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Effect of intercropping forage legumes with elephant grass on fodder production in intensive smallholder dairy farms in Uganda

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Abstract

Small holder dairy production based on elephant grass (Pennisetum purpureas) stall fed to crossbred (Bos taurus x Bos indicus) cows has been introduced in Uganda to improve household nutrition and income of the poor. Legimunous forage crops are cheap and convinient sources of proteins. A study was conducted in Masaka district of Uganda to determine the benefits of intercropping forage legumes with elephant grass under "real farm" situations. The results showed that intercropping increased forage yield by 22% and grazing time by 137 days. Total fodder dry matter yields was 12% higher in the wet than in the dry season. Legume dry matter yields between the wed and dry seasons did not differ significantly ($P \geq 0.320$). Protein contents and yields were also 1.3 and 1.4 times higher in the intercrops than in the monocrops. The study indicated that 0.405 ha of sole elephant grass was not sufficient to sustain a lactating cow for one year. Therefore the recommendation needs to be revised to 1.1ha of elephant grass in pure stand or 0.9 ha of forage legume intercrops. In eithere case, there is need for supplementary protein and energy to meet the demands of high producing cows.

Introduction

High human and animal production densities in some areas of sub Saharan Africa, such as Uganda, and the consequent increasing demand for food and feeds have led to permanent cultivation of more land, reduction of grazing and forest lands to expand crop production, and disappearance of traditional practices that formally allowed land to fallow (Ndikumana and de Leeuw 1996; Walshe *et. al.,* 1998). Nutrient balances are negative in many production systems (Romney *et. al*., 2003). Organic and inorganic fertilizer are used in insufficient amounts to prevent nutrient mining. Fertilizers and good quality feeds are too costly and inaccessible to poor farmers in the absence of credit provision. New and innovative crop, livestock and soil technologies for efficient recycling of nutrients among crops, animals and soil are crucial to sustain productivity of low-input mixed farming systems that dominate in the region.

Previous studies conducted in Uganda have shown that intensive dairy cattle production system using improved cattle breeds is an economically viable enterprise for income generation in resource poor households in Uganda (LSRP, 2000; Mwebaze, 2000). The realization of potential economic benefits however is impeded by inadequate year-round feed supply, resulting in protein and energy deficits and low animal productivity. Major feed resources for dairy cattle are low quality elephant grass fodder and crop residues either produced on-farm, transported from public land or purchased. However a significant component of this technology, lack the forage legume component in most production systems because farmers believe that intercropping forage legumes with elephant grass reduces the yield of elephant grass (LSRP, 2000). Intercropping elephant grass with forage legumes improves the quality and quantity of fodder (Mubiru *et. al.* 2001; Mwangi, 2002). Therefore, the main objective of this study therefore was to assess the effects of inter-row planted forage legume crops in *P. purpureum* on fodder quality and yields in smallholder dairy farming systems.

Materials and Methods

Study area and Selection of farmers

The study was conducted in four sub-counties (Kingo, Katwe/Butego, Bukulula and Kalungu) of Masaka district. The sub-counties were selected based on the number of farmers who expressed interest in participating in on-farm research to test elephant grass/legume mixtures for improved animal productivity. During a baseline survey (Kabirizi, 2002), sixteen (16) households were selected to participate in the trials based on the following criteria: (i) having a minimum of 0.5 ha of well established and managed elephant grass field (ii) availability of land and labour to plant and manage the fodder fields.

Discussions were held with the farmers on the objectives of the trials and the tasks they were expected to perform. Through seminars and farm visits, farmers were trained in various aspects of fodder management, data collection and recording.

Production, harvesting, sampling and measurement of DM yields and nutritive value of elephant grass with and without forage legumes

At the beginning of March 2002, each of the 16 households selected received seeds of *Desmodium intortum* (green leaf desmodium), *Macroptilium atropurpureum* (siratro) and *Centrocema pubescens* (centro) to sow on 0.5 ha of an already established elephant grass field. The seed rates were 3, 2 and 1 kg ha^{-1} of centro, siratro and desmodium respectively. The seeds were supplied by the project. The forage legumes were planted where elephant grass fodder had been harvested and the ground dug to leave only the stools. The variety of elephant grass that was planted on all the farms was "*Kawanda* 4 (KW4)", recommended by the various in-calf Heifer Projects. At sowing time, the three legume seed types were thoroughly mixed together and sown between elephant grass rows. The farm owners weeded the fields manually as necessary. They were encouraged to applycompost manure to the fields to improve soil fertility and fodder DM yields.

First sampling was done in mid May 2002, 10 weeks after planting the legumes and this continued every 45 days for 17 months. Herbage biomass yield was estimated by cutting fodder at ground level from three 1m x 1m randomly selected quadrates and weighed. At each harvest, three elephant grass plants were randomly selected from each quadrant for dry matter determation and chemical analysis. The harvested material was weighed and then separated into elephant grass fodder and legume species.

Sub-samples of about 0.3kg of each material were randomly taken, weighed and later oven dried at 60^{o}C to constant weight for 72 hours. Samples for chemical analysis were ground, sieved through a 1mm sieve and stored in airtight bottles.

Chemical analysis

Samples were analyzed for crude protein (CP) using A.O.A.C. (1990) methods. Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) were analysed using Van Soest and Roberts (1985) methods and. *In vitro* dry matter digestibitiy (IVDMD) by the Tilley and Terry (1963) technique. Crude protein yield (CYP) was calculated as the product of fodder DM yield and CP percentage. Calcium (Ca) and Phosphorus (P) contents were determined by first digesting the samples with a tri-acid mixture of surphuric acid, perchloric and nutric acids (Okalebo *et. al.*, 1993). Then Ca was assayed using an atomic absorption spectrometer and P content was determined using the ascorbic acid procedure. Metabolisable energy (ME) was estimated using a regression equation developed by Close and Menke (1986). ME (MJ/kg DM) = 0.15*IVDMD; where IVDMD = *in vitro* organic dry matter digestibility (%). Crude protein yield (CPY) was calculated as the product of DM yield and CP percentage.

Statistical Analysis
All data collected were captured and stored in Excel Spread Sheet Computer Software. The variables were Elephant Grass and forage legumes (EGL), and elephant grass monocrops (EG).

Chemical components were CP, CPY; IVOMD; ME; Ca; P and ME. Statistical analyses were carried out using a General Linear Model (GLM) procedure for Randomized Complete Block Design (RCBD) using SAS (Statistical Analytical Systems) (1999). The data collected were subjected to analysis of variance (ANOVA). The model used in the analysis was:
$Y_{ij} = \mu + P_i + S_j + H_k + PS_{ij} + e_{ijk}$, where:
Y_{ij} = fodder or grain yield or chemical component, μ = Overall mean; P=Effect of i^{th} Practice (P), 1-2 (monocrop; intercrop);
S=j^{th} Season [dry and wet]; H_k = k^{th} Household/plot (4 households x 3 plots);
PS_{ij} = the interaction between the i^{th} Practice at j^{th} Season; e_{ijk} =Random error

RESULTS AND DISCUSSION

Effects of elephant grass/forage legume intercropping on total fodder dry matter yield
Results on the effects of elephant grass/forage legume intercropping on fodder dry matter (DM) yields are shown in Table 1 and Figure 1.

Although the initial growths of the forage legumes in elephant grass fields was slow, siratro and desmodium established well but centro established very poorly in all the fields. Mwambi and Wambugu (2003) reported that elephant grass tillers tend to suppress the growth of forage legumes like centro in the establishment phase by limiting the amount of light. In this study, siratro and desmodium might have survived because they tolerate shading (Mureithi and Thorpe, 1993).

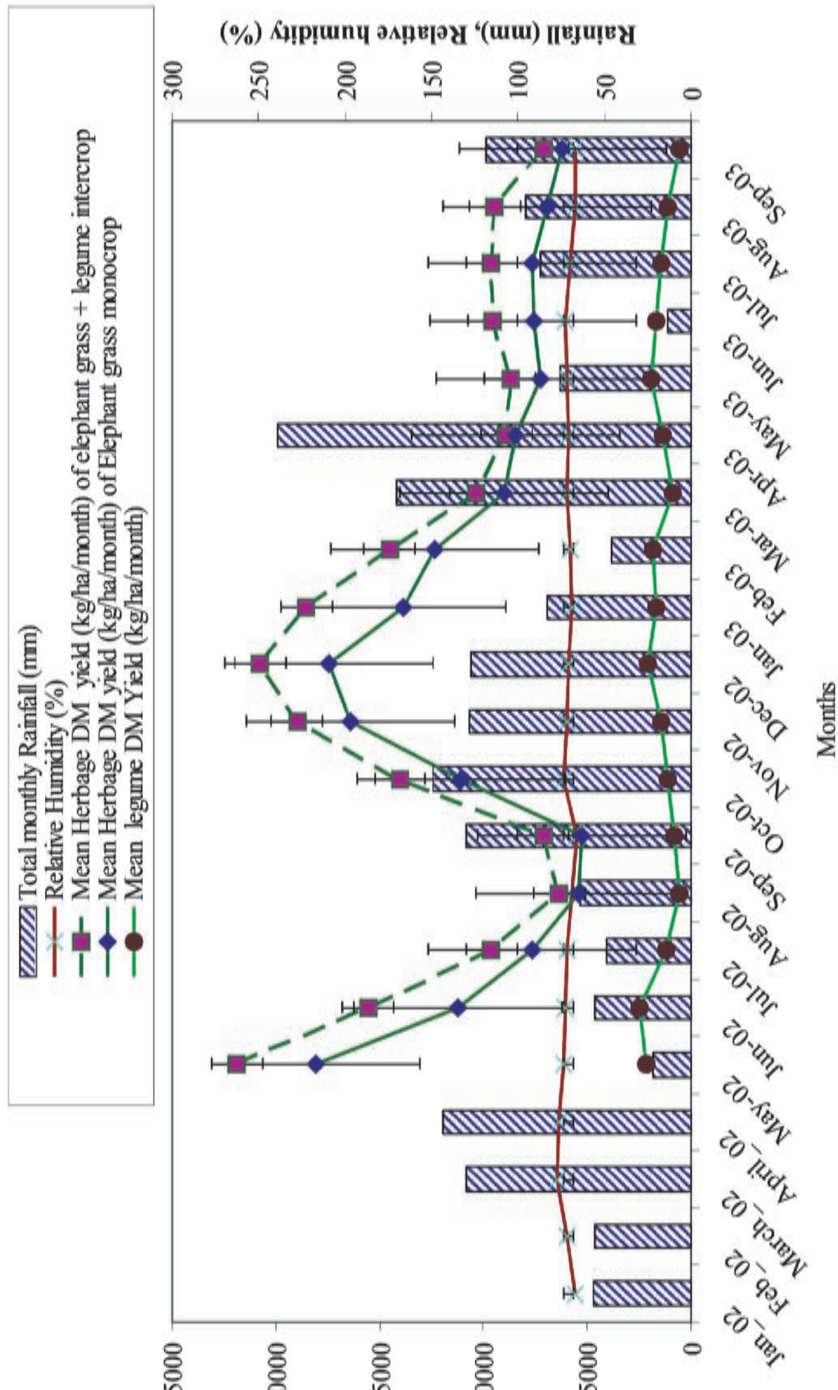
Mean height, total fodder yields in intercrops (EGL) and monocrops (EG) at all harvests were significantly ($p<0.0001$) higher (by 11.5; 21.8 and 7.3 percent) in intercrops than in monocrops. There was a high correlation (R^2=0.93) between total EGL dry matter yield and the DM yield of forage legumes in the intercrops. The higher growth rate of elephant grass plants and higher total DM yields in intercrops compared to monocrops indicated that: i) the presence of the

Table 1: Effects of intercropping forage legumes with elephant grass on height and yield components

Parameter	Monocrop	Intercrop	SEM
Plant height (cm)	79.1±1.60	88.2±1.47	0.93
Dry matter yield (kg ha^{-1})			
• Elephant grass	10,024.0±245.08	10,752.7±279.63	112.01
• Desmodium	-	892.3±36.46	-
• Siratro	-	430.3±24.04	-
• Centro	-	135.6±9.18	-
• Total DM Yield	10,024.0±245.08	12,210.9±303.78	224.46
Percentage of legumes	-	11.9±0.435	-
Percentage change in DM Yield	-	21.5±0.817	-

(Mean ±SEM) Standard error of the the mean

Figure 1: Monthly Herbage Dry Matter (DM) yields, rainfall and relative humidity on Small Holder Diary Farms in Masaka District (January 2002 - September 2003)



legumes enhanced the growth of elephant grass plants and improved total fodder DM yield; ii) total productivity per unit of land was greater in intercrop than in monocrop and/or improvement in total DM yields have been reported in elephant grass/legume intercropping systems (Mubiru *et. al.* 2001). However, Mureithi and Thorpe (1993); Katuromunda (2001); Mwangi and Wambugu (2001) and Mwangi (2002) reported no significant differences in fodder DM yields when a grass was intercropped with forage legumes. Mureithi and Thorpe (1993) and Mwangi (2002) noted that the higher DM yields in intercrops were the additive effects of the legume DM rather than the effects on elephant grass performance and that the intercrops were possibly utilizing resources (soil and space) more effectively resulting in a higher forage DM yield. The change in total DM due to intercropping elephant grass with legumes was about 22%.

Mean percentage of legumes in intercrops was less (about 12.0%) than 30%, a level that is recommended in grass/legume mixtures (Kabirizi, 1996). Overall, total DM yields of the intercrop was significantly higher ($p= 0.0343$) during the wet (6,488.72 ±224.46 kg ha^{-1}) than in the dry season (5,722.2±224.46 kg ha^{-1}), but there were no significant ($p= 0.3968$) differences in total DM yield of legumes and the proportion of legumes in intercrops during the dry season (780±82.56 kg ha^{-1} and 6.6% respectively) and wet season (677 ± 82.56 kg ha^{1} and 5.7% respectively). The higher overall DM yields of legumes in dry season than in wet season might have been due to: i) rationing of the forage legumes during the dry season when farmers harvested a small part of the field at a time with an intention of allowing the legumes more time to produce more foliage; ii) some farmers irrigated the legumes and; iii) DM yields of elephant grass during the dry season were very low, hence the shading effect on the legumes was small.

On the other hand, the low legume fodder DM yields in the intercrops during the wet season could have occurred as a result of shading effect of elephant grass on the legumes. The elephant grass had already put on leaves again by the third week after cutting. It was also observed that elephant grass had formed extensive rooting system that could have enabled it to out-compete the legume seedlings. Katuromunda (2001) reported that unlike forage legumes, grasses with extensive roots in the soil have a competitive advantage in acquisition of nutrients in the surface soil. Grass root residues might also have had a strong negative effect on legume growth. However, Mwangi, (2002) observed that studies in Kenya

Table 2: Effects of intercropping elephant grass with forage legumes on chemical Composition and *in vitro* dry matter digestibility of fodder (Mean±SED)

	Elephant grass fodder DM yield (Mean±SEM)		
***Chemical composition (% DM)**	**Monocrop**	**Intercrop**	**SEM**
Dry Matter content	18.9±0.20	18.5±0.20	0.14
Crude Protein	7.4±0.085	8.4±0.074	0.06
Crude Protein Yield (kg/ha/yr)	809.0±32.90	1163.3±55.42	35.9
Organic Matter	90.2±0.181	90.6±0.20	0.14
Neutral Detergent Fibre	65.7±0.27	63.1±0.27	0.21
In vitro Dry Matter Digestibility	60.1±0.08	62.0±0.11	0.09
Calcium	0.23±0.003	0.33±0.003	0.004
Phosphorus	0.22±0.004	0.25±0.006	0.004
*Metabolizable energy (MJ/kg DM)	9.2±0.01	9.4±0.01	0.011

Means within the same row with different superscripts differ ($p<0.05$); SEM: Standard error of the difference between the means; ME = 0.15*IVDMD (Close and Menke, 1986) have so far failed to lead to the identification of a practical on-farm management system capable of maintaining the legume at a proportion high enough to have any effects on overall forage nutritive quality while at the same time maintaining total fodder yield.

The absence of consistent beneficial effects of legumes on DM yields of the associated grasses has been recorded in other studies in the tropics (Ezenwa and Aken'ova, 1998). Akinyemi and Onayinka (1976) noted that it might be related to low amounts of N transferred from legumes to grasses, and/or the competitive effects of the legumes in the mixtures. Plant height and DM yield of elephant grass fodder in intercrops and monocrops significantly ($p=0.001$) increased during the wet seasons probably due to high soil moisture content and decreased ($p<0.0001$) during the dry seasons due to low moisture content.

In this study, desmodium proved to be the most suitable forage legume to be grown together with elephant grass. It significantly contributed ($p<0.0001$) about 61.2% of the total DM yield of the legumes in the intercrop while siratro and centro contributed about 29.5% and 9.3% respectively. The high percentage of desmodium in the intercrops could be an indication that it persisted during the dry and wet seasons and competed effectively for light, soil moisture and soil nutrients with elephant grass plants, characteristics that are very essential for a productive companion forage legume for elephant grass. Mwangi (2002) and Mureithi and Thorpe (1993) reported similar results when green leaf desmodium was intercropped with a grass. The better performance of desmodium in the mixtures compared to siratro and centro is an indication that more than one legume species should be included in a mixture because of their variation in DM yield and ability to compete with a grass. It is important to note that siratro, centro and desmodium are some of the forage legumes that have been evaluated on-station and recommended for mixtures in Uganda (Katuromunda, 2001). The recommendations were however mainly based on quantitative assessment without agronomic evaluation within the production systems. Such evaluation is clearly required as demonstrated by the variable performance of the three legume species in mixtures.

A similar study conducted by Mubiru *et. al.* (2001) in Masaka district reported higher but not significant ($p>0.05$) annual DM yields of elephant grass/centro intercrop (20,491 kg ha^{1}) and monocrop (18,236 kg ha^{-1}) than reported in this study. Some of the factors that could have contributed to lower DM yields than reported by Mubiru *et. al.* (2001) could have been: i) the long drought that lasted 4 months; ii) poor soils and agronomic practices (cutting management; weeding and low rates of manure application) that were inconsistent with the ecological dictates of specific locations. The study showed that fodder DM yields of the intercrops and monocrops varied significantly ($p<0.05$) within the different households. This might be an indication of the differences in management and other agronomic practices between households. Different cutting intervals therefore need to be investigated to determine the optimal time for harvesting EGL for feeding to ruminant livestock.

Another important factor that could have affected total fodder DM yields in intercrops and monocrops and needs further investigation was Napier Stunt Disease (Alicai et al. 2006) that was observed on elephant grass plants during the course of the study. The same disease has been reported in Kenya and Tanzania (Mulaa, 2005). Plants exhibiting signs of the disease were stunted with reduced internodes, retarded poor root formation and could be easily uprooted. Plant height range was 30-60 cm compared to a range of 1m and above for the healthy plants in the same fields. White spots (suspected to be insect skin casts) were also found on the affected plants and most farmers linked them to the virus. Field observations showed a higher infection in intercrops than in monocrops. The emergence of the grass virus has raised concern among the farmers because elephant grass fodder is the basal feed base for dairy cows. In view of the importance of livestock to the livelihoods of the people in Uganda and the dramatic symptoms of this elephant grass virus, it is imperative that urgent measures be taken to identify the cause and control of this virus. There is also a need to continue monitoring the occurrence and spread of the problem.

The results of total DM yields and DM of legumes in intercrops presented in this study were for a short period (17 months). The low DM yield of legumes in the mixtures during the wet and dry seasons is a major concern to the farmers and is a constraint to the adoption of the technology. Field observations made in April 2004 (22 months after the legumes were planted) showed that the legume content was less than 4% and the grass DM yield had declined by about 15%. There were no legumes at all in over 65% of the fodder fields that were established. The general decline in DM production of elephant grass and the legumes over that period could be attributed to effects of defoliation and hence fertility decline and depletion of feed reserves for regrowth. There is therefore a need to continue monitoring the performance of the intercrops for about 3 more years. Mwangi (2004), personal communication, recommended that studies on grass/legume mixtures should continue for over 4 years before any recommendations are made to farmers.

Recommendations for optimum carrying capacity on EGL mixtures or sole elephant grass fodder in zero grazing dairy cattle production systems

Humphreys (1991) recommended that animals should be given an opportunity to reject the lower quality material (such as stems) offered, so that the ratio of utilization is maximised and high milk production maintained. Forage allowance is further modified by the size of the animal and the daily intake as a fraction of body weight (% Body weight) according to NRC (2001). Humphreys (1991) therefore recommended that:

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

During the study time, 10 experimental cows feeding on EGL fodder were randomly selected and closely monitored during the dry season for 10 days. The quantity of fresh EGL fodder offered *ad libitum* and consumed by each of the 10 cows (about 450 kg) was recorded. The results showed that the average quantity of fresh EGL offered to each of the 10 cows for 10 days was 118.6 $\pm$ 0.90 kg d^{-1} but the actual quantity consumed was 54.2 $\pm$ 0.29 kg d^{-1}. During the dry season, most of the material that was offered to the animals was mature elephant grass with a legume content of less than 10% of the total diet. Therefore, the ratio of utilization was found to be about 0.46 $\pm$ 0.003. Humphreys (1991) recommended a ratio of utilization of 0.45. It is important to note that due to scarcity of fodder majority of farmers do not offer fodder their animals *ad. libitum*. They tend to feed the animals less than 50% of the required amount of feed and this partly explains the low animal productivity recorded during the dry season.

Thus a according to Humphreys (1991), a-450 kg cow with a daily DM intake of about 3% BW would consume about 13.5 kg DM per day, and with a ratio of utilization of 0.46, the daily forage allowance would be about 29.6 kg DM. This means that the annual fodder requirement for a farmer keeping one dairy cow would be approximately 10,834 kg DM. Government and NGOs that distribute in-calf heifers to resource poor farmers recommend establishment of 1 acre (about 0.405 ha) of EG for every mature cow of about 450 kg. Assuming an estimated annual fodder yield of 12,210 kg DM^{-1} and 10,024 kg ha^{-1} of EGL mixtures and sole elephant grass respectively (Table 1), the annual fodder DM yield from a recommended acreage of 0.405 ha (1 acre) would be about 4,945 and 4,060 kg DM respectively. Using recommendations by Humphreys (1991), of 29.6 kg DM per day of desirable forage allowance, the quantity of fodder produced from 0.405 ha of EGL and sole elephant grass fodder would therefore support one mature cow weighing 450 kg continuously for about 167 and 137days (5.6 and 4.6 months) respectively. This means that intercropping elephant grass with forage legumes would increase the grazing days by about 22% (30 days). A study by Mwangi (2002) indicated that integrating legumes into the Napier grass fodder system increased the carrying capacity from 8.2 heifers ha^{-1} to 9.8 heifers ha^{-1}. This study has therefore shown that the quantity of fodder available at any particular time of the year from a recommended acreage of 0.405 ha (1 acre) would not be sufficient to support a lactating dairy cow for a full year (366 days). Using results obtained in this study, the minimum acreage required to maintain a mature cow of about 450 kg for a full year would be about 0.89 ha (about 2.2 acres) of EGL (var KW_4) or 1.1 ha (2.7 acres) pure stand of elephant grass fodder (var KW_4). Therefore NGOs and Government agencies distributing in-calf heifers may need to adjust the recommendations according to agro-ecological region of the country.

Effect of intercropping elephant grass with forage legumes on chemical composition and *in vitro* dry matter digestibility of elephant grass with and without legumes

The effects of intercropping elephant grass with forage legumes on chemical composition and *in vitro* dry matter digestibility (IVDMD) of fodder are is shown in Table 2. Elephant grass + legume intercropping significantly ($p<0.0001$) increased overall mean crude protein contents (CP) and; CP yield (CPY); IVDMD; Ca; P and ME values by 11; 1.5; 1.1; 1.4; 1.1 and 1.0 times. Increased CP and CPY in elephant grass + legume intercrops has been reported by Mubiru (2001) and Katuromunda (2001). However, Mwangi (2001) reported no significant differences in CPY of *B. ruziziensis* grown alone or mixed with legumes. Legumes contributed more (about 26%) to total CP yields in the intercrops than they did to the total DM yield. Total CPY of the intercrops was significantly ($p<0.0001$) higher (1.2 times) during the wet season than during the dry season (885.7±81.14 kg/ha). The higher CPY values during the wet season might have been either due to the higher total DM yields of the intercrops than the monocrops or to improved management practices. Dry matter content was slightly lower ($p=0.0138$) in intercrops than in monocrops probably due to the presence of the legumes, and/or the manure that was applied manure on the fields.

Intercropping significantly ($p<0.0001$) reduced (1.04 times) NDF values. Significant differences ($p<0.05$) in OM and DM values were observed between the intercrops and monocrops. However, Katuromunda (2001) reported no significant differences in OM and NDF between intercrop and monocrop. The lack of significant differences in OM might have been due to low legume content in the intercrop since legumes have been reported to have a higher IVOMD than the grasses (Saka *et. al.* 1995). The Ca and P contents in the fodder reported in this study were lower than the estimated requirements (0.48 and 0.34% for Ca and P on DM basis respectively) in the rations of dairy cows (NRC, 2001).

Conclusions and recommendations

In conclusion, this study has shown that elephant grass/forage legume technology is of particular importance to resource poor crop/livestock farmers for it would provide improved fodder production. Improved feed supply would have a positive effect on milk yield, growth and reproductive performance. The results of the study however showed that the low DM yields of legumes in EGL intercrops during the dry season and are major constraints to the adoption of the technology as a dry season feed resource. More studies need to be done on EGL on how to maintain high proportion of forage legumes in mixtures. The study showed that CP levels and energy levels in EGL mixtures were less than the levels recommended for the growth and production of a lactating dairy cow (NRC, 2001). Thus feeds from EGL intercropping systems may not be able to support very high levels of production especially in lactating dairy cows when fed alone. Legume enrichment, for example with lablab and/or calliandra leaf hay and a concentrate has been suggested as possible methods of improving the forage quality (Kabirizi, 1996; Kabirizi *et. al.* 2000). There is therefore a need for more studies to evaluate the productivity of dairy cattle fed on feeds from intercropping systems supplemented with other sources of protein and energy sources. As the economic viability of any system determines its wide scale adoption, at farm level, an attempt should be made to examine the relative profitability of EGL vis-*à-vis* sole elephant grass fodder.

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