson, M.J. and Butterworth, M. H. 1986. A guide to conditioning scoring of zebu cattle. ILCA (International Livestock Centre for Africa.

Nitis, I. M. 1995. Sustainable forage production systems in the tropics. In: Ivans, M. (ed) *Animal Science and Research Development. Moving Towards a New Century.* Centre for Food and Animal Research agriculture and Agriculture-Food. Canada, Ottawa, Ontorio. Canada. pp. 261-280.

Njwe, R.M., Donfack, N.D., Djoukam, J. and Endeley, H.N.L. 1992. Performance of associations of *Brachiaria ruziziensis* with *Desmodium intortum*, *Desmodium uncinatum* and *Stylosanthes guyanensis* at Dschang, Cameroon. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). *The Complementarity of Feed Resources for Animal Production in Africa.* Proceedings of joint feed resources network workshop held in Gaborone, Botswana from 4th to 8th March, pp. 47-52.

Nkya, R., Abood, A.A. and Kessy, B.M. 1998. Improving the productivity of smallholder dairy cattle in peri-urban Morogoro, Tanzania. Paper presented in the third Research Council Meeting (RCM) on feed supplementation strategies for smallholder farms in Africa held in Vienna, from 7th to 11th September 1998.

Nnadi, L. and Haque, I. 1988. Forage legumes in African crop/livestock production systems. ILCA Bulletin. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 30, 10-19.

Norman, D.W., Worman, F.D. and Siebert, J.D. 1995. The farming systems approach to development and appropriate technology generation. FAO (Food and Agriculture, 1995).

Norton, B.W.. and Poppi, D.P. 1995. Composition and nutrional attributes of pasture legumes. In: D'Mello, J.P.F. and Devendra, C. (eds). *Tropical legumes in animal nutrition,* pp. 23-47.

Norton, L. 1994. The nutritive value of tree legumes. In: Gutteridge R C, Shelton H M (eds). Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, pp. 177-191.

NRC (Nutrient Requirements of Dairy Cattle) 2001. 7th edition. National Academy Press. Washington DC.

Nsubuga, H.S.K. 1993. Pastures in the feeding of dairy cattle in Uganda, with particular reference to zero grazing. In, Sabiiti, E.N., Bareeba, F.B. and Mwebaze, S. (eds.). Proceedings of the second Uganda Pasture Network workshop, Makerere, University, from 14th to 16th December 1992. pp. 64-68.

Nyatsanga, T. and Pierre, W.H. 1973. Effect of Nitrogen fixation by legumes on soil acidity. *Agronomy Journal,* 65, 936-940.

Ørskov, E. R. 1982. Protein Nutrition in Ruminants. Academic Press, Washington, DC.

Ovenell, K. H., K. S. Lusby, G. W. Horn, and R. W. McNew. 1991. Effects of lactational status on forage intake, digestibility, and particulate passage rate of beef cow supplemented with soybean meal, wheat middlings, and corn and soybean meal. *Journal of Animal. Science* 69, 2617–2623.

Ofori, F. and Stem, R.M. 1986. Maize/cowpea intercrop system. Effect of nitrogen fertilizer on productivity and efficiency. *Field crops Research* 14, 247-251.

Ogundola, F.I. 1989. Studies on the utilization of brewers dry grains and wheat offals by calves. In: Said, A.N. and Dzowela, B.H. (eds). *Overcoming constraints to the efficient uitlization of agricultural by-products as animal feed.* Proceedings of the fourth Annual Workshop held at the Institute of Animal Research, Mankon Station, Bameda, Cameroon, from 20th to 27th October 1987. ARNAB, Addis Ababa, Ethiopia. pp. 256-353.

Ogwang, B.H. 1974. Qualitative and quantitative evaluation of *Pennisetum purpureum x Pennisetum typhoides* hybride. MSc. Thesis. Makerere University, Kampala.

Okalebo, J.R, Gathua K.W. and Woomer P.L. 1993. Laboratory methods of soil and plant analysis. A Working Manual. Tropical Soil Biology and Fertility Programme. UNESCOROSTA, Nairobi, Kenya, pp. 88.

Okigbo, B.N. 1987. Cropping systems and related research in Africa. Special issue on the occasion of the 10th anniversary of the advancement of agricultural sciences in Africa (AAASA). Occasional Publication Series-OT-1.

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M. and Staal, S.J. 1999. *The Kenyan dairy sub-sector, A rapid appraisal.* Smallholder Dairy (Research and Development) Project Report. Nairobi, Kenya.

Orskov, E.R. and Ryle, M. 1990. Energy nutrition in ruminants. Elsevier science publishers, UK. pp. 144.

Osuju, P. O. 1994. Nutritional and anti-nutritional values of multipurpose trees used in agro-forestry systems. An invited paper presented at the 7th AAAP Animal Science Congress Symposium on "Agroforestry and Animal Production for Human Welfare". Bali, Indonesia, 11-16 July 1994.

Osuju, P.O., Khalili, H. and Umunna, N.N. 1995. The effects of cotton seedcake with or without molasses on feed utilization, purine excretion, and milk production of Boran (*Bos indicus*) cows fed a mixture of wheat and oat straw. *Tropical Agriculture* (Trinidad), 72, 63-69.

Otsyina, R. and Dzowela B. 1995. Importance of leuceana in Africa. pp 25-39. In: Ciesia, W.M. and Nshubemuki, L. (eds). Leuceana psyllid a threat to agroforestry in Africa. FAO Rome. pp. 237.

Palmer, B. and Schlink, A.C. 1992. The effect of drying on the intake and rate of digestion of the shrub legume *Callindra calothyrsus. Tropical Grasslands,* 26, 89-93.

Palmer, B., Macqueen D.J., Bray, R.A. 1995. Opportunities and limitations in calliandra. In: Shelton, H.M., Piggin, C.M., Brewbaker, J.L. (eds). *Leucaena-Opportunities and Limitations.* Proceedings of a Workshop held in Bogor, Indonesia, from 24th to 29th January 1994. ACIAR. No. 57. pp. 29-34.

Parga, J., Peyraud, J.L., Delagarde, R., 2000. Effect of sward structure and herbage allowance on herbage intake by grazing dairy cows. In *Grazing Management, The principles and practice of grazing for profit and environmental gain in temperate grassland system.* 29 Feburary-2 March, Harrogate. *British Grasslands Society,* 3, 44-46.

Payne, W.J.A. 1970. *Cattle Production in the Tropics, Breeds and Breeding.* Vol. 1, Essex, Longman. pp . 262-313.

Peters, M. and Lascano, C.E. 2003. Forage technology adoption, linking on-station research with participatory methods. *Tropical Grasslands,* 37,197-203.

Peterson, R.T., Karanja, G.M., Roothaert, R.L, Nyaata, E. and Kairuki I.W. 1998. A review of tree fodder production and utilization within smallholder agro-forestry systems in Kenya. *Agroforestry Systems,* 41,181-199.

Peterson, R.T., Kiruiro E. and Arimi, H.K. 1999. *Calliandra calothyrsus* as a supplement for milk production in the Kenya Highlands. *Tropical Animal Health and Production,* 31,115-126.

Pordomingo, A. J., J. D. Wallace, A. S. Freeman, and M. L. Galyean. 1991. Supplemental corn grain for steers grazing native rangeland during summer. *Journal of Animal. Science* 69, 1678–1687.

Preston, S. 1986. Better utilization of crop residues and by-products in animal feeding, Research guidelines. 2. A practical manual for research workers. FAO Animal Production and Health Paper, No. 52/2. FAO Rome.

Preston, S. 2001. Intercropping Principles and practices. *Agronomy Systems Guide. Appropriate technology transfer for rural areas (ATTRA).*

Preston, T. R. and Leng R. A. 1987. Matching ruminant production systems with available resources in the tropics and subtropics. Armidale, Australia, Penambul Books.

Purwantara, B., Achjadi, R. K., Tambing, S. N. and Wicaksono, C. N. 2001. The effect of season and milk production on reproductive performance in `dairy cows. Livestock Community and Environment. Paper presented during the 10th Conference of the Association of Institutions for Tropical Veterinary Medicine, Copenhagen, Denmark, 2001.

Randel, R.D. 1990. Nutrition and postpartum rebreeding in cattle. *Journal of Animal Science,* 68, 853-862.

Rangnekar, T and Thorpe, W. 2001. Smallholder dairy production and marketing—Opportunities and constraints. In: Proceedings of a South–South workshop held at National Dairy Development Board (NDDB), Anand, India, from 13th to 16th March 2001. pp. 523-546.

Raussen, T. 1998. Useful trees for farming. *Calliandra calothyrsus.* Agroforestry Research Network for Africa (AFRENA-Project Uganda). National Agroforesty Research Project. KARI-KEFRI-ICRAF, Embu, Kenya.

Read, M.P., Engles, E.A.N. and Smith, W.A. 1986. Phosphorous and the grazing uminant.1. The effect of supplementary phosphorous on sheep at Armoedsvlakte. *South African Journal of Animal Science*. 16, 1-6.

Robertson, B.M. 1988. The nutritive value of five browse legumes fed as supplements to goats offered a basal rice straw diet. MSc. Thesis. The University of Queensland.

Romney, D.L. and Gill, M. 2000. Intake of forages. In, *Forage Evaluation in Ruminant Nutrition*. In: Givens, D.J., Owen, E. Axford, R.F. and Omed, H.M. (eds). CABI Publishing. CAB International, Wallingford, Oxon, UK. pp. 43-62.

Romney, D.L., Thorne P., Lukuyu B. and Thornton P.K. 2003. Maize as food and feed in intensive smallholder systems, management options for improved integration in mixed farming systems of east and southern Africa. *Field Crops Research,* 84,159-168.

Roothaert, R., Horne, P. and Stur, W. 2003. Integrating forage legumes on smallholder farms in upland tropics. *Tropical Grasslands,* 37, 295-303.

Ruiz, M.E. 1983. Supplementing dairy cows in the tropics. The dairy Science Handbook. 33, 337-342.

Sabiiti, E.N. 1993. Forage Integration into crop/livestock Production Systems. In: Sabiiti, E.N., Bareeba, F.B. and Mwebaze, S. (eds). Proceedings of the second Uganda Pasture Network workshop held at Makerere University, Kampala. pp. 19-26.

Sabiiti, E.N. and Mugerwa, J.S. 1990. Forage research and development for livestock production in Uganda. In: Dzowela, B.H., Said, A.N., Asrat Wendem-Agenehu and Kategile, J.A. (eds). *Utilization of Research Results on Forage and Agricultural By-product Materials as Animal Feed Resources in Africa.* PANESA/ARNAB (Pastures Network for Eastern and Southern African Research

Network for Agricultural By-products). Proceedings of the First Joint workshop held in Lilongwe, Malawi, 5-9 December 1988. PANESA/ARNAB, Addis Ababa, Ethiopia. pp. 833-845.

Saka, A., Haque, I., Said, A.N. and Lupwanyi, N.Z. 1994. Forage legumes in crop/livestock systems in Sub-Saharan Africa. Environmental Sciences Working Document no. 24. International Livestock Center for Africa (INCA), Addis Ababa, Ethiopia. pp. 82.

Salawu, M.B., Acamovic, T., Stewart, C.S. and Maasdrop, B. 1997. Assessment of the nutritive value of *Calliandra calothyrsus*, its chemical composition and the influence of tannins, pipecolic acid and polyethylene glyocol on *in vitro* organic matter digestibility. *Animal Feed Science Technology,* 69, 207-217.

Samanya, J.P. 1996. Evaluation of feed resources for the zero grazing dairy production system in the fertile Lake Victoria Crescent zone of Uganda. A case study of Jinja women heifer project. MSc. Thesis. 1996. Makerere University.

SAS (Statistical Analysis Systems Institute Inc.). 1999. Statistical analysis Systems Institute (SAS/STAT). User's Guide. Version 8, Carry, NC, SAS Institute Inc, 1999.

Satter, L.D. and Wu Z. 2000. Balancing the animals' nutritional needs with environmental stewardship. *Advances in Dairy Technology,* 12, 43-57.

Sebillote, 1994. The systems approach and action. Paper presented at the 13th International Symposium on Systems-Oriented Research in Agriculture and Rural Dev., Montpellier, France, from 21st to 25th November 1994.

Seiler, R.J., Omar, A.R.S. and Salim, N. 1979. Nitrate poisoning in cattle fed Napier grass (*Pennisetum purpureum*). Kajian Veterinary.11, 10-13.

Shelton, H.M., Norton, B.W., Mullen, B.F., Gutteridge, R.C. and Dart, P.J. 1996. Utilization and nutritive value of *Calliandra calothyrsus* for forage, A review of research at the University of Queensland.. In: Evans, D.O. (ed). *Forest, Farm and Community Tree Research Reports (USA),* International Workshop on the Genus Calliandra, Bogor (Indonesia), from 23rd to 27th January 1996. Winrock International Inst. for Agricultural Development, Morrilton, AR (USA), Ministry of Forestry, Jakarta (Indonesia). Agency for Forestry Research and Development, Overseas Development Administration, London (United Kingdom). pp. 210–221.

Shenu, Y. and Akinola J.O. 1995. The productivity of pure and mixed grass-legume pastures in the Northern Guinea Savanna zone of Nigeria. *Tropical Grasslands,* 29,115-121.

Shiferaw, B.A., Tenhagen, B.A., Bekana, M. and Kassa, T. 2003. Reproductive performance of dairy cows in different production systems in the central highlands of Ethiopia. *Tropical Animal Health and Production,* 35, 551-561.

Singh, C.B., Rao, S.V.N. and Jain, D.K. 1995. *Farming systems research for improving livestock production and crop residue utilization.* National Dairy Research Institute, Kamal, India.

Singh, G.P. and Oosting, E.R. 1992. A model for describing the energy value of straw *Indian Dairyman XLIV,* pp. 322-327.

Singh, K.K. and Rathi, K.S. 2003. Dry Matter production and productivity as influenced by staggered sowing of mustard intercropped at different row ratios with chickpea. *Journal of Agronomy and Crop Science,* 189,169-173.

Skerman, N.H. and Riveros, F. 1990. *Tropical forage legumes*. FAO, Rome, Italy. pp. 420.

Skerman, N.H., Carmeron, D. F. and Riveros, F. 1988. *Tropical forage legumes*. Second edition. Food and Agriculture Organization of the United Nations. pp. 311-319.

Speedy, A. and Pierre-Luc, P. 1991. *Legume trees and other fodder trees as protein sources for livestock.* Proc of the FAO Expert Consultation held at the Malaysian Agriculture Research and Development Institute (MARDI) in Kuala Lumpar, Malaysia, from 14th to 18th October 1991.

Steele, K.W. and Vallis, I. 1988. The nitrogen cycle in pastures. In: Wilson, J.R. (ed), *Advances in Nitrogen Cycling in Agricultural Ecosystems.* CAB International, Wallingford, UK, pp. 274-291.

Steinbach, J. 1997. Alternatives to Crop Residues as Feed Resources in Mixed Farming Systems. In: Renard, C. (ed). *Crop Residues in Sustainable Mixed Crop/Livestock. Farming Systems.* International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) India. CAB International.

Tangka, F.K., Jabbar, M.A. and Shapiro, B.A. 2000. *Gender roles and child nutrition in livestock production systems in developing countries, A critical review.* Socio-economic and Policy Research Working Paper 27. ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 64

Thomas, T.A. and Dabas, B. 1982. *Lablab bean- A multipurpose legume crop.* National Bureau of Plant Genetic Resources, IARI Campus, New Delhi. pp. 23-25.

Tilley, G.E.D. 1989. Factors affecting the productivity of elephant grass. In, XVI *International Grassland Congress, from 4th to 11th October 1989, Nice, France.* Association francaise pour la production fourragere (The French Grassland Society), Versailles, France pp. 601.

Tilley, J.A.M. and Terry, R.A. 1963. A two-stage technique for *in vitro* digestion of forage crop. *Journal of British Grassland Society,* 19,104-105.

Titterton, M., Mhere, O., Maasdorp, B., Kipnis, T., Ashbell, G., Smith, T. and Weinberg, Z. 2002. Ensiling of tropical forages with Particular Reference to African Livestock Systems. Forage production and conservation for dry season feeding of smallholder dairy cattle in the semi-arid region of Southern Africa. Paper presented at the XIIIth International Silage Conference, from 11th to 13th September 2002.

Topps, J.H. 1994. Nutritional constraints affecting small-scale dairying in three districts of Kenya. In: Mutisi,C.; Gomez, M., Madsen, J. and Hvelplund, T. (eds). *Proceedings of the workshop on integrated livestock/crop production systems in the small scale and communal farming systems in Zimbabwe.* pp. 125-131.

Touvin, 1989. Grass/legume mixture associations in the tropics. Results of trials in wet and dry seasons. *Pasturages et alimentationdes es ruminants en zone tropicale humide*. First symposium on ruminant nutrition in tropical conditions. Guadelope, from 2nd to 6th June 1989. Paris, France. pp. 333-348.

Tumutegyereize, K., Hyuha T. and Sabiiti, E N. 1999. Factors affecting dairy production in the peri-urban areas of Kampala. *Uganda Journal of Agricultural Sciences*, 4: 7-11.

Tuwei, P.K., Kang'ara, J.N, Stewart, J.L, Ngugi, F. K. and Mueller-Harvey, I. 2003. Factors affecting biomass production and nutritive value of *Calliandra calothyrsus* leaf as fodder for ruminants. *The Journal of Agricultural Sciences*, Vol. 141. Part 1 August 2003.

Undi, M., Kawonga K.C. and Musendo R.M. 2001. Nutritive value of maize/pasture legume mixtures as dry season supplementation for sheep. *Small ruminant Research*, 40, 261-267.

Van Saun, R. J. and Sniffen, C. J. 1996. Nutritional management of the pregnant dairy cow to optimize health, lactation and reproductive performance. *Animal Feed Science and Technology*, 59, 13-26.

Van Soest, P.J. and Robertson, J.B. 1985. Analysis of forages and fibrous foods. A laboratory manual for Animal Science.613. Cornell University, Ithaca, NY.

Van Soest. 1982. *Nutritional Ecology of Ruminants*. O & B Books, Corvallis, OR.

Velarde, C.L., Quiroz, R. A., Darlo, R. E., Rocardo, C. and Miguel Holle. 2000. Evolving from Farming Systems Research to a more Holistic Approach, Experiences in the Angean Region. Paper presented for the workshop on "Developing the Basis of Rural Resource Management", ISNAR, The Hague, Netherlands, from 16 to18th February 2000.

Waisswa, C.D., Weisbjerg, M.R., Mutetika, D. and Hvelplund, F. 2003. Protein availability of some Ugandan feed resources for ruminants. In, Proceedings of the 30th Scientific Conference of Tanzania Society of Anima Production held at 4H Centre-

Tanga, October from 28th to 30th, 2003. TSAP(Tanzanian Society of Animal Production) Conference Series Vol. 30, (2003). pp. 138-147.

Wakhungu, J.W., Rege, J.E.O. and Itulya, S. 1991. Genetic and phenotypic parameters and trends in production and reproductive performance of the Kenya Sahiwal cattle. *Bulletin of Animal Health and Production in Africa*, 39, 365-372.

Walshe, M. J., Grindle J., Nell A. and Bachma M. 1998. Dairy Development in Sub-Saharan Africa, 1998 A Study of Issues and options. World Bank Technical paper number 135. Africa Technical Department Series.

Wandera, J.L., Kiruiro, E.M., Chemitei, V.C. and Bulimu, B.O. 1993. Factors limiting the use of fodders by smallholder dairy farmers in Kenya, Experiences from on-farm, farmer-managed, animal feeding trials. In: Ndikumana J. and de Leeuw, P. (eds). *Sustainable Feed Production and Utilisation for Smallholder Livestock Enterprises in Sub-Saharan Africa*. Proceedings of the Second African Feed Resources Network (AFRNET) Workshop held in Harare, Zimbabwe, from 6th to 10th December 1993. pp. 40-43.

Wanyama, J.M., Muyerkho, F.N., Masinde, A.A.O., Cheruiyot, D.T., Odongo, J., Ojowi, M. and Okeyo, R. 2003. Assessing factors influencing adoption of pastures and fodders amongst smallholder subsistence farmers in selected districts. *Tropical Grasslands,* 37, 219-226.

Weisbjerg, M.R., Waisswa,, C.D., Mutetikka, D. and Hvelplund, T. 2003. Protein availability of some locally available feed resources. Proceedings of the Livestock Systems Research Programme Annual workshop held at Kampala, from 18th to 20th March, 2003,

Whisnant, C.S., Kiser, T.E., Thompson, F.N. and Hall, J.B. 1985. Effect of nutrition on the LH response to calf removal and GnRH. *Theriogenology,* 24, 565-573.

Winrock International 1992. Animal Agriculture in Sub-Saharan Africa. Winrock International, Morrilton, Arkansas, USA.

Woulters, A.P. 1985. Fodder production for zero grazing, Recent research findings. Paper presented at the Animal Production. Society of Kenya Symposium on zero-grazing for Milk Production. Kabete, 22nd November 1985.

Zerbini, E. and Gemeda, T. 1994. Effect of work on dry matter intake, milk production and reproduction in multipurpose cows fed low quality roughage. *Livestock Research for Rural Development,* 6, 10-14.

Zinn, R. A., and F. N. Owens. 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. *Canadian Journal of Animal Science*. 66,157–166.

6. APPENDICIES

Appendix 6.1: Map of Uganda showing location of Masaka district

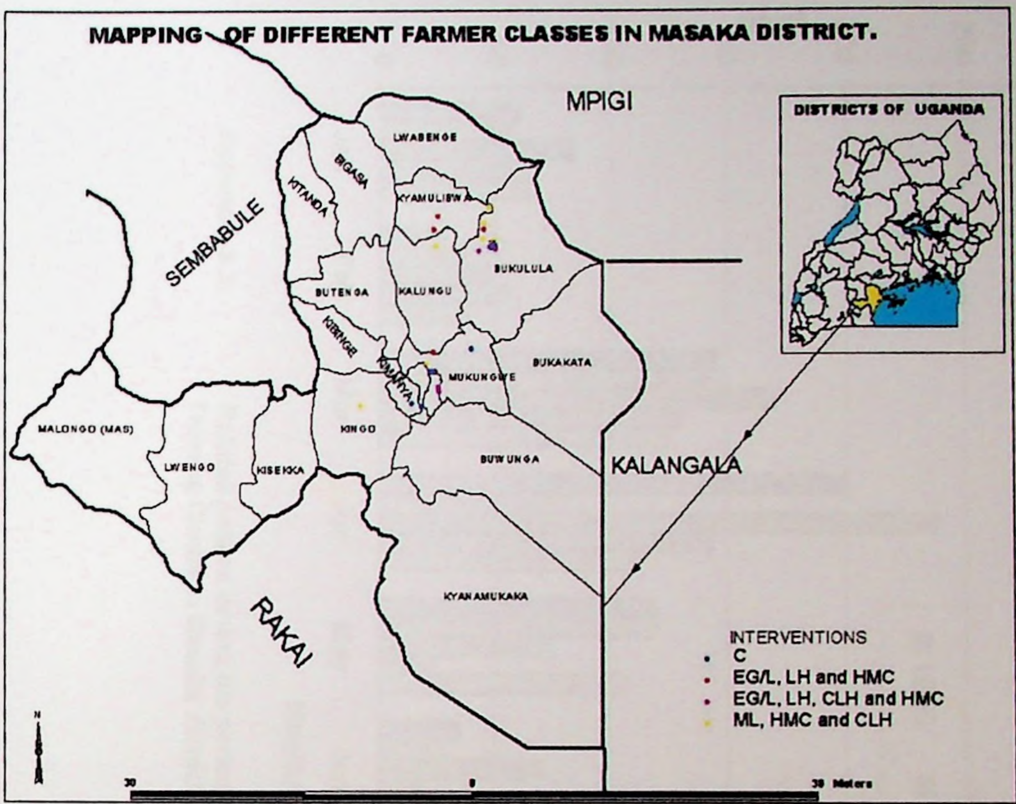
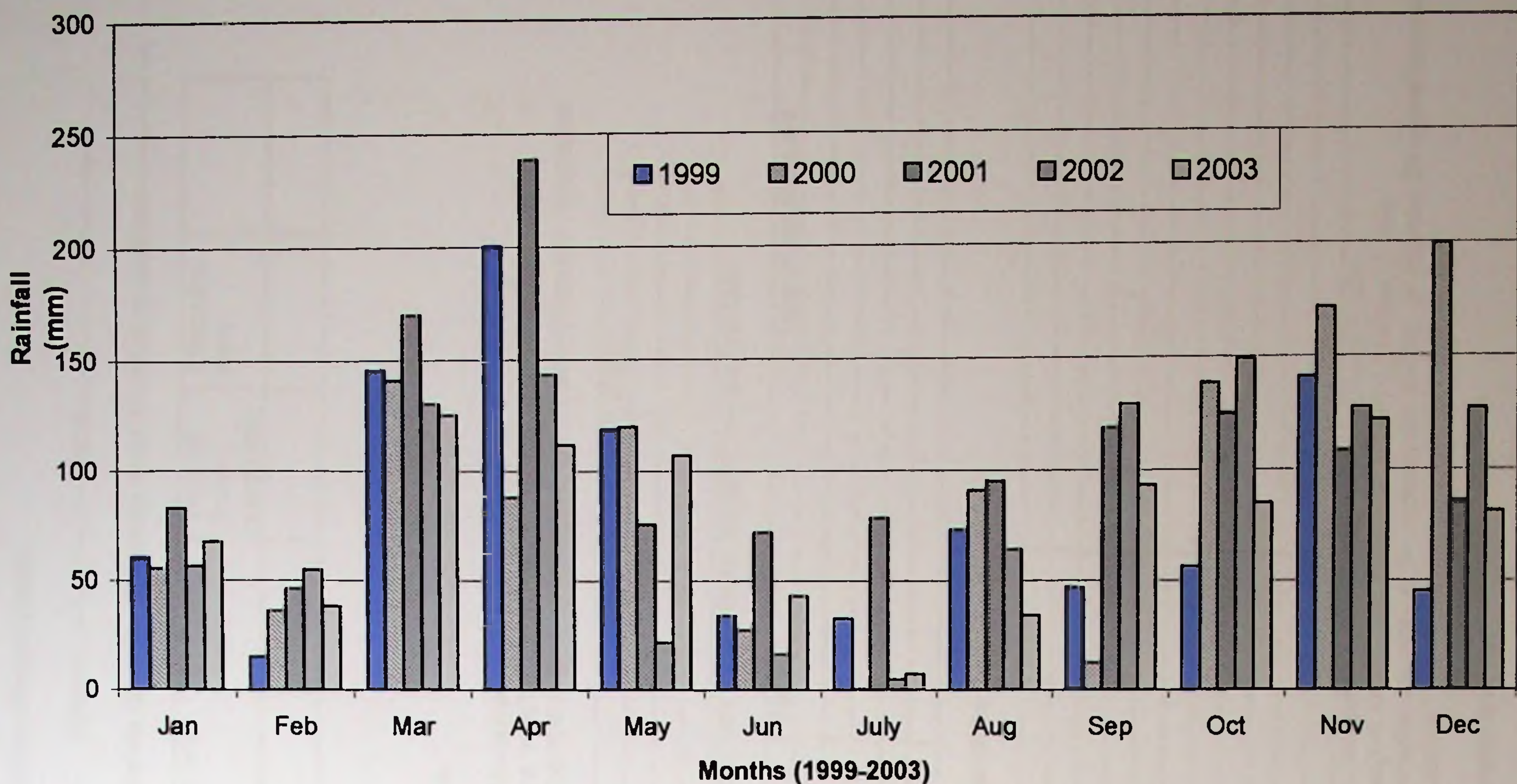


Figure 6.2: Map of Masaka district showing location of farmers who participated in the study



Appendix 6.3: **Rainfall pattern during the period of 1999 to 2003 at Kamenyamigo District Agricultural and Training Centre in Masaka district**

APPENDIX 6.4: SURVEY QUESTIONNAIRE: CHARACTERIZATION OF INTENSIVE SMALLHOLDER DAIRY CATTLE PRODUCTION IN MASAKA DISTRICT, UGANDA

Section A: Household and farm characteristics

a. County--------------------- Village--------------------- Parish--------------------------------

b. Provide the following details about the household head: Name of respondent-----------------

Sex	Age (yrs)	Marital status	Years of farming experience	Education level	

c..Main occupation
d.Off-farm activities

B. Household (HH) structure

i) Is the HH head the farm owner? [ ] if not, who is the farm owner? [ ]
ii) Is the HH a female or a male?
iii) Give number of HH members (incl. HH head) living permanently on the compound

Age categories	Males	Females	Total

iv) Activities of adults other than the HH head, including on- and off-farm

Adults	Sex	Type of employment

C: Farm activities and facilities

1. Grazing	
2. Collecting feed/fodder	
3. Planting forage	
4. Weeding forage	
5. Manuring forage	
6. Cleaning barn	
7. Milking	
8, Selling milk	
9. Preparing food	

i) If you employ long term labourers, how much do you pay them? [Ushs]
ii) Does the farm own transport for the farm related activities? [ ] 1=Yes; 2 =No
iii) If yes, which one (s) 1=tractor, 2= pick-up; 3= motorcycle; 4= car; 5= bicycle; 6= wheel barrow; 7= animal drought; 8= others

D. Land resource, ownership and use

a) Land ownership: 1=customary; 2=leasehold; 3= institutional; 4= rented; 5= titled; 6= milo land
b) Distance (km) of the farm to:

i) a road open to vehicles all year
ii) a seasonally passable road
iii) marketing center

c) What is the total land size in ha?
d) How many plots is it divided into?

Area in Ha	
fodder crops	
Food crops	
Fallow	
Forage legumes	
Number of fodder trees	
Other crops	

a. Which forage crops are you growing?

Forage crops	Acreage

b. Which fodder trees are you growing?

Fodder trees	Number/acreage

c. Which food crops are you growing?

Food crops	

4. Livestock inventory

a) Cattle

Cattle type	**Breed**			
	Local	Crosses	Exotic	Totals
Lactating cows				
Dry cows				
In-calf heifers				
Steers				
Bulls				
Heifers				
Calves				

b) **Breeds and number of cattle on the farm**

Breed	Breed			
	Calves	Heifers	Lactating cows	Dry cows
Friesians				
Jerseys				
Guernsey				
Crosses				

5. Feeds and feed management systems

a) What is your feeding system? 1= Stall-feeding; 2= Semi-Intensive; 2 =tethered

a) Which are your main sources of feed and when are they used? Place "X" in the boxes which correspond to the answers

Type	**Source**	**Dry season**	**Wet season**	**All year**		
Grasses	Own land					
	Public land					
	Purchased					
	Others					
Crop residues	Own land					
	Public land					
	Purchased					
Concentrates						
Agro-industrial by products						

c) Do you experience feed shortages? If yes, when?
1= Wet season; 2= dry season; 3= all year round

6. Source of planting materials

1= individual; 2 = from my farm; 3= farmer-to-farmer; 4 = group to group; 5 = from institution

7. Production costs

Activity	**Cost/ha**	**Who does it (Men, women, girls, boys, hired labour)**	
Land preparation			
Planting			
Weeding			
Fertiliser application			
Harvesting			
Feeding			
Others			

Estimated yield of planted fodder

8. Fodder utilization

a) Is fodder chopped before feeding it to the animals? 1=Yes; 2=No
b) Frequency of feeding 1 = ad libitum; 2= 3 times/day
c) Quantity of feed fed to animals (kg/day)

9. Do you use supplements for lactating cows? 1 =yes; 2 =no; is yes which ones?

Type	Source	Time of feeding	Average quantity given	Method of feeding	Others

9. What are your major constraints to utilization of:
    a) Concentrates
    b) Forages?

10. Do you conserve fodder? 1=yes; 2=no

11. If not, what strategies do you use to feed animals during periods of feed shortages?

12. Milk yield

Cattle breed	Dry season	Wet season		

How much milk do you use for:
a) home use
b) Calves
c) Sold
d) Given away

What is the cost of milk during the wet and dry season?

13. What are some of the strategies you use to improve feed resource availability and overall animal productivity? 1=on-farm trials/demonstrations; 2= training; 3 =farm tours; 3 =others

14. Would you be interested in participating in on-farm trials? 1= Yes; 2= No
If yes, what would be your contribution towards the maintenance of the trials? 1= purchase of seed; 2=labour; 3= land

Appendix 6.5: Least square mean values for major soil chemical properties before and after the forages were tested on smallholder dairy farms in Masaka district

		Period of study (Mean±SEM)			
Soil properties (mg/100g soil)	Forage	Before the trials	After the trials	SEM	Percent change
pH	C	6.30±0.11	6.04±0.07	0.045	-5.3
	EGL	5.85±0.16	6.05±0.09	0.045	+3.4
	L	6.26±0.15	6.36±0.13	0.045	+1.6
	ML	6.41±0.12	6.16±0.12	0.045	-3.9
OM	C	2.22±0.06	2.76±0.23	0.064	+24.3
	EGL	2.74±0.07	2.85±0.21	0.064	+4.0
	L	3.08±0.08	3.17±0.07	0.064	+2.9
	ML	3.07±0.08	3.54±0.19	0.064	+15.3
N	C	0.15±0.01	0.14±0.01	0.0030	-3.4
	EGL	0.14±0.01	0.15±0.01	0.0030	+7.1
	L	0.14±0.01	0.15±0.01	0.0030	+7.1
	ML	0.15±0.01	0.14±0.01	0.0030	-8.1
AVP	C	4.29±0.23	3.05±0.36	0.141	-28.9
	EGL	3.79±0.27	2.42±0.08	0.141	-36.1
	L	4.62±0.26	2.54±0.22	0.141	-45.0
	ML	4.30±0.37	2.18±0.08	0.141	-49.0
Ca	C	6.33±0.57	5.56±0.18	0.141	-12.2
	EGL	6.35±0.38	4.26±0.03	0.141	-32.9
	L	6.43±0.37	5.42±0.41	0.141	-15.7
	ML	5.71±0.21	5.39±0.22	0.141	-5.6

C=Calliandra; EGL=Elephant grass/legume mixtures; L=lablab; ML=maize/lablab intercrop; OM= Organic matter; N= Nitrogen; AVP= Available phosphorus; Ca=Calcium;
SEM= Mean±Standard Error of the Mean

Appendix 6.6: Total scores for the proposed on-farm forage technologies and energy supplements

	Total Score	Ranking
Forage technologies		
Basal forages		
Sole elephant grass with Maize/lablab stover	210	1
Elephant grass/legume mixtures	120	2
Setaria anceps/legume mixture (basal diet)	12	3
Tripscum laxum (Guatermala)	11	4
Protein supplements		
Calliandra callothyrsus leaf hay	190	1
Lablab purpureus hay	187	2
Gliricidia sepium	37	3
Sesbania seban	35	4
Leucaena leucocephola	2	5
Energy supplements		
Homemade concentrate	191	1
Commercial concentrates	91	2

Appendix 6.7: Establishing, managing and sampling elephant grass/forage legume mixtures

Poorly managed elephant grass fodder

A farmer removes weeds between grass rows where the forage legumes have been introduced

Elephant grass/legume intercrop, 10 weeks after introducing the forage legumes

Participatory sampling for biomass yield

Appendix 6.8: Production, management, conservation and utilization of maize/lablab fodder

60 days after introducing lablab seed into maize

About 3 months after planting maize seed

4 months after planting maize seed

Maize cobs being removed from maize/lablab residues

Drying maize cobs and maize/lablab stover in the background

A cow feeding on maize/lablab stover mixed with fresh elephant grass fodder

Appendix 6.9: Production, management and conservation of lablab fodder

a) Lablab purpureus cv Rongai fodder bank

b) Harvesting lablab herbage (about 90 days after planting)

c) Drying lablab foliage

d) A baling box with sisal strings for tying the bales

e) A bale of lablab hay

f) Bales of lablab hay stored on a rack constructed below the roof of a cow shed

Appendix 6.10: Production and conservation of calliandra fodder

Calliandra calothyrus tree

Calliandra trees planted as a hedgerow

A farmer drying calliandra (leaves and stems) on cemented floor

Dry leaves being separated from the stems

Calliandra leaf hay

Appendix 6.11: Estimated cost of production (Ushs per kg) of fodder on smallholder dairy farms

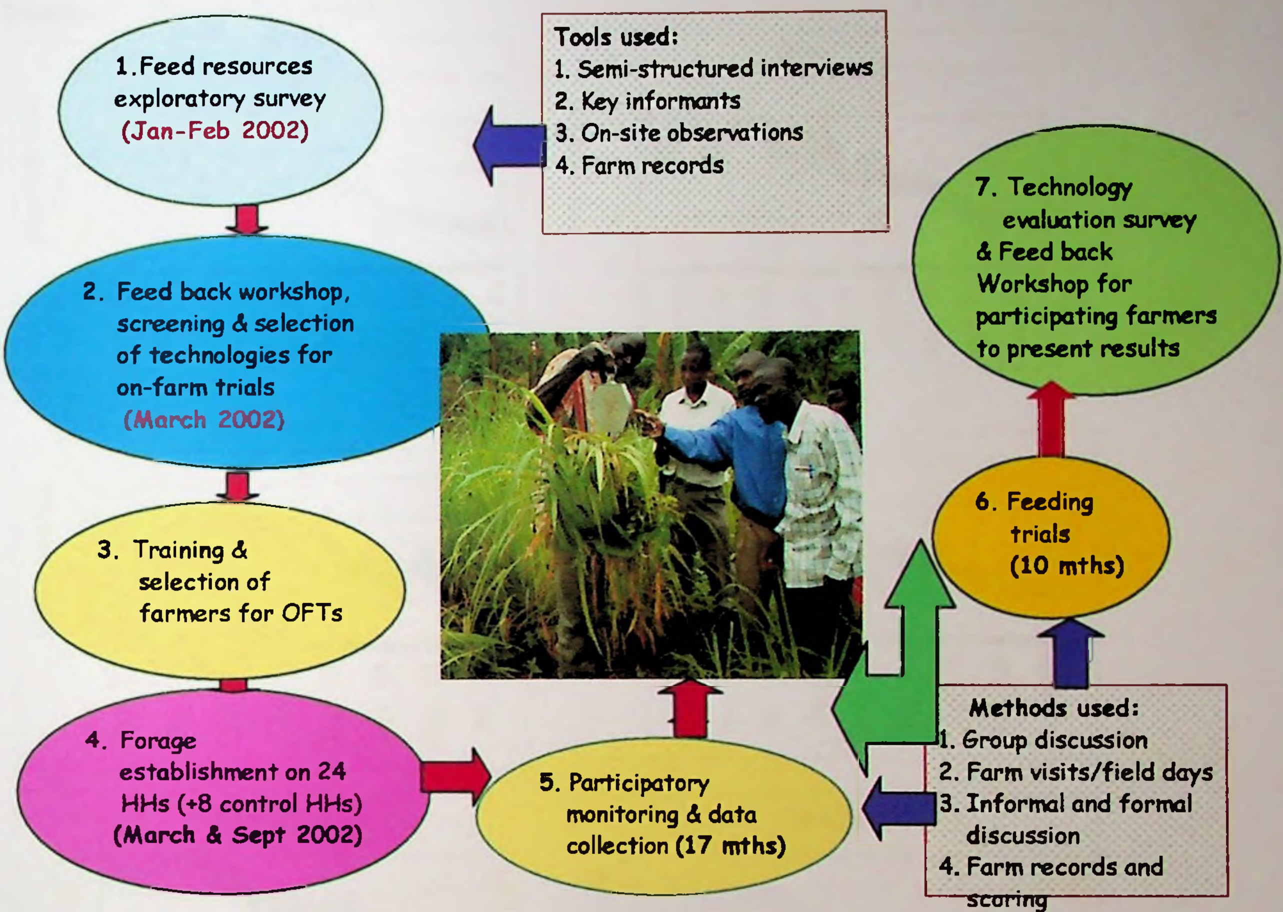
Parameter	Forages			
	Elephant grass/ legume mixture	Maize/lablab intercrop	Lablab hay	Sole elephant grass
a) Land preparation	100,000	100,000	100,000	100,000
b) Cost of seed				
i) Forage legume seed (for mixtures)	22,000	0	0	
ii) Lablab seed	0	30,000	0	0
iii) Elephant grass cuttings	60,000	0	0	0
iv) Maize seed	0	96,000	0	0
c) Planting				
Elephant grass	30,000	30,000	0	30000
Legumes in mixtures	20,000	0	0	0
Lablab	0	20,000	20000	0
Maize	0	20,000	0	0
d) Manure application	50,000	50,000	50,000	50,000
e) Weeding				
Elephant grass (7 times/year)	800,000	320,000	0	600,000
Maize/lablab intercrop	0	120,000	0	0
Lablab	0	0	120,000	0
h) Harvesting, drying & conservation				
Maize grain	0	50,000	0	0
Maize/lablab stover (twice)	0	200,000	0	0
Lablab hay	0	0	150000	0
Construction of a rack for storing hay	0	30,000	30000	0
Miscellaneous	50000	50000	50000	50000
TOTAL	**1,132,000**	**1,116,000**	**520,000**	**830,000**
Estimated yields (kg/ha)	12,210	5900	2500	10,024
Average cost per kg of fodder (Ushs)	95	190	210	85

Appendix 6.12: Average total fodder (kgs) consumed per cow during the study period (360 days)

	EGL + LH + HMC	EGL + LH + CLH +HMC	EGML + CLH + HMC	Farmer's practice
Fodder consumed (kgs for 360 days)				
Elephant grass /legume mixture	2,436	2,400	0	0
Sole elephant grass	0	0	1,656	2,547
Lablab hay	486	273	0	0
Calliandra leaf hay	0	360	360	0
Maize/lablab stover	0		1,219	0
Homemade concentrate	1,260	1,260	1,260	0
Yields/Outputs				
Mean yield (per farm)				
Maize grain (kg/ha)	0	0	3,000	0
Total Milk yield produced (lts)	3,656.50	3,872.50	4,307	2,833
Extra liveweight gained (kgs)	31.1	28.1	37.1	19.4

Appendix 6.13: Prices used in the calculations

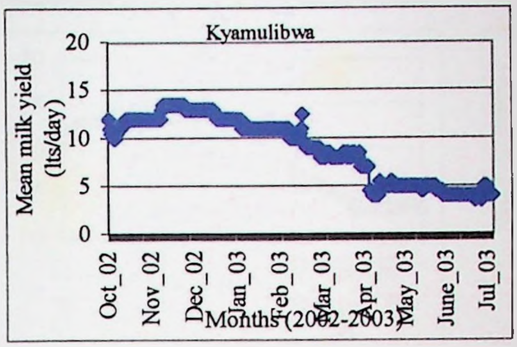
Item	Quantity	Rates (Ushs)	Total cost (Ushs)
a) **Legume seed**			
Siratro	0.5 kg/ha	8,000	4,000
Centro	0.5 kg/ha	6,000	3,000
Desmodium	0.5 kg/ha	30,000	15,000
Lablab	6 kgs	8,000	48,000
Elephant grass cuttings	10,000 cuttings	3	30,000
Maize seed (for 2 seasons)	8 kgs	1,200	96,000
Calliandra seedlings	500	100	50,000

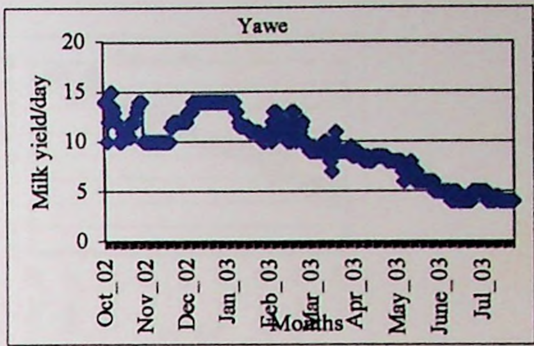


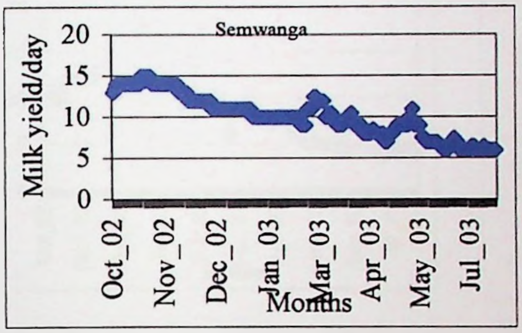
Appendix 6.14: **The participatory approach used during the testing and evaluation of forage legume technologies**

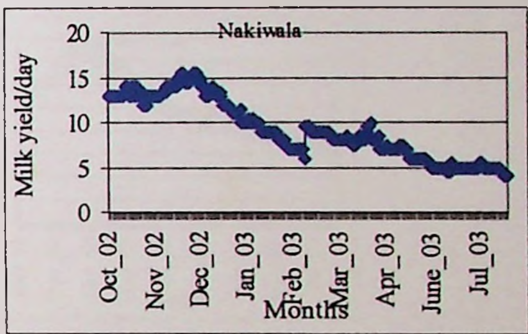
Appendix 6.15: **Lactation curves for 32 experimental cows used in the study during the period of 2002-003**

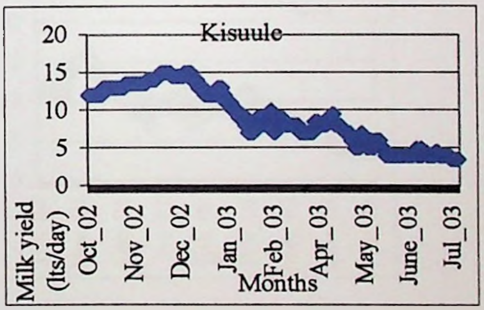
Treatment 1: EGL + LH + HMC

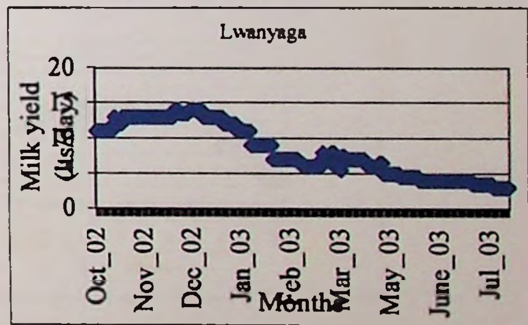


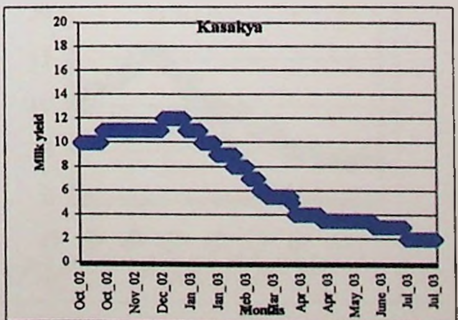


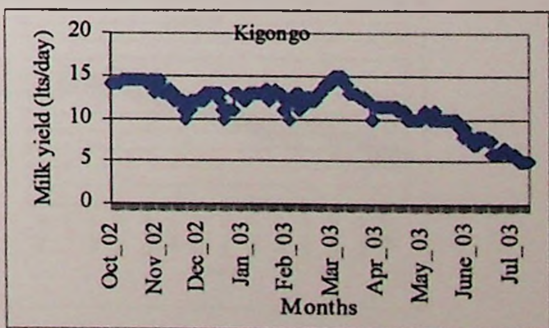




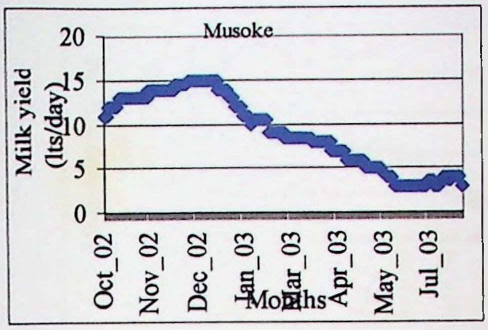


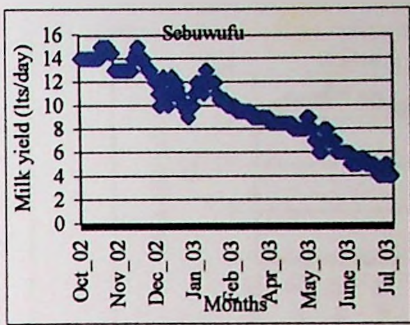


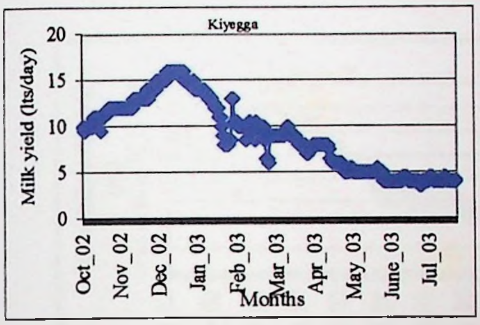


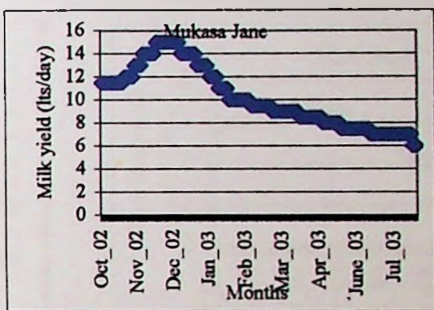


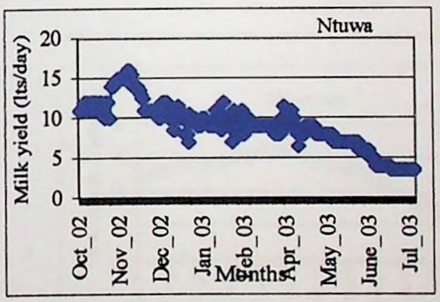
Treatment 2: EGL + LH + CLH + HMC

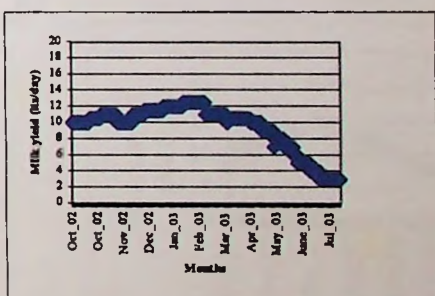


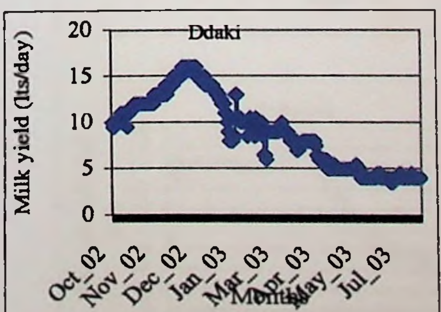


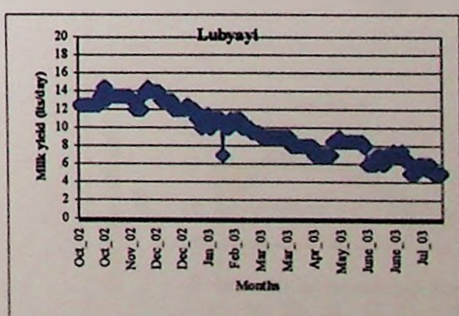




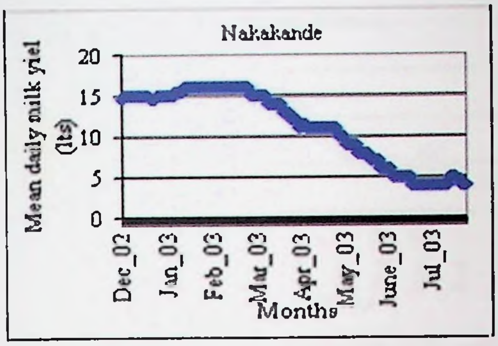


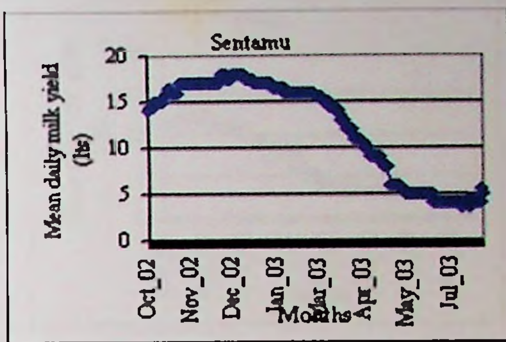


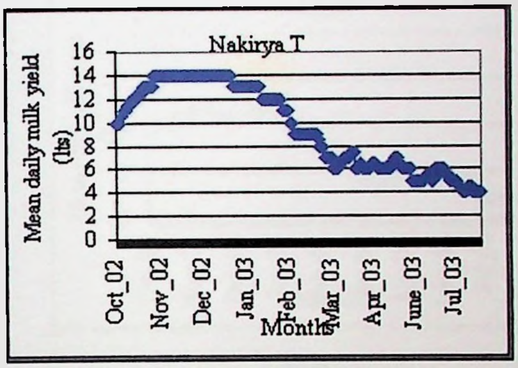


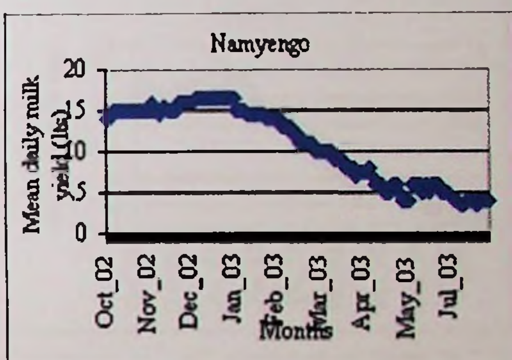


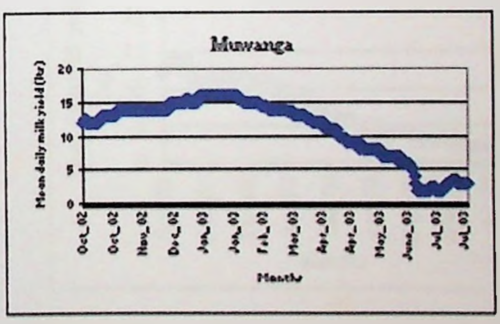
Treatment 3: EGML + CLH + HMC

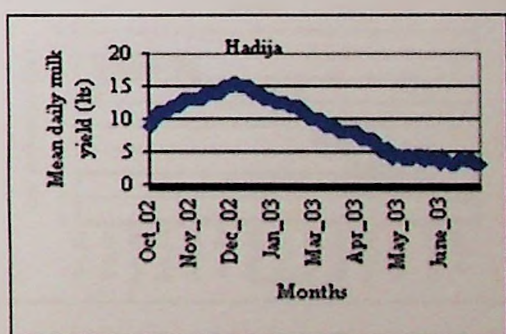


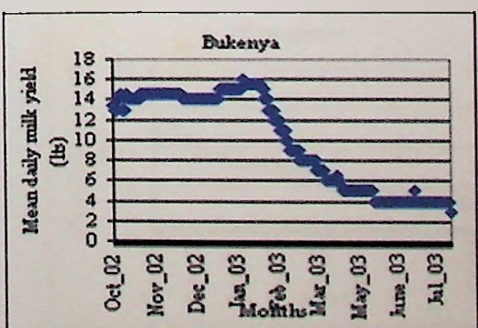


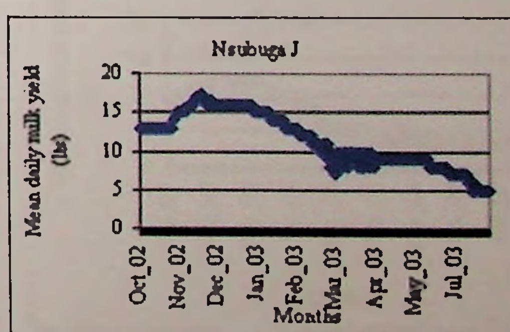




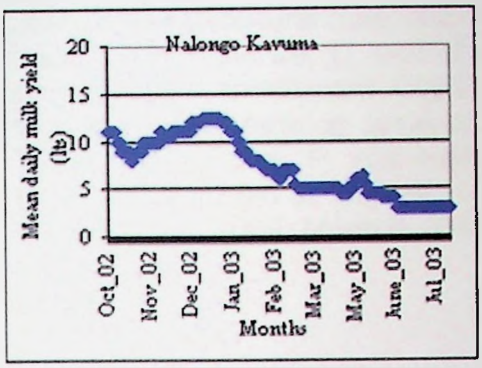


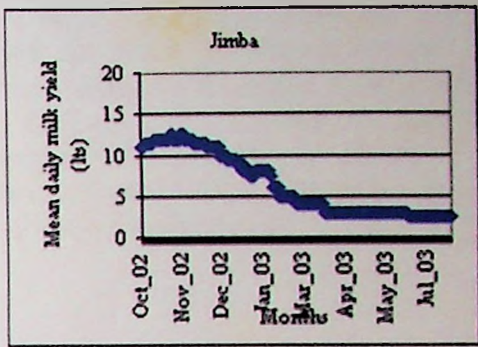


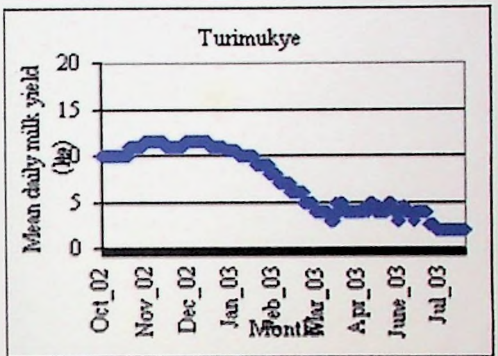


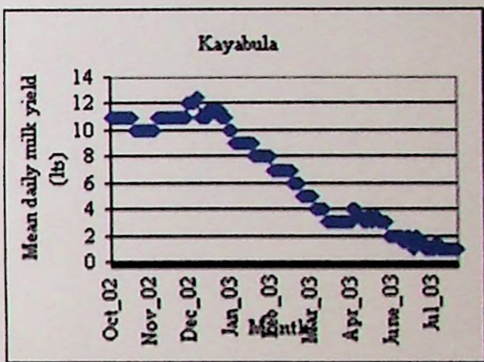


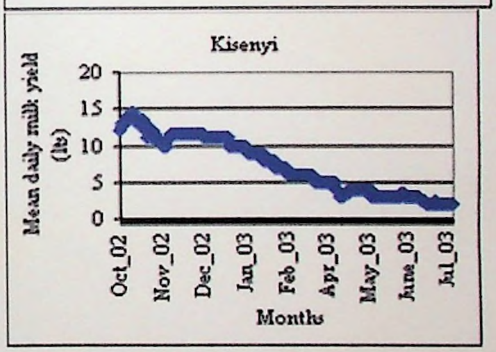
Treatment 4: Farmer's practice (sole EG)

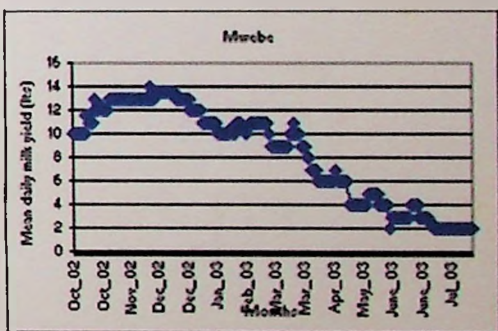


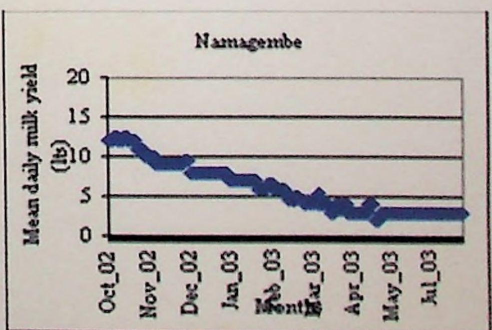


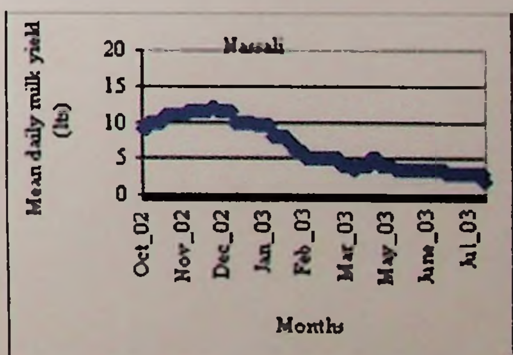












Appendix 6.16: Papers published in referred journals

1. Kabirizi, J., Mpairwe, D. and Mutetikka, D. 2004. Testing forage legume technologies with farmers: A case study of Masaka district, Uganda. *Uganda Journal of Agricultural Sciences*. Vol. 9. No.3.September 2004. pp. 906-913.
2. Kabirizi, J., Mpairwe, D. and Mutetikka, D. 2005. Improving fodder and food production in smallholder crop/livestock farms in `Uganda: Integrating forage legumes in the farming systems. In: Tenywa, J.S., Adipala, B., Nampala, P., Tusiime, G., Okori, P. and Kamuhangire, W. Proceedings of the 7th African Crop Science held at The Imperial Resort Beach Hotel, Entebbe Uganda from 5th to 9th Dec. 2005. *Uganda Journal of Crop Sciences* Vol. 7. pp. 119-121.