Ethiopian Journal of Animal Production

Volume: 10 Number: 1 2010 ISSN: 1607-3835

Official Journal of the Ethiopian Society of Animal Production (ESAP)

Ethiopian Journal of Animal Production

An Official Journal of the Ethiopian Society of Animal Production (ESAP)

Aims and Scope: The Ethiopian Journal of Animal Production is a peer reviewed journal publishing original basic and applied research articles, short communications, technical notes, review articles dealing with livestock and livestock related issues. Although the journal focuses on livestock production in Ethiopia, papers from similar agro-ecological regions of the world are welcomed.

EJAP is published by the Ethiopian Society of Animal Production (ESAP)

EJAP
ISSN: 1607–3835
Volume 10, Number 1
2010

Cover page by Wossene Abay

Contents

Breeding objectives and breeding plans for Washera sheep under subsistence and market-oriented production systems

Solomon Gizaw[a], Aynalem Haile[b], Tadelle Dessie[b]*

[a]Debre Birhan Agricultural Research Centre, P.O.Box 112, Debre Birhan, Ethiopia
[b]International Livestock Research Institute, P.O. Box 5689,Addis Ababa, Ethiopia

Abstract

A Washera sheep breed improvement project has been initiated in Amhara state, Ethiopia. However, breeding objectives and breeding plans/schemes to achieve the objectives have not been formally defined. In this study, we identified two Washera sheep production systems (subsistent and market-oriented). Breeding objectives addressing the two production systems were defined applying bio-economic models. The results indicate that twinning rate is economically the most important trait in both production systems. The results also indicate that a single selection index and hence a single breeding program could meet the breeding objectives of both systems. An index containing six month weight, twining rate and survival rate (or combined as number of lambs weaned) and feedlot gain could be used in Washera sheep improvement programs. Two alternative nucleus breeding schemes (a regional and zonal scheme) were planned and evaluated for their genetic and economic efficiency and operational feasibility. The regional scheme is designed to address the entire Washera sheep population (1.2 million), while the zonal scheme will serve part of the population. The regional scheme gives 58.9% more returns to investment. However, the nucleus size is too large to operate as a single flock. The nucleus could be split into multiple smaller flocks which need to be genetically linked through ram exchanges and across-flock genetic evaluation so that the nuclei operate as one big nucleus. Yet such a regional scheme seems to be operationally infeasible under the existing conditions. Operationally feasible breeding program for Washera sheep could be developed by setting up multiple independent nuclei for each zone with approximately 10% of the population. Such nuclei could be established for each zone gradually as resources allow.

Keywords: *Washera sheep; breeding objective; nucleus breeding scheme; production system; Ethiopia*

Introduction

Productivity of the indigenous livestock in developing regions is generally low as they have evolved in adaptation to the marginal production environment and are not effectively selected for increased productivity. Selective breeding is an indigenous livestock breed improvement practice among most communities in developing regions (Perezgrovas, 1995; Tano et al., 2003; Ouma et al., 2004; Nduma et al., 2008; Tesfaye, 2008; Solomon

* Corresponding author: s_gizaw@yahoo.com

et al., 2010). However, structured sheep breeding programs in developing regions, particularly in Africa, are lacking (FAO, 2007; Kosgey et al. 2006)). Lack of effective, sustainable breeding programs for local breeds is one reason that such breeds lose their competitive advantage, especially where production systems or external conditions are subject to change (Hiemstra et al., 2007).

Formalizing genetic improvement for smallholder conditions in developing regions is a challenging task (FAO, 2007). Livestock production in developing regions is generally characterized by small flock-size (particularly in mixed crop-livestock systems), communally shared grazing, uncontrolled mating, absence of pedigree and performance recording, diverse and multiple farmer breeding objectives/selection criteria and lack of genetic progress in productivity from traditional farmer selection practices. These characteristics limit the implementation of effective genetic improvement programs. To overcome these problems, nucleus breeding schemes have been suggested, in which genetic improvement is centrally organized in a population maintained in research institutes or government farms (Galal, 1986; Terill, 1986; Ponzoni, 1992; Kosgey, 2004). Nucleus breeding programs are already in place in quite a number of developing countries (for instance Menz, Washera and Bonga sheep nucleus flocks in Ethiopia). An alternative to centrally organized nucleus schemes is village (or community-based) selection programs, which are breeding activities carried out by communities of smallholder farmers (Sölkner et al., 1998; Wurzinger et al., 2008; Solomon et al., 2009). Both schemes have their merits and demerits. Solomon *et al.* (unpublished) proposed a combined nucleus and village-based breeding program.

A nucleus breeding program for Washera sheep has been developed with a very small nucleus size. However, there is no defined breeding objective and designed scheme to date for Washera sheep. Different nucleus schemes (open vs. closed) with different alternatives of nucleus size, proportion of commercial flock served by the nucleus, and migration of animals between the different tiers has been evaluated (Kosgey 2004; Gicheha et al. 2006). The effects of these parameters on the genetic and economic efficiency of breeding programs have been well established. In this study we opted to design a practical breeding program specific to Washera sheep. We evaluate two nucleus schemes in terms of their bio-economic efficiency and operational feasibility based on breeding objectives for Washera sheep defined in this study applying bio-economic models.

Materials and Methods

Description of Washera sheep

Washera, also known as Agew or Dangla, is a short-fat-tailed, short-haired, predominantly brown, and polled sheep breed indigenous to Ethiopia. It is one of the most productive sheep breeds in the country with large body size (Solomon et al., 2008a) and litter size of 1.11 (Mengistie, 2008). The breed mainly inhabits the wet, warmer mid-highlands (1600-2000 m a.s.l) of the Amhara Regional State (W. Gojjam, E. Gojjam, and Awi zones, and Alefa Takusa district in N. Gondar zone) and Benishangul-Gumz Regional state (Dangur and Madura districts), Ethiopia (Fig. 1). The Amhara and Agew communities rear the breed under mixed crop-livestock system.

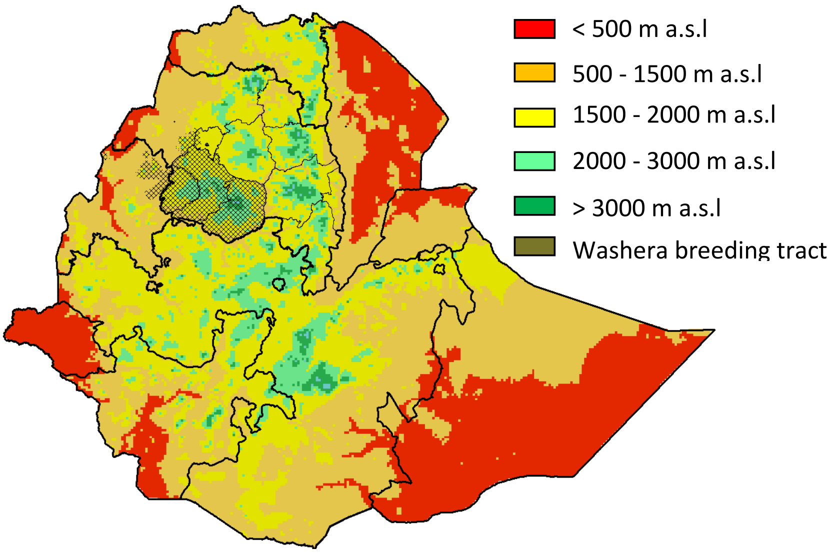


Fig. 1. Ecological and geographical distribution of Washera sheep in Ethiopia.

Definition of breeding objectives

Definition of production and marketing systems

Farmers' livestock breeding objectives can be defined through participatory approaches, in which farmers explicitly state their preferences for traits. In the current study, breeding objectives for Washera sheep were defined based on farmers' sheep production and marketing objectives (Mengiste, 2008; Personal observations), employing bio-economic models.

Washera sheep flocks are kept in communal grazing lands during the day time with little or no supplementary feeding. There is no planned breeding. Unintentional negative selection is practiced as ram lambs with good body conformation are sold at an early age of 3-6 months for immediate cash needs and inferior ones are maintained for breeding.

Based on the above production and marketing practices, Washera sheep production system can be classified as mainly subsistence. However, there are few market-oriented farmers who practice finishing. There is also an emerging export market where finished lambs are in good demand. Breeding objectives are normally defined based on current and anticipated future markets as livestock breeding programs are usually long-term investments. Therefore, in this study breeding objectives were defined for two production systems:

Subsistence: subsistence ewe-lamb system, producing 3-6 month lambs for sale

Market-oriented: subsistence ewe-lamb system, but integrated with finishing of 6-Month-old and culled rams for sale

Identification of breeding- objective traits

Breeding-objective traits should normally include traits that are known to influence profitability of a livestock farm as well as farmers' traits (color, tail, appearance, beauty traits, etc). In this study, only economic traits (except chest girth which could represent farmers trait 'general appearance') that influence profit of the farm are identified. The following biological component traits that influence revenue and costs associated with products of subsistence and market-oriented production systems were identified:

Subsistence: Six month weight (SWT), mature weight (MWT), number of lambs weaned represented by twinning rate (TWN) and pre-weaning lamb survival (PWS), chest girth representing general appearance (CG).

Market-oriented: mature weight (MWT), number of lambs weaned represented by twinning rate (TWN) and pre-weaning lamb survival (PWS), feedlot gain (ADG) and carcass dressing % (DP).

Derivation of economic weights

Bio-economic model

Bio-economic models relating the different breeding-objective traits with components of production and marketing in subsistence and market-oriented Washera sheep production systems were constructed. The models were constructed using Excel spread sheet program. The model was designed so that effects of genetic improvement in breeding-objective traits could reveal changes in values of revenue and expenses in the different production systems. For instance, effect of improvement in dressing percentage was modeled in such a way that a 1% improvement in dressing percentage would result in a 1% increase in sale value of live sheep.

Marginal economic values for each trait were estimated as a change in profit resulting from an increase in one additive genetic standard deviation in the trait value due to selection. Additive genetic standard deviations were calculated as

$\sqrt{\sigma_p^2 * h^2}$ $\sqrt{\sigma_p^2 * h^2}$ where $\sigma_p^2\sigma_p^2$ is phenotypic variance and h^2h^2 is heritability estimate.

Phenotypic variances were obtained from a Washera sheep feedlot experiment for feedlot gain and dressing percentage, and from on-farm Washera sheep monitoring data (Mengistie, 2008) for the rest of the traits.

Economic weight for each trait is calculated as a product of its marginal economic value (which was calculated by a model developed in Excel spread sheet) and the respective discounted genetic expression coefficient (DGE). DGE and economic weights were internally calculated by ZPLAN (Willam et al., 2008) using the undiscounted economic values as inputs.

Sources of revenue and costs

Progeny structures for a 500 ewe flock were defined based on reproduction parameters for Wahera sheep (Table A1) to calculate the costs and revenues. Costs and revenues were calculated on per ewe basis. Profit was calculated as the difference between revenue and expenses per ewe joined and year.

Sources of revenue included both tangible (direct regular cash income from sale of surplus lambs, finished lambs, manure and skin) and financing and insurance benefits. Financing benefits result from inflow (investing capital/saving) and outflow (spending capital) of livestock providing the function of banking which is mostly not accessible in developing rural areas. Financing benefit was calculated as (Bosman et al. 1997)

$$B_f = b_f * V$$

where b_f is average inflation rate in Ethiopia during three quarters in 2006 and 2007 (NBE, 2007). Outflow value in Ethiopian Birr (ETB), V, is expressed per ewe and year for each class of disposable animals as

$$V_i = N_i * W_i * P_{\mathrm{kg}} \qquad [1]$$

where N_i is number of animals available for sale per ewe and year in class i animals, W_i average weight in class i animals, P_{kg} price per kg of live weight.

Sheep in most parts of Ethiopia have important function as insurance against crop failure and other social needs. Insurance benefits were calculated based on breeding ewes and rams which are assumed to remain in the flock and available as insurance and also to avoid double counting that results from considering the other classes of animals. Insurance benefit was calculated as

$$B_i = b_i * V$$

where b_i is percentage of the value of an average flock required to meet the value of interest paid on money borrowed (at interest rate of 10.5%) to cover for crop failure in an average crop farm plus an assumed ETB 300 medical expense per year; V is calculated as above in [1] but considering only breeding stock. Input parameters for calculating revenue per ewe per year in subsistence sub-systems and per slaughter animal bough in per year are given in Table A1 and A2.

Three sources of variable expenses (feed, management and veterinary costs) were identified. Input parameters for calculating expenses per ewe per year are given in Table A1 and A2.

Breeding plan

Alternative breeding schemes for Washera sheep were designed and evaluated using the method developed for this purpose and incorporated in a computer program, ZPLAN (Willam, et al., 2008). ZPLAN uses gene flow methods and selection index procedures to simulate breeding plans. Based on genetic, biological and economic variables, the program calculates genetic gain for the aggregate breeding value, the annual response for each trait and the profit per female animal due to selection. Profit is calculated as a difference between costs and returns.

Breeding scheme and Selection pathways

A two-tier breeding scheme with a nucleus (breeding unit) and a village population (production unit) was simulated. Genetic gain is generated in the nucleus flock and disseminated via rams to the village population where no selection activity is assumed. There is no transfer of animals from the village to the nucleus flock, i.e. the scheme is a closed nucleus breeding unit.

Two closed nucleus breeding schemes (regional or zonal) were considered. A regional scheme simulates a selection program addressing the entire Washera sheep population. The population of Washera sheep is estimated to be 1227700 (Solomon et al, 2009) based on distribution of sheep populations by administrative regions and zones (CSA, 2005). The number of breedable females in the population can be calculated based on flock structure in the population. Breedable females constitute about 58.8% of the flock in Washera sheep (Mengiste, 2008). Thus there are some 723000 breedable ewes in the population. The regional scheme is designed to serve 25% of the population in the first phase of the breeding program. This is because of resource limitations and not all the Washera sheep farmers may participate in the breeding program. Besides, genetic gain achieved in the nucleus and the participating farmers' flocks could be transmitted to non-participants through purchase, loan and communal use of rams. The regional program can designed with a single nucleus flock or multiple genetically linked nucleus flocks which operate as one big nucleus. If such a scheme is not feasible, independent smaller nucleus flocks can be established each to address 10% of the population in contiguous districts (Zonal breeding scheme). The nucleus is 5% of the base population.

Six selection groups are defined to indicate the selection pathways. A selection group is defined by both, type of parents (one sex) passing genes and type of offspring receiving their genes. Rams born in the nucleus are selected to breed rams (sires to breed sires, RB>RB) and ewes (sires to breed dams, RB>EB) for the nucleus. Females are also selected in the breeding unit to breed rams (dam to breed sires, EB>RB) and ewes (dams to breed dams, EB>EB) for the nucleus. Rams selected in the nucleus are also transferred to commercial flocks to improve the ewes (sire to breed dams, RB>EC). The top best rams are first selected for the nucleus. Ewes in the production unit are used to breed ewes for the production unit (EC>EC).

Selection criteria and genetic parameters

Three selection indexes were constructed. Index 1, assumed to reflect the breeding objective of subsistent farmers, included SWT, TWN and PWS. Index 2 (SWT, TWN, PWS, ADG, DP) and Index 3 (SWT, TWN, PWS, ADG) are alternative indexes reflecting the objectives of market-oriented farmers. Sources of information for the traits include own performance, sires, dams and paternal half sibs. ADG and DP were evaluated on 10% of half sibs of the candidate animals, which are to be finished and slaughtered for carcass evaluation. Genetic parameters used are presented in Table 1. Since estimates for Washera sheep are not available, available estimates for other local and exotic breeds were used.

Table 1. Phenotypic standard deviations (σ_p), heritabilities along diagonal, and genetic (above diagonal), phenotypic (below diagonal) correlations used in the simulated selection

Traits	σp	SWT	MWT	ADG	DP	TWN	PWS	CG
SWT	1.20	0.35	0.93	0.62	-0.22	0.09	0.10	0.98
MWT	2.31	0.42	0.30	0.78	-0.06	0.08	0.09	0.80
ADG	4.51	0.44	0.34	0.25	-0.17	0.08	0.09	0.50
DP	2.45	-0.07	-0.05	-0.09	0.42	0.00	0.00	-0.05
TWN	0.25	0.09	0.O8	0.09	0.00	0.10	- 0.02	0.60
PWS	0.18	0.10	0.09	0.09	0.00	0.00	0.09	0.10
CG	7.37	0.77	0.74	0.40	-0.05	0.50	0.06	0.31

σ_p Phenotypic standard deviation. SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/head/day); DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.

Source: Abegaz et al. (2002); Rege et al. (2002); Solomon (2002); Snowder and Van Vleck (2003); Safari and Fogarty (2003); Safari et al. (2005); Solomon et al. (2007; 2008b).

Biological, technical and economic parameters

Gene flow between populations and groups of animals is defined by constructing transmission matrix. The transmission matrix is constructed based on estimates of productive lifetime, survival rate and age at first lambing of animals in each selection group. Other reproductive parameters such as lambing frequency and twinning rate are required to calculate the proportion of selected animals and selection intensities. These biological and technical parameters are given in Table 2.

Table 2. Biological and technical parameters for the nucleus and commercial populations

	Nucleus	Base
Simulated population size (breedable females)		
Regional breeding scheme	8900	178016
Zonal breeding scheme	516	10325
Transfer of animals between nucleus and commercial		
Fraction of nucleus dams born in commercial	0.0	
Fraction of commercial dams born in nucleus		0.0
Fraction of nucleus sires born in commercial	0.0	
Fraction of commercial sires born in nucleus		1.0
Productive lifetime (years)		
Sires	0.67	1.33
Dams	4.0	7.0
Number of lambings per year	0.67	1.37
Reproductive parameters		
Mating ration (female to male)	50	100†
Lambing interval (years)	0.73	0.73
Conception rate	0.90	0.90
Age at first lambing (years)	1.5	1.5
Twinning rate	1.11	1.11
Survival of Rams	0.95	0.93
Survival of Ewes	0.95	0.93
Preweaning lamb survival	0.90	0.85
Male lambs suitable for breeding	0.90	0.90
Female lambs suitable for breeding	0.90	0.90

† Mating ratio in base population is doubled to 100 ewes to 1 ram since mating is year-round in villages.

Selection costs

Overhead (fixed) and variable costs incurred in running the proposed breeding program are given in Tables 3. Overhead costs were calculated for the zonal and regional schemes separately. Costs were internally discounted by ZPlan over the investment period. The breeding program is planned for an investment period of 15 years. Time units for discounting were mean generation interval for fixed costs (2.03 years) and mean age of animals when costs occur for variable costs. The costs are not those incurred in running the farm, but extra costs incurred as a result of introducing selection activities. Similarly the returns do not include the whole return obtained from farm output, but the extra return obtained as a result of genetic gain.

Table 3. Fixed over head costs and variable costs before discounting per ewe per year in the breeding unit under zonal and regional scheme and the average time of cost occurrences in years

Cost element	Costs (Birr) Zonal scheme	Regional scheme	Years
Over head costs (per ewe)			
Animal breeding expert (genetic evaluation)	4.36	4.04	2.4
Technical field assistant/ data encoder	23.25	5.39	2.4
Data processing facilities and supplies and communications	8.72	2.81	2.4
Variable costs (per ewe)			
Identification	6.33	6.33	0
Measuring 6 month weight (labor, weighing balance)	1.02	0.17	0.5
Recording litter size	0.05	0.10	1.42
Recording pre-weaning survival	0.05	0.10	0.25
Feedlot test (ADG; feeding and weighing labor)	2.67	1.22	0.75
Carcass analysis (carcass kit, weighing scale, labor, carcass analysis expert)	2.61	1.94	0.75

Results

Breeding objectives

Table 4 gives marginal economic values of traits for the subsistence and market-oriented Washera sheep production systems. Twinning rate, sale weight (at six months of age) and pre-weaning survival are the main objective traits in order of importance for the subsistence system. For the market-oriented producer, twinning rate, pre-weaning survival and six month weight are important traits.

Table 4. Undiscounted† economic values per unit increase in genetic merit for traits in the subsistence and market-oriented systems

Breeding objective traits	Economic values: Subsistence breeding objective	Market-oriented breeding objective
SWT	16.93	24.56
MWT	7.63	7.63
ADG	0.00	4.25
CG	0.00	0.00
TWN	19.80	39.79
PWS	14.61	29.37
DP	0.00	10.69

SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/head/day); DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.

† ZPLAN requires values being calculated before discounting.

Genetic responses

Table 5 presents expected annual genetic responses in breeding-objective traits in the subsistence and market-oriented production systems under the regional and zonal breeding schemes. Responses were generally very similar. Genetic responses in individual traits were slightly higher in the market-oriented system and under the regional scheme. Responses to the overall breeding objective (monetary genetic gain) were higher for the market-oriented system and under regional scheme. There was also a small difference in responses when selection was based on the two alternative indexes constructed for the market-oriented system. All responses were positive except for dressing percentage.

Table 5. Annual genetic responses to selection based on indexes reflecting subsistence and market oriented breeding objectives under regional and zonal breeding schemes

† Breeding scheme/ objective	Selection criteria	Breeding objective traits							
		SWT (kg)	MWT (kg)	ADG (kg)	CG (cm)	TWN	PWS (%)	DP (%)	Breeding objective (Birr)
Zonal Scheme									
Subsistence	Index 1	0.30	0.42	0.44	1.43	0.003	0.002	-0.13	8.52
Market oriented	Index 2	0.30	0.42	0.45	1.42	0.004	0.003	-0.09	11.57
	Index 3	0.30	0.42	0.56	1.43	0.004	0.003	-0.14	11.73
Regional Scheme									
Subsistence	Index 1	0.31	0.43	0.44	1.44	0.003	0.003	-0.14	8.57
Market oriented	Index 2	0.30	0.42	0.46	1.43	0.004	0.003	-0.11	11.64
	Index 3	0.30	0.42	0.57	1.44	0.004	0.003	-0.09	11.79

† See text for description.

Index 1: SWT, TWN, PWS; Index 2: SWT, TWN, PWS, ADG, DP ; Index 3: SWT, TWN, PWS, ADG

SWT Six month weight; MWT Mature weight; ADG Feedlot gain (g/head/day); DP dressing out percentage; TWN Twinning rate; PWS Pre-weaning survival; CG Chest girth.

The genetic superiority of selected animals which flows into the base population from the different selection pathways (responses per generation for the breeding objectives) in the different selection groups ranged from Birr 14.58 to 33.71. The responses were higher in sire selection groups (RB>RB and RB>EB; see text for notations) than dam selection groups (EB>RB and EB>EB). This was due to the higher selection intensity in sire selection groups (2.19) than in dam groups (0.87). The accuracy of selection, which is the correlation between the selection index and the breeding objective (aggregate genotype), was 0.63 in subsistence and 0.53 in market-oriented breeding objective.

Costs, returns and profit

Returns per trait, overall returns and profit per ewe and year are presented in Table 6. All returns are positive except returns from dressing percentage. The highest returns were obtained from improving SWT. Returns per trait, overall returns and profits were higher for the market-oriented breeding objectives and for the regional breeding schemes. However, the two selection indexes gave similar results.

Table 6. Returns and profits per ewe per year (Birr) for subsistence and market-oriented systems under regional and zonal breeding schemes

	Zonal Scheme			Regional Scheme		
	subsistence	Market oriented		subsistence	Market oriented	
	Index 1	Index 2	Index 3	Index 1	Index 2	Index 3
Overall return	63.08	85.51	86.63	63.41	85.95	87.07
Return / trait						
SWT	38.49	54.96	54.96	38.69	55.25	55.25
MWT	24.03	23.81	23.75	24.16	23.94	23.87
ADG		14.34	17.78		14.41	17.87
TWN	0.36	0.76	0.79	0.37	0.77	0.80
PWS	0.19	0.43	0.44	0.19	0.43	0.44
DP		- 8.79	-11.11		- 8.84	-11.17
Profit /ewe/year	21.74	39.04	42.70	45.41	64.86	67.89

Discussion

Breeding objectives

In this study, we defined breeding objectives and planned a closed nucleus breeding program for genetic improvement of Washera sheep in Ethiopia. The production and marketing objectives and the breeding objectives defined here for Washera sheep are similar to those defined by Solomon et al. (2010) for traditional sheep production in Ethiopia employing a farmer participatory approach. The results indicate that twinning rates is economically most important trait under both subsistence and market-oriented systems. Dressing percentage is an important breeding objective trait for market-oriented farmers. The trait reflects the objectives of market-oriented farmers, feedlot operators, who may not keep breeding flock, and consumers. Pre-weaning survival of lambs and twinning rates are also important traits.

Differences in production strategies and breeding objectives between groups of farmers within a traditional management system are often much greater than commonly understood (Sölkner et al. 1998; Solomon et al., 2010). In our study, two sheep production systems (subsistence and market-oriented) with two separate breeding objectives were defined for Washera sheep. This underscores the idea that differences in production systems in which a breed is used and the breeding objectives needs to be considered when developing breeding programs (Phocas et al., 1998; Hirooka and Groen, 1999; Vargas and van Arendonk, 2004; Barwick and Henzel, 2005; Wolfová et al., 2005). The rationale is that a single breeding program may not satisfactorily meet the different objectives under different production systems. Responses in trait units in the subsistence and market-oriented systems in the current study are similar (especially when the response values are rounded). However, the market-oriented objective yields more responses for the overall breeding objective (37.8%) and profit (96.1.8%) than the subsistence systemobjective.

Selection index

Three selection indices, one reflecting the subsistence breeding objective and two alternative indexes reflecting the market-oriented objective were constructed and evaluated. The two alternative indices for the market oriented breeding objective gave similar responses in trait units. However, dressing percentage (DP) gave negative returns to investment because of the negative genetic gain in DP and the extra cost of carcass analysis. The negative genetic gain could be due to its antagonistic relations with the other traits in the selection indexes constructed in this study. The index excluding DP gave 9.4% more profit over the index including DP. This trait may not therefore be included in the selection indexes. Besides to returns to investment, the decision as to which of the indexes to use depends on the expertise and ease of measurement of carcass dressing percentage. Using DP as a selection criterion also entails that 10% of the animals in each halfsib group will not be available for breeding as they are slaughtered for measuring DP according to the breeding plan designed in this study. The patterns of genetic responses in trait units are generally very similar for all breeding objective traits when any of the indexes were used.

Breeding program

The breeding program proposed in this study is a nucleus breeding program. Livestock breeding schemes designed to suit the breeding structures in developing regions broadly include village (or community-based) breeding schemes (Solkner, 1998; Wurzinger et al., 2008; Solomon et al., 2009) and station-based nucleus breeding schemes (Ponzoni, 1992; Kosgey, 2004). Both schemes have their merits and demerits. Genetic progress could be slow under village programs because of inaccurate genetic evaluation due to the difficulties of implementing advanced selection tools such as selection on Best Linear Unbiased Prediction of breeding values and inefficient utilization of selected animals due to uncontrolled village breeding practices. On the other hand, nucleus breeding programs entail overhead selection costs in nucleus flocks (though cost of establishment and maintenance of the flocks may not be considered as the flocks could serve other purpose, particularly in research farms) to fulfill the continuous supply of improved rams to village flocks. Besides, farmers breeding objectives may not be fully addressed by breeding objectives and selection criteria defined by project experts in nucleus centers. This has great implications in the success of livestock projects since breeding strategies that base on farmers' indigenous knowledge and preferences are more suitable and sustainable than exotic technologies. To cater for farmers preferences, a new pilot station-cum-village based sheep breeding scheme has been designed and implemented for Menz sheep (unpublished). The design integrates the merits of station-based and village-based breeding schemes. Such a design could be adopted for the already ongoing and new nucleus breeding programs including Washera sheep selection program.

Alternative designs of nucleus breeding programs relating to the nucleus size, operation of breeding tiers (open vs. closed schemes), etc. have been evaluated elsewhere (e.g. Kosgey 2004; Gicheha et al. 2006)). In this study we opted to develop a breeding program specific to Washera sheep. Two alternative breeding schemes were designed (a regional and zonal scheme). The regional scheme is designed to address the entire Washera sheep population (estimated 1.2 million), while the zonal scheme will serve part of the population. Both schemes yielded similar responses to selection in terms of trait units. The regional scheme gives 58.9% more returns to investment over the zonal scheme. However, the regional scheme seems to be operationally difficult. The nucleus size is too large to operate as a single flock. Thus the nucleus needs to be split into many smaller flocks which need to be genetically linked to operate as one big nucleus. This can be achieved by designing across-flock genetic evaluation and exchange of rams. This obviously poses a huge operational difficulty. The zonal scheme could be easily adopted as it involves setting up an independent nucleus for each zone with approximately 10% of the population. Such nucleus flocks could be established for other zones as required and depending on resource availability.

Operational considerations in running such a scheme includes that farmers participating in the breeding program need to practice controlled breeding as the scheme assumes that all rams in the target base population use rams from the nucleus. To this end, it is recommended to distribute rams to organized villages using communal grazing and thus communal rams. Use of improved rams in common will also increase the mating ratio more than assumed in this study. This will increase genetic progress and profit from investment more than estimated here.

The breeding scheme designed in this study is a closed nucleus scheme. Open nucleus schemes are superior to closed nucleus schemes in terms of genetic and economic efficiencies because of a higher expected mean genetic value of nucleus replacements and because such a system will integrate farmers' resources, reduce overhead costs and encourage more farmer participation (Bondoc & Smith 1993; Kinghorn 2000). However, open nucleus schemes are operationally rather difficult, particularly in developing regions. The closed nucleus flock proposed in this study could develop into an open scheme as experience buildup in the breeding program. Supply of nucleus rams to cooperative villagers could facilitate the adoption of open schemes. Furthermore, the level of inbreeding could build up faster in closed flocks compared to open flocks, particularly in small nucleus flocks. Thus it is important to consider large flocks and planned mating in closed nucleus programs.

Conclusion

Setting up a regional breeding program would be more profitable. However, operationally feasible breeding program for Washera sheep could be developed by setting up multiple independent nucleus flocks for each zone with approximately 10% of the population. Such nuclei could be established gradually as resources allow. Such scheme with 500 breeding ewes in the nucleus could serve 10 000 breeding ewes in the base population.

Our results demonstrate that twinning rate is economically most important trait under all systems of production. The results also indicate that an appropriately constructed single selection index and hence a single breeding program could serve the subsistence and market-oriented breeding objectives defined in this study. An index containing six month weight, twining rate and survival rate (or combined as number of lambs weaned) and feedlot performance (fattening gain) could be used in Washera sheep improvement.

Acknowledgement

The authors would like to acknowledge the financial and technical support obtained from International Livestock Research Institute (ILRI) and Amhara Regional Agricultural Research Institute (ARARI) in the course of this study.

References

Abegaz, S., Negussie, E., Duguma, G., Rege, J.E.O., 2002. Genetic parameter estimates for growth traits in Horro sheep. J. Anim. Breed. Genet. 119, 35-45.

Barwick, S.A., Henzell, A.L., 2005. Development successes and issues for the future in deriving and applying selection indices for beef breeding. Aust. J. Exper. Agric. 45, 923-933.

Bondoc O.L., Smith C. (1993) Deterministic genetic analysis of open nucleus breeding schemes for dairy cattle in developing countries. J. Anim. Breed. Genet., 110, 194–208.

Bosman H.G., Moll H.A.J., Udo H.M.J. (1997). Measuring and interpreting the benefits of goat keeping tropical farm systems. Agricultural Systems 53:349-372.

Gicheha, M.G., Kosgey, I.S., Bebe, B.O., Kahi1, A.K. (2006). Evaluation of the efficiency of alternative two-tier nucleus breeding systems designed to improve meat sheep in Kenya

J. Anim. Breed. Genet. 123: 247–257.

Hirooka H., Groen A.F. (1999). Effects of production circumstances on expected responses for growth and carcass traits to selection of bulls in Japan. J. Anim. Sci. 77:1135-1143.

Kinghorn B. (2000). Nucleus breeding schemes. In: B. Kinghorn, J. van der Werf, M. Ryan (eds), Animal Breeding, Use of New Technologies. Post Graduate Foundation in Veterinary Science of the University of Sydney, Sydney, Australia, pp. 152–158.

Kosgey, I.S., 2004. Breeding objectives and breeding strategies for small ruminants in the tropics. PhD thesis, Wageningen University, Wageningen.

Mengiste Taye, Girma Abebe, Solomon Gizaw, Sisay lemma, Abebe Mekoya, markos Tibbo. (2009). Growth performance of washera sheep under smallholder management system Ethiopia. *Trop Anim Health Prod,* DOI 10.1007/s11250-009-9473-x.

Ndumu, D.B., Baumung, R., Wurzinger, M., Drucker, A.G., Okeyo, A.M., Semambo, D., Sölkner, J., 2008. Performance and fitness traits versus phenotypic appearance in the African Ankole Longhorn cattle: A novel approach to identify selection criteria for indigenous breeds. Livestock Science 113, 234–242.

Ouma, E., Abdulai, A., Drucker, A.G., Obare, G., 2004. Assessment of farmer preferences for cattle traits in smallholder cattle production systems of Kenya and Ethiopia. Proc. Deutscher Tropentag 2004. Humboldt-University Berlin, Germany. October 5 to 7, 2004.

Perezgrovas, R., 1995. Collaborative application of empirical criteria for selection high quality fleeces: Tzotzil shepherdesses and sheep scientists work together to develop tools for genetic improvement. http://www.unesco.org/most/bpik17-2.htm.

Phocas F., Bloch C., Chapelle P., Be´cherel F., Renand G., Me´nissier F. (1998) Developing a breeding objective for a French purebred beef cattle selection program. Livest. Prod. Sci. 57:49–65.

Rege, J.E.O., Tembely S., Mukasa-Mugerwa E., Sovani S., Anindo D., Lahlou-Kassi A., Nagda S., Baker, R.L., 2002, Effect of breed and season on production and response to infections with gastro-intestinal nematode parasites in sheep in the highlands of Ethiopia. Livest. Prod. Sci. **78**, 159–174.

Safari, E., Fogarty, N.M., Gilmour, A.R., 2005. A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. Livest. Prod. Sci. 92, 271-89.

Safari A, and Fogarty N.M. (2003). Genetic parameters for sheep production traits: Estimates from the literature. Technical Bulletin 49, NSW Agriculture, Orange, Australia.

Snowder G. D., Van Vleck L. D. (2003). Estimates of genetic parameters and selection strategies to improve the economic efficiency of postweaning growth in lambs. J. Anim. Sci. 81:2704-2713.

Sölkner, J., Nakimbugwe, H.,Valle Zarate, A., (1998). Analysis of determinants for success and failure of village breeding programs. Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, 25:273–281.

Solomon Gizaw, Hans Komen, Johan A.M. van Arendonk (2010). Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems. *Livestock Science, 128: 67-74.*

Solomon Gizaw, Komen, van Arendonk, J.A.M. (2009). Optimal village breeding schemes under smallholder sheep farming systems. *Livest. Sci.* 124:82–88.

Solomon Gizaw (2008a). Sheep resources of Ethiopia: Genetic diversity and breeding strategy. PhD thesis, Wageningen University, Wageningen.

Solomon Gizaw, Komen, H., van Arendonk, J.A.M., (2008b). Selection on linear size traits to improve live weight in Menz sheep under nucleus and village breeding programs. *Livestock Science* (2008) doi: 10.1016./j.livsci.2008.01.006.

Solomon Gizaw, Sisay Lemma, Komen, H., van Arendonk, J.A.M., (2007). Estimates of genetic parameters and genetic trends for live weight and fleece traits in Menz sheep. Small Rumin. Res. 70:145-153.

Solomon Gizaw (2002). Genetic evaluation of Menz and Awassi x Menz crossbred sheep in Ethiopia. MSc thesis, NDRI, India.

Vargas B., van Arendonk J. A. M., (2004). Genetic comparison of breeding schemes based on semen importation and local breeding schemes: framework and application to Costa Rica. J. Dairy Sci. 87:1496–1505.

Tano, K., Kamuanga, M., Faminow, M.D., Swallow, B., 2003. Using conjoint analysis to estimate farmers' preferences for cattle traits in West Africa. Ecol. Econ. 45 (3), 393–407.

Tesfaye Getachew, 2008. Characterization of Menz and Afar Indigenous sheep breeds of smallholders and pastoralists for designing community-based breeding strategies in Ethiopia. Msc thesis, Haramaya University, Haramaya.

Willam, A., Nitter, G., Bartenchlager, H., Karras, K., Niebel, E., Graser, H.-U. (2008). ZPLAN-mannual for a PC-program to optimize livestock selection schemes. Manual Version 2008 for Source Code "z10.for". Institute of Animal Production in the Tropics and Subtropics. Universität Hohenheim, Stuttgart, Germany.

Wolfová M., Wolf R., Zahrádková J., Přibyl J., Daňo J., Krupa E., Kica J. (2005). Breeding objectives for beef cattle used in different production systems 2. Model application to production systems with the Charolais breed. Livest. Prod. Sci. 95:215-230.

Wurzinger, M., Willam, A., Delgado, J., Nurnberg, M., Zarate, A.V., Stemmer, A., Ugarte, G., Solkner, J., 2008.. Design of a village breeding program for a llama population in the High Andes of Bolivia. J. Anim. Breed. Genet. 125, 311–319 311.

Appendix

Table A1. Production parameters used for defining breeding objectives

Production parameters	Subsistence	Market oriented
Nr. of lambings per year	1.37	1.37
Conception rate	0.90	0.90
Litter size	1.11	1.11
Lamb survival 0-3 months	0.85	0.85
Lamb survival 3-6 months	0.90	0.90
Ewe replacement rate	0.10	0.10
Ram replacement rate	1.00	1.00
Mature ewe weight (kg)	28.5	28.5
Mature ram weight (kg)	32.3	32.3
Six month weight (kg)	16.2	16.2
Finishing duration (days)		90.00
Finishing ADG of lambs (kg/d)		0.13
Finishing ADG of culled rams (kg/d)		0.12
Sale weight of finished lambs		Variable*
Sale weight of finished culled rams		variable
Carcass dressing %		48.1
Finishing feed intake of lambs (kg/d)		0.50
Finishing feed intake of culled rams (kg/d)		0.50
Manure (kg/head/night)		0.19

* Varies with weight at six month and ADG during finishing which vary with selection.

Sources: Amha (1995); Abebe (1999); Solomon (2002); Mengiste (2008).

Table A2. Sources of revenue and expenses and values used for defining breeding objectives

Sources of revenue	Subsistence	Market-oriented
Male lambs, 6 month old (ETB/kg live weight)	15.00	
Female lambs, 6 month old (ETB/kg live weight)	13.00	
Finished lambs, 9 months (ETB/kg live weight)		Variable*
Culled ewe 7 years old (ETB/kg live weight)	5.78	5.78
Culled ram (ETB/kg live weight)	7.84	
Culled ram finished (ETB/kg live weight)		14.49
Culled ewes 7 yrs old (ETB/kg)	5.78	5.78
Skin (ETB/pc)	30.00	30.00
Manure (opportunity cost of commercial fertilizer, ETB/kg)	0.18	0.18
Financing benefit (Bf = inflation rate)	0.06	0.06
Insurance benefit (Bi = ETB/ewe or ram/year)	0.09	0.09
Sources of expenses		
Feed cost		
Grazing opportunity cost (ETB/head/d)	0.01	0.01
concentrate for finishers (ETB/kg)		0.60
Management cost		
labor for herding and feeding (ETB per head/d)	0.03	0.05
transport and marketing tariff (ETB/head)	3.50	3.50
Veterinary cost		
Dewormimg (ETB per head/yr)	1.12	1.12
Vaccination (ETB per head/year)		0.20
Fxed costs (ETB per head per year)	0.50	0.50

Evaluation of poultry litter as substitute of urea in urea molasses block on growth and carcass characteristics of finished lamb

*Getahun Kebede[1] and Kassahun Melese[1] **

[1]Debre Zeit Agricultural Research Center, P.O.Box 32, Debre Zeit, Ethiopia

Abstract

This study examined the replacement effect of urea molasses block with dried caged layers excreta (PE) on feed intake, digestibility, growth performance, carcass characteristics and cost of production of growing lambs. Treatments (T) varied only with type of feed block supplemented: where dried PE replaced urea of a block (weight by weight) at 0%, 25%, 50%, 75% and 100% in treatments 1, 2, 3, 4 and 5, respectively. Lambs were randomly allotted to treatments in a Complete Randomized Design, individually penned and fed daily on tef straw ad libitum and 300 g of noug cake (Guizotia abyssnica) in addition to block supplementation. Dry matter (DM) intakes of straw, noug cake, feed blocks and total feed were improved significantly ($p<0.001$) with inclusion of block PE up to 50%. Straw DM intake was increased ($p<0.01$) from 419 g in T1, to 472 g in T2, but not depressed at higher rates of PE inclusion. Block DM intake increased from 148g (T1) to 179 g (T5), and the corresponding total intakes were 832 and 890 g, respectively. Digestibility coefficients were not considerably affected ($p>0.05$) by treatments ranging from 0.60 to 0.64; 0.32 to 0.43 and 0.62 to 0.67 for DM, ash, organic matter, respectively. The average daily weight gain was increased ($p<0.001$) with block PE inclusion, in which both the highest weight gain (54g) and feed conversion efficiency (18.1g DMI/g gain) were attained by lambs in T2.. The highest cold carcass weight (11.3 kg) and dressing percentage (45.4) were observed at the highest inclusion rate of PE (T5). Profit per lamb was highest in T2 (79.9 ETB) and lowest in T5 (67.9 ETB). Cost of production of a block was reduced from 2.05 to 1.43 ETB as PE inclusion increased from 0 to 100 %. Moreover, no health problem was detected in lambs due to feeding PE containing block. This study indicates that use of PE as a substituent for urea in urea molasses block production improves growth performance and feed utilization, and reduces cost of lamb feeding.

Keywords: *Intake; growth; digestibility; lamb; feed cost*

Introduction

As is true in many tropical countries, ruminant animal production in Ethiopia is often constrained by poor nutrition. Feed resource bases are mainly natural pasture and crop residues (Alemayehu, 1998b) that are characterized by containing lower crude

*Corresponding Author: kasishmele@gmail.com

protein and higher fiber contents than optimal for adequate intake and digestibility. The deficit in quality and quantity of available feed resources is often aggravated by dry season and drought occurrence resulting in low animal performances. To improve the production and productivity of animals, the utilization efficiency of the feed resources should be optimized by providing animals with supplements rich in deficient nutrients. Moreover, to maximize profit from production it is necessary to minimize cost of production, in which supplying the nutrient demands of animals represents the single and largest expense. In this case, supplementation strategy based on locally available, low cost and nutrient-rich feeds is of a choice for low income farmers.

Supplementing cereal straws with fermentable nitrogen, soluble carbohydrates, minerals and other nutrients improve their utilization by ruminants (Badurdeen *et al*., 1994, Rafiq *et al*., 1996). Molasses and urea are known to respectively contain available energy and nitrogen and are used in feeding. (Preston and Leng, 1990). On its own, urea is bitter and unpalatable. Combining it with molasses makes the urea more palatable. A safe way of feeding urea is by preparing it into a Urea Molasses Block (UMB). This preparation is an excellent way of providing readily degradable protein and readily fermentable energy to ruminant animals, and they help increase the protein supply to the animal. There are many cases where it can be economical to supplement urea molasses block to ruminants raised on low quality roughages. Urea molasses block contains soluble and fermentable nitrogen from urea, highly fermentable energy from molasses and essential minerals, providing a range of nutrients required by rumen micro-organisms and the host animal. Studies on supplementation of urea molasses block has proven improved performance and feed utilization of ruminant animals (Chen et al., 1993; Hadjipanayiotou et al., 1993b). Urea/molasses feed blocks have been widely advocated to increase the intake and digestibility of poor quality pastures and roughages (Leng, 1984; Hadjipanayiotou et al., 1993b). The use of feed blocks is particularly convenient because they are then easy to transport and the blocks readily give their nutrients to the animals. Making these nutrients in the form of multi-nutrient feed blocks with cement as a binder also ensures slow release of the otherwise toxic molasses and urea. Availability of fermentable nitrogen and readily available carbohydrates and minerals supplied through UMB facilitates the growth of cellulolytic microbes which results in better utilization of wheat straw (Leng, 1984). The feeding of the blocks is a convenient and inexpensive method of providing a range of nutrients required by both the rumen microbes and the animal, which may be deficient in the diet. The main justification for using the blocks depends on their convenience for packaging, storage, transport and ease of feeding (Jayasuriya and Smith, 1999).

There is often, a limitation on extent of production and utilization of feed block due to fluctuations in the price, availability and quality of ingredients used. To be economical in feed block production, it is common to add or replace the constituents with relatively cheap and available feed resources. Studies have shown that most poultry manure/litter contains 25 to 50% crude protein (Fontenot and Hancock, 2001) and significant amounts of Ca, P, K and numerous trace minerals (Ruffin and McCaskey, 1990; Mekasha et al., 2002). Thus, the manure has been incorporated in the diet of ruminants since it serves as a source of nitrogen and minerals in addition to its low cost. Previous studies (Hadjipanayiotou et al., 1993; Paul et al., 1993; Murthy et al., 1995; 1996; Lanyasunya et al., 2006) on inclusion of poultry manure in the diets of ruminant animals have proven improved performances. Poultry manure is also known to contain pathogens and drug residues that may be hazardous to animals and human health. However, the negative aspects of the manure, particularly of the pathogens can be removed from manure through ensiling (Hadjipanayiotou, 1982; Daniels et al., 1983) and deep stacking (Strickler, 1977) or using methods such as fumigation, autoclaving and dry heating with or without formaldehyde (Jakhmola et al., 1988).

In Ethiopia, use of UMB as supplement to ruminant animals in the traditional production system is limited by its low production associated with scarcity and price fluctuation of inputs used. In this case, the use of urea in UMB production is unlikely at smallholder farmers mainly because of its increased price and demand for fertilizer use resulting in increased cost of block production, also limiting its wider application. However, today, a number of traditional and emerging commercial poultry farms in Ethiopia account for the presence of about 39.6 million chicken populations (CSA, 2007/8). Commercial poultry farms contribute substantially to the production of tones of poultry manure, annually. This has created an opportunity to use the manure as alternative source of nutrients (mainly non-protein nitrogen) in ruminants diet, which otherwise can be dumped unwisely and causes environmental pollution. Thus, the objective of this study was to evaluate the inclusion effect of dried caged layer's waste for urea in UMB on feed intake, digestibility, growth rate, carcass characteristics and cost of feeding lambs.

Materials and Methods

Study area

The experiment was conducted at Debre Zeit Agricultural Research Center located at 45 km south east of Addis Ababa, at an altitude of 1900 m.a.s.l. (between 8.44°N latitude and 39.02°E longitude). The maximum and minimum temperature and the mean annual rainfall of the area are 24.3°C, 8.9°C and 851mm, respectively.

Feed block preparation

Caged-layer waste was collected from poultry farms around Debre Zeit town and sun dried at air temperature (21oC) followed by grinding it before used in feed block making. Other ingredients used in the block preparation were: molasses, wheat bran, cement (used as binding agent), fertilizer graded urea and common salt. Five types of feed blocks varying only in the levels (weight/weight) of poultry excreta replaced urea were produced (Table1). A homogenous mixture of block ingredients was manually assured followed by placing the mix in a wooden mould (length,12cm; width, 21cm and height,10cm) that produced a 2 kg molded feed block at a time. The blocks were dried under shade at good ventilation before supplemented to lambs.

Table1. Types of ingredients used and percentage inclusion in feed block preparation

Block Type	Molasses %	Wheat bran %	Cement %	Urea %	PE %	Salt %
B1	45	25	15	10	0	5
B2	45	25	15	7.5	2.5	5
B3	45	25	15	5	5	5
B4	45	25	15	2.5	7.5	5
B5	45	25	15	0	10	5

B1, B2, B3, B4, B5 = feed blocks used in treatment (T) 1,2,3,4 and 5 respectively; PE = poultry excreta

Animals management and dietary treatments

Thirty-five highland yearling male lambs (Arsi-Bale breed) with mean initial weight of 21.27 $\pm$0.76kg were bought from local market. After acclimatization to environment, animals were arranged into five equal weight groups of seven animals each and assigned to treatments in a Complete Randomized Design. Dietary treatments were different only with the type of feed block supplemented, where PE replaced urea of the block (w/w) at 0% in T1, at 25% in T2, at 50% in T3, at 75% in T4 and at 100% in T5. All animals were individually penned and fed on tef straw *ad libitum* and 300 g/head/day of noug cake in addition to free access to block supplementation. The lambs were adapted to diets for 14 days before commencing data collection for a period of three months. Pure water was freely available to all animals at all the times. Noug cake was supplemented daily at 0800 h in the morning, while the remaining feeds were offered at 0900 h. Data on feed offered and refused were taken daily, and the live weight was measured fortnightly after overnight fasting (≈16 hours).

At the end of intake and growth trial, the value of each finished lamb was estimated at the prevailing market price. Three animals were then, randomly selected per treatment and transferred to metabolic crate with slotted floor. The animals were adapted to the crate and the attached fecal bags for three days followed by digestibility trial for seven days. The amount of voided feces per lamb/day was weighed, sub-sampled and placed in freezer at -20^{o}C, pending analysis. Moreover, two lambs were randomly selected per treatment, devoid of experimental feed for 16 hours, weighed and slaughtered for carcass analysis. The carcass was eviscerated and body components such as head, feet, skin, blood, visceral organs (kidneys, liver, heart and lungs), testicles, fat deposited, full and empty guts were weighed. The cold carcass weight was taken after freezing at 4 ^{0}C for 24 hours. After removing the tail, the carcass was spited along the dorsal middle line with a band saw. Rib eye area was measured after tracing the eye muscle (longissimus muscle) at the 12/13th rib position.

Sample chemical analysis

Feeds and fecal samples were analyzed for dry matter, nitrogen, calcium and phosphorus according to the procedures of AOAC (Association of Analytical Chemists) 1990. Neutral detergent fiber and acid detergent fiber were also determined by Van Soest detergent system (1985).

Economic analysis

Partial budget analysis was applied to estimate the economic importance of treatment diets. At the end of feeding period, the prevailing market (sale) price of each finished lamb was estimated using four local sheep traders, and the average of estimates were taken as sale price of an animal. Finally, the total variable costs were deducted from total sale price of lambs to estimate the relative profitability of the diets. Costs of all other inputs were taken at their market prices during the experiment.

Statistical analysis

Data of feed intake, digestibility and live weight gain were analyzed using GLM procedures of SAS (1999). Treatments means were separated using Duncan's multiple range test whenever GLM declared significance. Daily weight gain of individual animal was estimated by regressing weight changes over 14 days of feeding period.

Results and Discussion

Chemical composition

The chemical compositions of experimental feeds are shown in Table 2. Crude protein (N*6.25) content of block was decreased as the proportion of poultry excreta (PE) replacing urea increased implying that more quantities of nitrogen was obtained from urea than equal quantity of PE. Percentages of fiber fractions decreased, but total ash increased as the block PE level increased.

Table 2. Nutrient composition of experimental diets (% of DM, except for DM)

Feed Items	Nutrients						
	DM	Ash	CP (6.25*N)	ADF	NDF	Ca	P
Tef straw	93.00	8.00	3.91	22.00	40.00	nd	nd
Noug cake	97.00	15.00	30.12	16.00	19.00	nd	nd
T1	96.65	14.98	36.82	25.91	43.73	5.44	0.76
T2	96.07	13.38	32.08	22.97	37.53	5.41	0.66
T3	95.49	11.72	27.34	20.03	31.33	5.24	0.51
T4	95.03	15.45	20.32	17.88	31.09	5.97	0.59
T5	93.77	19.03	19.34	15.47	32.28	5.11	0.39

Where, DM = dry matter; CP = crude protein; ADF = acid detergent fiber; NDF = nutrient detergent fiber; Ca = calcium; P = phosphorus; N = nitrogen; nd = not determined

Intake and digestibility

There was significant difference ($p<0.05$) among treatments in straw DM, ash, N, NDF and ADF intake (Table 3). The highest ($p<0.05$) intake of straw DM and the associated nutrients (with the exception to ADF) was observed in lambs supplemented with block containing 25% poultry manure (T2). The highest ($p<0.05$) intakes of total DM, N and NDF were recorded for T2. Further increase in the substitution rates did not depress ($p>0.05$) intakes of straw DM, Ash, ADF and NDF. However, straw nitrogen (N) intake was higher at lower than at higher inclusion rates of poultry excreta. However, the lowest ($p<0.05$) intakes of total DM, NDF and ADF were recorded for T4.

Except for T4, in most cases dry matter intakes of feed block and noug cake were significantly improved ($p<0.05$) with PE inclusion, although there was no apparent differences among inclusion rates. On the other hand except for T4 and T5 total intake of DM and Ash was increased significantly ($p<0.05$), while that of N and NDF reduced ($p<0.001$) with block PE inclusion. The increased intake of total ash with inclusion of PE partly indicated PE to be an important source of minerals for ruminants. Increased in total ash intake could also be contributed by increased intake of straw and noug cake that in turn increased the crude mineral consumed by lambs. The increased total DM intake associated with block PE inclusion has revealed PE to be an important source of nutrients for improved feed utilization. Similar to the present study, poultry manure containing concentrate mixture supplemented to sheep (Hadjipanayiotou et al., 1993b) and a crossbred calves (Paul et al., 1993) have been shown to improve feed intake.

Table 3. Nutrient intake(g/day) of experimental diets

Measure-ments	Feed items	Treatments						
		T1	T2	T3	T4	T5	SE	p-value
DM	Straw	(419)[b]	(472)[a]	(440)[b]	(433)[b]	(429)[b]	9.97	p<0.01
	Noug cake	(264)[b]	(285)[a]	(279)[a]	(282)[a]	(282)[a]	4.69	p<0.05
	Block	(148)[bc]	(162)[ab]	(194)[a]	(114)[c]	(179)[ab]	13.07	p<0.001
	Total	(831)[b]	(919)[a]	(913)[a]	(829)[b]	(890)[a]	16.69	p<0.001
ASH	Straw	(33.5)[c]	(39.2)[a]	(36.9)[b]	(37.5)[ab]	(36.6)[b]	0.72	p<0.001
	Noug cake	(39.6)[b]	(42.7)[a]	(41.9)[a]	(42.2)[a]	(42.2)[a]	0.71	p<0.05
	Block	(22.2)[b]	(21.3)[b]	(22.8)[b]	(17.7)[b]	(34.1)[a]	2.00	p<0.001
	Total	(95.3)[c]	(103)[b]	(102)[bc]	(97.4)[bc]	(113)[a]	2.21	p<0.001
N	Straw	(2.65)[c]	(3.30)[a]	(3.15)[ab]	(3.07)[b]	(2.62)[c]	0.05	p<0.001
	Noug cake	(12.7)[b]	(13.7)[a]	(13.5)[a]	(13.6)[a]	(13.6)[a]	0.21	p<0.05
	Block	(8.74)[a]	(8.31)[a]	(8.49)[a]	(3.71)[b]	(2.67)[b]	0.52	p<0.001
	Total	(24.1)[a]	(25.3)[a]	(25.1)[a]	(20.4)[b]	(18.9)[b]	0.59	p<0.001
NDF	Straw	(170)[b]	(185)[a]	(174)[a]	(173)[a]	(178)[a]	3.96	p<0.05
	Noug cake	(50.2)[b]	(54.1)[a]	(53.1)[a]	(53.5)[a]	(53.5)[a]	0.85	p<0.05
	Block	(64.9)[a]	(60.8)[a]	(60.9)[a]	(35.6)[b]	(57.9)[a]	4.5	p<0.001
	Total	(285)[a]	(300)[a]	(288)[a]	(262)[b]	(289)[a]	6.03	p<0.001
ADF	Straw	(87.6)[ab]	(73.4)[c]	(80.0)[bc]	(79.5)[bc]	(89.6)[a]	2.94	p<0.001
	Noug cake	(42.3)[b]	(45.5)[a]	(44.7)[ab]	(45.0)[a]	(45.1)[a]	0.72	p<0.05
	Block	(38.5)[a]	(37.2)[a]	(38.9)[a]	(20.5)[b]	(27.7)[b]	2.62	p<0.001
	Total	(168)[a]	(156)[bc]	(164)[ba]	(145)[c]	(162)[ba]	4.00	p<0.001

Superscripts in the same row (for each measurement) with different letters are significantly different

The apparent digestibility coefficients of DM, OM and ash were not significantly ($p>0.05$) different among treatments (Table 4).However, the apparent digestibility coefficients of CP varied among treatments ($p<0.001$), being highest (0.76) in lambs supplemented with a feed block containing 100% PE than that without (0.62). The non-significant difference among treatments in the digestibility coefficients of DM, OM and ash indicated that lambs utilized PE as effective as urea in the block.

Table 4. Least squares means values of digestibility coefficients, growth performance and feed conversion efficiency

Parameter	T1	T2	T3	T4	T5	SE	P-value
DM	0.64	0.62	0.63	0.63	0.61	0.02	ns
Ash	0.43	0..33	0.42	0.42	0.32	0.05	ns
OM	0.67	0.62	0.67	0.66	0.66	0.02	ns
CP	0.62^{c}	0.55^{d}	0.74^{ab}	0.69^{b}	0.76^{a}	0.02	P<0.001
IBWT(Kg)	21.2	21.5	20.9	21.6	21.1	0.76	ns
FBWT(Kg)	24.9	26.3	24.8	24.8	24.6	0.84	ns
ADG(g)	41.3b	54.0a	43.6ab	34.9b	39.7b	4.37	p<0.05
FCR(g DMI/ g gain)	20.5^{ab}	18.1^{a}	22.5^{ab}	24.8^{b}	23.8^{ab}	2.23	p<0.05

Superscripts in the same rows with different letters are significantly different; ns = not significant; DM=Dry matter; OM=Organic matter; CP=Crude protein IBWT=Initial body weight; FBWT=Final body weight; ADG =Average daily gain; DMI =Dry matter intake; FCR = feed conversion ratio

The increase in dietary CP digestibility associated with increased substitution rates of block PE seem to be strange as it appeared to show lower digestibility of urea than PE, whilst urea is 100% degradable in rumen. This observation indirectly indicated that increased apparent CP digestibility with PE containing block supplementation might largely be contributed by increased digestibility of CPs of straw and noug cake associated with improved rumen fermentation, which could also be explained from increase in their corresponding CP intake. In other words, other than serving as N source, PE could also serve as a source of essential nutrients, perhaps minerals that foster microbial growth and dietary CP digestibility. Similar to the present result, Muthy et al. (1996) observed comparable nutrient digestibility in Nellore lambs and goat supplemented with concentrate containing different levels of poultry droppings.

Growth performance

There was no significant difference (p>0.05) in final body weights of lambs among treatments (Table 4). All animals supplemented with their respective feed block tended to increase live weight at the end of feeding period, the maximum weight being 26.35 kg achieved by lambs supplemented with 25% PE containing block (T2). The average daily live weight change was significantly different (p<0.001) among treatments, where the highest (54.0g) and the lowest (34.9g) gains were achieved at 25 (T2) and 75% (T4) replacement levels, respectively. Although not statistically significant (p>0.05), feed conversion ratio was the highest in lambs supplemented with block containing 25% PE (T2). The improved growth performance of lambs supplemented with block containing PE could be due to improved total dry matter intake, digestibility of protein and feed conversion efficiency. This result agrees with the reports of Murthy et al. (1996) who observed improved average daily gain in lambs(56.9g) and kids(44.6g) supplemented with pellets containing 15 to 30% dried poultry manure. Moreover, studies by Hadjipanayiotou et al. (1993b) have shown that inclusion of PE in the diets of dry Chios ewes improved growth and feed utilization. In the present study, no adverse effect on health status of lambs was noticed associated with PE containing block supplementation.

Carcass characteristics

The mean values of edible and non-edible carcass traits of slaughtered lambs (n=2 per treatment) are shown in Table 5. The magnitudes of most edible carcass components such as hot and cold carcasses, kidney, liver, heart, kidney fat, omental fat and total ribs were increased in animals supplemented with feed block containing PE than that without. Moreover, carcass weights and dressing percentages were increased as block PE inclusion level increased. Lambs supplemented with feed block at 100% PE had the highest carcass weight (11.3 kg) and dressing percentage (45.4). Similarly, most non-edible carcass traits such as head, feet, testicle, scrotal fat, lung, spleen, pancreas, penis, and subcutaneous fat weights were increased in lambs supplemented with PE containing block.

Table 5. Mean values (n=2) of carcass components of experimental lambs

Traits	Treatment				
	T1	T2	T3	T4	T5
a. Edible carcass components:					
Kidney (g)	66.2	73.9	67.4	67.3	69.6
Liver (g)	302	339	295	295	278
Heart (g)	134	149	128	125	134
Empty gut (kg)	1.29	1.47	1.41	1.45	1.18
Pelvic fat (g)	27.6	13.9	21.6	33.8	21.4
Kidney fat (g)	41.4	35.3	56.9	89.2	62.8
Omental and Mesentric fat (g)	115	138	176	192	211
Hot carcass (kg)	9.15	9.20	10.5	10.3	11.3
Cold Carcass (kg)	9.59	11.1	10.9	9.49	9.92
Lean thickness (mm)	4.50	4.0	3.5	3.5	4.0
Tail (g)	569	410	325	435	365
Total ribs (g)	91.3	145	115	119	130
Ribs fat (g)	12.0	5.7	10.3	8.05	8.8
Ribs lean (g)	61.5	108	81.4	87.4	99.4
Rib eye area (cm2)	8.25	11.1	8.25	6.4	9.5
Slaughter wt (kg)	25.2	28.0	24.5	26.0	25.0
Dressing percentage	36.2	32.9	42.9	39.7	45.4
b. Non-edible carcass components:					
Head (Kg)	1.75	1.87	1.81	1.81	1.71
Feet (g)	462	495	454	467	458
Skin (kg)	1.81	1.81	1.87	2.10	1.88

Blood (kg)	1.26	1.18	0.94	1.08	1.06
Testicle (g)	253	326	286	253	313
Scrotal fat (g)	12.0	38.7	49.9	46.2	45.4
Ribs bone (g)	16.8	26.5	20.7	18.8	20
Full gut (kg)	6.99	8.23	6.94	8.28	3.67
Lung	242	306	270	260	252
Spleen (g)	33.1	43.9	30.9	37.5	29.6
Pancreas (g)	27.6	31.2	31.8	34.4	25.4
Urinary Bladder (g)	30.2	21.6	25.4	28.3	25.1
Penis (g)	47.5	47.6	44.2	41.2	41
Subcutaneous fat (mm)	2.0	3.5	3.0	2.0	2.5

n=no of slaughtered animals

Economic Analysis

Detail of all costs involved and profit obtained from feeding lambs is shown in Table 6. All treatments resulted in a positive net returns with the highest profit per lamb in T2 (79.9 ETB) and the lowest in T5 (67.9 ETB). This finding was also supported by research works on lactating Shami and Black Syrian Mountain goats and Shami heifers and bull calves, where cost of feeding was considerably reduced by supplementing a concentrate mixture of dried poultry manure (Hadjipanayiotou et al., 1993). The total variable costs were, however, higher for lambs supplemented with PE containing block than that without, which could be due to improved feed consumption that contributed to increased feed cost. On the other hand, cost of a block production was reduced from 2.05 ETB, where there is no PE inclusion, to 1.43 ETB at complete substitution of urea with PE (100%). This could be due to differences in the prevailing prices of urea and PE. Cost of block feeding was highest (14.3 ETB/lamb) at 25% PE inclusion, but reduced thereof, at higher substitution rates influenced by the lower cost of PE compared to urea and change in extent of consumption. Although sensitivity of other input costs matter profitability, partial or total replacement of feed block urea with PE in this study appeared to be an affordable strategy.

Table 6. Partial budget analysis for lambs finished on experimental diets (in ETB/lamb)

Criteria	Treatment				
	T1	T2	T3	T4	T5
Income from sale (1)	246	260	245	245	243
Variable costs:					
Purchase of sheep	80	80	80	80	80
Feed cost:					
Tef straw	24.8	30.3	25.6	27.8	27.5

	Nug cake	19.2	22.4	21.7	22.2	22.2
	Urea	4.43	3.98	3.17	0.94	0.0
	PE	0.0	0.15	0.36	0.32	0.68
	Molasses	2.84	3.41	4.07	2.43	3.87
	Common salt	0.54	0.65	0.78	0.46	0.74
	Cement	2.84	3.41	4.07	2.43	3.87
	Wheat bran	2.31	2.76	0.14	1.97	3.14
Block cost/treatment						
Cost of ingredients/block(2 kg)						
Labour cost:						
	Perdiem	1.61	1.61	1.61	1.61	1.61
	Feed preparation & data collection	25.7	25.7	25.7	25.7	25.7
	Vet. service	1.50	1.50	1.50	1.50	1.50
	Transportation	4.57	4.57	4.57	4.57	4.57
Total variable cost(2)		170	180	173	172	175
Net return(1-2)		75.9	79.9	72.0	72.9	67.9
Net return over control		-	3.98	-3.74	-3.03	-8.0

Tef straw = 10 ETB/bale, (1 bale = 15kg); Noug cake =0.85 ETB /kg; Urea = 3.5 ETB/kg; Air dried poultry excreta = 0.4 ETB/kg; Molasses = 0.5 ETB/litre; Wheat bran = 0.73 ETB/kg; Common Salt = 0.86 ETB/kg; Cement = 1.5 ETB/kg; ETB=Ethiopian Birr

Conclusion

This study indicated that the layers-cage waste is an alternative source of nutrients (mainly of protein) and replaces urea in molasses block manufacturing, improves feed utilization and performance of growing lambs, and reduces cost of feeding. Given the gap in feed availability to ruminants, especially during the dry season, UMB containing PE can be potential sources of readily available energy and nitrogen. Undoubtedly, this will ensure that the animals are not just being maintained but will be sustained for productive purposes such as weight gain. Apart from low price, feed blocks containing PE are nutritionally as good as feed blocks containing urea. Therefore, where there is a poultry farm, it is wise to incorporate poultry excreta in feed block production so as to be economical in production and promote its wider application, besides enhancing recycled use of the manure.

Urea-molasses blocks containing PE can play a positive role in extensive animal production systems. Therefore, there should be a mechanism to transfer the technology to the smallholder farmers who can be benefited through the utilization of such types of technologies. If UMB is properly disseminated and extended, it will play a vital role for poverty alleviation of poor livestock farmers. Research on feed blocks manufacturing should be pursued while diversifying the ingredients to include other agro-industrial by-products and to design blocks for higher performance levels with the inclusion of good quality protein sources.

Acknowledgement

The authors are grateful to Ethiopian Institute of Agricultural Research, in particular to Debre Zeit Agricultural Research Center, for financial support and encouragement for the implementation of this work. We also thank assistant research staffs of the small ruminant research unit who participated genuinely for the research accomplishment.

References

Alemayehu Mengistu 1998b. The borana and the 1991-92 drought: rangeland and livestock resource study; Institute for Sustainable Development (ISD), Addis Ababa, Ethiopia

AOAC (Association of Analytical Chemists) 1990. Official methods of analysis. 15thedition

Badurdeen, A. M., M. N. Ibrahim and S. S. E. Ranawana.1994. Methods to improve utilization of rice straw. III: Effect of urea ammonia treatment and urea molasses blocks supplementation on intake, digestibility, rumen and blood parameters. Asian-Aust. J. Anim. Sci. 7:363-372.

CSA (Central Statistics Authority) of Ethiopia 2007/8. Agricultural sample survey, volume II, Report on Livestock characteristics statistical bulletin 417. pp21

Chen, YZ., Wen, H., Ma X, Li Y, Gao, Z. and Peterson, MA. 1993. Multi-nutrient lick blocks for dairy cattle in Gansu Province, China; *Livestock Research for RuralDevelopment.* **5**(3):60–63. http://www.lrrd.org/lrrd5/3/china.htm

Daniels, L. B., Smith, M. J., Stallcup, O .T. and Rakes, J .M. 1983. Nutritive value of ensiled broiler litter for cattle; Animal Feed Science and Technology 8: 19-34

Fontenot, P. J. and Hancock, W. J.2001. Animal proteins prohibited in ruminant feed; code of federal regulations, title 21, part 589.2000. FDA public hearing, Kansas city, MO, October 30, 2001

Hadjipanayiotou, M .1982. Laboratory evaluation of ensiled poultry litter; Animal Production 35: 157-161

Hadjipanayiotou, M., Labban, LM., Kronfoleh, AR., Verhaeghe, L., Naigm, T., Al-Wadi M. and Amin, M. 1993 .Studies on the use of dried poultry manure in ruminant diets in Syria; *Livestock Research for Rural Development* 5(1)

Hadjipanayiotou, M., Verhaeghe, L., Kronfoleh, A. R., Labban, L. M., Amin, M., Al-Wadi, M., Badran, A., Dawa, K., Shurbaji, A., Houssein, M., Malki, G., Naigm, T., Merawi, A. R. and Harres, A. K. 1993b. Urea blocks. II. Performance of cattle and sheep offered urea blocks in Syria. *Livestock Research for Rural Development*, 5 (3):16-23 Retrieved http://www.cipav.org.co/lrrd/lrrd5/3/syria2.htm.

Jakhmola, R.C., Kundu, S. S., Punj, M. N., Singh, K., Kamira, D. N. and Singh, R. 1988.

Animal excreta as ruminant feed; scope and limitationsunder Indian conditions; Animal Feed Science and Technology 19: 1-23

Jayasuriya, M.C.N. and Smith, T. 1999. IAEA working document on Guidelines for developing feed supplementation packages, Vienna, Austria.

Lanyasunya, T. P., Wang H. Rong, Abdulraza, S. A., Kaburu, P. K. , Makori, J. O., Onyango, T. A. and Mwangi, DM. 2006. Factor limiting use of poultry manure as protein supplement for dairy cattle on smallholder farms in Kenya; International Journal of Poultry Science 5(1):75-80. http://www.pjbs.org/ijps/fin417

Leng, R. A. 1984. The potential of solidified molasses based blocks for the correction of multi-nutritional deficiencies in buffaloes and other ruminants fed low quality agro-industrial byproducts. In: *The Use of Nuclear Techniques to Improve Domestic Buffalo Production in Asia*. IAEA: Vienna: 135-150.

Murthy, K. S., Reddy, M. R. and Reddy, G. V. N. 1995. Utilization of cage layer droppings and poultry litter as feed supplements for lambs and kids;Small Ruminant Research 16:221-225

Murthy, K. S., Reddy, M. R. and Reddy, G. V. N. 1996. Nutritive values of supplements containing poultry droppings/litter for sheep and goats. Small Ruminant Research 21:71-75

Onwuka, C.F.I. 1998. Molasses block as supplementary feed resource for ruminants. *Archivos de zootecnia vol. 48, núm. 181, p. 89-94.*

Paul, B. N., Gubta, B. S. and Srivastava, J. P. 1993. Influence of feeding unconventional cakes and poultry manure mixture on growth and feed efficiency in crossbred calves. Indian Journal of Animal Nutrition 10:169-171

Preston, T.R. and R.A. Leng. 1990. Matching ruminant production systems with available resources in the Tropics and Sub-tropics. CTA, Netherlands.

Rafiq, M., J. K. Jadoon, K. Mahmood and M. A Naqvi. 1996. Economic benefits of supplementing lambs with urea molasses blocks on ranges of Pakistan. Asian-Aust. J. Anim. Sci. 3: 127-132.

Ruffin, B. G. and McCaskey, T.A. 1990. Broiler litter can serve as a feed ingredient for beef cattle; Feedstuffs 62: 13

Yoseph Mekasha, Azage Tegegn, Alemu Yami and Umunna, N. N. 2002. Evaluation of non-conventional agro-industrial by-products as supplementary feeds for ruminants: *in vitro* and metabolism study with sheep; Small Ruminant Research 44: 25–35

SAS (Statstical Analysis System) 1999. SAS Institute Inc., Cary, NC. USA

Strickler,R. H. 1977. Deep stacking broiler litter as a means of storage for use in feeding beef cows *In*: alternate nitrogen sources for ruminants, pp 56-57. Conference, 9-11 November 1977, Atlanta, Georgia, USA

Van Soest, P. J. and Robertson, J. B. 1985. Analysis of forage and fibrous foods, alaboratory manual for animal science 613

Nitrogen Uptake, Recovery and Use-efficiency in forage oat (*Avena sativa* L.)

Aklilu Mekasha [1*], *Y.P. Joshi* [2] *and Alemayehu Mengistu* [3]

[1.] Melkassa Agricultural Research Center; P.O. Box 436; Nazareth, Ethiopia.

[2] G.B. Pant University of Agriculture & Technology, Pantnagar-263145, India

[3] Research and development consultant; Addis Ababa, Ethiopia

Abstract

Study was conducted to investigate effects of different levels of nitrogen on nitrogen content, uptake, recovery and use-efficiency of forage oat. Two-third of five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) in the form of urea ($CO(NH_2)_2$), was applied at planting time and the remaining one-third - 30 days after sowing on soils with pH 7.3, 238 kg ha^{-1} available nitrogen, 0.7% organic carbon, 47.3 kg ha^{-1} available phosphorous and 284.37 kg ha^{-1} exchangeable potassium. It was found that total nitrogen uptake by the crop and the nitrogen content in plant tissue significantly increased ($P < 0.05$) with successive levels of nitrogen applied upto 120 kg ha^{-1} ; whereas, the apparent recovery and the use-efficiency declined significantly ($P < 0.05$) with successive levels of the applied nitrogen. The implication is that the efficiency of fertilizer use is inversely related with level of application and that of the uptake and content in plant tissue and dry mater yield of the crop. In the present study optimum level for maximum rate of yield increment could not be more than 120 kg N ha^{-1}. The decrease in recovery and use efficiency was reflected in yield only at a rate higher than the optimum level.

Keywords: *Forage oat; Nitrogen; Recovery; Uptake; Use-efficiency*

Introduction

Among all essential nutrients to plants, nitrogen is the most important essential element in nutrition of almost all plants. It is an important constituent of physiologically important compounds like nucleotides, phosphatides, vitamins, enzymes, hormones and chloroplast that promotes growth and development in plants (Pandey and Sinha, 2006). The nutritional importance of nitrogen probably is higher in forage crops than in grain since ruminant animals relay on low quality protein present in the diet to derive. Most of the protein comes from pasture or cultivated crops that normally constitute the bulk of feed. Efficient use of grasses for higher production of animal protein thus depends upon adequate concentration of nitrogen in the herbage (Hopkins *et al.,* 1994).

Nitrogen is frequently deficient in soils (Havlin *et al.*, 1999) and plants grown on nitrogen deficient soils show stunted growth, yellowish color and reduced yield (Pandey and

*Corresponding Author: aklilumekasha@yahoo.com

Sinha, 2006). Grazing animals also suffer from the deficiency. As a result, forage and pasture agronomists often apply nitrogenous chemical fertilizers at a higher dose based on results of soil test. On the other hand, over application of such nutrients beyond the level of uptake and use by the crop is wastage. The adverse effects could be avoided and the application tuned to economic level by careful selection and development of responsive crops and varieties to high and conversely low levels of nitrogen (Below, 2002). This study was therefore, conducted to see the response of forage oat to different levels of nitrogen in terms of uptake, recovery and use efficiency of the applied nitrogen-as urea.

Materials and Methods

The study site

The study was conducted at Govind Ballbah Pant University of Agriculture and Technology, India. The site is located at 29.5^o N latitude and 79.3^{o}E longitude with 243.8 m altitude above mean sea level. It is characterized by subhumid tropical and subtropical climate with shallow water table and gentle slope. The long term meteorological data shows that the mean annual rainfall is about 1385 mm; the maximum temperature of the year occurs in summer, which often exceeds 40^{0}C in May and June with mean monthly minimum temperature below 10^{0}C in January. The soil was generally Beni silty clay loam under the order mollisol. It is slightly alkaline in reaction (pH 7.3), low in available nitrogen (238 kg ha^{-1}), medium in organic carbon (0.7%), available phosphorous (47.3 kg ha^{-1}) and exchangeable potassium (284.37 kg ha^{-1}).

Treatments, design and management practices

The treatments consist of nitrogen fertilizer in the form of urea ($CO\ (NH_2)_2$) applied at the rate of 0, 40, 80,120 and 160 kg ha^{-1}. Two-third of the level was applied at planting and the remaining one-third 30 days after sowing. The nitrogen level was laid out in a Randomized Complete Block Design with four replications in net plot areas of 4 m^2. The crop was sown at 100 kg ha^{-1} seed rate by drilling in furrows opened 4-5 cm deep at 25 cm spacing in between rows. The plots were irrigated at 20-25 days interval depending on moisture /precipitation status and the need of the crop. A total of 4 irrigations were given to meet water requirement of the crop. Herbicide 2-4, D was also applied to all plots at 1.0 kg a.i. ha^{-1} 25 days after sowing with one supplementary hand weeding 50 days after sowing.

Data collection and analysis

The crop was harvested when it reached 50% heading stage. The harvested green herbage was weighed plot wise and sub samples of about 200g were taken and oven dried at 70^{O}C to constant weight. The dried samples were ground by laboratory Willey mill to pass 1 mm sieve and composite samples of 0.5 g were digested with sulfuric acid and analyzed for total nitrogen content by Micro-Kjeldhal method (Jackson, 1973). The nitrogen uptake, apparent recovery, use-efficiencies and dry matter yields of the crop were determined by the following equations:

Nitrogen Uptake (NU)

The nitrogen removed by the crop was determined by multiplying the percentage of total nitrogen content of the plant tissue with the dry matter yield of the crop:

$$\text{Nitrogen uptake (kg/ha)} = \frac{\text{DM yield(kg ha}^{-1}\text{) X total nitrogen content (\%)}}{100}$$

Apparent Nitrogen Recovery (ANR)

The apparent nitrogen recovery was determined as percentage of the ratio of that portion of the applied nitrogen absorbed by the crop to the total nitrogen applied through urea:

Apparent N recovery (%) =

$$\frac{\text{N uptake from treated plot (kg ha}^{-1}\text{) - N uptake from control plot (kg ha}^{-1}\text{)}}{\text{Amount of N applied (kg ha}^{-1}\text{)}} X\,100$$

Nitrogen Use-Efficiency (NUE)

The agronomic nitrogen use-efficiency was determined as the ratio of yield difference between nitrogen treated and untreated plots to the amount of nitrogen applied:

$$\text{NUE} = \frac{\text{DMY from treated plot (kg ha}^{-1}\text{) - DMY from control plot (kg ha}^{-1}\text{)}}{\text{Amount of N applied (kg ha}^{-1}\text{)}}$$

Dry Matter Yield (DMY)

The dry matter yield was determined as product of green forage yield multiplied by the dry matter content of the crop:

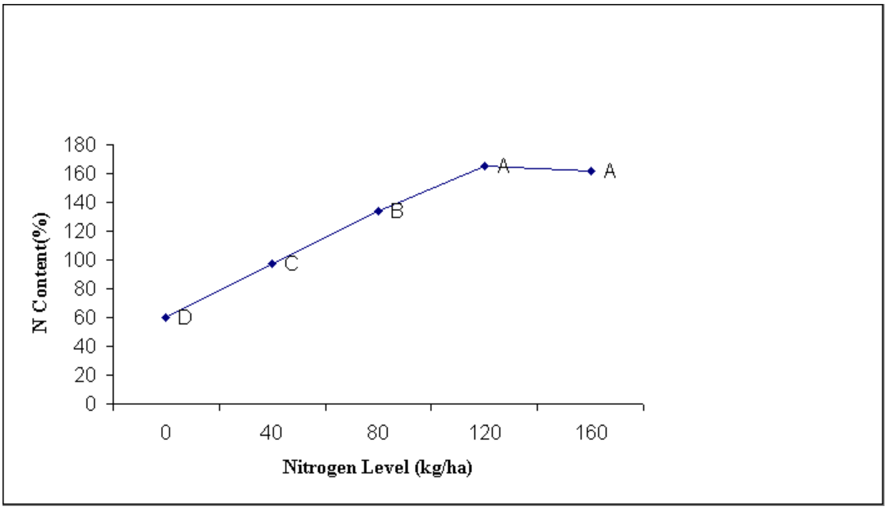
$$\text{Dry matter yield (ton ha}^{-1}\text{)} = \frac{\text{Green forage yield (ton ha}^{-1}\text{) X Dry matter content (\%)}}{100}$$

Finally the data on all parameters were subjected to analyses of variance according to Cochran and Cox (1957) and results were depicted in graph using Microsoft excel spread sheet. On figures levels of nitrogen which did not show significant difference at $P > 0.05$ were denoted by the same letters.

Results and Discussions

Nitrogen content

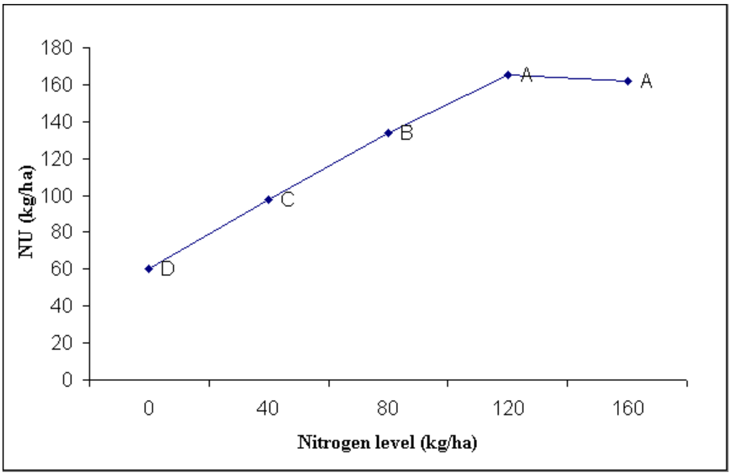
Nitrogen content in plant tissue increased significantly ($P<0.05$) with levels of the applied nitrogen (Fig 1). The highest content of 1.71% was recorded at 120 kg N ha^{-1} and further increasing the dose level to 160 kg N ha^{-1} did not show any increment in nitrogen content of the plant tissue. Similar increase in nitrogen content with levels of applied nitrogen was reported by several authors on different crops. Kirkham and Wilkins (1994) noticed consistently higher concentration of nitrogen in plants harvested from plots assigned to the highest dose. The increase in total nitrogen content with dose levels could be due to the fact that availability of more nitrogen enabled the crop to synthesis more cellular organelles to which nitrogen is a building block. The range of total nitrogen content (1.17% to 1.71%) observed, however, is lower when compared to the reports of Aklilu (2005) for the same crop harvested at 30, 60 and 90 days after sowing. The discrepancy could be because of differences in stage of plant growth at harvest. At early stages of growth, plant tissues contain higher amount of total nitrogen. Bloom *et al.* (1985) coined the high nitrogen content at early stages to luxury consumption. The young actively growing roots absorb nitrogen both as ammonium and nitrate ions voracious beyond the capacity of the plant to assimilate. The excessively absorbed nitrate is accumulated in vacuoles and made available for assimilation when the external source is depleted (Below, 1995). This accumulation of nitrate along with more synthesis of protein by young growing leaves could thus result in high percent total nitrogen content regardless of level of applied nitrogen. At later stages of growth, 50% heading observed in present study diminished to 1.17 - 1.71 % perhaps because of depletion of plant reserve, nitrogen supply from the soil, less efficient recovery and dilution of the absorbed nitrogen with high dry matter accumulations. Karlen *et al.* (1988) also accounted the net loss of aerial nitrogen accumulation during the transition from vegetative to reproductive phase, in the absence of sink, to volatilization loss in maize.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 1. Effect of different levels of nitrogen on Nitrogen (N) content (%) of forage oat

Nitrogen uptake

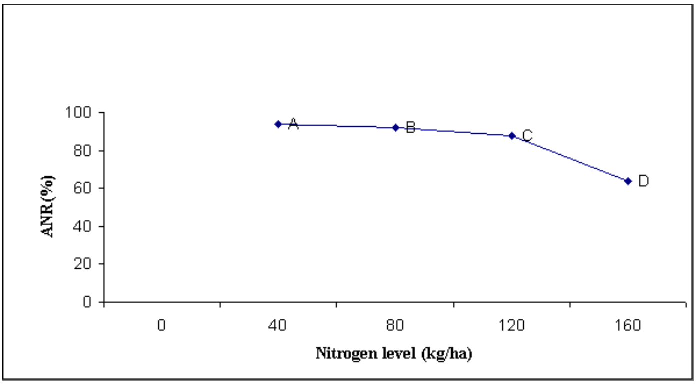
The Nitrogen removed by the crop from soil also increased significantly ($p<0.05$) with successive levels of applied nitrogen from 60 kg uptake recorded at 0 kg N ha^{-1} to 166 kg uptake observed at 120 kg N ha^{-1} and declined to 162 kg uptake noticed at 160 kg N ha^{-1} (Fig 2). The increase in uptake observed in present study is in agreement with the reports of Verma and Joshi (1998) in Teosinte (*Euchlaena maxicana* L.) and Tripati (1994) in oats grown on soils with low fertility. The higher uptake with increased dose level might be due to increased availability of nitrogen in soils with better development of roots of the crop on which nitrogen has positive effect as observed by Chacraborty *et al.* (1999). On the other hand, the decreasing trend observed at above 120 Kg N ha^{-1} was related to the same decrease in nitrogen content since uptake was calculated as a product of nitrogen content and dry matter accumulation in plant tissue. Apart from fertilizer nitrogen (given in the form of urea), the crop also removed about 60 kg from soil available nitrogen which might have made the observed level of uptake (removal) to be at more than the level of applied nitrogen.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 2. Effect of different levels of nitrogen on Nitrogen Uptake (NU) of forage oat

Apparent recovery

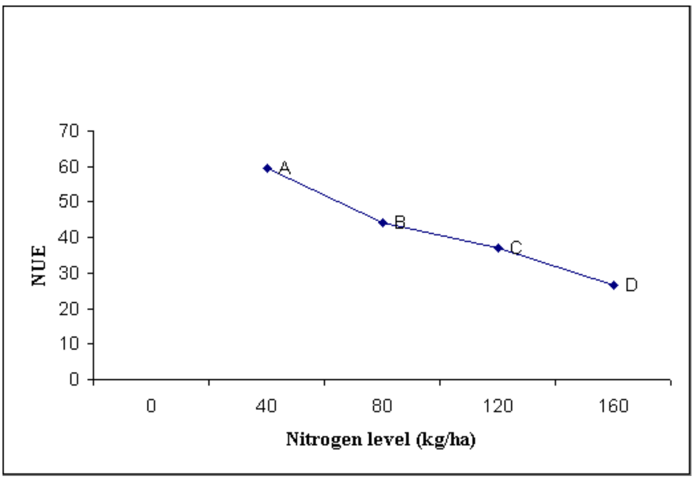
Unlike the nitrogen content and uptake, the recovery of part of the applied nitrogen explained by the apparent recovery (Fig 3), decreased significantly ($p<0.05$) with successive levels of applied nitrogen from 94 % revealed at 40 kg N ha-1 to 64 % recorded at 160 kg N ha-1. Similar trends have been reported in wheat (Kumar et al., 1995), rice (Shivay and Singh, 2003) and sorghum (Nyamudeza et al., 2003; Ammaji and Suryanaryana, 2003). The decrease in recovery with increased levels of applied nitrogen could be due to genetic limitation of the crop to takeup more nitrogen beyond its capacity to assimilate and also loss of the applied soil nitrogen through denitrification, volatilization, leaching, and immobilization (Havlin et al., 1999; Brady and Weil, 2002). Ammaji and Suryanaryyana (2003) accounted this to the operation of the law of diminishing return in sorghum.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 3. Effect of different levels of nitrogen on Apparent Nitrogen Recovery (ANR %) of forage oat

Nitrogen use-efficiency

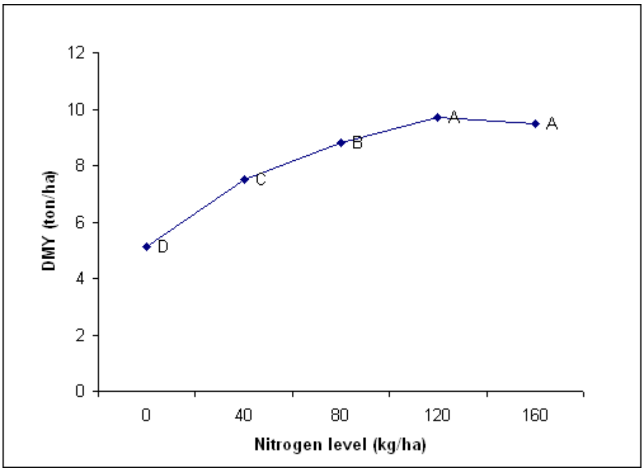
In a similar fashion to recovery, the agronomic nitrogen use-efficiency of the crop decreased significantly ($p<0.05$) with successive levels of applied nitrogen from 60 recorded at 40 kg N ha^{-1} to 26 revealed at 160 Kg N ha^{-1} (Fig 4). The decrease in efficiency of use, i.e the amount of dry matter produced by a unit of the applied nitrogen, was related to the amount of applied nitrogen recovered by the crop. Low recovery of the applied fertilizer nitrogen along with other losses suggested by Karlen *et al.* (1988) might have accounted to the decrease in efficiency of fertilizer use for production of targeted yield.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 4. Effect of different levels of nitrogen on Nitrogen Use Efficiency (NUE) of forage oat

Dry matter yield

The dry matter yield of present study increased significantly ($p<0.05$) with levels of applied nitrogen (Fig 5). Maximum dry matter yield of 9.7 ton ha^{-1} was recorded by application of 120 Kg N ha^{-1}. Increasing the dose level to 160 Kg N ha^{-1} however, reduced the dry matter yield to 9.5 ton ha^{-1}. The increase in yield with successive level of nitrogen masked the associated loss of nitrogen explained by both decreasing apparent recovery and use efficiency of the crop. The dry mater yield continued to increase with decreasing recovery and use efficiency till no more yield increment was recorded at above 120 Kg N ha^{-1}. The observation suggests, it might be better to consider efficiency of the crop to improve recovery and use of the applied nitrogen to attain production of both biologically and economically targeted yields.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 5. Effect of different levels of nitrogen on Dry Matter Yield (DMY) of forage oat

Conclusions and Recommendations

Forage yield and quality are the two important aspects for which fertilizer management is required. Nitrogen is by far important for its role in improving yield and quality of the crop. Increasing the amount of fertilizer beyond certain threshold however, did not improve yield and quality of the crop. The dry matter yield of present study increased significantly with successive levels of applied nitrogen and the maximum yield of 9.7 ton ha^{-1} was recorded at 120kg N ha^{-1} and thereafter, there was no yield increment. The total nitrogen content in plant tissue also increased with uptake. The origin of the nitrogen in plant tissue was both from uptake of mineralized soil available nitrogen and the applied nitrogen as urea. Whereas, the recovery of the portion of the applied nitrogen and the efficiency of use for production of dry matter decreased significantly with successive levels of applied nitrogen. The loss in applied nitrogen was reflected in dry matter yield reduction at only above 120 kg N ha^{-1}. From the observation it could be advisable to consider efficiency of the crop to recommend fertilizer rates rather than relying on yield and or soil test *perse.*

Acknowledgement

The authors are grateful to the Ethiopian Agricultural Research Institute for funding the study through the Agricultural Research and Training Project (ARTP).

References

Aklilu Mekasha 2005. Studies on growth yield and quality of forage oat (*Avena sativa L.*) varieties under different levels of nitrogen. M.Sc. Thesis. G.B. Pant University of Agriculture & Technology, Pantnagar, India.

Ammaji, P. and Suryanaraana, K. 2003. Yield and nutritive value of fodder sorghum varieties as influenced by different levels of nitrogen. *The Andhra Agricultural Journal* 48 (3&4): 1999-2002

Below, F. E. 1995. Nitrogen metabolism and crop productivity. *In: Mohamed Pessarkali (ed.)* Handbook of plant and crop Physiology 2nd ed. Marcel Dekker, New York.

Bloom, A. J., Chapin, F. S. and Mooney, R. 1985. Resource limitation in plants an economic analogy. *Annual Review of Ecological System* 16**:**363-392

Brady, N. C and Weil, R. R. 2002. *Nature and properties of soils*, 3rd ed., Pearson. education Inc., India. P 544.

Chakraborty, T., Subrata M., Saswat, H., Mandal S. and Haldar, S. 1999. Effect of different levels of nitrogen and cutting on growth, forage and grain yield of oat (*Avena sativa*). *Crop Research Hisar* 18(1**): **39-45

Havlin, J. L., Beaton J. D., Tisdale, S. L. and Nelson, W. L. 1999. *Soil fertility and fertilizers*: *An introduction to nutrient management* 6th edition. Pearson Education, Inc., India.

Hopkins, A., Adamson, A. H. and Bowling, P. J.1994. Response of permanent and reseeded grassland to fertilizer nitrogen. II Effect on concentrations of Ca, Mg, K, Na, S, P, Mn, Zn, Cu, Co, and Mo in herbage at a range of sites. *Grass and forage Science* 49**:**9-20.

Jackson, M.L.1973. *Soil chemical analysis,* Prentice-Hall, Inc., New Delhi.

Karlen, D. L. and Flannery, R. L. 1988. Aerial accumulation and partitioning of nutrients by corn. *Agronomy Journal* 74: 562.

Kirikham, E. W. and Wilkins, R. J. 1994.The productivity and response to in-organic fertilizers of species rich wetland hay meadows on the Somerset Moors: The effect of nitrogen, phosphorous and potassium on herbage production. *Grass and forage Science*49:163-175.

Kumar, A., Sharma, D. K. and Sharma, H. C.1995. Nitrogen uptake, recovery and N-use efficiency in wheat (*Triticum aestivum*) as influenced by nitrogen and irrigation levels in semi-arid sodic soils. *Indian Journal of Agronomy* 40(2): 198-203.

Nyamudeza, P., Azam-Ali, S. N., Marshall, S. and Chiduza, C. 2003. Effect of tied furrows and N on yield, N uptake, and N use-efficiency on maize and sorghum in semi-arid Zimbabwe. *Tropical Agriculture* 80(3): 193-198.

Pandey, S. and Sinha, B. K. 2006. *Plant physiology,* 4^{th} edition. Vikas Publishing house Pvt. L., Newdelhi, India.

Shivay, Y. S. and Singh, S. 2003. Effect of planting geometry and nitrogen level on growth, yield and nitrogen use-efficiency of Scented hybrid rice (*Oryza sativa*). *Indian Journal of Agronomy* 48(1): 42-44

Tripathi, S. B. 1994. Response of oat grown as pure and mixed with sweet clover to nitrogen application of various soil fertility. *Forage Research* 20(4): 278-284

Verma, S. K. and Joshi, Y. P. 1998. Effect of nitrogen and seed rate on leaf area index, nitrogen content, nitrogen uptake and dry matter yield of Teosinte (*Euchlaena maxicana* Schrad) at different growth stages. *Forage Research* 24 (1): 45-47

Livestock production and utilization of sweet potato vines as source of feed in two districts of southern Ethiopia

Netsanet Beyero, Adugna Tolera and Girma Abebe*

Department of Animal and Range Sciences, Hawassa University, P.O. Box 5, Hawassa, Ethiopia

Abstract

A diagnostic survey was carried out in Badawacho and Sodo Zuria districts of Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia. The districts were characterized by mixed crop-livestock production system. The average land holding per household is 1.29 ha in the Badawacho district and 0.58 ha in Sodo Zuria district. Livestock have multiple roles. Households keep cattle mainly as a source of draft power in Sodo Zuria and as source of milk in Badawacho districts. The main purpose of keeping small ruminant was as a source of cash income. The average livestock holding per household was 2.60 and 1.97 TLU in Badawacho and Sodo Zuria districts, respectively. The survey indicated that the main dry season feed resources are crop residues, whereas natural pasture is the main source of feed in the wet season. According to the respondents, feed shortage is the major livestock production constraint in both Badawacho and Sodo Zuria districts. Feeding sweet potato vine to livestock is commonly practiced in both districts, mainly as fresh and also after curing. The bulk of sweet potato vine is obtained during harvesting of sweet potato tubers. Households use a smaller portion of the vine for propagation. But the larger proportion of the residue that is left aside is available for feeding to livestock.

Keywords: *feed resources; sweet potato vine; livestock production constraints; Ethiopia*

Introduction

Livestock productivity in most production systems is mainly constrained by feed inadequacy in terms of quantity and quality (Getnet et al., 2003). Grazing and browsing on natural pastures and poor quality crop residues are the main sources of feed in most parts of east Africa (Owen, 1994). Currently, with the rapid increase of human population and expansion of arable land and with the steady decrease in grazing land, the use of crop residues is increasing. However, cereal straws and stovers, which form the bulk of crop residues, are characterized by their low digestibilities (<50%), low metabolizable energy content (<7.5 MJ/Kg DM), low intake (10-15 g DM/Kg live weight), and low content of available minerals and vitamins (Owen, 1985).

Other agricultural by products such as sweet potato vines, cassava leaves, banana leaves and peels, sugar cane leaves and enset (*Ensete vintricosum*) leaves could also serve as important sources of supplementary feed during the dry season. Sweet potato

*Corresponding author:atolera@yahoo.com

is traditionally grown to provide tubers for human consumption and vines can be used as useful supplementary feed for livestock in areas where the crop is grown (Tolera et al., 2000). This study is designed to assess the utilization of sweet potato vine for animal feeding in parts of southern Ethiopia.

Materials and Methods

The study area

A diagnostic survey was conducted in July and August 2005 to describe livestock production system and assess the utilization of sweet potato vines as animal feed in Sodo Zuria and Badawacho districts in Southern Nations, Nationalities and Peoples Regional State (SNNPRS), southern Ethiopia. Sodo Zuria district is located at $6^0$49'N and $39^0$47' E and lies approximately 400 km southwest of Addis Ababa. The district covers an area of 481 km^2 and has an altitude range of 1700-3000 m.a.s.l (Mohammed Saleem, 1995; Irvin, 2000). Rainfall averages 1100 mm per year and is bimodal, with the short rains from February or March - April and the long rains from June - September or October (Tolera and Said, 1992). The area has an annual mean temperature of 18^0C. Badawacho district is located at 7^0 4'N and 38^0 00'E and it lies approximately 328 km south west of Addis Ababa (EMA, 1988). The area has an annual mean temperature of 18^0C, and receives an annual rainfall of 900 to 1200 mm (Badawacho district Office of Agricultural and Rural Development, Unpublished).

Sampling technique

Sodo Zuria and Badawacho districts were purposively selected because they are among the areas known to have high potential for sweet potato production. From a total of 50 Peasant Associations (PAs) in Badawacho district three (Weyira Mazoria, Weyira Gere, and Lalo Gerbe) and from a total of 31 PAs in Sodo Zuria districts three (Ziga Borkoshe, Gilo Bisare and Sore Meshido), a total of six representative PAs and 30 households from each PA were randomly selected. Accordingly, a total of 180 households were selected for the interview purpose.

Data collection

Data collection was carried out using a pre-tested questionnaire and information related to household land holding (grazing and cultivated land), land-use patterns, main means of income, herd size, livestock species composition, the purpose of livestock keeping, available feed resources, seasonal availability, livestock production constraints and utilization of sweet potato vine as animal feed in the study areas were collected. Extension personnel who work in agricultural and rural development offices of the districts collected the primary data under the supervision of the researcher. Secondary information was also gathered from district Bureau of Agriculture.

Data management and statistical analysis

Descriptive statistics was employed to describe the various variables in the livestock production systems including household size, herd size, land holding and land use pattern and available feeds. The data was analyzed statistically using SPSS software, version 10.0 (SPSS, 1999).

Results and Discussion

Household characteristics

The mean household size in Sodo Zuria was higher than that of Badawacho district. The average family size was 6.7 persons with a range of 2-13 persons in Badawacho district. Similarly average family size in Sodo Zuria district was 7.9 persons with a range of 2-13 persons per household. The proportion of adults (age class of 15-64 years) per household in Badawacho district was 49.4 % and children (age<15 years) make up 45.5 %, while the proportion of older people (>64 years) in the household was 5.0 %. In Sodo Zuria district 43.2 %, 51.9 % and 4.94 % of household members fall in the age class of (<15 years), (15-64 years) and (>64 years), respectively.

The number of children per household varies from 1-11 in both districts with a mean of 4.9 and 6.0 in Badawacho and Sodo Zuria district, respectively, which indicate that the two districts are among the densely populated areas in the country.

Out of the household heads interviewed in Badawacho district, about 42.2% and 12.2% had educational level of primary and secondary schools, respectively, while the remaining 45.6 % did not have any formal education. About 61.1% of household heads had educational background of primary and secondary schools in Sodo Zuria district, while the rest 38.9% did not have any formal education. The result of the two districts showed that more proportion of the household heads were literate (54.4% and 61.1% in Badawacho and Sodo Zuria districts, respectively). Educated manpower is a social capital that could facilitate generation as well as adoption of new technologies.

Landholding of Households

Average land holding was 1.29 ha per household in Badawacho district and 0.58 ha per household in Sodo Zuria district. This included cultivated land, natural pasture as well as area of homestead. As compared to previous studies, which reported a land holding of 0.96 ha (Tolera, 1990), the landholding has diminished over time in Sodo Zuria. The mean cultivated area was 1.09 ha or (84.5%) in Badawacho district and about 0.42 ha (72.4%) of the farm size in Sodo Zuria district. This result is greater than the privately owned cultivated land (57% of the total land holding) that was reported in Wolayita

Sodo (Irvin, 2000). This implies that there is an increasing competition for land between livestock and crop production.

The average privately owned grazing land was 0.15 ha (11.3%) in Badawacho district and 0.14 ha (24%) of the farm size in Sodo Zuria district. The latter value is by far less than the privately owned grazing land (0.23 ha/household) reported earlier for Wolayita Sodo (Tolera and Said, 1992). This is possibly due to high human population growth in the district, which led to the conversion of private grazing lands into crop land. The relatively higher grazing land allotted by households in Sodo district is due to lack of communal grazing land as compared to Badawacho. It indicated that, more land will be needed to produce food crops, thereby reducing the land available for pasture and fodder. As a result, crop residues will assume greater importance as livestock feed than natural pasture through time.

Crop production

The dominant crops in both districts are maize, sweet potato, haricot beans, teff (*Eragrostis tef*) and enset (*Ensete ventricosum*). Maize is the leading crop in both districts. Area of land used for maize production was 0.43 ha and 0.28 ha in Badawacho and Sodo Zuria districts, respectively (Table 1). The reason for this may be because of higher productivity of the crop as compared to others, and price advantage in relation to sweet potato in the districts. In area coverage, sweet potato was the second leading crop in both districts, it accounts for 0.26 ha and 0.22 ha in Sodo Zuria and Badawacho districts, respectively.

Table 1. Area of land (ha) allocated for production of different crops in Badawacho and Sodo Zuria districts (mean ± SE)

Crop type	Badawacho	Sodo Zuria
Maize	0.43±0.12	0.14±0.07
Sweet potato	0.22±0.05	0.13±0.04
Teff	0.21±0.08	0.02±0.02
Haricot bean	0.14±0.05	0.04±0.02
Wheat	0.03±0.02	0.03±0.03
Potato	0.02±0.02	0.01±0.01
Enset	0.02±0.01	0.04±0.02
Barley	0.02±0.01	0.01±0.01

Many farmers also grow minor crops, which were not ranked; these include pumpkin, sugar cane, cabbage, coffee and Khat (*Catha edulis*). The priority of the farmers is to meet their subsistence requirements. Of the crops, teff, sugar cane, coffee and the stimulant crop Khat are grown primarily for income generation. Of the major crops, both maize and sweet potato are the major staple diets in Badawacho and Sodo Zuria districts. According to the respondents, maize is the major staple diet followed by sweet potato and teff in Badawacho district (Table 2). This corroborates with the area coverage of the crops in the district (Table 1). On the other hand sweet potato followed by maize and ens*e*t are the three major staple diets in Sodo Zuria district. In similar way, Tolera and Said (1992) reported maize, sweet potato and enset as the major food crops in Wolayita Sodo.

Table 2. Percent farmers reporting the different crops as major staple food in Badawacho and Sodo Zuria districts

Crop Type	Badawacho (N=90)	Sodo Zuria (N=90)
Maize	76.4	35.6
Sweet Potato	21.1	53.3
Enset	1.4	7.8
Wheat	-	2.2
Haricot bean	-	1.1
Teff	1.1	-
Total	100.0	100.0

Livestock species composition

According to the respondents, farm animals raised in the two districts include: cattle, goats, sheep, poultry and equine (donkey). The average livestock holding per household in Tropical Livestock Unit (TLU) during the study period was 2.60 and 1.97 in Badawacho and Sodo Zuria district, respectively (Table 3). Bigger herd size per household in Badawacho district is probably due to larger grazing land per household than in Sodo Zuria district.

Table 3. Livestock holding per household and herd/flock structure in Badawacho and Sodo Zuria districts

Location	Badawacho			Sodo Zuria		
Heads of animal species	Mean ± SE	Percent	Mean (TLU)	Mean ± SE	Percent	Mean (TLU)
Total livestock	5.14		2.60	4.00		1.97
Cattle	3.51±0.07	100	2.33	2.70±0.06	100	1.79
Cows	1.38±0.08	39.38		0.90±0.07	33.33	
Oxen	0.62±0.06	17.66		0.57±0.07	20.98	
Bulls	0.32±0.08	9.12		0.21±0.05	7.82	
Heifers	0.57±0.07	16.24		0.50±0.07	18.52	
Calves	0.62±0.06	17.60		0.52±0.06	19.34	
Sheep	1.14±0.07	100	0.12	1.00±0.05	100	0.10
Lambs	0.55±0.08	48.25		0.34±0.07	34.44	
Ewes	0.50±0.07	43.86		0.53±0.06	53.34	
Rams	0.09±0.04	7.89		0.12±0.04	12.22	

Location	Badawacho			Sodo Zuria		
Heads of animal species	Mean ± SE	Percent	Mean (TLU)	Mean ± SE	Percent	Mean (TLU)
Goats	0.22±0.03	100	0.02	0.18±0.03	100	0.02
Kids	0.07±0.03	31.82		0.07±0.03	37.51	
Does	0.14±0.05	63.64		0.10±0.03	56.24	
Bucks	0.01±0.01	4.54		0.01±0.01	6.25	
Donkeys	0.25±0.05	100	0.13	0.12±0.04	100	0.06

Oxen comprised 17.7 percent of the cattle herd in Badawacho and 20.9 percent in Sodo Zuria district (Table 3). Given the need for use of oxen as source of draft power for crop production, the result is logical. Moreover, in Sodo Zuria district oxen may also be kept for fattening purpose to generate cash income. However, the proportion of cows, accounted for 39.4 percent of cattle herd, is higher in Badawacho than that of Sodo Zuria district, which accounts for only 33.3 percent. Moreover, proportion of young animals (heifers and calves) in the cattle herd was 16.2 percent and 17.6 percent in Badawacho and 18.5 percent and 19.3 percent in Sodo Zuria, respectively.

Among small ruminant, the average goat holding per household was 0.02 TLU both in Badawacho and Sodo Zuria districts (Table 3). This is smaller than the number (0.25 TLU) reported by Tolera and Said (1992). The proportion of does, accounting for 64.8% of goat flock, is higher in Badawacho than in Sodo Zuria district, which is 56.2%. However, the proportion of kids in the goat flock was 37.5% and 30.2% in Sodo Zuria and in Badawacho districts, respectively. Average sheep holding per household in TLU was more or less similar in both districts (0.11 and 0.10 in Badawacho and Sodo Zuria, respectively). Donkey population was higher in Badawacho than in Sodo Zuria district.

According to the respondents in both districts, the population of livestock shows a decreasing trend over the last five years. This could be due to high human population density, increased cultivated land and concomitant decrease in communal and private grazing lands. The result implies a need for alternative feed sources in the area, and a declining condition of livestock to household nutrition and income generation.

Source of income

Livestock make a substantial contribution to the economy of smallholder farmer in Ethiopia (Gryseels, 1988). Mixed farming is the dominant system in both districts. But in most farms cropping is the main activity while livestock stands second. In Badawacho district, sale of crop products was the main source of income followed by sale of livestock and livestock products (Table 4). Sale of crops followed by animal products and animal sales were the important sources of income in Sodo Zuria district (Table 4). The minimal income from livestock could be due to inadequate livestock services (Irvin, 2000) to enhance the productivity of the livestock sector.

Table 4. Percentage of responses reported on income generating activities in Badawacho and Sodo Zuria districts

Activities	Badawacho (N=90)	Sodo Zuria (N=90)
Crop sale	87.8	63.3
Livestock sale	11.1	10.0
Sale of animal products	1.1	16.7
Total	100	100

Purpose of keeping livestock

In both districts, livestock are reared for multiple purposes. They serve as a source of food, cash income, draft power (land preparation and threshing of wheat, barley and teff), manure and hide and skin. In Sodo Zuria district, the first objective of cattle rearing is for draft power (Table 5). This is because crop production was the main farming activity at the moment in the district. Only 15.6% of the respondents ranked milk production as a major role of cattle rearing. The role of livestock for saving and income generation through sale of live animal is given lesser priority. On the contrary, more than 75% of the households rear cattle primarily for milk production followed by the role as a source of draft power and saving of money in Badawacho district.

Table 5. Percent respondents reporting the purpose of keeping cattle and small ruminants in Badawacho and Sodo Zuria districts

Purpose of cattle keeping	Badawacho (N=90)	Sodo Zuria (N=90)
Milk	77.7	15.6
Draft	18.9	71.1
Saving	2.2	8.9
Cash income	1.2	4.4
Total	100.0	100.0
Purpose of keeping small ruminants		
Income	73.3	69.1
Saving	15.1	20.1
Meat	5.4	2.0
Skin	4.0	2.6
Manure	2.8	5.2

The main purpose of rearing small ruminant in both districts was for income generation through sale of live animals (Table 5). In Badawacho district about 15.1% of the respondents ranked sheep and goats as a means of cash reserve. Small ruminants are also used as a source of skin and manure.

Available feed resources

The principal feed resources available to livestock in the study areas include natural pasture, crop residues and fodder trees (Table 6). Generally, residues from cereals (maize, wheat and barley), were found to contribute more to the feed resource base than those from other crops. Getnet and Ledin (2000) reported that in the highlands of Ethiiopia, livestock are mainly dependent on crop residues and natural pasture for their feeds. Also Tolera and Said (1992) indicated that enset and sweet potato vines are used as a dry season feed resources in Welayita Sodo. The magnitude of availability of each type of feed resources varied between the two districts. The difference could be attributed to the variation in land use system and the average size of land holding in the two districts.

Table 6. Percent respondents reporting the feed resources available in Badawacho and Sodo Zuria districts during the wet and dry seasons (N=90)

Feed resources	Wet season		Dry season	
	Badawacho	Sodo Zuria	Badawacho	Sodo Zuria
Natural pasture	78.8	68.9	2.2	24.4
Crop residue	17.8	3.3	56.7	37.4
Hay	1.2	22.2	38.9	17.6
Industrial by-products			1.1	0.5
Fodder trees	2.2	2.2	1.1	17.8

Different studies indicate that crop residues are the most important dry season livestock feed in most countries, as availability of natural pasture is the main limiting factor during the dry season (Preston and Leng, 1984). As human population density rises, the importance of crop-residues feeding increases relative to uncultivated forage. This is reaffirmed by the present survey that more than 55 percent of the Badawacho district respondent reported crop residue followed by hay and natural pasture to be the main feed resource in the dry season. Most of the crop residues are used as livestock feed, but their supply is seasonal. In Sodo Zuria 37.4% of the respondents indicated crop residue as the main feed resource in dry season followed by feed from natural pasture and fodder trees (Table 6). Crop residue is more important as a source of feed in Badawacho than in Sodo Zuria district, this may be due to the availability of large cropping land in Badawacho than in Sodo Zuria district.

In the wet season, available natural pasture was higher in Badawacho than in Sodo Zuria. This may be due to the fact that the land available for natural grazing and browsing is rapidly decreasing due to the increasing human population and increasing demand for cropping land, to cope with the high and increasing human population pressure in Sodo Zuria district. As the report by Tolera and Said (1992) showed, the use of concentrate feeds is very minimal. Agro-industrial by-products such as oilseed cakes and flour mill by-products are not available in the area. Acute shortage of land and inadequate feed supply constrain animal output in Wolayita Sodo.

Utilization of sweet potato vine as animal feed

Majority of the respondents (98.9%) in Badawacho and (87.8%) in Sodo Zuria districts indicated that sweet potato vine was used as animal feed (Table 7). Similarly Tolera and Said (1992) reported that sweet potato vines as well as *enset* and cassava leaves are used as dry season feeds in Wolayita Sodo. In Badawacho district 51.1% of the respondents use sweet potato vine as fresh, 45.6% use in cured form and the remaining rest 2.2% used in both fresh and cured form (Table 7). On the other hand, 45.6% of the respondents in Sodo Zuria used as fresh and 35.6% in cured form and only 4.4% used both in fresh and cured form of the vine as animal feed.

Table 7. Percent respondents reporting utilization of sweet potato vine in Badawacho and Sodo Zuria districts

Responses on use	Form of use	Badawacho (N=90)	Sodo Zuria (N=90)
Yes	Fresh	51.1	47.8
	Cured	45.6	35.6
	Both	2.2	4.4
	Total	98.9	87.8
No		1.1	12.2

In terms of animal species, cows followed by calves, sheep and oxen were reported to be the main animals fed sweet potato vine in Badawacho district. Also cows followed by oxen, calves, sheep and goat are the animals fed sweet potato vine in Sodo Zuria district. In both districts, cows were given preference to feed sweet potato vine, this may be related with milk production. In both districts the respondents indicated that goats have less preference for sweet potatoes vines than cattle and sheep. In the presence of alternative feeds sources and given the behavior of goats as selective feeders, goats may tend to prefer other shrubs as the major diet. However, previous studies conducted elsewhere (Branckaert, 1993) and on-station experiment conducted at Hawassa University after this survey (Netsanet et al Unpublished) showed that goats can readily consume and devour sweet potato vines.

Livestock production constraints

The respondents in both districts mentioned a number of problems affecting livestock production, but shortage of feed was indicated as the main constraint for livestock keepers (Table 8). In another study, Tolera and Said (1992) reported shortage of grazing land and inadequate feed supply as the major problems facing livestock producers in the area. Farmers face very high feed shortage especially in the dry season (December-May).

Table 8. Percent respondent reporting livestock production constraints in Badawacho and Sodo Zuria districts

	Cattle production		Small ruminant production	
Constraints	Badawacho (N=90)	Sodo Zuria (N=90)	Badawacho (N=90)	Sodo Zuria (N=90)
Feed shortage	90.0	85.6	62.2	68.9
Land shortage	7.8	6.5	14.5	13.8
Disease problem	2.2	7.9	21.3	9.6
Predator			2.0	7.7
Total	100.0	100.0	100.0	100.0

According to Irvin (2000) weight loss, reduction in milk production, reduction in draft power and deaths of young and adult livestock occur during the dry season. During that time the farmers always need other supplemental feed resources for their livestock (Table 9). As Irvin (2000) reported, some measures taken by farmers to combat these feed shortages are feeding livestock with feeds normally intended for human beings such as sweet potato tubers, maize grain and *gefetano enset,* which is normally reserved for sick animals. The harvesting time of sweet potato overlaps with this time of feed shortage (Table 10). This is also one advantage to overcome these feed shortage by providing the vine while human beings use the tubers. As Tolera et al (2000) indicated, sweet potato is traditionally grown to provide tubers for human consumption and the vines can be used as supplementary feed for livestock. Crops having food and feed value such as sweet potato are gaining more acceptances in systems where land is limited and maximum output from a given area is required.

Table 9. Percent respondents reporting the need of supplemental feed in Badawacho and Sodo Zuria districts

Time of the year when supplements needed	Badawacho (N=90)	Sodo Zuria (N=90)
December-May	81.2	79.7
Always	18.8	20.3
Total	100	100

The other constraints of livestock production indicated by the respondents in the study area include land shortage and disease problem (Table 8). The same holds true to the constraints of small ruminant production in both districts, but the weight given to the constraints is different. In addition to cattle production problems, predator is one additional problem to the production of small ruminants in both districts.

Table 10. Percent respondents reporting different sweet potato harvesting time in Badawacho and Sodo Zuria districts

Time of harvest	Badawacho (One harvest per year)	Time of harvest	Sodo Zuria (Two harvest per year)
February-April	41.1	January and May	45.6
February-March	32.2	October and February	24.4
May-July	26.7	October and May	20.0
		November and March	10.0
Total	100.0	Total	100.0

The survey showed the importance of sweet potato in the study areas. The fact that sweet potato vine and tuber can be grown and harvested during the dry season, when acute feed shortage occurs, makes it a strategic food/feed crop.

Conclusions

In both districts, shortage of feed was identified as the main constraint affecting livestock production, particularly during the dry season. As human population density rises, the importance of crop-residues feeding increases relative to natural pasture. The culture of feeding sweet potato vine exists in Badawacho and Sodo Zuria districts of Southern Ethiopia. The bulk of sweet potato vine is obtained during harvesting of sweet potato tubers. The harvesting time of sweet potato overlaps with the time of critical feed shortage. This helps to alleviate the problem of livestock feed shortage by providing the vine while human beings use the tuber.

Acknowledgement

The research work was financed by the Norwegian Center for International Cooperation for Higher Education (NUFU) as part of a collaborative project between Hawassa University and Norwegian University of Life Sciences through a project entitled “Enhancing Food Production and Nature Management, Pro 16/2002”. We thank the interviewed farmers for their time and willingness to share their knowledge of their farm and farming system.

References

Branckaert, R. 1993. Strategies for sustainable development of small ruminants: Burundi - a case study. In: Mack M (Ed.). Strategies for sustainable animal agriculture in developing countries, Proceedings of the FAO Expert Consultation held in Rome, Italy, 10–14 December 1990, FAO Animal Production and Health Paper 107

EMA (Ethiopian Mapping Authority),1988. National Atlas of Ethiopia. Berhanena Selam

Printhing press, Addis Ababa.

Getnet, A. and Ledin, I. 2000. Available feed resources and the role of cultivated forage crops in the small holder farming systems in the central highlands of Ethiopia. In: Proceedings of the 8th Annual conference of the Ethiopian Society of Animal Production (ESAP), Addis Ababa, Ethiopia. pp. 265-274.

Getnet. A., Abreham, G., Fekede, F. and Tadesse, T. 2003. Effect of methods and dates of clearing regrowth of Rhodes (*Chloris gayana*) and Colored Guinea grasses (*Panicum coloratum*) on seed productivity. In: Proceedings of the 11th Annual conference of the Ethiopian society of Animal production (ESAP), Addis Ababa, Ethiopia. pp. 297-302

Gryseels, G. 1988. The role of livestock in the generation of smallholder farm income in two vertisol area of central Ethiopia highlands. In: Jutzi S C, Haque I, McIntire J and Stares J E S (Eds.). Management of Vertisols in sub-Saharan Africa. Proceedings of a conference held at ILCA, Addis Ababa, Ethiopia. 31 August - 4 September 1987. ILCA, Addis Ababa. pp. 345-358.

Irvin, S.A. 2000. An assessment of the Demand for Forages by Smallholder Farmers in Wolayta Soddo, Ethiopia. M.Sc Thesis. Imperial College at Wye, England.

Mohamed Saleem, M.A. 1995. Fragile east African Highlands: A development vision for smallholder farmers in the Ethiopian Highlands. *Outlook on Agriculture*, 24 (2): 111-116.

Owen, E. 1985. Crop residues as animal feeds in developing countries use and potential use. In: Wanapat, M. and Devendra, C. (Eds.). Relevance of Crop Residues as Animal Feed in developing Countries. Proc. International Workshop held in Khon Kaen, Thailand, November 29-December 2, 1984, Funny Press, Bangkok, pp. 25-42.

Owen, E. 1994. Cereal crop resides as animal feed for goats and sheep. *Livestock Research for Rural Development,* Vol 6, № 1, http://www.cipav.org.co/lrrd/lrrd6/1/owen.htm

Preston, T.R. and Leng, R.A. 1984. Supplementation of diets based on fibrous residues and by-products. In: Sundstol F and Owen E (Eds.), Straw and other fibrous by-products as feed. Elsevier, Amsterdam, The Netherlands.

SPSS (Statistical Package for Social Sciences). 1999. SPSS for Windows. Version 10.

Tolera, A. 1990. Animal Production and Feed resource Constraunts in Wolayita Sodo and the Supplementary Value of *Desmodium intortum, Stykosanthes guianensis and Macrocyloma axillare* when fed to growing sheep feeding on a basal diet of maize stover. MSc.Thesis, Agricultural University of Norway.

Tolera, A. and Said, A.N. 1992. Prospects for integrating food and feed production in Welayita Sodo, Ethiopia. In: Stares J E S, Said A N and Kategile J A (Eds.) The complementary of feed resources for animal production in Africa. Proceedings of the joint feed resources networks workshop held in Gaborone, Botswana, 4-8 March 1991. African Feeds Research Network, ILCA (International Livestock Center for Africa), Addis Ababa, Ethiopia, pp. 309-318.

Tolera, A., Merkel, R.C., Goetsch, A.L., Sahlu, T. and Negesse, T. 2000. Nutritional constraints and future prospects for goat production in east Africa, In: Merkel R C, Abebe G and Goetsch A L (Eds.). Proceedings of the conference on opportunities and challenges of enhancing goat production in east Africa, November 2000, Langston University, Langston, USA and Debub University, Awassa, Ethiopia. pp 43-56.

Integrated fodder and grain crops production on upland black clay soils (*Vertisols*)

Solomon Mengistu[1*], Diriba Geleti[1] and Cherinet Woyimo[1]

[1]*Ethiopian Institute of Agricultural Research, Debre Zeit Research Center, P.O. Box 32, Debre Zeit, Ethiopia.*

Abstract

In Ethiopia, livestock productivity is highly constrained mainly by feed shortage. The objectives of this experiment were to assess the possibility of sequential cropping of annual fodder legumes with chickpea under rain fed conditions on black clay soil (*Vertisol*) and explore the effect of these crops on grain yield of a succeeding cereal crop. The experiment was conducted on a heavy soil (cracking type clay, *Vertisol*) at two locations: Debre Zeit 1800 m altitude (9° N and 39° E, 45 km SE of Addis Ababa) and Akaki, 2200 m. (8° 45' N and 39° E, 15 km SE of Addis Ababa). The experiment consisted of a rotation involving three phases: fodder (*Phase I*) (four annual legumes), pulse (*Phase II*) (chickpea) and cereal (*Phase III*) (durum wheat). The fodder and chickpea were grown sequentially over the main rainy season while wheat was grown in the following year. A split-plot in RCBD was used; the fodder and chickpea crops as the sub-plot treatments and four application rates of fertilizer N on wheat in the second year as the main-plot treatments. The result of the experiment over the three cycles showed most fodder species to have produced high quality fodder with dry matter yield of 2-5 t ha^{-1}. Chickpea, grown as double crop gave an average grain yield of 8-20 qha^{-1}. The precursor legume crops increased wheat grain yield over that obtained from plots that had been fallow in the preceding phase. This positive effect on wheat grain yield was not consistent over years and locations; nonetheless, the general trend indicated that wheat yield had been enhanced due to incorporation of fodder and grain legumes in the rotation. Overall, the study indicated that sequential cropping of annual fodder species and chickpea under rain-fed conditions on *Vertisols* as being technically feasible system with considerable promise to alleviate feed shortage at the smallholder farmer level. Moreover, the technology is deemed to offer an additional advantage of more efficient utilization of black clay soils in the medium and high-altitude highlands of Ethiopia.

Keywords: *annual fodder legumes; chickpea; sequential crop;Vertisols; wheat*

* *Corresponding Author: solomonmgt1@yahoo.com*

Introduction

In Ethiopia, livestock, especially cattle play a pivotal role in the predominantly crop-livestock mixed farming system of the highlands, by providing food, cash income, and most importantly, farm power. However, the productivity of livestock has remained very low due to various factors, the most important one being feed shortage both in quantity and quality. Most of the available feed comes from crop residues and the natural pasture from marginal areas. Improved pasture production is almost inexistent at subsistent farm level mainly because farmers have very limited capacity to allocate labor, finance and, above all, arable land, a scarce resource, for pasture production. Livestock productivity can be improved if animal population is kept commensurate with the available feed resource. This balance can be realized only if the existing backward traditional livestock production system is transformed into a market-oriented and specialized form of production based on improved genetic makeup of animals.

In the short term, an alternative strategy to avert the feed crisis is deemed to be through introducing improved pasture technologies that integrate fodder crops with food crops in various techniques. A possible entry point has been identified by observing the traditional cropping cycle on black clay soils where it was deemed technically possible to introduce fodder crops in the traditional crop sequences in a way that does not detrimentally affect the yield of food crops. This technique, known as sequential cropping, is a shorter version of crop rotations based on three different crop categories-fodder, pulse and cereal.

The traditional cropping cycle in most Ethiopian highlands generally involves two seasons under cereal followed by a pulse phase (e.g., tef-wheat-chickpea). This can be modified to accommodate short-duration annual fodder crops that could be grown as a double crop with a drought tolerant pulse (chickpea or grass pea) in between any two cereal phases particularly on black clay soils (*Vertisols*) that retain residual moisture for sometime.

Vertisols are reported to occupy about 12.6 million hectares of arable and grazing lands accounting for 10.26 per cent of the country (Berhanu Debele, 1987). Water logging is a serious problem during the main rainy season (July-August), in most of the highland *Vertisols*. Seedbed preparation involves a laborious job of deep furrow tillage (*dirdaro*) using oxen plough to facilitate drainage. In flat landscapes where water logging is more severe, farmers are obliged to delay sowing of the more sensitive crops by several weeks until drainage improves. For drought tolerant pulse crops (chickpea and grass pea) sowing is delayed towards the end of the rainy season and the land meant for these crops stays idle for about three-fourth of the growing season. This practice was observed to offer an opportunity of introducing a short duration fodder legume as a double crop with drought tolerant pulse crops (chickpea and grass pea) that are adapted to utilize the residual moisture of *Vertisols*. Selected ecotypes among the annual fodder legumes such as vetches, medics and clovers are well suited for this purpose. Some native clovers such as *Trifolium quartinianum* and *T. steudneri* are well adapted to *Vertisols* and even favored by water logging, with reported yield potential of 4 to 7 t ha^{-1} dry herbage (Kahurananga, J. and Asres Tsehay, 1984). These species with their fast growth rate and tolerance of water logging, offer opportunities for integrating them with drought tolerant pulse crops in a technique of sequential cropping.

The present long-term study was therefore aimed to assess the technical feasibility of sequential cropping of fodder and grain legumes, and determine the fodder yield of a number of annual fodder species during a growing period that is governed by earliness of rain and the latest possible planting time of chickpea. The study also aimed to explore the combined effects of chickpea and elite annual fodder species on grain yield of a subsequent cereal crop so as to finally develop an integrated package of food and forage crop production technology that would also contribute to an efficient utilization of highland *Vertisols*.

Materials and Methods

Experiment Location

The experiment was conducted at two locations: Debre Zeit (9° N and 39° E, 45 km SE of Addis Ababa), and Akaki (8° 45' N and 39° E, 15 km SE of Addis Ababa). Debre Zeit (1850 m altitude) represented the medium highland and Akaki (2200 m), the highland sub-zones of the central Ethiopian highlands. The long term total annual rainfall at Debre Zeit is 850 mm, and at Akaki, 1025 mm; in both sites, about three-fourth of the total falling during the big rainy season, June-September. The mean annual temperature is 18.5 and 11.5 ^{o}C at D Zeit and Akaki, respectively. The soil at both locations is black cracking type clay under the order *Vertisol*. The soil sampled (plough layer) from Debre Zeit was slightly acidic in reaction (pH 6.5); total N, 0.112%; C, 1.24%; organic matter, 2.0%; available P, 2.86 ppm; K, 1.63 and CEC, 48 meq./100g soil. The sample from Akaki had a pH of 7.66; total N, 0.101%; C, 1.18%; organic matter, 2.3%; available P, 2.22 ppm, K, 1.69 and CEC 62 meq./100g soil.

Treatments

The trial consisted of three consecutive phases. The first (*Phase I*) was fodder phase that involved four annual fodder legumes including vetch (*Vicia dasycarpa*); clover (*Trifolium quartinianum* and *T. steudneri*) and medic (*Medicago scutellata*); the second (*Phase II*) was pulse (chickpea, var. DZ 1011), and the third (*Phase III*) was a cereal phase (durum wheat, var. Kilinto). The first two phase crops were raised as double crop one after the other during the main growing season of the first year of each cycle. Accordingly, in

Phase I, the fodder legumes were sown at the beginning of the rains around late-June and maintained till mid-September when they were harvested and replaced by chickpea (*Phase II*) which lasted up to December. In the following year the cereal phase (*Phase III*) continued when wheat was grown in the usual cropping season during the main rains. Thus each cycle (consisting of three phases) took two years to accomplish. The experiment was repeated for three cycles, lasting for six years in total.

The *Phase I* fodder crops were four annual legumes in three genera and they are valued for fast growth with fodder yield potential of 4-7 ton DM ha^{-1} (Kahurananga J. and Asres Tsehay, 1984). These were planted at the beginning of the rainy season at the rate of 10, 20 and 25 kg ha^{-1} recommended for clovers (Kahurananga J. and Asres Tsehay, 1984), medics and vetch (Bogdan A., 1977), respectively. Phosphorus (TSP) fertilizer was applied at a sub-optimal rate of 20 kg P ha^{-1} at planting to enhance nodulation. This sub-optimum rate was fixed considering affordability of price at farmers' level and the rate reported as optimum (Haque and Jutzi, 1984), which is about double of the rate used in this experiment. A partial season fallow (F1) (fallow during June to mid-September and thereafter followed by chickpea); a full season fallow (F2) (fallow throughout the first year) treatments were included for comparison. Plot size was 2m by 3m ($6m^2$). These six treatments (sub-plots for *Phase III*) were arranged in four identical blocks with the purpose to explore how these treatments interact with incremental levels of N fertilizer application (main-plot treatments) on the subsequent wheat crop. Each block was replicated three times.

In *Phase II*, after harvesting the fodder crops, an early variety of chickpea (DZ-1011) was planted on each of the vacated plots at the rate of 75 kg ha^{-1} in rows 30 cm apart (Tebikew Damte *et al*, 2009) towards the end of the rainy season, around September 12-15 (Debre Zeit) and September 15-20 (Akaki). Prior to planting, the vacated plots were lightly tilled lengthwise without disturbing inter-plot path, using a traditional oxen plough. The variety used as well as the planting procedures were uniform for all plots. Moreover, the tilling and planting operations were accomplished in the same day so as to avoid excessive lose of residual soil moisture. Plot size and shape was maintained the same as the preceding fodder phase. Competitive coarse weeds were removed by hand.

In *Phase III* (year 2), the plots were carefully tilled lengthwise (as for chickpea in *Phase II*) using oxen plough and durum wheat (var. Kilinto) was planted at the rate of 150 kg ha^{-1} during normal sowing time: mid-July and late-July at Debre Zeit and Akaki, respectively. Durum wheat was selected for this purpose because it is grown by the majority of the subsistence farmers in the area. Four incremental levels of nitrogen fertilizer were applied ranging from zero level to an optimum level recommended for the variety (Efrem *et al*, 1994). The four levels of application (main-plot treatments) were: without N (0 N), low level (18 kg N ha^{-1}), sub-optimum (32 kg N ha^{-1}), optimum level (64 kg N ha^{-1}). The N source was di-ammonium phosphate (DAP), at the higher rates the complement was adjusted from urea fertilizer.

Measurements and Sampling

Herbage yield of each species in the fodder phase (*Phase I*) was determined by cutting the central rows of the stand at ground level using an open-ended sampling quadrat measuring 0.5 by 1.0 m. Three randomly placed quadrats were used, thus net sampling area was 1.5 m^2. The harvested herbage was measured using field balance and sub-samples were taken and dried in an oven at 65 ^oC over 72 hours period for dry matter yield (DM) and fodder quality determination. Harvesting time was a compromise between high biomass yield from a stand as mature as possible, and the latest possible planting time of chickpea that insured successful germination and establishment, which more or less coincided with the time when most farmers in the area plant chickpea (about mid September). In the pulse phase (*Phase II*), chickpea was harvested at full maturity (around December of each cycle) and grain and straw yields were determined by sampling the central rows. In the cereal phase (*Phase III*), wheat was harvested at full maturity (about late October of each cycle), and both grain and straw yield was determined by sampling the central rows of each plot leaving the border rows on the either side.

Data Analysis

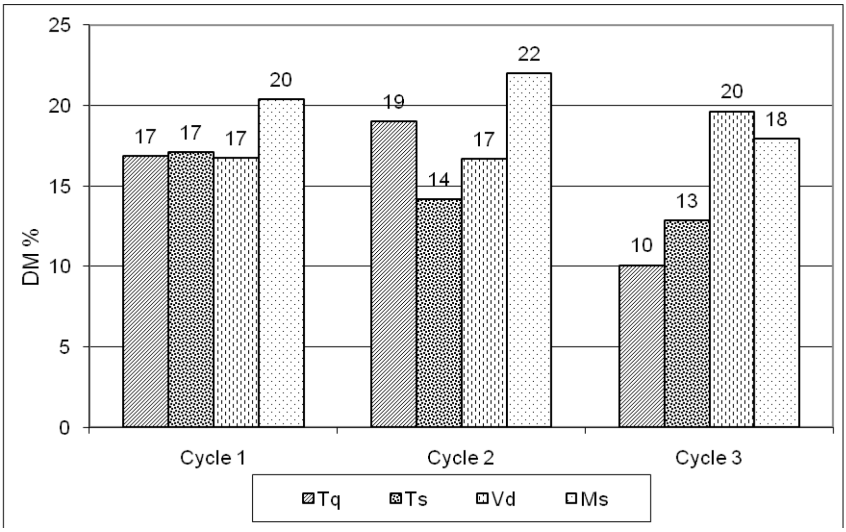
Data was analyzed separately for each phase. The data was subjected to analysis of variance according to Gomez and Gomez (1984) appropriate for the designs employed (RCBD for the first two phase treatments and split-plot for the third phase treatment. Data analysis was facilitated using SAS program (SAS Institute, 1999), and means were separated by using the LSD method.

Results and Discussions

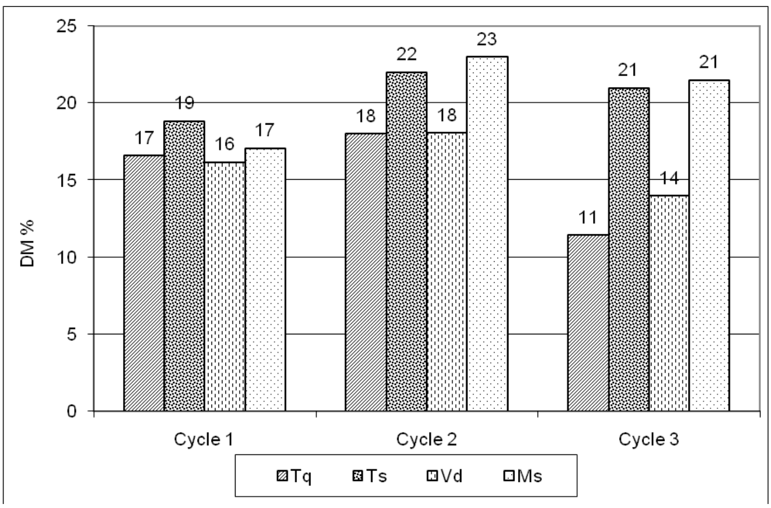
The result of the experiment over three cycles (six years in total) from two locations is presented phase by phase (*Phase I*, fodder; *Phase II*, chickpea; *Phase III*, wheat) as follows.

Phase I- Fodder Crops

The dry matter yield of the fodder species was a function of the length of the growing period that was governed by the prevailing rainfall distributionand the latest possible planting time of the subsequent pulse crop (chickpea). Therefore, taking precaution against any delay in the planting time of chickpea, fodder species were harvested by mid-September at 70-75 and 75-80 days after sowing at Debre Zeit and Akaki, respectively. At this growth period, the species were at different stages of maturity as manifested by their flower initiation. *Medicago scutellata* and *Trifolium steudneri* were relatively fast-maturing and reached 50% flowering at harvest. *Vicia dasycarpa* reached initial flowering while *T quartinianum* was in vegetative stage until it was harvested. Accordingly, the dry matter content of the harvested herbage varied widely with the species and ranged from 10 to 23% (Figure 1).



1.a) Debre Zeit

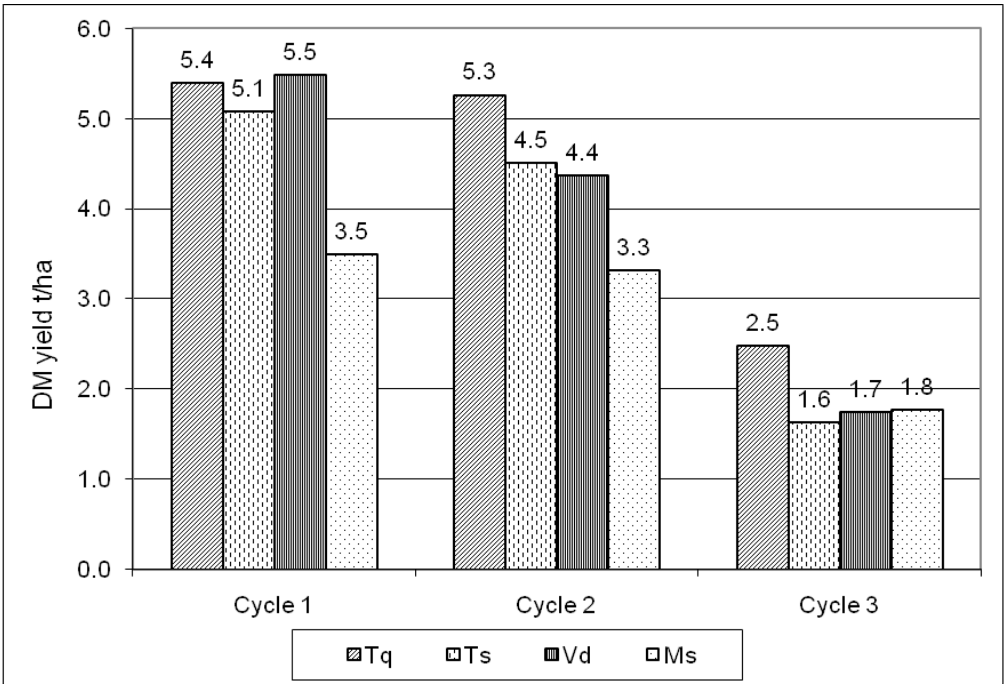


1.b) Akaki

Designations: Tq= *Trifolium quartini anum*; Ts= *T. steudneri*; Vd= *Vicia dasycarpa*; Ms= *Medicago scutellata*

Figure 1. Dry matter percent by weight of herbage samples from four fodder species grown as double crops with chickpea at Debre Zeit (1.a) and Akaki (1.b) sites

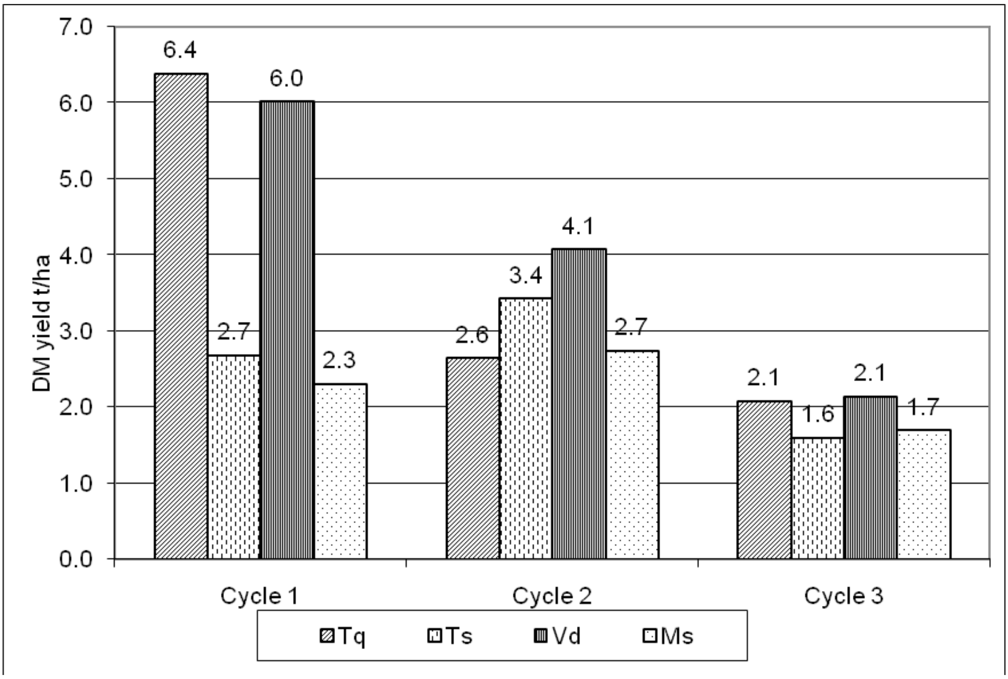
The average dry matter (DM) yield of these crops varied widely according to species, location and the harvesting time which depended upon the prevailing rainfall distribution. At Debre Zeit, the warm weather favored better accumulation of DM and the average dry herbage yield ranged 3.5-5.5, 3.3-5.3, and 1.6-2.5 t ha^{-1} in the first, second and third cycles respectively (Figure 2). Interspecies difference in average DM yield was statistically significant (P<0.05) for the last two cycles. Consistently over the three cycles, *Trifolium quartinianum* and *Vicia dasycarpa* had the highest DM yield.



Note: LSD (alpha 0.05) for Cycle II= 0.667; Cycle III= 0.437. Designations: Tq= Trifolium quartinianum; Ts= T. steudneri; Vd= Vicia dasycarpa; Ms= Medicago scutellata

Figure 2. Herbage yield of four annual fodder legume species each grown as double crop with chickpea for three cycles on a Vertisol at Debre Zeit.

At Akaki, most of the fodder species delayed to mature due mainly to the cool temperature (11.5 °C). Fortunately, the rainfall distribution being fairly longer (June to late September) than that at Debre Zeit (June to mid September), the crops were allowed to grow for longer growth period which somewhat compensated for the slower growth rate. The average DM yield ranged 2.3-6.4, 2.6-4.1, and 1.6-2.1 t ha^{-1} in *Cycle I*, *Cycle II*, and *Cycle III*, respectively. Interspecies difference in mean DM yield at Akaki was statistically significant in all cycles (P<0.05), and the highest yield was from *Vicia dasycarpa* which appeared to be favoured by the cool temperature (Figure 3).



Note: LSD (alpha 0.05) for *Cycle I*= 0.992 ; *Cycle II*= 0.425; *Cycle III*= 0.401. Designations:: Tq= *Trifolium quartinianum*; Ts= *T. steudneri*; Vd= *Vicia dasycarpa*; Ms= *Medicago scutellata*

Figure 3. Herbage yield of four annual fodder legume species grown as double crop with chickpea for three cycles on a Vertisol at Akaki

Generally, the DM yield of the fodder species from a growth period not exceeding eighty days can be taken as satisfactory in view of the complementary value of the second crop, chickpea. The DM yield of *Trifolium quartinianum* and *T. steudneri* nearly equaled the yields reported under full season growth (4-7 t DM ha^{-1}) (Kahurananga J. and Asres Tsehay, 1984). Similarly, *Medicago scutellata* yielded about three-fourth of its reported yield (5-6 t DM ha^{-1}) when grown as full season crop (Johnson and Lloyd, 2005).

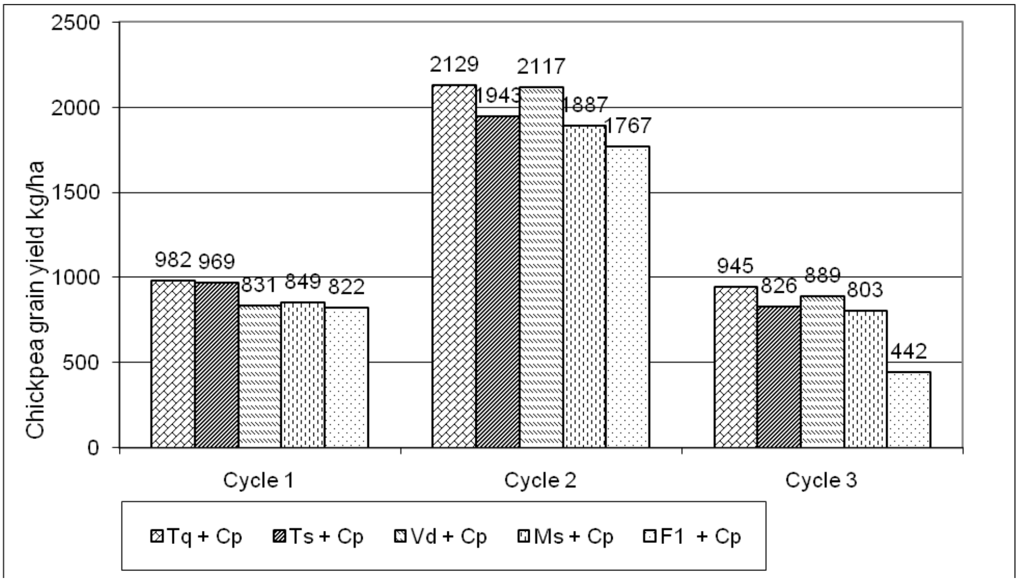
The nutritional quality of the fodder species as determined by laboratory analysis for the more critical attributes did not vary greatly among species and between locations (Table 1). The in-vitro digestibility (>40%) and crude protein (>22%) recorded for all the species was reasonably high and generally falls within the standard nutritional levels reported for tropical ruminant livestock (Kearl, 1982). The observed high nutritional quality is actually expectable from such early harvested fodder crops, most of which were from initial to 50% flowering at the time of harvest.

Table 1. Crude protein (CP) and in-vitro dry matter digestibility (IVOMD) of annual forage legume species grown as double crop with chickpea on a *Vertisol*, at Debre Zeit and Akaki sites.

Fodder species	Debre Zeit		Akaki	
	CP%	IVOMD%	CP%	IVOMD%
Trifolium quartinianum	24.10	39.63	21.49	49.64
Trifolium steudneri	26.67	41.55	26.12	72.92
Vicia dasycarpa	26.44	46.32	18.33	73.81
Mdicago scutellata	23.48	48.00	22.94	47.94

Phase II - Chickpea

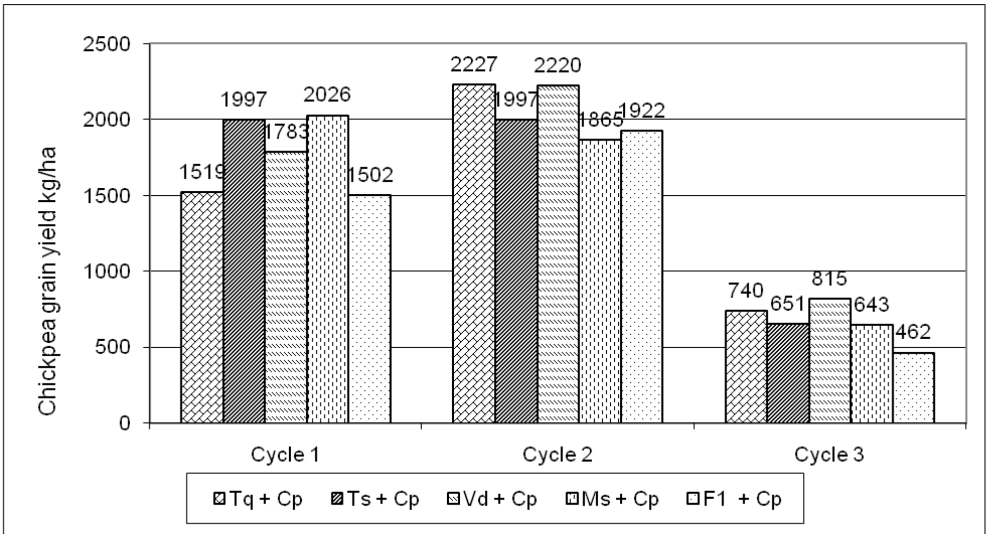
Almost uniformly over the three cycles of the experiment, within a few days after harvesting fodder crops, chickpea was planted on the vacated plots around September 10-12 (Debre Zeit) and September 15-20 (Akaki), when intermittent rain was available to initiate germination. Thereafter, the crop utilized the residual soil moisture retained by the heavy clay soil colloids of the *Vertisols*. At Debre Zeit, mean grain yield was in the range 822-982 kg ha^{-1} in *Cycle I* and there was no significant (P>0.05) difference due to the effect of the preceding fodder crops (Figure 4). In C*ycle II*, the yield was more than twofold of that in cycle I probably due to the more favourable climate in the growing season of the year. The mean grain yield difference due to species effect from the preceding phase was significant (P<0.05). While in *Cycle III*, the magnitude of average grain yield was closely related to that in *Cycle I* and the effect of the fodder species from the preceding phase was manifested by a significant (P<0.05) mean grain yield difference.



Note: LSD (alpha 0.05) for Cycle II= 111.3; Cycle III= 253.4. Designations: "T. q.+Cp" = Trifolium quartinianum before chickpea; "T.s+Cp" = T. steudneri before chickpea; "V.d+Cp" = Vicia dasycarpa before chickpea; "M.s+Cp" = Medicago scutellata before chickpea; "F1+Cp" = Fallow (partial) before chickpea.

Figure 4. Grain yield of chickpea var. DZ-1011 grown as double crop with fodder species for three cycles on a Vertisol at Debre Zeit

At Akaki, the mean grain yield was generally higher than that at Debre Zeit especially during the first two cycles, which ranged 15000-20000 kg ha^{-1} and 18000-22000, in *Cycles I* and *II* respectively, while the average yield in *Cycle III* was low across treatments (462-815 kg ha^{-1}) (Figure 5), which may be due to seasonal fluctuation in rainfall distribution. Treatment effects of the preceding fodder crop types on grain yield of chickpea was not significant (P>0.05) in the first cycle. However in *Cycles II* and *III*, there was significant (P<0.05) difference in chickpea grain yield due to the effects of the different fodder species in the preceding phase. Accordingly, grain yield was the highest due to the effects of *Vicia dasycarpa* and *Trifolium quartinianum* and the least due to partial fallow (*F1*). *T. steudneri* and *Medicago scutellata* had moderate effects on chickpea grain yield (Figure 5).



Note: LSD (alpha 0.05) for Cycle II= 176.4; Cycle III= 130.2. Designations: "T. q.+Cp" = Trifolium quartinianum before chickpea; "T.s+Cp" = T. steudneri before chickpea; "V.d+Cp" = Vicia dasycarpa before chickpea; "M.s+Cp" = Medicago scutellata before chickpea; "F1+Cp" = Fallow (partial) before chickpea.

Figure 5. Grain yield of chickpea var. DZ-1011 grown as double crop with fodder species for three cycles on a Vertisol at Akaki

In general, the grain yield produced from chickpea grown in a double crop system by utilizing residual moisture during the later part of the growing season is comparable to that produced as full season crop at farmers' level around Debre Zeit (Tebikew Damte *et al*, 2009). In addition, earlier research reports on the yield potential of chickpea varieties developed from native lines, including DZ-1011, ranged between 800 and 2000 kg ha^{-1} on *Vertisols* around Debre Zeit (Geletu Bejiga, *et al*, 1994). Therefore, the grain yield obtained in the present experiment can be considered satisfactory especially in view of the additional benefit obtained from the high quality fodder produced that can be made available to stock at the time when livestock face critical feed shortage (Jutzi S. *et al,* 1987).

Phase III- Wheat

The third phase of the experiment involved a cereal crop which was durum wheat, var. Kilinto. The data on the effect of the precursor food and fodder legume crops on wheat performance, particularly in terms of grain yield, was not consistent over locations and cycles. Therefore, the outcome of the data analyzed separately for each cycle and location is presented as follows.

Cycle I- In the first cycle, the mean grain yield of Kilinto showed significant (P<0.05) difference in response to the treatments in the preceding phases as well as to the nitrogen fertilizer application rates at both Debre Zeit and Akaki sites (Table 4). The interaction effect of the precursor crops and fertilizer levels was also significant (P<0.05) at Debre Zeit but not at Akaki. Two of the precursor fodder species, *Trifolium quartinianum* and *Vicia dasycarpa* significantly contributed to higher grain yield of wheat at both locations while the other two, *T. steudneri* and *Medicago scutellata* had intermediate effect uniformly at both locations and the least was that of partial fallow (*F1*) and full season fallow (*F2*). Generally, across most treatments, grain yield at Akaki was inferior to that from Debre Zeit. This is attributed to the cool temperature (11 ^{o}C) and possibly to the waterlogged condition and associated effects of poor aeration on plant physiology.

Table 4. Grain yield response of durum wheat var. Kilinto to sequentially grown precursor crops of annual fodder species and chickpea in *Cycle I*, at Debre Zeit and Akaki sites

4a. Debre Zeit

Phases I & II crops (Fodder + chickpea)	Phase III. Wheat yield (Kg/ha) at four levels of N_2 application				
	64 N*	32 N	18 N	0 N	Mean
T. quartinianum + CP	2885AB	2790BC	2385EFG	1575IJ	2409B
T. steudneri + CP	2790BC	2446DEF	2227FG	1414JK	2219C
V. dasycarpa + CP	3052A	2891AB	2559CDE	1876H	2594A
M. scutellata + CP	2672BCD	2318FG	2162G	1569IJ	2181C
ρF1 + CP	2448DEF	1698HI	1689HI	1286KL	1780D
@F2	2171G	1496IJK	1322KL	1156L	1536E
LSD (α0.05)	235.5				
N_2 means	2670A*2	2273B	2057C	1479D	
LSD (α0.05)	127.6				117.8
C.V. %	6.73				

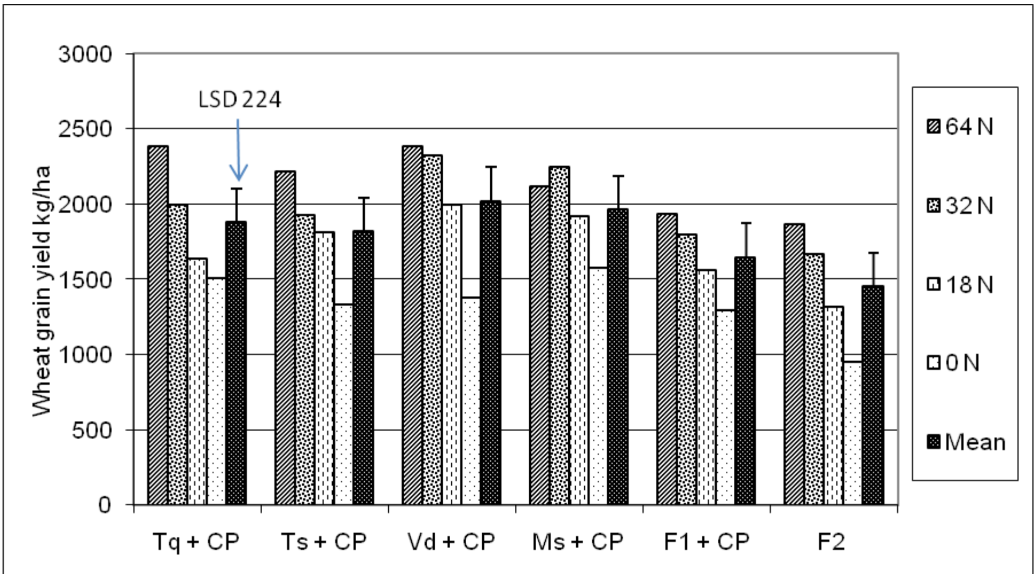
* N fertilizer levels: optimum level (64 kg N/ha), sub-optimum (32 kg N/ha), low level (18 kg N/ha), & zero (without N). DMΘ = dry matter herbage; *1NS = Not significant; ©CP = chickpea; ρF1= partial season fallow during phase I; @F2= fallow for full season during phases I and II. *2Means followed by similar letters are not significantly different at α 0.05.

~

4b. Akaki

Phases I & II crops (Fodder + chickpea)	Phase III. Wheat yield (Kg/ha) at four levels of N_2 application				
	64 N*	32 N	18 N	0 N	Mean
T. quartinianum + CP	1591	1308	1107	853	1215AB
T. steudneri + CP	1420	1430	979	803	1158BC
V. dasycarpa + CP	1556	1431	1175	877	1259A
M. scutellata + CP	1481	1182	962	796	1105C
[p]F1 + CP	1415	1030	782	702	982D
[@]F2	1427	999	715	708	962D
LSD (α0.05)	*[1]NS				
N_2 means	1481A	1230B	953C	790D	
LSD (α0.05)	73.51				101.2
C.V. %	11.01				

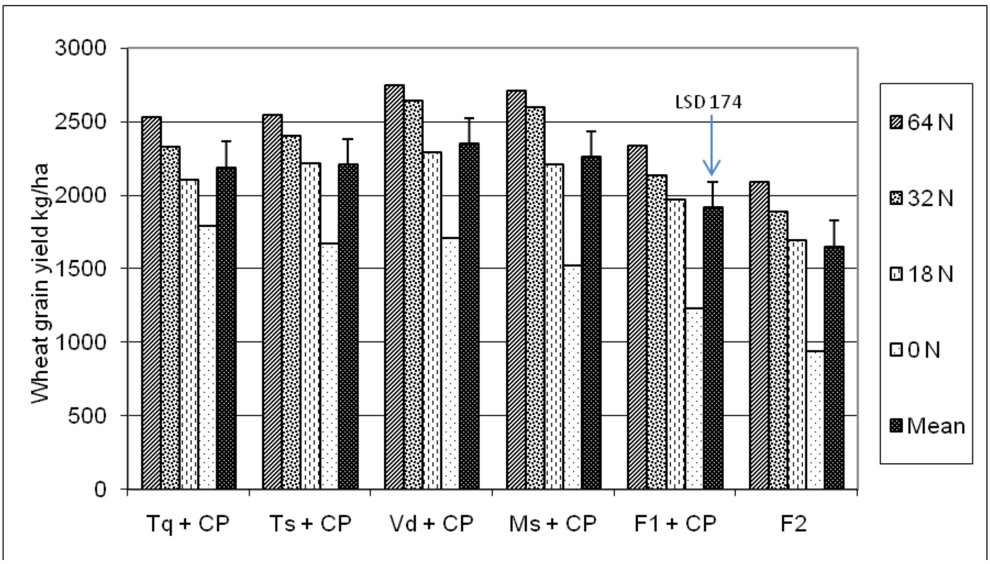
Cycle II- In the second cycle, main effects of precursor double crops (fodder and pulse) and N fertilizer levels were significant ($P<0.05$) while interaction of these were not significant ($P>0.05$) in their effect on mean grain yield of durum wheat at both locations (Figure 6). While nitrogen fertilizer application rate contributed to significant variation in mean grain yield with an increasing trend proportional to the rate of N application. At both locations, wheat grain yield was higher when the preceding crops were the fodder crops as compared with that when the preceding phase of the rotation was either partial (*F1*) or full season fallow *(F2*). Effect of partial fallow was better than full season fallow in enhancing grain yield of wheat especially at Akaki which can be attributed to the more favourable conditions that might have led to higher vigour and growth rate that apparently enhanced the N_2 fixation efficiency of chickpea at the site during that cycle (observe chart *Cycle II* in Figure 5). In this cycle inter species difference amongst the four fodder species in the yield of wheat was not significant which may imply that all the species had fairly equal positive effects on the yield of wheat.



***Note.** N fertilizer levels: 64N= optimum level (64 kg N/ha), 32N= sub-optimum (32 kg N/ha), 18N= low level (18 kg N/ha), & 0N= zero (without N).

Precursor crops: Chickpea (CP) followed by: Tq= *Trifolium quartinianum*; Ts= *T. steudneri*; Ms= *Medicago scutellata*; Vd= *Vicia dasycarpa*; F1= Partial fallow period before chickpea; F2= full season fallow.

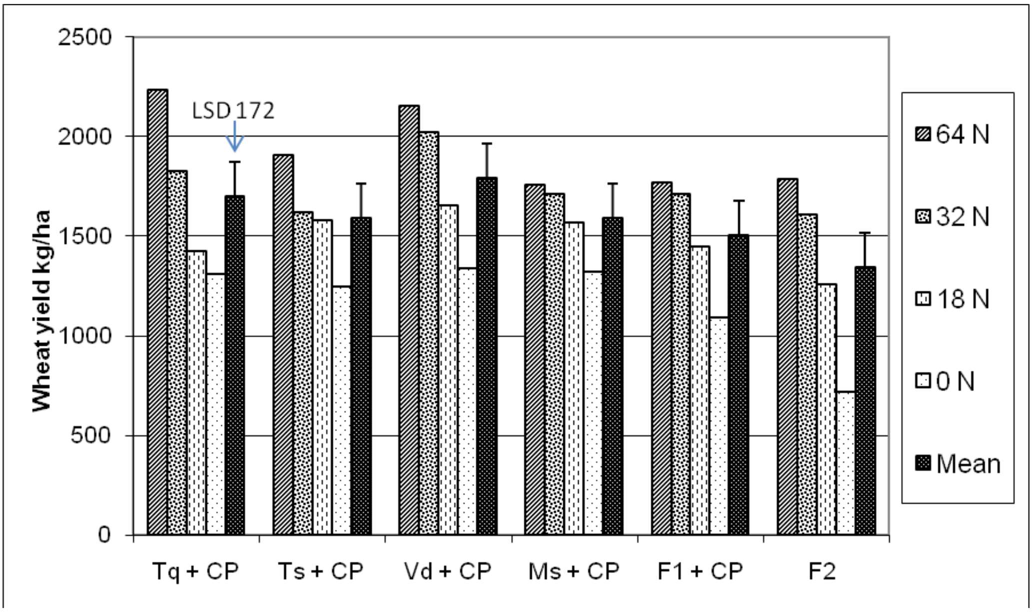
6a) Debre Zeit



6b) Akaki

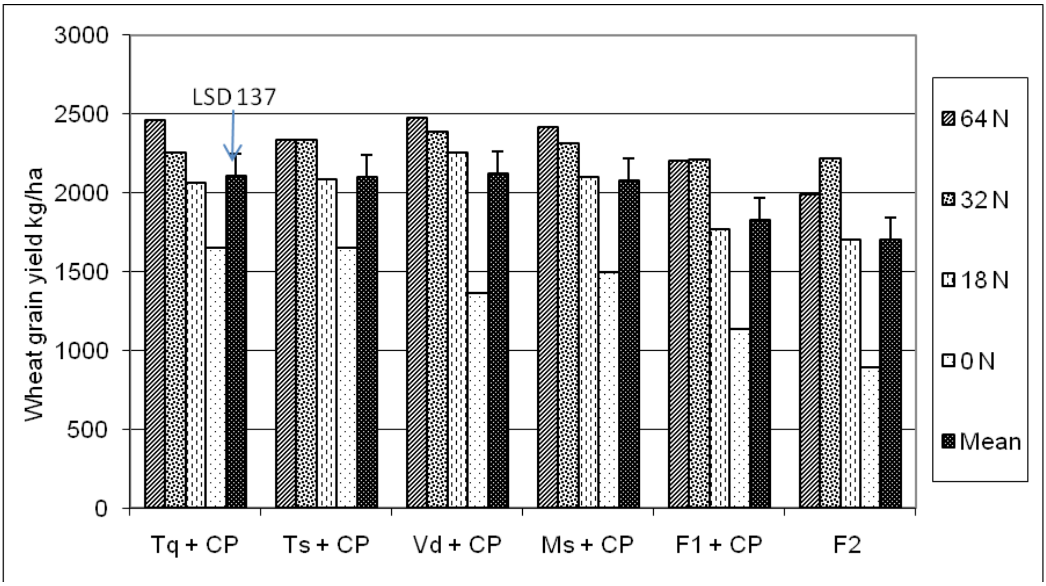
Figure 6. Grain yield (kg/ha) of durum wheat var. Klinto grown subsequent to a double crop of annual fodder legume species and chickpea at four levels of nitrogen fertilizer on a Vertisol at Debre Zeit and Akaki sites (Cycle II of experiment).

Cycle III- As in *Cycle II*, in the third cycle of the experiment, main effects (fodder species and N_2 levels) but not the interactions of these had significant difference in mean grain yield of durum wheat. At Debre Zeit, significant (P<0.05) inter-species difference was exhibited among the four fodder precursor crop species in their effect on mean grain yield of wheat (Figure 7). At Debre Zeit, wheat grain yield was significantly higher when the precursor crops were *Trifolium quartinianum* and *Vicia dasycarpa*, as compared to the yield when the precursor crops were the other two species (Figure 7a). While at Akaki, all the fodder species had more or less similar effect on wheat grain yield as was in *Cycle II*. Generally, the mean grain yield (averaged over all levels of N_2) grouped the precursor treatments into two: the fodder species that significantly increased wheat grain yield and the fallow treatments (*F1* and *F2*) that resulted in relatively lower grain yield of wheat. The partial fallow and the full season fallow had no significant (P<0.05) difference, and this might be due to poor growth condition and so low efficiency of N fixation of chickpea in the partial fallow treatment.



7a) Debre Zeit

***Note.** N fertilizer levels: 64N= optimum level (64 kg N/ha), 32N= sub-optimum (32 kg N/ha), 18N= low level (18 kg N/ha), & 0N= zero (without N).
Precursor crops: Chickpea (CP) followed by: Tq= Trifolium quartinianum; Ts= T. steudneri; Ms= Medicago scutellata; Vd= Vicia dasycarpa; F1= Partial fallow period before chickpea; F2= full season fallow.



7b) Akaki

Figure 7. Grain yield (kg/ha) of durum wheat var. Klinto grown subsequent to a double crop of annual fodder legume species and chickpea at four levels of nitrogen fertilizer on a Vertisol at Debre Zeit and Akaki sites (Cycle III of experiment)

Overall, the outcome of the third phase (cereal phase) of the experiment in particular was not consistent over locations and years (cycles) such that combined data analysis over locations or years would not be appropriate. Interaction effects were not significant except in the initial cycle. One of the reasons could be due to the exploratory nature of the experiment, especially in the third phase (cereal) that is subject to influence of numerous factors besides the too many treatments considered. This would suggest that where the emphasis is on the contribution of the precursor crops on cereal crops, each potential fodder species must be evaluated one at a time so as to reduce technical difficulties as well as the amount of complexity in data analysis. This may allow a more precise determination of yield increment of the subsequent cereal crops, including the amount of biologically fixed N_2 accretion to the soil.

Conclusion

In the face of the highly increasing demand for arable land in the Ethiopian highlands, allocation of cultivable land for pasture crops seems unlikely now and in the near future. An alternative promising approach would be fitting fodder crops into the existing cropping system without displacing food and cash crops.

The present long-term study capitalized on a shorter version of crop rotation- “Sequential” or “Double cropping” so modified to accommodate short duration fodder crops. It is to be noted that the two antecedent crops (forage and pulse) are grown during a season, one after the other whereby the two crops do not overlap, the second being sown only after the harvest of the first. In the present study, short-duration native clovers and medics were successfully grown in one cropping season sequentially with chickpea on a black heavy clay soil (Vertisol). The advantages of the double crop technology were twofold: production of food grain and high quality fodder and improve productivity of a subsequent non-legume crop (wheat) through Rhizobial nitrogen fixation by both fodder and pulse crops. The fodder phase enabled to produce high quality fodder (CP 23-27%; IVDMD 40-48 %) fodder with an average DM yields ranging from 2.2 to 6.4 t ha-1 which is comparable to the yield obtained from these species when grown as full-season crop (Kahurananga J. and Asres Tsehay, 1984). Chickpea, which succeeded the fodder crop had normal establishment and growth and did not suffer terminal drought stress and the grain yield ranged 8 to 20 quintals ha-1, which was also comparable to the yield from the same variety produced in the traditional way as full-season crop by farmers around Debre Zeit (Tebikew Damte et al, 2009.). Wheat yield recorded at low and suboptimal level of N2 fertilizer application was in the range 15-25 q ha-1, indicating the complementary value of the fodder crops in maintaining the N content of the soil through biological fixation. This yield range was again close to that produced at farmers' level in areas where the variety had been distributed (Tesfaye Tesema et al, 1993; Efrem Bechere, 1994). Therefore, the present long-term experiment enabled to identify a number of short-duration forage legumes with attributes of: tolerance to water logging; fast growth and high DM accumulation potential that confer an opportunity of growing them as double crop with late-season pulse crops such as chickpea (also possible with grass pea, data not shown). Moreover, the phenology and growth form of these crops make them well suited for conserved fodder production in which they can be raised either as pure stand or in mixture with annual fodder grass species such as oats (Solomon Mengistu, 2006).

A notable feature of this food and fodder crop integration technology is that the traditional cropping cycle has not been altered. Therefore, the technology is expected to have high scope for adoption by the smallholder farmers as has been learned from an on-farm verification trials launched in three Woredas around Debre Zeit (Adaa, Lume and Ginbicho) (data not shown). Further on-farm verifications of the technology at a national level should ideally include areas from the medium and higher-highland zones (1500 m altitude and above) characterized by mixed crop/livestock farming systems; where black heavy clay soils (Vertisols) make up a good proportion of the arable land; mean annual rainfall of at least 800 mm, with a continuous distribution of about 90 days or longer.

References

Berhanu Debele. 1985. *The Vertisols of Ethiopia Their properties, classification and management.* 5th Meeting of the Eastern African Soil Correlation and Land Evaluation Sub-Committee, 4-10 December 1983, Wad Medani Sudan. World Soil Resources Report 56. FAO, Rome. pp. 31-54.

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

Efrem Bechere, Tesfaye Tesema and Demisse Mitiku. 1994. Improved varieties of durum wheat in Ethiopia. Research Report Series No 2. Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia.

Geletu Bejiga and Abebe Tulu 1982. The influence of planting dates on the yield of three chickpea (*Cicer arietinum*) varieties. Eth. J. Agri. Sci. 4(2): 61-66

Gomez, K.A. and Gomez A.A. 1984. Statistical procedures for agricultural research. (Second ed.) John Willey and Sons New York. pp. 89-97.

Johnson, B. and Lloyd, D. 2005. The role of annual medics in Queensland agriculture. Queensland Government Department of Primary Industries and Fisheries. Plant Science, Toowoomba, Queensland. <http:www2.dpi.qld.gov.au/pastures/3625.html> Accessed May, 2010.

Jutzi, S. and Haque, I. 1984. Some effects of P and N/P fertilization on three African clovers (*Trifolium tembense*, *T. rueppellianum, and T. steudneri*) on a P deficient Vertisol. ILCA Newsletter 3:5-6.

Jutzi, S., Haque I. and Abate Tedla. 1987. The production of animal feed in the Ethiopian highlands. Paper presented at the First National Livestock Improvement Conference, 11-13 Feb. 1987. IAR, Addis Ababa, Ethiopia.

Kahurananga, J. and Asres Tsehay. 1984. Preliminary assessment of some annual Ethiopian Trifolium species for hay production. Tropical Grasslands 18 (4): 215-217.

Kearl, L.C.1982.Nutreint Requirement of Ruminants in Developing Countries. International Feedstuffs Institute, Utah Agricultural Experiment Station, Utah State University Longman 84322.USA. pp 381.

SAS (Statistical Analysis System) Institute, 1999. SAS/STAT user's guide, Version 8, SAS Inst, Cary, North Carolina.

Solomon Mengistu. 2006. Evaluation of oats and native annual clover species as mixed fodder crops and assessment of their suitability for rotational production with cereal crops. Proceedings of the 14th ESAP Conference, 5-7th Sept., 2006. A.A., Ethiopia. pp. 43-52.

Tebikew Damte, Asnake Fikre, Kibebew Asefa, and Lijalem Korbu, 2009. Improved chickpea (*Cicer arietnum* L.) technologies and seed production in Ethiopia. Ethiopian Institute of Agricultural Research (EIAR), Debre Zeit, Ethiopia.

Tesfaye Tesema, HC Becker, H.C. Getachew Belay, Demise Mitiku, Efrem Bechere and Seifu Tsegaye. 1993. Performance of Ethiopian tetraploid wheat landraces at their collection sites. Euphytica 71: 221-230.

Management of Napier Grass (*Pennisetum Purpureum* (L.) Schumach) for High Yield and Nutritional Quality in Ethiopia: A Review

Z.K. Tessema[1] and M. Alemayehu[2]*

[1]Department of Animal Sciences, College of Agriculture, Haramaya University, PO Box 138, Dire Dawa, Ethiopia

[2] Addis Ababa, Ethiopia, E-mail: alemayehumengistu@yahoo.com

Abstract

Development of the livestock subsector in Ethiopia is hindered by many constraints, of which the unavailability of quality feed is a major factor. This result in low growth rates, poor fertility and high mortality rates of ruminant animals in the country. Increased livestock production can be achieved through the cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses in Ethiopia. Amongst the recommended improved forage crops in Ethiopia, Napier grass can provide green forage throughout the year.With appropriate management practices it also best fits to intensive small scale farming systems. Moreover, Napier grass grows well in soil conservation areas, around homesteads and along roads under smallholder conditions in Ethiopia but it lacks proper management and utilization practices. Therefore, this paper highlights results of different management practices so far undertaken to increase the yield and quality of Napier grass, indicate gaps and possible future research and development directions that deserve attention for better utilization and management of Napier grass in Ethiopia.

Keywords: *Biomass yield; Frequency of defoliation; Feed shortage; Improved pasture; Nutritive value; Plant height at cutting*

Introduction

Livestock production is an integral part of the agricultural activities in Ethiopia. The livestock sector provides 12-16% of the total Gross Domestic Product (GDP) and 30-35% of the agricultural GDP in the country (Ayele et al., 2002). Moreover, livestock contributes about 60-70% of the livelihoods of the Ethiopian population (Ayele et al., 2002; Tessema et al., 2010a). However, the development of the livestock subsector in Ethiopia is hindered by many constraints, of which the unavailability of quality feed is a major factor (Manaye et al., 2009). The main feed resources for livestock in Ethiopia are natural pasture and crop residues, which are low in quantity and quality for sustainable animal production (Alemayehu, 2004). This results in low growth rates, poor fertility and high mortality rates of ruminant animals (Odongo et al., 2002). Farm animals

*Corresponding author: tessemaz@yahoo.com

thus rarely meet their nutritional requirements and so their productivity is low and draught power from oxen is minimal, thereby affecting food crop production under the smallholder farming systems (Seyoum et al., 1998; Tessema et al., 2010b).

Increased livestock production can be achieved through cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses (Muia et al., 2001; Kahindi et al., 2007; Tessema et al., 2010a, b). Improved pasture crops have many advantages such as providing quality feed and improving soil fertility. The cost incurred for perennial pasture production is high only during the establishment year (Jϕrgensen et al., 2010) but declined thereafter and this approach could be the way forward in feed resources improvement strategies in Ethiopia at large. Amongst the promising forage species promoted in Ethiopia, Napier grass could play an important role in providing a significant amount of high-quality forage to the livestock industry (Ndikumana, 1996; Tessema, 2005) both under the smallholder farmer and intensive livestock production systems with appropriate management practices (Seyoum et al., 1998; Alemayehu, 2004).

Adaptation of napier grass

Napier grass (*Pennisetum purpureum Schumach*), also known as elephant grass, occurs naturally throughout tropical Africa (Lowe et al., 2003), particularly in east Africa (Kariuki et al., 1998; Mwendia et al., 2006), and has been introduced to all tropical and sub-tropical areas of the world (Lowe et al., 2003; Kahindi et al., 2007). Characteristically, Napier grass is vigorous and highly productive forage, which can withstand long periods of drought (Lowe et al., 2003; Tessema, 2005). Although little or no growth takes place during these drought periods, it rapidly recovers with the onset of rains (Mwendia et al., 2006; Wijitphan et al., 2009) and can survive in drought for more than five years (Woodard et al., 1991). It is a tall, stout and deep rooted perennial bunch grass well known for its high yielding capability and value as forage for livestock with good agronomic practices (Woodard et al., 1991). Moreover, Napier grass is an erect and tall perennial grass up to 5m heights with prolific tillering ability after cutting or grazing and adaptive to well-drained fertile soil. Because of the importance of Napier grass in the small-scale livestock farming enterprises, it is one of the most widely used fodder crops amongst small-scale livestock producers in Kenya (Mwendia et al., 2006; Mutegi et al., 2008), Malaysia (Hassan et al., 1990), Pakistan (Butt et al., 1993; Wijitphan et al., 2009), Tanzania (Kabuga and Darko, 1993), Thailand (Jϕrgensen et al., 2010), USA (Woodard et al., 1991), Napier grass is superior to other tropical grasses in terms of dry season growth and forage quality (Odongo et al., 2002; Wijitphan et al., 2009) and can support large tropical livestock units per hectare (Muia et al., 2001). It also performs well in low, mid and highland areas of Ethiopia (Seyoum et al., 1998; Tessema, 2005, 2008). Napier grass is popular among dairy farmers as it produces a lot of leaves, which are utilized as a cut and carry system (Kariuki et al., 1998; Nyaata et al., 2002; Mutegi et al., 2008). Therefore, with appropriate management practices, Napier grass can provide a continual supply of green forage throughout the year and best fits in intensive small scale farming systems in Ethiopia (Tessema, 2005, 2008; Tessema et al., 2010b).

Agronomic practices for establishment of napier grass

Napier grass is propagated vegetatively by using rootstock, stem cuttings or shoot tips planted at a distance of 1 m between rows and 0.50 m between plants (Tessema, 2008). Spacing could be adjusted on performance basis and in areas of moisture stress, narrower spacing both between rows and plants is recommended. Plants from root splits make more rapid early growth and give high herbage yields than from stem cuttings or shoot tips. Moreover, older and hardened stems are more reliable than young materials for easy establishment and tiller formation (Woodard et al., 1991). It can be planted during the main rains on coarse and weed free seedbed. It requires a minimum fertilizer at a rate of 100 kg ha^{-1} in the form of diammonium phosphate (DAP) for establishment and N fertilizer in the form of urea at a rate of 50 kg ha^{-1} should be applied close to the root slips once the Napier grass was well established on red soil under rain fed conditions (Tessema et al., 2002a, b) and 50 kg ha^{-1} urea should be top dressed annually for continuous growth and maintaining its quality (Tessema et al., 2003a). Moreover, manure is also another option for fertilization. Napier grass has higher productivity under irrigation although it is produced under rain fed condition in Ethiopia. Regular hoeing is important to control weed. It should be harvested any time of the year when it reaches the optimum harvesting stage depending on soil types and in areas where frost occurs, it should be harvested before the onset of frost.

Factors affecting the performance of napier grass

Varietal difference: Napier grass screening for high yield and adaptability to biotic and abiotic environmental stresses and nutritional values has been conducted in mid and highland areas of Ethiopia. There are variations in growth characteristics, dry matter (DM) yield, chemical composition and nutritive values among different Napier grass varieties (Ndikumana, 1996; Seyoum et al., 1998; Tessema, 2005). According to Ndikumana (1996) Napier grass ILRI accessions No: 16798, 16791, 16786 and 16835 were highly productive in most of the agro-ecological environments in sub-Saharan Africa, from sea level to the highlands above 2000 meter above sea level. Moreover, variations in morphological characteristics, yield, chemical composition, *in vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) values among 10 Napier accessions evaluated in the central highlands (Seyoum et al., 1998) and in north-western Ethiopia (Tessema, 2005; Table 1, 2 and 3) has been reported. There were also considerable variations in DM yields between years among Napier grass accessions (Seyoum et al., 1998; Tessema, 2005). This might be due to the perennial nature of Napier grass, which produces many tillers and dense vegetative growth as the pasture consolidates. In 10 Napier grass varieties, Fernandes et al. (1996) found significant differences in crude protein (CP) and IVDMD values. Short Napier grass accessions usually have high leaf to stem ratio (LSR) (Ndikumana, 1996; Tessema, 2005), which is an indicator of good quality.

Table 1. Morphological characteristics of Napier grass accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998-2000 growing seasons

Accession	ILPP	LSR	NTPP	Survival (%)	Vigour	Plant height (cm)
14983	16.1^{a}	4.0^{b}	169.7^{a}	90.5^{abc}	4.0^{ab}	149.7^{ab}
14984	12.5^{b}	3.2^{bc}	88.3^{b}	88.1^{bc}	4.0^{ab}	154.9^{ab}
15743	8.0^{c}	8.7^{a}	77.0^{b}	85.7^{bc}	3.0^{bc}	78.0^{c}
16834	15.7^{a}	2.3^{cd}	69.7^{bc}	92.9^{ab}	3.0^{bc}	146.9^{ab}
16835	11.7^{b}	2.8^{bcd}	54.6^{c}	81.4^{c}	4.0^{ab}	147.3^{ab}
16786	10.8^{bc}	3.4^{bc}	67.8^{bc}	87.9^{bc}	3.3^{bc}	151.4^{ab}
16791	12.7^{b}	1.2d^{e}	73.3^{bc}	94.0^{ab}	3.3^{bc}	162.6^{a}
16798	7.5^{c}	3.2^{bc}	48.0^{c}	79.8^{c}	5.0^{a}	160.6^{a}
16836	8.3^{c}	0.8^{e}	63.0^{bc}	100.0^{a}	2.0^{c}	144.4^{ab}
Local	16.6^{a}	4.0^{b}	82.3^{b}	95.2^{ab}	4.0a^{b}	136.53^{b}
SE (±)	0.58	0.54	8.7	3.6	0.41	6.58
CV (%)	8.27	27.43	17.87	6.84	20.08	8.05

Source (Tessema, 2005); ILPP = internode length per plant (cm); LL = leaf length (cm); LSR = leaf: stem ratio; NLPP = number of tillers per plant

Table 2. Least square means of dry matter yield (t ha^{-1}) of Napier grass accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998-2000 growing seasons

ILRI accession	Year				Nutrient yield (t ha-1)			ranking
	1998	1999	2000	Mean	CPY	DDMY	DOM	
14983	5.85^{bc}	29.67^{ab}	26.10^{a}	20.54^{a}	2.25	14.5	65.2	1
14984	7.23^{ab}	27.00^{ab}	18.13^{bc}	17.46^{ab}	2.16	12.24	64.7	4
15743	3.40^{cd}	13.08^{cd}	6.57^{ef}	7.68^{ef}	0.84	5.33	64.0	9
16834	7.49^{ab}	15.83^{cd}	6.77^{ef}	10.03^{de}	1.17	6.57	60.3	8
16835	7.76^{ab}	13.70^{cd}	8.50^{def}	9.99^{de}	1.39	7.93	64.9	7
16786	5.19^{bc}	26.23^{ab}	14.43^{cd}	15.29^{bc}	1.74	10.30	62.1	5
16791	5.15^{bcd}	32.13^{a}	24.03^{ab}	20.44^{a}	3.20	14.29	64.5	2
16798	9.51^{a}	34.57^{a}	16.87^{c}	20.31^{a}	2.29	14.29	64.9	2
16836	2.04^{d}	9.43^{d}	2.43^{f}	4.64^{f}	0.35	3.09	61.4	10
Local	6.45^{abc}	20.90^{ab}	12.27^{cde}	13.21^{cd}	1.74	8.26	57.5	6
SE (±)	0.58	1.62	1.24	1.29	1.67	9.37	63.0	

Source (Tessema, 2005); Columns with different letters are significantly different at P<0.05; CPY = crude protein yield, DDMY= digestible dry matter yield and DOM= digestible organic matter

A minimum CP of 15% is required for lactation and growth of cattle (Van Soest, 1994). However, Napier grass accession (ILRI 16791) harvested at 1.0 m height had a CP content of 15.7% which is higher than the recommended value (Tessema, 2005; Table

3). The neutral detergent fiber (NDF) values of the ten Napier grass accessions tested in the northwestern parts of Ethiopia were ranged from 53-65% (Table 3), which is below the average value for tropical grasses (66%)) and below the threshold level of NDF for tropical grasses and beyond which DM intake of cattle is negatively affected (Van Soest, 1994). The Ca values of most of the Napier accessions were above the recommended level of 0.43% of DM for cattle and the P contents were also above the minimum requirement of 0.17% in DM for grazing ruminants (McDowell, 1985). Of the 10 Napier grass accessions from the International Livestock Research Institute; 4 accessions could be categorized as high quality while two accessions and a local type as medium quality forage, which could satisfy ruminant animal production (Tessema, 2005; Table 3). Most of the Napier grass accessions could supply CP, ME and Ca above the production requirements of a 12 weeks lactating Holstein Friesian dairy cow weighing 500 kg (Kearl, 1982; Table 4). Accordingly Napier grass ILRI accessions 14983, 16791, 16798 and 14984 could be recommended under rain fed conditions in smallholder ruminant production systems in mid and highland areas of Ethiopia.

Table 3. Chemical compositions, *in vitro* dry matter digestibility and metabolizable energy (MJ kg^{-1} DM) of Napier accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998-2000 growing seasons

	Chemical composition									Nutrient yield (t/ha)			
	Ash	CP	NDF	ADF	ADL	Ca	P	IVD-MD	ME	DMY	CPY	DDMY	DOMY
14983	20.2^{b}	12.2^{d}	53.5^{f}	29.3^{efg}	3.46	0.73^{b}	0.43^{ab}	70.7^{a}	9.77^{a}	20.5	2.3	14.5	65..2
14984	19.7^{c}	12.4^{d}	54.7^{e}	29.6^{ef}	4.61	0.7^{bc}	0.28^{de}	70.1^{ab}	9.69^{ab}	17.6	2.2	12.2	64.7
15743	20.8^{a}	10.9^{g}	52.7^{g}	28.8^{g}	3.12	0.71^{b}	0.41^{b}	69.4^{ab}	9.59^{ab}	7.7	0.8	5.3	64.0
16834	18.6^{e}	11.7^{e}	57.9^{c}	30.3^{cd}	3.16	0.8^{a}	0.31^{cd}	65.5^{bc}	9.04^{bc}	10.3	1.2	6.6	60.3
16835	17.5^{f}	13.9^{b}	60.2^{b}	29.7^{def}	3.20	0.64^{c}	0.47^{a}	70.4^{a}	9.73^{a}	10.1	1.4	7.9	64.9
16786	19.4^{cd}	11.4^{ef}	56.5^{d}	32.0^{b}	3.70	0.4^{e}	0.27^{de}	67.4^{ab}	9.30^{ab}	15.3	1.7	10.3	62.1
16791	19.0^{de}	15.7^{a}	54.5^{e}	29.2^{fg}	3.82	0.65^{c}	0.24^{e}	69.9^{ab}	9.67^{ab}	20.4	3.2	14.3	64.5
16798	19.6^{c}	11.3^{f}	56.4^{d}	30.6^{c}	3.80	0.5^{d}	0.26^{de}	70.4^{a}	9.73^{a}	20.3	2.3	14.3	64.9
16836	11.3^{g}	7.5^{h}	64.6^{a}	36.6^{a}	4.09	0.3^{f}	0.25^{e}	66.7^{abc}	9.21^{abc}	4.6	0.4	3.1	61.4
Local	20.2^{b}	13.2^{c}	58.2^{c}	29.9^{de}	3.34	0.5^{d}	0.35^{c}	62.6^{c}	8.61^{c}	13.2	1.7	8.3	57.5
SE ±)	0.14	0.09	0.13	0.20	0.37	0.008	0.003	7.33	0.23	-	-	-	-

Source (Tessema, 2005); CP = crude protein; NDF = neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; Ca = calcium; P = phosphorus; IVDMD = in vitro dry matter digestibility; ME = metabolizable energy; DMY = dry matter yield; CPY = crude protein yield; DDMY digestible dry matter yield.

Table 4. Potential of Napier grass accession to support livestock production based on nutrient requirements

Weight and production status of Animal	DOM (%)	CP (g day-1)	ME (MJ day-1)	Ca (g day-1)	P (g day-1)
Nutrient requirement	55	821	85.5	28	27
Potential of Napier grass					
14983	65.2	102.58	76.7	76.65	45.15
14984	64.7	101.745	73.5	73.5	29.4
15743	64.0	100.69	74.7	74.55	43.05
16834	60.3	94.92	84.0	84	32.55
46835	64.9	102.16	67.2	67.2	49.35
16786	62.1	97.65	42,0	42	28.35
16791	64.5	101.54	68.2	68.25	25.2
16798	64.9	102.16	52.5	52.5	27.3
16836	67.4	96.7	31.5	31.5	26.25
Local	57.5	90.4	52.5	52.5	36.75

Source (Tessema, 2005)

Effect of plant height at cutting under rain fed conditions

Growth characteristics: The number of internodes per tiller, number of leaves per tiller and per plant increased with increased cutting heights while leaf: stem ratio and leaf length were greater with the shorter plant height at cutting (Tessema et al., 2003; Table 5). This value might be due to undisturbed growth for the highest plant height at cutting. Butt et al. (1993) found that the overall stem fraction increased with cutting height, due to the maturity of the plant. Tillers per plant, base circumference and internodes length per tiller were significantly affected by plant height at cutting (Tessema et al., 2003a). Kamel et al. (1983) in Egypt found that the number of tillers per plant of Napier grass increased with plant height at cutting. In a cut-and-carry system, height at cutting is reported to affect the growth characteristics and productivity of Napier grass (Mureithi and Thorpe, 1996).

Table 5. Growth characteristics of Napier grass as influenced by height at cutting under rain fed conditions

Growth characteristics	Plant height at cutting (m)			
	0.5	1	1.5	SE (±)
Internode number per tiller	5.6^{c}	7.7^{b}	9.0^{a}	0.19
Internode length per tiller (cm)	12.8^{c}	15.0^{b}	17.4^{a}	0.41
Number of leaves per tiller	20.5^{c}	25.6^{b}	33.8^{a}	1.58
Total leaves per tiller	438.7^{c}	728.9^{b}	1036.5^{a}	53.2
Leaf length (cm)	53.3^{a}	48.5^{b}	48.6^{b}	1.47
Leaf: stem ration	3.04^{a}	1.33^{b}	1.17^{b}	0.16
Number of tiller per plant	21.3^{b}	28.2^{a}	30.3^{a}	1.23
Basal circumference per plant (cm)	60.3^{b}	63.1^{b}	73.7^{a}	1.94

Source (Tessema et al., 2003a)

Biomass production: The DM yield of Napier grass has been significantly affected by plant height at cutting **(**Tessema et al., 2002a; 2003b; Table 6). The highest value of 9.5 t ha^{-1} is reported from cutting at 1.0 m height during the establishment year in north-western part of Ethiopia. Several other studies have reported similar results in different parts of the world (Liang, 1982; Kamel et al., 1983; Hassan et al., 1990, Muinga et al., 1992; Mureithi and Thorpe, 1996). More than 25 t ha^{-1} DM yield per annum of was obtained from well-managed Napier grass harvested at 1.0 m height on red soil under rain fed condition in the north-western part of Ethiopia (Tessema, 2005) but the average total forage yield varies from 10-15 DM t ha^{-1} $year^{-1}$ under rain fed condition in the central highlands of Ethiopia harvested at a similar height (Seyoum et al., 1998). This difference might be due to the variation in altitude where both studies have been conducted since the central highland has a higher elevation than northwestern Ethiopia. Plant height at cutting had a significant effect on annual DM yields of Napier grass in the central highlands of Ethiopia and cutting at 1.0 m height produced a higher yield than cutting at 0.5 and 1.5 m (Seyoum et al., 1998). Generally, the productivity of Napier grass per annum can be rapidly and substantially altered by variation in defoliation or cutting management (Tessema et al., 2002a, b; 2003).

Table 6**. L**east square means of dry matter yield (t ha^{-1} $year^{-1}$ of Napier grass as influenced by plant height at cutting and fertilizer application under rain fed conditions

Plant height at cutting (m)	Fertilizer application					
	0^{xy}	46^{x}	92^{x}	1^{y}	2^{y}	Mean
0.5	6.99^{defg}	6.95^{defg}	5.51^{fg}	5.88^{efg}	4.18^{g}	5.90
1.0	6.58^{efg}	10.67^{abc}	12.34^{a}	7.84^{cdef}	8.58^{bcdef}	9.18
1.5	8.45^{bcdef}	9.05^{abcde}	10.28^{abcd}	8.16^{cdef}	11.72^{ab}	9.53
Mean	7.31	8.89	7.29	7.29	8.16	8.21

Source (Tessema et al., 2002b); ^{X} = N fertilizer (kg ha^{-1}); ^{Y} = ^{c}attle manure (t ha^{-1}); ^{abcdef} numbers with similar superscript do not significantly differ (P<0.05)

Chemical composition: An increase in plant height at cutting in Napier grass resulted in a reduction in CP, ME, IVDMD in north-western Ethiopia (Tessema et al., 2002b; Table 7). Similarly, plant height at cutting height had a remarkable effect on CP content and IVDMD than DM, Ash and fibre contents of Napier accessions in the central highlands of Ethiopia (Seyoum et al., 1998). The mean CP content of Napier grass accessions at 0.5, 1.0 and 1.5 m height at cutting were 20.2, 14.3 and 12.3%, respectively while the respective IVDMD of the three cuts were 74, 72 and 62%. Napier grass harvested at 0.5 m height (younger stage) contains satisfactory levels of CP, Ca and P that can sustain acceptable growth rates in dairy heifers (Kariuki et al., 1998). Moreover, the young Napier grass (0.5 m) showed better quality and performance than the recommended cutting height (1.0 m), which is frequently used by farmers, in Kenya (Kariurki et al., 1999). The observed mean CP content harvested at 0.5 m height were considered to be adequate to meet higher requirements and allow modest average daily gains (Kariuki et al., 1998; Seyoum et al., 1998; Tessema et al., 2002b). Generally, based on CP and digestible DM yield, 1.0 m height at cutting is appropriate to obtain better yield and quality forage of Napier grass under rain fed conditions in the mid and highland areas of Ethiopia (Seyoum et al., 1998; Tessema et al., 2002a, b; Table 8).

Table 7. Chemical composition and in vitro dry matter digestibility (% DM basis) of Napier as influenced by plant height at cutting under rain fed conditions in north-western Ethiopia

	Plant height at cutting (m)			
Parameters	0.5	1.0	1.5	SE (±)
Dry matter (%)	20.0^{b}	18.2^{b}	24.0^{a}	0.77
Ash	16.8^{a}	16.6^{a}	15.2^{b}	0.32
Crude protein	20.0^{a}	11.5^{a}	9.6^{c}	0.31
Neutral detergent fiber	58.3^{c}	61.6^{b}	63.5^{a}	0.55
Acid detergent fiber	30.3^{c}	35.5^{b}	37.4^{a}	0.47
Acid detergent lignin	3.0^{c}	3.7^{b}	4.2^{a}	0.12
ADF-ash	5.7^{b}	7.9^{a}	7.4	0.30
Cellulose	21.6^{c}	23.9^{b}	25.8^{a}	0.61
Hemicellulose	228.0^{a}	26.1^{b}	26.1^{a}	0.20
Calcium	0.80^{a}	0.60^{b}	0.5^{b}	0.03
Phosphorus	0.21^{a}	0.2^{a}	0.1^{b}	0.004
In vitro dry matter digestibility	71.7^{a}	65.5^{b}	61.03^{c}	0.43
Metabolizable energy (MJ.kg-1 DM)	9.9^{a}	9.0^{b}	8.39^{c}	0.61

Source (Tessema et al., 2002b)

Table 8. Total nutrient yield (t ha-1) of Napier grass as influenced by plant height at cutting under rain fed condition

Plant height at cutting:	DM yield (t ha-1)	CP (%)	CP yield		IVDMD (%)	Digestible DM yield	
			Cut -1	Day-1		Cut -1	Day-1
0.5 (68 days)	5.90^{b}	20.0^{a}	1.18^{a}	0.0174^{a}	71.74^{a}	4.23^{b}	0.0622^{a}
1.0 (93 days)	9.18^{a}	11.5^{b}	1.06^{b}	0.0114^{b}	65.50^{b}	6.01^{a}	0.0647^{a}
1.5 (114 days)	9.53^{a}	9.6^{c}	0.91^{c}	0.0080^{c}	61.03^{c}	5.82^{a}	0.0510^{b}

Source (Tessema et al., 2002b); DM = dry matter; CP = crude protein; IVDMD = in vitro dry matter digestibility

***In vitro* DM digestibility:** Plant height at cutting is reported to have a significant effect on IVDMD contents. As height at cutting increased from 0.5 to 1.5 m, there has been a decline in IVDMD content from 72-61% (Tessema et al., 2002a, b; Table 7). This finding is in agreement with Taliafero et al. (1975), who reported that grasses harvested at a relatively advanced stage of development had depressed IVDMD values.

In *sacco* rumen degradability

Dry matter degradability- Studies conducted in Ethiopia showed that plant height at cutting had a significant effect on rumen in *sacco* dry matter degradability (DMD) percent and their degradability characteristics incubated up to 120 h (Tessema et al., 2002b; Tessema and Baars, 2004; Table 9). There was a reduction in DMD and its degradability characteristics of Napier grass at increased plant height at cutting due to increased lignifications, thereby reducing its digestibility. Potential (PD) and effective (ED) degradabilities at rumen outflow rate of 0.03 h^{-1} were higher for Napier grass cut at 0.5m height than at 1.0 and 1.5 m height. This might be explained by the higher LSR of the grass at 0.5 m height (3.04 LSR) than at 1.5m height (1.33 LSR) (Seyoum et al., 1998; Tessema et al., 2002b). Similarly, Kabuga and Darko (1993) reported that DMD linearly decline with increasing age of growth of grass species in the tropics, which is generally attributed to the increase in structural components (cell walls), a decline in the leave to stem ratio, and an increase in the proportion of senescent plants. Digestibility decrease as plants mature and differences in digestibility of grasses were influenced by leaf to stem ratio (Tessema et al., 2003a). In very young grass, the stem is more digestible than the leaf, whereas with advancing maturity, the digestibility of the leaf fraction decreases slowly and that of the stem fraction falls rapidly (Minson, 1990). Minson (1990) also indicated that organic matter digestibility varies with the proportion of cell contents and cell wall constituents.

Table 9. In sacco rumen dry matter degradability characteristics of Napier grass as influenced by height of plant at cutting

Rumen DMD characteristics	Height at cutting (m)			
	0.5	1.0	1.5	SE (±)
Washing loss/readily fermentable fraction (A), %	20.0^a	16.0^b	13.8^c	0.69
Insoluble but fermentable fractions (B), %	63.9^a	60.7^b	60.1^b	0.51
Rate of degradability (A+B), %	83.9^a	76.7^b	73.9^c	0.50
Rate of degradation of B (c), h	0.0532	0.0531	0.0434	0.003
Lag phase (L), h	1.40^a	1.77^a	2.75^b	0.38
Effective degradability (ED), %	61.8^a	55.9^b	51.7^c	0.66

Source (Tessema et al., 2002a)

The potential degradable and undegradable fractions and the duration of the lag time are affected by plant height at cutting in Napier grass (Tessema et al., 2002a). According to Van Soest (1994) the lag time in the degradation of fibrous feeds is caused by the substrate and a long lag time is one of the factors limiting intake and utilization of fibrous feeds. The relatively long lag time at 1.5 m cutting height could be a reflection of its probable higher lignocellulose content compared with 0.5 and 1 m cuttings.

Effect of defoliation frequency on performance of Napier grass

Amongst the major agronomic practices required for high production and quality of Napier grass are harvesting at appropriate cutting (stubble) heights above ground level and defoliation frequencies (days between cutting) (Butt et al., 1993; Tessema et al., 2003a; Jϕrgensen et al., 2010). Maintaining a minimum cutting height above ground level is considered as an important and easy pasture management practice (Tessema et al., 2010b) because it helps to maintain plant vigor, facilitates re-growth of the plant following cutting and maintains sufficient forage as well as stabilizing the plant within the soil (Wijitphan et al., 2009; Jϕrgensen et al., 2010). However, very frequent defoliation of the plant either by grazing or cutting, affects the growth and development of the pasture, whereas delayed defoliation frequency may enhance the growth and development of the pasture (Nyaata et al., 2002; Tekletsadik et al., 2004). Cutting of Napier grass close to ground level may negatively affect the re-growth ability by reducing tiller development. In contrast, a higher cutting height of Napier grass may result in underutilization, and the quality of the plant as forage is reduced by a higher cutting height (Butt et al., 1993; Tessema et al., 2003a).

Growth characteristics

The number of tillers per plant, number of internodes per plant, number of leaves per tiller and per plant, leaf length per plant, and basal circumference per plant of Napier grass increased as the defoliation frequency decreased, whereas leaf to stem ratio increased as the frequency of defoliation increased, possibly due to undisturbed growth of Napier grass for a longer period (Tessema et al., 2010b; Table 10). According to previous studies (Butt et al., 1993; Tessema et al., 2003a; Wijitphan et al., 2009), the overall growth characteristics increased with increasing maturity of Napier grass. The number of leaves per tiller and per plant and basal circumstance per plant increased with increasing days between cuttings, while leaf to stem ratio and leaf length per plant decreased as the days between cutting increased (Tessema et al., 2003a; Tessema et al., 2010b). The decreasing trend observed in leaf to stem ratio as the growth period increased is in agreement with the report of Butt et al. (1993), who indicated that the reduction in leaf proportion and an increase in stem fraction of Napier grass following delayed harvest occurred due to maturity. This confirms that Napier grass harvested following delayed defoliation frequency had a greater quantity of structural components which may have contributed to the decline in leaf to stem ratio. This is also supported by Kabuga and Darko (1993) who reported that tropical grasses harvested at advanced stages of growth have increased structural components and a decline in the ratio of leaves to stems (Butt et al., 1993; Wijitphan et al., 2009). Previous studies have shown that the number of leaves per plant increased with increasing days between cuttings of Napier grass (Tessema et al., 2003a; Taye et al., 2007). The longer the vegetative growth of the plant, the greater the number of leaves produced from the newly emerging tillers (Butt et al., 1993). Nyaata et al. (2002) and Taye et al. (2007) reported that the number of tillers per plant, leaf length per plant, number of leaves per tiller and the basal circumference of the plant increased as the interval after cutting increased. This may be due to the longer physiological growth phases of the plants in the reduced cutting frequency (Butt et al., 1993; Wijitphan et al., 2009).

Table 10. Effect of defoliation frequency (DF) and cutting height (CH) on morphological characteristics of Napier grass at Haramaya University, eastern Ethiopia

	Morphological characteristics						
	NTPP€	NLPT	TLPP	LLPP	NIPP	BCPP	LSR
Defoliation frequency							
60	13.7[b]	9.0bc	122.4[c]	69.8[c]	0.0[c]	59.6[b]	1.13[a]
90	19.9[a]	10.0[b]	199.0[b]	87.3[b]	2.3[b]	84.0[a]	0.76[b]
120	18.5[a]	12.2[a]	225.7[a]	98.6[a]	6.1[a]	89.2[a]	0.41[c]
Cutting height							
5	17.6[a]	10.3[a]	181.3[a]	88.8[a]	2.7[a]	77.2[a]	1.0[a]
10	16.1[a]	10.9[a]	175.5[a]	88.3[a]	2.5[a]	70.0[a]	0.9[a]
15	15.8[a]	10.5[a]	165.9[a]	88.8[a]	2.4[a]	80.5[a]	0.8[a]
20	17.8[a]	10.0[a]	178.0[a]	84.0[b]	2.8[a]	82.3[a]	0.7[a]
25	18.9[a]	10.2[a]	192.8[a]	76.1[c]	2.9[a]	78.0[a]	0.7[a]
Defoliation frequency							
P	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	4.12	1.22	31.07	5.25	0.85	14.26	0.08
Cutting height							
P	0.757	0.812	0.695	0.002	0.905	0.738	0.089
LSD	NS	NS	NS	6.78	NS	NS	NS
DF x CH							
P	0.556	0.941	0.715	0.544	0.977	0.984	0.032
LSD	NS	NS	NS	NS	NS	NS	NS
CV (%)	11.9	16.11	17.09	8.24	7.95	14.57	7.39

Source (Tessema et al., 2010b); [€] NTPP = number of tiller per plant; NLPT = number of leaf per tiller; TLPP = total number of leaf per plant; LLPP = leaf length per plant; NIPP = number of internodes per plant; BCPP = basal circumference per plant; LSR = leaf stem ration. Numbers with the same superscript within a column and within a factor are not different (P<0.05).

Dry matter yield

The DM yield increased as frequency between cuttings increased from 60 days - 120 days (Tessema et al., 2010b; Figure 1). According to previous studies (Tessema et al., 2002b; Tessema et al., 2003a), the DM yield of Napier grass increased as defoliation interval increased. A significant increase in DM yield occurring following long regrowth period with a tendency towards maturity was reported by Kariuki et al. (1998). It has been observed that Napier grass DM yield increased 6.8 t ha-1 at 3 weeks post establishment to 13.0 t ha-1 10 weeks post establishment at a number of locations in Kenya (Kariuki et al., 1998). This indicates that a long harvest interval is necessary to achieve high herbage yields of Napier grass (Tekletsadik et al., 2004; Tessema et al., 2010b).

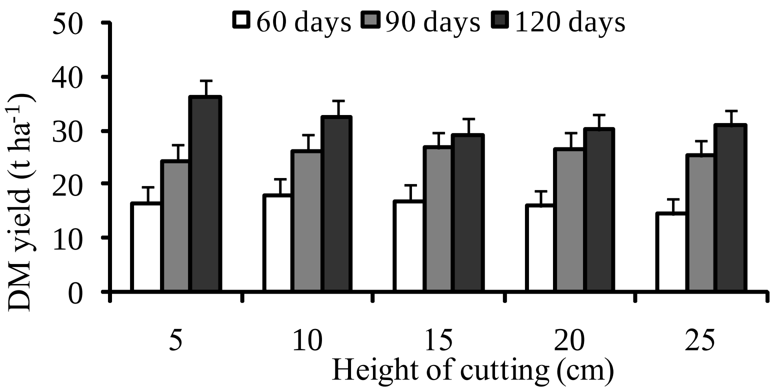


Figure 1. *Effect of defoliation frequency and cutting height on dry matter yield (t ha-1) of Napier grass (Pennisteum purpureum (L.) Schumach) at Haramaya University, eastern Ethiopia*

Chemical composition and IVDMD

Total ash, CP, hemicellulose, and IVDMD contents of Napier grass decreased as defoliation interval increased from 60 to 120 days after establishment (Tessema et al., 2010b; Table 11). However, DM, ADF, ADL and cellulose contents showed an increasing trend with an increase in frequency of defoliation. It is widely reported that CP and IVDMD decrease as defoliation interval increases (Tessema et al., 2002a). In contrast, NDF, ADF, ADL, and cellulose increase with increasing days of defoliation (Kabuga and Darko, 1993).

Table 11. Effect of frequency of defoliation (DF) and cutting height (CH) on chemical compositions and in vitro dry matter digestibility of Napier grass at Haramaya University, eastern Ethiopia.

	Chemical composition and IVDMD (% DM basis)								
	DM[λ]	TA	CP	NDF	ADF	ADL	CELL	HC	IVDMD
Defoliation frequency									
60	90.4[c]	13.8[a]	12.1[a]	54.6[a]	36.0[b]	3.4[b]	29.7[b]	33.7[a]	63.9[a]
90	91.5[b]	13.4[a]	10.6[b]	54.7[a]	39.8[a]	3.5[b]	33.6[a]	29.2[b]	62.9[a]
120	92.8[a]	12.3[b]	8.0[c]	54.8[a]	41.0[b]	4.0[a]	33.9[a]	28.0[c]	56.9[b]
Cutting height									
5	91.9[a]	13.5a	11.4[a]	54.9[a]	37.9[a]	3.5[a]	31.9[a]	30.8[a]	60.8[a]
10	92.3[a]	13.1[ab]	9.8[ab]	54.4[a]	38.9[a]	3.8[a]	32.1[a]	30.1[a]	62.9[a]
15	92.4[a]	12.8[b]	9.3[b]	54.7[a]	39.7[a]	3.7[a]	33.1[a]	29.9[a]	61.0[a]
20	93.6[a]	12.9[b]	9.4[b]	54.8[a]	39.4[a]	3.7[a]	32.7[a]	30.5[a]	60.9[a]
25	92.6[a]	13.5[a]	11.2[a]	54.6[a]	38.7[a]	3.5[a]	32.3[a]	30.2[a]	60.4[a]

	Chemical composition and IVDMD (% DM basis)								
	DM[λ]	TA	CP	NDF	ADF	ADL	CELL	HC	IVDMD
Defoliation frequency									
P	0.001	0.001	0.001	0.144	0.001	0.001	0.001	0.001	0.001
LSD	0.38	0.42	1.21	NS	1.16	0,21	1.03	0.71	1.85
CH									
P	0.191	0.021	0.018	0.153	0.328	0.274	0.388	0.303	0.466
LSD	NS	0.54	1.58	NS	NS	NS	NS	NS	NS
DF x CH									
P	0.034	0.171	0.434	0.056	0.071	0.163	0.141	0.231	0.002
LSD	0.87	NS	NS	NS	NS	NS	NS	NS	4.14
CV %	0.56	4.27	5.75	1.31	3.98	7.68	4.23	3.15	4.92

Source (Tessema et al., 2010b); [λ] DM = dry matter; TA = total ash; CP = crude protein; NDF = Neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; CELL = cellulose; HC = hemicellulose; IVDMD = *in vitro* dry matter digestibility; NS, not significant; Numbers with the same superscript within a column and within a factor are not different (P<0.05).

Effect of fertilizer application on performance of Napier grass

Growth characteristics: Studies showed that the number of tillers per plant, number of internodes per tiller base circumference and internodes length per tiller were significantly affected by fertilizer application with the highest values at 1.5 m in Napier grass (Tessema et al., 2003a; Table 12). Kamel et al. (1983) in Egypt found that the number of tillers per plant of Napier grass increased with N levels, although animal manure and chemical fertilizers had no effect on tillers per plant in the early stage of growth in Taiwan (Liang, 1982). Cattle manure did not have as much effect on growth as N fertilizer, perhaps because only small amounts of manure were applied in the study or because cattle manure has only a long-term effect on soil-plant interaction.

Table 12. Growth characteristics of Napier grass as influenced by fertilizer application under rain fed conditions

Growth characteristics	Fertilizer application					
	0^{d}	46^{d}	92^{d}	1e	2e	SE (±)
Internode number per tiller	8.3^{a}	6.9^{b}	7.3^{b}	7.4^{ab}	7.3^{b}	0.24
Internode lengeth per tiller (cm)	14.7^{b}	16.9^{a}	14.9^{ab}	14.3^{b}	14.3^{b}	0.54
Number of leaves per tiller	28.8	25.1	25.9	26.2	27.4	2.05
Total leaves per tiller	860.2	717.3	834.4	620.6	640.6	68.7
Leaf length (cm)	48.8	52.8	51.4	48.5	49.2	1.90
Leaf: stem ration	1.91	1.84	1.72	2.14	1.62	0.21
Number of tiller per plant	28.5^{ab}	27.9^{ab}	31.1^{a}	23.0b	22.5^{b}	1.59
Basal circumference per plant (cm)	67.3^{ab}	67.9^{ab}	71.3^{a}	58.9^{c}	62.9^{bc}	2.50

Source (Tessema et al., 2003a); [d] = N fertilizer (kg ha^{-1}); [e] = cattle manure (t ha^{-1}); Numbers within a row with similar superscript do not significantly differ (P<0.05)

Biomass production: The DM yield of Napier grass was significantly affected by fertilizer application with the highest DM yield of 8.9 t ha^{-1} by the application of 46 kg N ha^{-1}. Similarly, application of cattle manure at a rate of 2 t ha^{-1} gave a higher DM yield of Napier grass compared to 1.0 t ha^{-1} and without N and manure application (Tessema, et al., 2002b; Table 6). However, the effect of cattle manure on DM yield when compared to inorganic fertilizer application was not pronounced, which might be due to the small amount of manure applied and the slow nutrient releasing as the manure was not yet fully decomposed. For instance, a ton of cattle manure (DM basis) contains 8 and 4 kg of N and P, respectively (Tessema et al., 2002a). However, some studies reported that the DM yield of Napier grass was proportional to the amount of applied manure. The use of 30 t ha^{-1} farmyard manure increased growth and DM yield of Napier grass harvested at 1.5 m in Paraguay (Averio et al., 1991). Similarly, more than 25 t ha^{-1} DM yields per annum is obtained from well-managed and fertilized Napier grass with 92 kg ha^{-1} N on red soil under rain fed condition in the north-western Ethiopia (Tessema, 2005).

Chemical composition and IVDMD: Fertilizer application per se had no significant effect on IVDMD and ME of Napier grass. Crude protein and hemicellulose increased whereas ash, ADF-ash, and P decreased as a result of an increase in the level of N application (Tessema et al., 2002b; Table 13). According to Taliaferro et al. (1975), addition of N tended to increase IVDMD of grasses when compared with plots receiving no N. Nitrogen fertilization of grasses affects herbage digestibility only slightly and improved DMD during the earlier part of growth period but at the advanced stage of maturity the DMD of N-fertilized grass was inferior to the non-fertilized ones (Daniel, 1996). Dressings of fertilizers can markedly affect the mineral content of plants, and it is also known that the application of N fertilizer can increase the CP of herbage and influence the amide and nitrate content (Van Soest, 1994). Generally application of 92 kg ha^{-1} N in the form of urea provided the highest yield and total nutrient per ha in Napier grass under rain fed condition in mid and highland areas of Ethiopia (Table 14).

Table 13. Chemical composition and in vitro dry matter digestibility (% DM basis) Napier as influenced by fertilizer application under rain fed conditions

	Fertilizer application					
Parameters	0wz	46w	92w	1z	2z	SE (±)
Dry matter	21.9	19.40	20.50	21.80	20.40	0.99
Ash	16.50^{a}	15.70^{b}	15.10^{c}	16.50^{ab}	17.10^{a}	0.41
Crude protein	12.60c	14.50^{ab}	15.10^{a}	13.40^{bc}	12.90^{c}	0.40
Neutral detergent fiber	61.31	61.44	61.78	60.42	60.51	0.71
Acid detergent fiber	34.99	34.08	34.98	34.03	34.01	0.61
Acid detergent lignin	3.59	3.66	3.79	3.61	3.55	0.15
ADF-ash	7.02^{a}	6.86^{a}	6.05^{b}	7.42^{a}	7.74^{a}	0.38
Cellulose	24.39	23.56	25.14	23.00	22.73	0.79

	Fertilizer application					
Parameters	0wz	46w	92w	1z	2z	SE (±)
Hemicellulose	26.32[c]	27.36[a]	27.13[ab]	26.40[bc]	26.35[c]	0.26
Calcium	0.63	0.63	0.59	0.68	0.70	0.04
Phosphorus	0.20[ab]	0.19[a]	0.17c	0.20[ab]	0.21[a]	0.01
IVDMD	65.90	66.16	65.53	66.19	66.67	0.55
ME (MJ.kg -1 DM)	9.09	9.12	9.03	9.13	9.19	0.78

Source (Tessema et al., 2002a); [w] = N fertilizer (kg ha^{-1}); [z] = cattle manure (t ha^{-1}); IVDMD = *in vitro* dry matter digestibility; Numbers within a row with similar superscript do not significantly differ (P<0.05)

Table 14. Total nutrient yield (t.ha-1) of Napier grass as influenced by fertilizer application under rain fed conditions in north-western Ethiopia

Fertilizer application	DM yield (t.ha-1)	Crude protein (%)	Crude protein yield		IVDMD (%)	Digestible DM yield	
			Cut -1	Kg N-1		Cut -1	Kg N-1
0 N kg ha-1	7.31[c]	12.6[c]	0.92[c]	-	65.90	4.82c	-
46 N kg ha-1	8.89[a]	14.5[ab]	1.29[b]	0.008[az]	66.16	5.88[ab]	0.0231[a]
92 N kg ha-1	9.38[a]	15.1[a]	1.42[a]	0.0054[b]	65.53	6.15[a]	0.0145[b]
1 t ha-1 manure	7.29[c]	13.4[bc]	0.98[c]	-	66.19	4.83[c]	-
2 t ha-1 manure	8.16[b]	12.9[c]	1.05[c]	-	66.67	5.44[b]	-

Source (Tessema et al., 2002a); DM = dry matter; IVDMD = *in vitro* dry matter digestibility

Supplementation of Napier grass with multipurpose trees

Multipurpose fodder trees (MPT) and shrubs have often considerable potential in mixed crop-livestock production systems to alleviate and compliment the low feeding value of roughage diets (Tessema and Baars, 2004; Manaye et al., 2009). They are seldom exclusively fed, mostly as a supplement to enhance the utilization of fibrous feeds. An important attribute of MPT is their positive effect on digestibility when used as a supplement to fibrous basal feeds (Solomon et al., 2003). The increased DM and/or OM digestibility of low quality feeds by supplementing MPT could be due to the retention of adequate level of rumen ammonia and the removal of amino acid deficiency at tissue level (Solomon et al., 2003). On top of these, the OM digestibility of MPT is higher than grasses due to the fact that MPT supply soluble carbohydrates and fermentable N for rumen and post rumen function (Smith, 1992).

Chemical composition and IVDMD: Studies indicated that the DM, ash, CP, and ADL contents of Napier grass increased as the proportion of Sesbania (10, 20, 30 and 40% *Sesbania sesban* in DM basis) in the nixture increased. The DM, ON and CP intake and DM, ON, CP and NDF digestibilities of Napier grass –Sesbania mixtures were higher than sole Napier grass alone (Manaye et al., 2009; Table 15 and 16). The average daily wight gain was higher in animals fed a diet containing 300 g DM^{-1} Sesbania as compared to the sole Napier grass. The CP contents of different Napier-

Sesbania mixtures were above the minimum CP level of 7.5% required for adequate rumen function in ruminants (Van Soest, 1994). The minimum CP content required for lactation and growth of cattle is 15% (Van Soest, 1994) suggesting that the 70:30 and 60:40% Napier-Sesbania mixtures were above the recommendation. The advantage of perennial legume in a mixed pasture is their higher protein value compared to grass alone (Minson, 1990; Lemma et al., 1991). The low fibre content of Sesbania might have contributed to the increasing CP and IVDMD in Napier grass. The important attributes of MPT are their positive effects on digestibility and to enhance utilisation of fibrous feeds when used as a supplement to fibrous basal feeds (Solomon et al., 2003; Tessema and Baars, 2004). The increased DMD of low quality feeds by supplementing MPT could be due to maintenance of adequate levels of rumen ammonia and removal of amino acid deficiency at the tissue level (Solomon et al., 2003). Moreover, the DMD of MPT is higher than grasses since MPT supply soluble carbohydrates and fermentable N for rumen and post rumen function (Smith, 1992). Napier-Sesbania mixtures could adequately supply CP, ME and Ca above the production requirements (Kearl, 1982) of a 12 weeks lactating dairy cow weighing 500 kg since the nutrient, digestibility and intake increases with the level of Sesbania in the Napier mixture (Table 16). It can be concluded that feeding a sole diet of young Napier grass to sheep could result in reseanably god performance and inclusion of above 300 g DM^{-1} Sesbania in the Napier diet did not have further beneficial effects. This shows that Sesbania leaves would increase the digestibility and intake of matured Napier grass and could be used as an effective supplement under smallholder conditions in Ethiopia.

Table 15. Chemical composition (g kg-1 DM) and digestibility (%) of Napier grass (N) mixed with different proportions of Sesbania (S)

Feeds	Chemical composition					Digestibility (%)				
	OM	CP	NDF	ADF	ADL	DM	OM	CP	NDF	ADF
SSesbania alone	757	248	399	299	80	-	-	-	-	-
Napier alone	854	120	715	406	65	65.8^{b}	71.8^{b}	69.8^{b}	69.0^{b}	51.5^{a}
N + 100 g kg-1 S	841	133	684	395	66	74.4^{ab}	80.4^{ab}	82.0^{a}	75.7^{ab}	42.6^{b}
N + 200 g kg-1 S	834	146	652	384	68	77.1^{a}	81.8^{a}	83.4^{a}	77.3^{ab}	29.0^{c}
N + 300 g kg-1 S	825	159	621	374	70	82.0^{a}	85.8^{a}	87.8^{a}	81.2^{ab}	11.8^{d}
N + 400 g kg-1 S	815	171	589	363	71	84.1^{a}	85.3^{a}	88.5^{a}	82.6^{a}	4.8^{e}

Source (Manaye et al., 2009); Means with different superscripts in a column are significantly different at P<0.05

Table 16. Mean daily dry matter and other nutrient intake and average daily weight gain () of local sheep fed Napier grass mixed with different levels of Sesbania sesban

Feeds	Daily DM and nutrient intakes (g kg $W^{-0.75}$ day^{-1})							ADWG (g day-1)
	DM	OM	CP	NDF	ADF	ADL	Ash	
Napier alone	57.9^{b}	47.5^{b}	7.0^{d}	41.4^{ab}	23.5^{a}	3.8^{b}	8.5^{d}	75.6^{b}
N + 100 g kg^{-1} S	63.1^{a}	51.1^{ab}	8.4^{c}	43.2^{a}	25.0^{a}	4.2^{b}	9.8^{c}	87.0^{ab}
N + 200 g kg^{-1} S	63.7^{a}	51.0^{ab}	9.3^{b}	41.6^{ab}	24.5^{a}	4.3^{b}	10.6^{bc}	86.2^{ab}
N + 300 g kg^{-1} S	63.6^{a}	50.2^{ab}	10.1^{b}	39.4^{b}	23.8^{a}	4.4^{b}	11.1^{ab}	103.0^{a}
N + 400 g kg^{-1} S	67.9^{a}	52.9^{a}	11.6^{a}	40.0^{b}	24.8^{a}	4.8^{a}	12.5^{a}	93.3^{ab}
SEM	0.002	0.001	0.000	0.001	0.001	0.000	0.000	7.5

Source (Manaye et al., 2009); SEM = standard error of the mean; Means with different superscripts in a column are significantly different at P<0.05

In sacco rumen degradability

Dry matter degradability-The proportions of Sesbania leaves mixed with Napier grass had a linear (P<0.05) effect on rumen DMD contents (Tessema and Baars, 2004; Table 17). There were no differences in DMD for the insoluble but gradually degradable fractions (B), and the lag phase (L), but other DMD characteristics had increasing linear (L: P<0.01) effects as the proportions of Sesbania increased in the mixture. However, the DMD lag time had quadratic (P<0.01) and cubic (P<0.01) effects. The PD, ED, and the rate of degradability of the B fraction (c) showed an increasing linear (P<0.01) effect as the proportion of Sesbania increased in the diet. Sesbania supplementation increased the rate of degradation and potential degradability (PD) for sheep fed a low quality basal diet (Nsahlai and Umunna, 1996). Incubation of Sesbania in the rumen of sheep affected the extent of DMD, the intercept (a), the slowly degradable component (b), rate of degradation (c), PD and lag time (Nsahlai and Umunna, 1996; Bonsi et al., 1995). Supplementation of Sesbania improved the fractional rumen out flow rate and out flow rate of liquids for sheep fed fibrous basal feeds (Bonsi et al., 1995). The faster degradation of Sesbania leaves released greater amounts of rumen metabolities, which probably enhanced rumen microbial function and proliferation (Bonsi et al., 1994; Bonsi et al., 1995) that might have improved feed digestibility. Compared with the foliages of other MPT, Sesbania has lower fibre levels that degraded faster in the rumen of animals fed a low quality basal diet, and it will tend to exhaust within a short time. Feeding fast degrading foliages, such as Sesbania, improved rumen ecology (i.e., N, minerals and isoacids), and they might further enhance forage intake since they move out the rumen faster and thus reduce rumen fill (Bonsi et al., 1994; Bonsi et al., 1995). This might have contributed to increase DMD as the proportion of Sesbania in Napier mixture increased.

Table 17. In sacco rumen dry matter degradability characteristics of Napier grass as influenced by different proportions of Sesbania in the mixture (g kg-1 DM)

	Proportion of Sesbania in the mixture						Probability [a]		
Parameters	0	100	150	200	250	SE (±)	L	Q	C
The readily fermentable fraction, g kg^{-1} DM	191	186	206	273	338	30	**	NS	NS
The insoluble but fermentable fraction, g kg^{-1} DM	559	586	593	527	477	24	NS	NS	NS
Potential degradability, g kg-1 DM	750	772	799	800	816	8	**	NS	NS
Rate of degradation of insoluble fraction, /h	0.04	0.05	0.05	0.07	0.07	0.02	**	NS	NS
Lag (L), h	5.6	4.3	4.5	5.0	6.1	0.8	NS	NS	NS
Effective degradability, g/kg	510	533	578	602	638	7	**	NS	NS

Source (Tessema and Baars, 2004); [a]Probability for linear (L), quadratic (Q), and cubic (C) trends; * $P < 0.05$; ** $P < 0.01$; NS = not significant

Intercropping Napier grass with herbaceous legumes

Intercropping Napier grass with *L. purpureus* and *D. intortum* significantly (P<0.01) out yielded the sole Napier grass and Napier grass associated with *L. purpureus* found to be better than either sole Napier or Napier grass + *D. intortum*. Intercropping Napier grass with *L. Purpureus* and *D. interterm* have resulted a significant difference on CP, CPY, fiber fractions (NDF, ADF, ADL, Cellulose and hemicellulose) and IVOMD (Taye et al., 2007). Moreover, Napier grass intercropped with Stylosanthes cv. Seca was more degradable than sole Napier grass. It can be concluded that *Lablab, Desmodium*, and *Stylosanthes* could form a better association with Napier grass and are recommended for intercropping in mid and semi-arid agro-ecologies of Ethiopia.

Summary and conclusion

Large productions of Napier grass are available in soil conservation areas, homestead plots, around road sides and other areas in Ethiopia, which indicated that Napier grass has no competition for land for food crop cultivations. Therefore, Napier grass could be easily established using rootstock and/or stem cuttings at a spacing of 1 m between rows and 0.50 m between plants under smallholder conditions for ruminant feeding. Spacing could be adjusted on performance basis and in areas of moisture stress, narrower spacing both between rows and plants is recommended. Plants from root splits make more rapid early growth and give high herbage yields than from stem cuttings under rain fed conditions in Ethiopia. However, older and hardened stems are more reliable than young materials for easy establishment and tiller formation if Napier grass is established by stem cuttings. Studies conducted in Ethiopia have shown that Napier grass has fast regrowth ability, high DM yield and nutritive values compared to other improved pasture species if harvested at an appropriate stage under rain fed conditions in mid and highland areas of Ethiopia. Therefore, the available management practices such as harvesting Napier grass when the plant reaches 1m height, or harvesting at 90 days interval, or mixing Napier grass with Sesbania up to 25%, or growing Napier grass with *Lablab purpureus* or *Desmodium intortum/unicinatum or Stylosanthes* or with forage vetch or with other multipurpose browse species or applying 92 kg ha^{-1} N or 2 t ha^{-1} cattle manure (DM basis) per annum could be practiced and followed by the livestock development and extension systems in Ethiopia. Further studies on intake and animal performances related to these management practices are suggested to develop Napier-based diets for smallholders' in different agro-ecological parts of Ethiopia.

References

Alemayehu, M. 2004. Pasture and forage resource profiles of Ethiopia. EDM Printing Press, Addis Ababa.

Aveiro, A.R., Siewerdt, L. and Junior-Silveira, P. 1991. Napier grass (*Pennisetum purpureum*): effects of irrigation, farmyard manure and chemical fertilizers. 1. Dry matter content and total dry matter yield. Revista-da-Sociedade-Brasileira-de-Zootecnia (Brazil) 20: 339-347.

Ayele, S, Assegid, W. Jabbar, M.A., Ahmed, M.M. and Belachew, H. 2002. Livestock marketing in Ethiopia. A review of structure, performance and development initiatives, In: Socio-economics and policy research working paper 52. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Berihun, M. 2005. Effect of planting patterns and harvesting days on yield and quality of Bana grass [*Pennisetum Purpureum* (L.) x *Pennisetum Americanum* (L.)]. MSc. Alemaya University, Alemaya, Ethiopia.

Bonsi, M.L.K., Osuji, P.O., Nsahlai, I.V. and Thah, A.K. 1994. Graded levels of *Sesbania sesban, Leucaena leucocephala* as supplements to tef straw given to Ethiopian Menz sheep. Animal Production 59: 235-244.

Bonsi, M.L.K., Osuji, P.O. and Thah, A.K. 1995. Effect of supplementing tef straw with different levels of Leucaena or Sesbania leaves on the degradability of tef straw, Sesbania, Leucaena, Tagasaste and Vernonia and on certain rumen and blood metabolitities in Ethiopian Menz sheep. Animal Feed Science and Technology 52: 101-129.

Butt, N.M., Donart, G.B., Southward, M.G. Pieper, R.D and. Mohammad, N. 1993. Effect of defoliation on plant growth of Napier grass. Tropical Science 33: 101-120.

Daniel, K. 1996. Effects of nitrogen application and stage of development on yield and nutritional value of Rhodes Grass (*Chloris gayana*). Ethiopian Journal of Agricultural Science 15: 86-101.

Hassan, W.E., Phipps R.H. and. Owen, E. 1990. Dry matter yield and nutritive value of improved pasture in Malaysia. Tropical Agriculture (Trinidad) 67: 303-309.

Jϕrgensen, S.T., Pookpakdi A., Tudsri S., Stölen O., Ortiz R. and Christiansen J.L., 2010. Cultivar-by-cutting height interactions in Napier grass (*Pennisetum purpureum* Schumach) grown in a tropical rain-fed environment Acta Agriculturae Scandinavica, Section B- Plant Soil Science 60: 199-210.

Kabuga J.D. and Darko, C.A. 1993. *In sacco* degradation of dry matter and nitrogen in oven dried and fresh tropical grasses and some relationships to in vitro dry matter digestibility. Animal Feed Science and Technology 40: 191-205.

Kamel, M.S., Abdel-Raouf, M.S., EI-Din, S.A.T. and Abbas, T. 1993. Effects of cutting height and frequency and nitrogen application rate on growth and forage yield of Napier grass, *Pennisetum purpureum,* Schum. Annals of Agricultural Science, University of Ain Shams (Egypt) 29: 607-625.

Kariuki, J.N., Gitau, G.K, Tamminga, S, Van Bruchem, J., Muia, J.M.K. and Jrunga, K.R.G. 1998. Effect of feeding Napier grass, lucerne and sweet potato vines as sole diets to dairy. heifers on nutrient intake, weight gain and rumen degradation. Livestock Production Science 55: 12–20.

Liang, J.C. 1982. The response of Napier grass (*Pennisetum purpureum*) to animal manure and chemical fertilizer. 1. Effects on dry matter yield and quality. Journal of Agricultural Association of China (Taiwan) 109: 64-74.

Lowe, A.J., Thrope W., Teale, A. and Hanson, J. 2003. Characterization of germplasm accessions of Napier grass (*Pennisetum purpureum* and *P. purpureum* x *P. glaucum* hybrids) and comparison with farm clones using RAPD. Genetic Resource and Crop Evolution 50: 121-132.

Manaye, T., Tollera, A. and Zewdu, T. 2009. Feed intake, digestibility and body weight gain of sheep fed Napier grass mixed with different levels of *Sesbania sesban*. Livestock Science 122: 24–29.

McDowell, L.R. 1985. Nutrition of grazing ruminants in warm climates. Animal Feeding and Nutrition (Monograph). Academic Press Inc., London, UK.

Minson, D.J. 1990. The chemical composition and nutritive values of tropical grasses. *In:* Skerman and Riveros (eds.) Tropical grasses. FAO, Rome.

Muia, J.M.K., Tamminga, S., Mbuguam, P.N. and Kariuki, J.N. 2001. Rumen degradation and estimation of microbial protein yield and intestinal digestion of Napier grass (*Pennisetum purpureum*) and various concentrates. Animal Feed Science and Technology 93: 177-192.

Mureithi, J.G. and Thorpe, W. 1996. The effects of herbaceous legume Inter-cropping and Mulching on the productivity of Napier grass (*Pennisetum purpureum*) and total forage yield in coastal lowland Kenya. In: J. Ndikumana and de Leeuw P. (ed.). Sustainable feed production and utilization for small holder livestock Enterprises in Sub-Sahara Africa. Proceedings of the Second African Feed Resource Network (AFRNET), Harare, Zimbabwe, 6-10 December 1993. AFRNET (Africa Feed Resources Network), Nairobi, Kenya, pp. 45-50.

Mutegi, J.K., Mugendi, D.K., Verchot. L.V. and Kung'u J.B. 2008. Combining Napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. Agroforestry Systems 74: 37-49.

Mwendia, S.W., Wanyoike. M., Wahome, R.G. and Mwangi, D.M. 2006. Farmer's perceptions on importance and constraints facing Napier grass production in central Kenya. Livestock Research for Rural development. Volume 18, Article No. 160. Retrieved April 8, 2010, from http://www.lrrd.org/lrrd18/11/mwen18160.htm.

Ndikumana, J. 1996. Multilocational evaluation of Napier and Pennisetum hybrids: Highlights of from the Addis Ababa. AFRNET (Africa Feed Resources Network) newsletter 6: 1-11.

Norton, B.W., 1982. Differences between species in forage quality. In: Hacker, J.B. (eds) Nutritional Limits to Animal Production from Pastures. Farnham Royal, Commonwealth Agricultural Bureaux. pp. 89-110.

Nsahlai, I.V. and Umunna, N.N. 1996. Sesbania and Lablab supplementation of Oat hay basal diet fed to sheep with or without maize grain. Animal Feed Science and Technology 61: 275-289.

Nyaata, O.Z., O'neill, M.K., Dorward P.T. and Keatinge J.D.H. 2002. Harvesting strategies for improved mixtures of Calliandra and Napier grass in the central Kenyan highlands. Journal of Sustainable Agriculture 19: 77-95.

Odongo, N.E., Tanner, J., Rommey, D.L., Plaizier, J., Van Straaten, P. and Mcbride, B. 2002. The effect of supplementing Napier grass (*Pennisetum purpureum*) with Rock Phosphate and steamed bone meal compared with commercial mineral mix on phosphorus absorption in cattle. Tropical Animal Health and Production 34: 329-338.

Seyoum, B. and Zinashi, S., Tadesse, T.T. and Liyusew, A. 1998. Evaluation of Napier (*Pennisetum purpureum*) and Pennisetum hybrids (*Pennisetum purpureum* x *pennisetum typhoides*) in the central highlands of Ethiopia. Proceedings of the 5th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-17, 1997. Addis Ababa, Ethiopia, pp. 194-202.

Smith, O.B. 1992. Fodder trees and fodder shrubs in range and farming systems of tropical humid Africa. In: A., Speedy and P.L. Pugliese (Eds). Legume Trees and other Fodder Trees as Protein Sources for Livestock. FAO Animal Production and Health Paper No. 102. FAO, Rome, Italy. pp. 43-60.

Solomon, M., Peters, K.J. and Azage, T. 2003. *In vitro* and *in situ* evaluation of selected multipurpose trees, wheat bran and *Lablab purpureus* as potential feed supplements to tef (*Eragrostis tef*) straw. Animal Feed Science and Technology 105: 159-170.

Taliaferro, C.M., Horn, F.P., Tucker, B.B., Totusek, R., and Morrison, R.D. 1975. Performances of three warm-season perennial Grasses and a Native Range Mixtures as influenced by N and P fertilization. Agronomy Journal 67: 291-291.

Taye, B., Solomon, M. and Prasad, N.K. 2007. Effects of cutting dates on nutritive value of Napier *(Pennisetum purpureum)* grass planted sole and in association with Desmodium *(Desmodium intortum)* or Lablab (*Lablab purpureus*). *Livestock Research for Rural Development, Volume 19, Article #11.* Retrieved January 26, 2010, from http://www.lrrd.org/lrrd19/1/bayb19011.htm

Tessema, Z. 2005. Variation in growth, yield, chemical composition and *in vitro* dry matter digestibility of Napier grass accessions (*Pennisetum purpureum).* Tropical Science 45: 93-99.

Tessema, Z. 2008. Effect of plant density on morphological characteristics, dry matter production and chemical component of Napier grass (*Pennisetum purpureum* (L.) Schumach). East African Journal of Sciences 2: 55-61.

Tessema, Z. and Baars. R.M.T. 2004. Chemical composition, *in vitro* dry matter digestibility and ruminal degradation of Napier grass (*Pennisetum purpureum (L.)* Schumach.) mixed with different levels of *Sesbania sesban* (L.) Merr.). Animal Feed Science and Technology 117: 29-41.

Tessema, Z., Baars, R.M.T., Alemu, Y. and Dawit, N. 2002a. *In Sacco* dry matter and nitrogen degradation and their relationship with *in vitro* dry matter digestibility of Napier grass (*Pennisetum purpureum* Schumach.) as influenced by plant height at cutting. Australian Journal of Agricultural Research 53: 7-12.

Tessema, Z., Baars, R.M.T. and Alemu, Y. 2002b. Effect of plant height at cutting, source and level of fertilizer on yield and nutritional quality of Napier grass (*Pennisetum purpureum* Schumach.). African Journal of Range and Forage Science 19: 123-129.

Tessema, Z., Baars, R.M.T. and Alemu, Y. 2003. Effect of plant height at cutting and fertiliser on growth of Napier grass (*Pennisetum purpureum* Schumach.). Tropical Science 43: 57-61.

Tessema, Z.K., Mihret, J. and Solomon, M., 2010a. Effect of defoliation frequency and cutting height on growth, dry matter yield and nutritive value of Napier grass (*Pennisetum purpureum* (L.) Schumach). Grass and Forage Science (in press).

Tessema, Z.K., Ashagre, A. and Solomon, M., 2010b. Botanical composition, yield and nutritional quality of grassland in relation to stages of harvesting and fertilizer application in the highland of Ethiopia. African Journal of Range and Forage Science (in press).

Wijitphan S., Lorwilai P. and Arkaseang C. 2009. Effects of plant spacing on yields and nutritive values of Napier grass (*Pennisetum purpureum* Schum.) under intensive management of nitrogen fertilizer and irrigation. Pakistan Journal of Nutrition 8: 1240-1243.

Woodard, K.R., Prine, G.M. and Bates, D.B. 1991. Silage characteristics of Elephant grass as affected by harvest frequency and genotype. Agronomy Journal 93: 347-551.

The Effect of Replacing Meat and Bone Meal with Soybean Meal on the Performance and Economic Returns of Broiler Chickens

*Kassa Shawle[1 *], Kelay Belihu[2] and Tadelle Dessie[3]*

[1]Komblocha Agricultural College, P.O.Box 56, South Wollo, Ethiopia

[2]Addis Ababa University Faculty of Veterinary Medicine, P.O.Box 34, Debre Zeit, Ethiopia

[3]International Livestock Research Institute (ILRI), P.O.Box 5689, Addis Ababa, Ethiopia

Abstract

The experiment was carried out to determine the effects of replacing meat and bone meal (MBM) with soybean meal (SBM) in starter and finisher diets on daily feed intake, body weight gain, food conversion ratio, water consumption, economic efficiency and carcass characteristics. A total of 306 day old broiler chickens were divided into six diet groups (each group with three replicates). Each replicate had 17 birds. Diet 1 was a commercial diet; diet 2 had 26% MBM; diet 3 had 6.5% SBM and 19.5% MBM; diet 4 had 13% SBM and 13% MBM; diet 5 had 19.5% SBM and 6.5% MBM and diet 6 had 26% SBM. At the end of the experiment (seven weeks), one male and female broilers were slaughtered from each replicate to evaluate the carcass development and abdominal fat. Feed intake and body weight gain of the birds were significantly ($p<0.05$) higher for diet 1 for the entire period of feeding, while both traits were inferior for diet 2. The highest feed conversion ratio was recorded for diet 2 ($p<0.05$). The rate of survival was not significantly different among treatments ($p>0.05$). The lowest abdominal fat percentage was observed for diet 1 and diet 6. Diet 1 comprised the highest eviscerated and breast weight percentage ($p<0.05$). The results of this study showed that using MBM beyond 6.5% significantly depressed the body weight gain, feed consumption, feed conversion ratio and increased cost of production.

Keywords: *Broiler; Meat and Bone Meal; Soybean Meal; Starter and Finisher*

Introduction

The fastest way of meeting the growing demand for protein of animal origin is through increasing the productivity of livestock and poultry and by lowering the cost of production to bring animal protein within the reach of more people that badly needs it. High feed cost is the single most important constraint to the expansion of animal production, which account for about 70% of the total production costs of broiler meat (Teguia and Beynen, 2005). Thus, exploring of full potential of all feed resources is a necessity for a successful poultry production.

* Corresponding author: reta2000k@yahoo.com

The other reason for seeking alternative protein source is the occurrence of Bovine Spongiform Encephalopathy (BSE) in the world in the last few years, which has raised a great concern on risks for human health (CEC, 2000). The disease was being transmitted to animals by the use of concentrate feed incorporating meat and bone meal (MBM) from infected animals (Speedy, 2004). As a preventative measure designed to stop the spread of the disease and minimize the potential risks to humans, the use of animal byproducts in manufacturing of animal feeds was prohibited (CEC, 2000). Authorities from countries such as Saudi Arabia, a major broiler chicken importer, also adopted this policy.

In the past, meat and bone meal was a primary protein source in animal diets in many areas in the world, but now a days due to its price and disease risk, broilers are fed diets exclusively formulated with plant-based ingredients Soybean meal is the preferred protein source in animal feed due to its relatively high protein content and a balanced amino acid composition (Brookes, 2000). It has also a high content of potassium, which is an electrolyte known to induce water consumption. The abundant availability of competitively priced soybeans on world markets today should be able to replace the protein material formerly derived from meat (Brookes, 2001).

The knowledge of the nutritional characteristics of Ethiopian soybean and its optimal levels of inclusion in poultry ration is very crucial to the sector especially at this time when animal feeds originating from meat are becoming expensive and risky. Therefore, the objective of this study was, to determine the effect of partial and full replacement of meat and bone meal (MBM) by soybean meal (SBM) on performance, carcass characteristics and economic advantage on broilers.

Materials and Methods

Study site

The study was conducted at the Debre Zeit Agricultural Research Center, located at 47 km South of Addis Ababa at an altitude of 1900m .a. s. l., latitude of 8° 44`N and longitude of 38° 57`E. The average (25 years) annual rainfall is 851mm with an average minimum and maximum temperature of 8.9°C and 26°C, respectively. The average relative humidity is 58.6 percent (DZARC, 2002).

Study animals

Cobb 500 strain of broiler chickens represents the study animals. It was the cross of Cornish and the Barred Plymouth Rock that gave rise to the first of the modern, commercial breeds, the Cobb. Cobb 500 is developed for intensive, indoor production; it is certainly a fast grower compared to Ross birds and has been known to grow too quickly for its legs to cope with its weight. It has proven ability to perform well in a wide range of environments, satisfying demand for maximum meat output. It has an excellent feed conversion ratio. Now a days, Cobb 500 strain is widely used in and around Debre Zeit.

Three hundred and six day old Cobb 500 broiler chicks received from Alema farm (local poultry company) located at Debre Zeit was used for the experiment and the chicks were randomly allotted to six dietary treatments replicated three times. Each replica has seventeen (17) birds and subjected in a completely randomized design (CRD).

Diet preparation and experimental design

Birds were provided daily with a known amount of feed and water *ad libitum*. Feed and water were weighed every morning and offered to the respective groups. The chickens were allocated to six diet groups where the MBM is progressively replaced by SBM from 0% to 100%. The diet groups were diet 1 which was a commercial ration, diet 2 with 26% MBM, diet 3 with 19.5% MBM and 6.5% SBM, diet 4 with 13% MBM and 13% SBM, diet 5 with 6.5% MBM and19.5% SBM and diet 6 with 26% SBM. The ration contains around 22% and 20% crude protein and 3000kcal/kg and 3200kcal/kg of metabolizable energy for starter and finisher broiler chicks, respectively. The nutrient composition of the soybean meal and meat and bone meal used for the study is presented in Table 1, whereas the ingredients and nutrient composition of starter and finisher diets are indicated in Tables 3 and 4.

Table 1. Proximate compositions of soybean meal and meat and bone meal used for the trial

Feed stuff	DM (%)	CP (%)	CF (%)	FE (%)	NFE (%)	MM (%)	Ca (%)	P (%)
MBM	97.69	42.90	0.00	18.74	4.09	34.27	12.70	0.97
SBM	95.14	44.31	7.89	9.86	31.45	6.50	0.29	0.60

DM=Dry matter; CP= Crude protein; CF= Crude fiber; FE=Fat extract; NFE= Nitrogen free extract; MM= Mineral matter; Ca= Calcium; P= Phosphorus.

Table 2. Ingredients and nutrient composition of starter diets

	----------Diets ----------					
Feed stuff (kg/100kg)	1	2	3	4	5	6
Maize	-	58.00	57.50	57.75	57.50	57.00
MBM	-	26.00	19.50	13.00	6.50	-
SBM Eth.	-	-	6. 50	13.00	19.50	26.00
Noug cake	-	12.50	13.00	12.75	13.00	13.50
Broiler premix1	-	1.00	1.00	1.00	1.00	1.00
Salt	-	0.50	0.50	0.50	0.50	0.50
Soybean oil	-	2.00	2.00	2.00	2.00	2.00
Total	-	100.00	100.00	100.00	100.00	100.00

	----------Diets ----------					
Feed stuff (kg/100kg)	1	2	3	4	5	6
Composition result after proximate analysis						
DM (%)	90.57	93.93	93.60	92.31	92.45	92.36
CF (%)	5.79	6.15	5.87	6.73	9.04	6.52
CP (%)	22.27	21.14	23.56	22.30	23.19	22.55
FE (EE) (%)	6.21	10.41	14.00	9.49	9.69	9.80
NFE (%)	60.39	48.06	43.87	51.63	49.98	54.76
MM (%)	5.70	14.25	12.71	9.85	8.11	6.38
Ca++ (%)	1.19	4.00	3.17	2.18	1.46	0.88
P (%)	0.47	0.78	0.74	0.61	0.36	0.33
ME (Kcal/kg DM)	3542.89	3389.82	3675.15	3467.42	3345.60	3647.43

1 Broiler premix 1% per kg contains: Vitamins: Vitamin A,1000000IU; VitaminD3, 200000IU;Vitamin E, 1000mg; Vitamin K, 225mg; vitamin B1, 125mg; vitamin B2, 500mg; vitamin B3, 1375mg; vitamin B6, 125mg; vitamin B12, 1mg; vitamin PP,4000mg; folic acid, 100mg; Choline Chloride, 37500mg; Biotin, 0mg. Trace elements: Iron, 0.45%; Copper,0.05%; Manganese, 0.6%; Cobalt, 0.01%; Zinc,0.7%; Iodium, 0.01%; Selinium, 0.04%; Minerals: Calcium, 29.7%. Other Additives: Anti—oxidant (BHT) 0.05%.

Table 3. Ingredient and nutrient composition of finisher diets

	----------Diets---------					
Feed stuffs (kg/100kg)	1	2	3	4	5	6
Maize	-	60.00	60.00	60.00	60.00	60.00
MBM	-	26.00	19.50	13.00	6.50	-
SBM Eth.	-	-	6.50	13.00	19.50	26.00
Sorghum	-	8.50	8.50	8.50	8.50	8.50
Noug cake	-	2.00	2.00	2.00	2.00	2.00
Premix general1	-	1.00	1.00	1.00	1.00	1.00
Salt	-	0.50	0.50	0.50	0.50	0.50
Soybean oil	-	2.00	2.00	2.00	2.00	2.00
Total	-	100.00	100.00	100.00	100.00	100.00
Laboratory result composition after chemical analysis						
DM%	90.97	92.63	92.44	92.37	91.77	91.77
CF%	6.34	3.87	3.26	4.93	4.70	4.66
CP%	19.82	16.57	17.92	18.46	17.52	18.32
FE (EE)%	6.46	11.44	8.26	7.17	8.90	8.35
NFE%	61.96	56.13	60.36	59.12	61.98	61.96
MM%	5.42	11.99	10.20	10.32	6.90	6.71
Ca++%	1.17	0.89	0.92	0.89	0.87	0.85
P%	0.62	0.79	0.81	0.79	0.65	0.64
ME Kcal/kg DM	3518.93	3740.87	3695.02	3482.70	3736.75	3718.13

[1] Broiler premix 1% per kg contains: **Vitamins**: Vitamin A,1000000IU; VitaminD3, 200000IU;Vitamin E, 1000mg; Vitamin K, 225mg; vitamin B1, 125mg; vitamin B2, 500mg; vitamin B3, 1375mg; vitamin B6, 125mg; vitamin B12, 1mg; vitamin PP,4000mg; folic acid, 100mg; Choline Chloride, 37500mg; Biotin, 0mg. **Trace elements:** Iron, 0.45%; Copper,0.05%; Manganese, 0.6%; Cobalt, 0.01%; Zinc,0.7%; Iodium, 0.01%; Selenium, 0.04%; **Minerals:** Calcium, 29.7%. **Other Additives:** Anti—oxidant (BHT) 0.05%.

Housing and management

Litter system housing, which is partitioned into 18 equal-sized pens, was used. Before placing the experimental birds into the pens, the whole unit was cleaned, disinfected and littered with properly dried tef *(Eragrostis tef)* straw. Subsequently, the necessary sanitary precautions were observed. The house was electrically heated using 250 watt bulbs two per pen. Experimental chickens were vaccinated for NCD; using HB1 at 2nd day and Lasota at day 23 through ocular routes and Gumboro at day 7 and 21 with drinking water.

Data collected and performance parameters considered

The body weights of birds were taken as a group using sensitive balance weekly until the end of the study period (seventh week). Feed and water offered to the chicken were measured every morning and refusals were recorded the next morning and the difference between offers and refusals were calculated. Then mean weekly feed consumption was calculated for each replicate for seven weeks. Body weight gain and feed conversion ratios were calculated based on the mean weekly body weight and feed consumption.

The price of feed and mortality were recorded. Feed intake per bird and price of feed per kilogram were used to calculate the cost of feed consumed by a bird for the period. The cost per kilogram of weight gain was calculated according to the procedures of Sonaiya *et al.* (1986) and Ukachukwu and Anugwa (1995), which involves taking the product of price per kilogram of feed and feed-to-gain ratio of birds consuming such diets. The economic benefit was estimated by considering partial budget analysis assumptions, according to the principles developed by Upton (1979). The prices of the different diets (prices/kg) at the starter, finisher and entire period of feeding were noted.

At the end of the study, two broilers (one male and one female) per replicate were randomly removed and starved over night. They were then weighed and slaughtered by cervical dislocation as described by Oluyemi and Roberts (2000). The slaughtered birds were plucked manually after scalding in hot water. Eviscerated percentage was calculated by removing the viscera, head, shank, lungs and heart but with liver, gizzard and neck. The abdominal fat, drumstick and thigh together, liver and gizzard were measured and expressed as percent of live weight.

Laboratory analysis of feed samples

Representative samples of all the feed ingredients used in the study were sent to National Veterinary Institute for chemical analysis by proximate principles. The dry matter (DM %), crude protein (CP %), mineral mater (MM %), crude fiber (CF %), fat extract (%), nitrogen free extract (%), Ca (%) and P (%) composition of the experimental diets (formulated feed) and the test materials (MBM and SBM) were analyzed using the method of A.O.A.C. (1990). ME was estimated by employing the formula proposed by Wiseman (1987), ME (Kcal/kg DM) = 3951+ 54.4EE - 88.7CF – 40.8Ash.

Statistical analysis

Variance between treatments was analyzed using the General Linear Model (GLM) procedures of the Statistical Analysis Systems using SPSS (release 15.0, 2006) software. When the analysis of variance revealed the existence of significant differences among treatment means, then Duncan Multiple Range Test (Duncan, 1955) was used to locate treatment means that were significantly different from one another. Before analysis, mortality count data were transformed using the square root transformation.

Results

Feed intake

The mean daily feed consumptions during the starter phase are given in Table 4. Mean total feed intake was significantly higher (P<0.05) in the starter phase for the groups fed on diet 1 (48.64g/bird) followed by those under diet 5 (41.16g/bird) and diet 4 (41.11g/bird). The least mean daily feed intake was observed for diet 2 (29.91g/bird). Chicks kept on MBM and SBM-containing treatments were inferior (p<0.05) in terms of finisher feed intake when compared to those on diet 1(Table 5). Chicks on diet 5 and diet 6 had the next highest intake. The level of MBM in the diet groups was inversely related to feed intake.

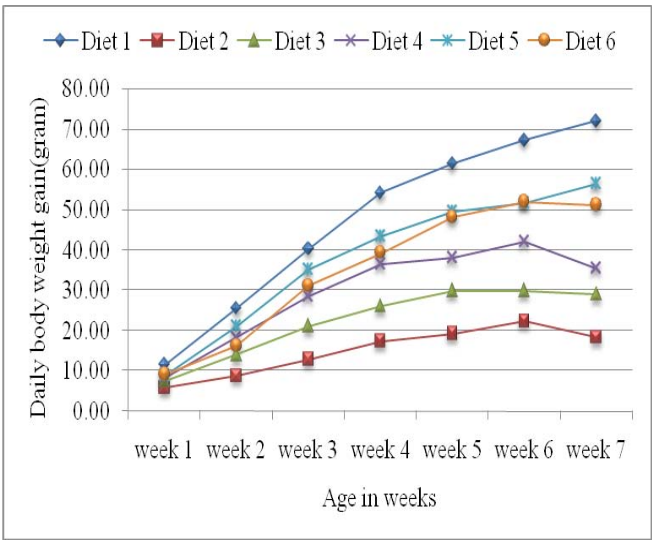


Figure 1. Average weekly feed intake during the study period in the different experimental groups

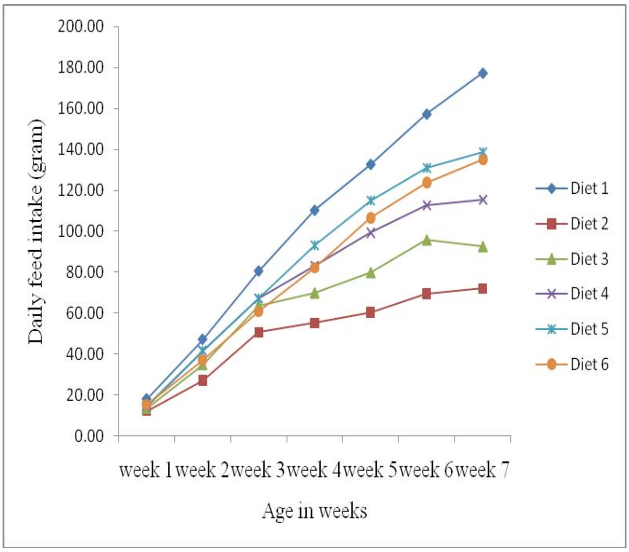


Figure 2. Daily body weight gain in the different treatment groups in the respective weeks during the study period

Body weight gain

In the starter phase, the mean daily body weight gain of the group assigned to the commercial ration (diet 1) was significantly higher (25.74g), followed by that of the groups fed on diet 5 (21.70g). As the level of MBM increased from 6.5% to 26% in the treatment groups, the body weight gain decreased significantly (P<0.05). Similar results were found in the finisher phase too. The highest daily weight gain was recorded for chicken kept on diet 1 (66.02g) (Table 5). Those chickens on diet 5 (52.17g) and diet 6 (49.36g) showed the next higher weight gain. The least daily weight gain was recorded for diet 2 (20.05g/day).

Feed conversion ratio

Feed conversion ratio of the experimental chicks in the starter and finisher phases are shown in Table 4 and 5. The least amount of feed required for a unit of weight gain was observed in chicks kept in diet 1 (1.81) and diet 5 (1.85) (p<0.05). The highest feed required for a unit of weight gain was observed for diet 2. Similar to weight gain, as the level of MBM was beyond 6.5% the feed required for a unit of gain also increased significantly in all phases of feeding (p<0.05).

Mortality

The mortality of chicks during the starter phases ranged from 0% in chicks kept under diet 1and 5 to 5.9% in those kept under diet 2 and 3. In the finisher phase, mortality ranged from 0% in diet group 1 to 5.9% in diet group 5 (Table 4 and 5). However, there was no significant difference (P>0.05) among the different diet groups in both the starter and finisher phases.

Economic efficiency

Diet 2 incurred the highest cost per unit of body weight gain both in the starter (9.29 Birr) and finisher (9.64 Birr) phases followed by diet 1 and diet 3 (Table 4 and 5). The least costs per unit of body weight gain was found in chicks under diet 5 and diet 6 in both the starter and finisher phases (p<0.05). These two diet combinations (groups) were economically feasible than the use of commercial diet or higher levels of MBM. Level of inclusion of MBM seems to have shown strong negative correlation with cost of feed consumed per kg live weight gain. Moreover, uniformity of birds' and size was negatively affected by higher level of MBM in the diet.

The economic return in terms of partial budget analysis from broilers raised under different treatment feed costs are presented in Table 7. In this experiment, the highest net profit of 23.70 Birr per bird was obtained from the sale of processed broiler carcass reared under the feeding regimen of commercial diet followed by diet 6 (19.84 Birr) and diet 5 (19.73 Birr). The least profit was earned from diet 2 (2.40 Birr).

Mean eviscerated and organ weight

The highest eviscerated yield (%) was achieved by chickens on diet 1 (73.80%) followed by those on diet 6 (70.54%) and diet 5 (69.21%), while the lowest yield (%) was observed in groups on diet 2 (66.17%) (Table 8). However, the value for chickens on diet 2 were not statistically different from those on diet 3 (66.93%), and diet 4 (68.57%). The eviscerated parts included were carcass parts, liver, gizzard and neck. Mean abdominal fat percent was highest for chickens on diet 3, 4 and 2. The least abdominal fat proportion was recorded for diet 1 and 6. The result from this experiment showed that there seems to be a positive correlation between the level of inclusion of MBM and an abdominal fat content. Chicken kept in diet 1 again yielded the highest proportion of breast meat cut (30.44%) followed by diet 6 (26.43%), 5 (26.27%), 4 (25.49%) and 3 (24.35%). The least percent was recorded for diet 2. Thigh and drumstick portions were not statistically significant (p>0.05) among each feeding groups. In contrary, the liver and gizzard weight proportions were higher for diet 2but it was not significantly different (p>0.05) from diet 3, 4 and 5 (Table 8).

Table 4. Response of broiler chicks to different dietary combinations of MBM in starter diets by SBM (0-21 days)

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Initial body weight (g/bird)	35.64±0.09	35.78±0.07	35.77±0.18	35.78±0.09	35.59±0.09	35.78±0.18
Mean daily weight gain(g/ bird)	25.74 ±0.32^{a}	9.17 ±0.57^{e}	14.13 ±0.80^{d}	18.34 ±0.57^{c}	21.70 ±0.49^{b}	18.81 ±0.90^{c}
Final body weight (g/bird)	576.26±6.65^{a}	228.36 ±11.85^{e}	332.49 ±16.61^{d}	421.27±11.80^{c}	491.28 ±10.23^{b}	430.82 ±18.91^{c}
Mean daily feed intake(g/ bird)	48.64 ±0.41^{a}	29.91 ±1.17^{d}	37.94 ±2.07^{bc}	41.11 ±0.51^{b}	41.16 ±0.78^{b}	36.79±1.09^{c}
Mean total feed intake (g/ bird)	1021.39 ±8.51^{a}	628.03±24.62^{d}	796.81 ±43.53^{bc}	863.24 ±10.72^{b}	864.31 ±16.35^{b}	772.49 ±22.96^{c}
FCR (feed : gain)	1.81 ±0.01^{d}	3.04 ± 0.08^{a}	2.50 ±0.08^{b}	2.14±0.10^{c}	1.85 ±0.01^{d}	1.92 ±0.04^{d}
Mortality*	0.00±0.00	1.00±0.00	0.58 ±0.58	0.67±0.33	0.00 ±0.00	0.33±0.33
Cost per kg of starter diet (Birr)	3.51	2.84	2.90	2.96	3.02	3.07
Feed cost/kg of gain	6.63±0.05^{b}	9.29±0.22^{d}	7.80±0.23^{c}	6.65±0.30^{b}	5.73±0.03^{a}	6.01±0.12^{a}
Cost/total feed consumed	3.59±0.03^{a}	1.78±0.07^{e}	2.31±0.13^{d}	2.56±0.03^{bc}	2.61±0.05^{b}	2.37±0.07^{cd}

[abcdef] Means within a row followed by different superscripts are significantly different (p<0.05);

* Mortality count data were transformed by square root method; Values are means ± standard errors

Feed cost/kg gain=FCR X kg feed cost; Cost/ total feed consumed= FCR X kg feed cost X total weight gained; Values are means ± standard errors

Table 5. Effect of replacement of MBM in broiler finisher diets (22-49 days) by SBM

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Initial body weight (g/ bird)	576.26±6.65^{a}	228.36 ±11.85^{e}	332.49 ±16.61^{d}	421.27±11.80^{c}	491.28 ±10.23^{b}	430.82 ±18.91^{c}
Mean daily weight gain(g/ bird)	66.02± 0.36^{a}	20.05±0.39^{e}	29.69±1.31^{d}	39.47±1.64^{c}	52.17±1.79^{b}	49.36±1.53^{b}
Total body weight gain (g/bird)	1782.56±9.61^{a}	541.29±10.60^{e}	801.76±35.25^{d}	1065.79±44.22^{c}	1408.58±48.33^{b}	1332.78±41.40^{b}
Final body weight (g/bird)	2358.82±10.51^{a}	769.66±3.19^{f}	1134.25±50.18^{e}	1487.06±47.52^{d}	1899.86±56.43^{b}	1763.61±50.55^{c}
Mean daily feed intake(g/ bird)	149.75±1.34^{a}	66.62±2.47^{e}	87.47±3.99^{d}	106.40±3.59^{c}	123.80±1.80^{b}	116.04±2.93^{b}
Mean total feed intake (g/bird)	4043.07±36.19^{a}	1798.64±66.72^{e}	2361.68±107.78^{d}	2872.80±96.85^{c}	3342.72±48.68^{b}	3133.02±79.20^{b}
FCR (feed : gain)	2.26±0.02^{a}	3.33±0.14^{c}	2.95±0.05^{b}	2.71±0.04^{b}	2.38±0.08^{a}	2.35±0.04^{a}
Mortality*	0.00±0.00	0.33±0.33	0.33±0 .33	0.33±0.33	0.80±0.42	0.33±0.33
Cost per kg of finisher diet (birr)	4.04	2.90	2.96	3.01	3.07	3.13
Feed cost/ kg of gain	9.16±0.10^{cd}	9.64±0.40^{d}	8.72±0.15^{bc}	8.12±0.11^{b}	7.30±0.24^{a}	7.36±0.14^{a}
Cost/total feed consumed	16.33±0.15^{a}	5.22±0.19^{e}	6.99±0.32^{d}	8.65±0.29^{c}	10.26±0.15^{b}	9.81±0.25^{b}

[abcdef] Means within a row followed by different superscripts are significantly different (p<0.05);

* Mortality count data were transformed by square root method; Values are means ± standard errors.

Feed cost/kg gain=FCR X kg feed cost; Cost/ total feed consumed= FCR X kg feed cost X total weight gained; Values are means ± standard errors

Table 6. Response of replacing MBM in broiler diets (0-49 days) by SBM

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Initial body weight (g/ bird)	35.64±0.09	35.78±0.07	35.77±0.18	35.78±0.09	35.59±0.09	35.78±0.18
Mean daily weight gain(g/bird)	48.39±0.22^{a}	15.29±0.07^{f}	22.89±1.05^{e}	30.23±0.99^{d}	38.84±1.18^{b}	35.99±1.05^{c}
Total body weight gain (g/bird)	2323.18±10.48^{a}	733.88±3.21^{f}	1098.49±50.33^{e}	1450.92±47.58^{d}	1864.36±56.52^{b}	1727.82±50.48^{c}
Final body weight (g/ bird)	2358.82±10.51^{a}	769.66±3.19^{f}	1134.25±50.18^{e}	1487.06±47.52^{d}	1899.86±56.43^{b}	1763.61±50.55^{c}
Mean daily feed intake(g/ bird)	105.51±.59^{a}	50.56±1.53^{e}	65.80±3.11^{d}	77.83±1.99^{c}	87.65±1.34^{b}	81.36±2.09^{c}
Mean total feed intake (g/bird)	5064.5±28.25^{a}	2426.7±73.38^{e}	3158.5±149.03^{d}	3736.0±95.43^{c}	4207.0±64.39^{b}	3905.5±100.16^{c}
FCR (feed : gain)	2.18±0.02^{a}	3.30±0.09^{d}	2.88±0.06^{c}	2.58±0.02^{b}	2.26±0.06^{a}	2.26±0.02^{a}
Mortality*	0.00±0.00	1.14±0.14	0.91±0.50	0.80±0.42	0.80±0.42	0.47±0.47
Feed cost/ kg of gain(1-49th day)	8.57±0.08^{c}	9.53±0.25^{d}	8.47±0.18^{c}	7.72±0.06^{b}	6.91±0.18^{a}	7.05±0.08^{a}
Total feed Cost (1-49th day)	19.92±0.12^{a}	7.00±0.21^{e}	9.30±0.44^{d}	11.20±0.29^{c}	12.87±0.20^{b}	12.18±0.31^{b}

^{abcdef} Means within a row followed by different superscripts are significantly different (p<0.05); Values are means ± standard errors;

* Mortality count data were transformed by square root.

Feed cost/kg gain=FCR X kg feed cost; Cost/ total feed consumed= FCR X kg feed cost X total weight gained; Values are means ± standard errors

Table 7. Average production cost and returns fed different treatment rations

Partial production costs	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Day old chick cost	8.00	8.00	8.00	8.00	8.00	8.00
Feed cost (Birr)	19.92	7.00	9.30	11.20	12.87	12.18
Total cost	27.92	15	17.3	19.2	20.87	20.18
Average carcass weight (kg)	1.78	0.60	0.90	1.20	1.40	1.38
Price/kg of carcass (supermarket)	29.00	29.00	29.00	29.00	29.00	29.00
Total carcass Sale (Birr)	51.62	17.40	26.10	34.8	40.60	40.02
Net profit	23.70	2.40	8.80	15.60	19.73	19.84

Table 8. Effect of treatment diets on carcass and organs weight and abdominal fat deposition and their share in live weight (%) at 49 days of age

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Live weight(g)	2423.48±146.94^{a}	907.92±101.14^{d}	1342.42±44.16^{c}	1750.68±86.87^{b}	2014.43±155.06^{b}	1951.50±81.77^{b}
Eviscerated wt (PLWT)*	73.80±0.35^{a}	66.17±0.94^{d}	66.93±1.01^{cd}	68.57±0.67^{bcd}	69.21±1.04^{bc}	70.54±0.59^{b}
Breast (PLWT)	30.44±0.79^{a}	22.14±1.53^{c}	24.35±0.95^{bc}	25.49±0.74^{b}	26.27±0.99^{b}	26.43±0.52^{b}
Thigh + drumstick (PLWT)	22.72±0.24^{a}	21.51±0.38^{ab}	20.89±0.31^{b}	21.53±0.49^{ab}	20.99±0.96^{b}	22.29±0.53^{ab}
Liver (PLWT)	1.88±0.09^{c}	2.38±0.06^{a}	2.11±0.14^{abc}	2.09±0.12^{abc}	2.20±0.10^{ab}	2.03±0.09^{bc}
Gizzard (PLWT)	1.51±0.06^{b}	1.87±0.15^{a}	1.51±0.10^{b}	1.42±0.07^{b}	1.28±0.06^{b}	1.51±0.07^{b}
Abdominal fat (PLWT)	1.75±0.14^{d}	3.75±0.43^{ab}	4.01±0.38^{a}	3.35±0.32^{ab}	2.88±0.25^{bc}	2.23±0.38^{cd}

^{abcd} Means within a row followed by different superscripts are significantly different ($p<0.05$); Values are means ± standard errors;
PLWT = percent live weight proportion of the organ; *Eviscerated weight includes the edible carcass, neck of the bird, Gizzard and liver.

Discussion

The feed intake and body weight gain of broilers were higher for commercial diet both in the starter and finisher phases. On the contrary, reduced feed intakes as well as body weight gain were observed for diet 2 (diet containing 26% of MBM). This is due to the increased level of MBM, which depresses intake. This finding is in agreement with other previous reports on different species of animals. Liu (2000) indicated that 10 or 15% inclusion of MBM depressed broiler chick performance as compared to a soybean meal diet. Salmon (1977) reported reduced weight gains as MBM increased from 7.5 to 15% in turkey diets. Amino acid deficiency especially of lysine is the main factor to be considered in the low chick performance when using high levels of MBM in the diet (Liu, 2000). In addition to that there was limitation in its use in poultry rations due to variability in protein quality of MBM (Bozkurt *et al.,* 2004).

Next to commercial ration a better feed intake and weight gain was recorded for the diet containing 19.5%SBM and 6.5%MBM in the starter phase. This could possibly be due to the synergetic effect of two or more protein sources in the diet, which encourages more feed intake than feeding SBM or MBM separately. This result is in agreement with those of Sibbald (1975) and McDonald *et al.* (1995) who reported that a combination of different protein source has associative effect in amino acid complementarity that satisfy requirements of the broilers better and improve performance. Similarly, the weight gain of diet 5 and diet 6 were not significant ($p>0.05$) in week 1, 4, 5, 6, and 7. This indicates that a full SBM diet could practically substitute fully MBM in the above specified weeks mainly in the finisher phase and totally substitute the higher inclusion levels of MBM in all weeks. This result is in agreement with that of Arafa *et al.* (2001) who reported that the effect of feeding diets containing all-vegetable protein versus mixture of vegetable and animal protein sources on feed consumption, live body weight gain and feed conversion ratio of broiler chicks were not significantly different from those of the fish meal diet. The increased levels of MBM incorporated in poultry diets might reduce costs partially as cheaper protein, calcium and phosphorus source than those conventional feedstuffs (Waldroup, 2002). However, the inclusion did not exceed 10% in poultry rations, due to variability in protein quality of MBM (Bozkurt *et al.,* 2004).

The economic results of broiler production are highly dependent on the efficiency of conversion of feed to product (Washburn, 1980). In this study, the FCR values of chickens on diet 1, 5 and 6 were not different for the whole period of growth. This indicates that both diets could possibly interchangeably used for broiler ration with lower production costs. The increased level of MBM had negative effect on FCR, and this is attributed to lower protein quality and nutrient digestibility of MBM. This was demonstrated in some reports (Bozkurt *et al.,* 2004; Johnson and Parsons, 1997; Wang and Parsons, 1998) that low quality MBM supplementation to broiler chick diets had detrimental effects on bird performance. The feed efficiency declined in all treatments as the birds grew up. This finding is in agreement with that of Milton (2003) and MAFRA (2008). This is mainly because heavy birds use increasing quantities of feed to maintain their body mass, and less is used for growth.

The final judge in any feeding program is the economics of the operation; reduction in feed cost is basic for profitability of broiler operations. The economic analysis results indicated that both practices, feeding diets with lower level of MBM and without MBM, provided positive net benefits at all levels per kg of body weight gain. The highest body weight gain with lower feed cost in starter and finisher phases was obtained from diets 5 and 6 without a significant difference between them. However, the highest net benefit was obtained from diet 1 (23.70 Birr).

Higher relative proportion of abdominal fat was observed for the diets containing MBM beyond 6.5% (diets 2, 3 and 4) in the ration. This might be due to the higher energy-protein ratio in the diets. It was reported previously that the smaller the energy-protein ratio, the less fat will be deposited (Rezaei et al., 2004; Farrel, 1974; Bartov et al., 1974; Lesson et al., 1988; Yashamita et al., 1975). The other reason for high fat deposition might be the low lysine level in high level of MBM in the experimental diets (Leeson and Summers 2001). Rezaei et al. (2004) reported a trend of reduction in fat pad percentage due to increased Lysine level. The highest breast meat was observed in diet 1 followed by diet 4, 5 and 6. This could be due to the fact that the commercial diet might had synthetic amino acid like lysine, whereas the lower level of MBM and a full soybean meal diet may also fulfill these amino acids for the birds. Increasing Lysine level in diet increased breast meat percentage significantly as shown in other research reports (Bilgili et al., 1992; Gorman and Balnave, 1995; Han and Baker, 1994; Kidd et al., 1998).

Conclusion

The result of this experiment clearly showed that in terms of biological efficiency and economic response, the commercial diet purchased from local producer showed superior performance over the other treatments during the starter and finisher phase. From the MBM and SBM combination diets, 6.5% MBM and 19.5% SBM in both parameters showed a better efficiency for the first 3 weeks of age; Similarly, in the finisher phase MBM could safely and economically be substituted with total SBM both in their feed efficiency and economic return. On the other hand, abdominal fat deposition increases as the level of MBM increased. Economically a better profit was gained from SBM diet than MBM diets. The nutrient content of seeds vary depending on the type of climate and soil, and therefore evaluation of the amino acid profile and nutrient content of Ethiopian SBM is required. To completely replace animal origin protein sources and improve amino acid balance in the diet, other plant source protein should be investigated; The level of MBM included in this experiment perform better at 6.5%, but the higher levels significantly depressed growth performance. This suggests that MBM should not be used at a higher level than 6.5% of the diet.

Acknowledgements

The financial support of Federal Ministry of Rural Development and Extension ATVET department is appreciated. The authors are also beholden for the facilities and services provided by the Debre Zeit Agricultural Research Institute and Addis Ababa University, faculty of veterinary Medicine.

References

A.O.A.C. (Association of Official Analytical Chemist) (1990): 15th ed. AOAC Arlington, Verginia, USA, Pp12-98.

Arafa, A. S., Abdallah, A.G. and Adbel-Latif, K.O. (2001): Influence of feeding all – vegetable protein versus animal protein diets on performance, carcass characteristics and immune response of broiler chicks reared in hot climate. Egyptian J. Nutrition and feeds, 4 (special issue): 991-1003.

Bartov, I., Bornstein, S. and Lipstein, B. (1974): Effects of calorie to protein ratio on the degree of fatness in broilers fed on practical diets. *Br. Poult. Sci.*, **15**:107–117.

Bilgili, S.F., Moran, Jr. E.T., and Acar, N. (1992): Strain cross response of heavy male broiler to dietary lysine in the finisher feed: Live performance and further processing yields. *Poult. Sci.,* **71**: 850-858.

Bozkurt, M., Basmacioglu, H. and Ergül, M. (2004): Effect of Dietary Concentration Meat and Bone Meal on Broiler Chickens Performance. *Int. J. Poult. Sci.,* **3** (11): 719-723.

Brookes, G. (2000): GM and non GM ingredient market dynamics and implications for the feed industry. **I**n: Proceedings of the 6th International Feed Production Conference, Pp 308-314.

Brookes, G. (2001): The EU animal feed sector: Protein ingredient use and the implications of the ban on use of meat and bone meal. Canterbury, UK, Brookes West.15, Jan, 2001. Pp 1-22.

CEC (2000): Council Regulation 2000/766 concerning certain protection measures with regard to transmissible spongiform encephalopathies and the feeding of animal protein. *Off. J. Eur. Communities*, **43** (L306): 32-33.

Debre Zeit Agricultural Research Center (DZARC) (2002): Monthly meteorological report.

Duncan, D. B. (1955): Multiple range and F-tests. Biometrics. **11**:1-42.

Farrel, D.J. (1974): Effect of dietary energy concentration on utilization of energy by broiler chickens on body determination by carcass analysis and predicted using tritium. *Br. Poult. Sci.,* **15**: 25-41.

Gorman, I. and Balnave, D. (1995): The effect of dietary lysine and Methionine on the growth characteristics and breast meat yield of Australian broiler chickens. *Aust. J. Agric. Res.,* **46**: 1569-1577.

Han, Y. and Baker, H.D. (1994): Digestive lysine requirement of male and female broiler chicks during the period three to six weeks post hatching. *Poult. Sci.,* **73**: 1739-1745.

Johnson, M.L. and Parsons. C.M. (1997): Effects of raw material source, ash content, and assay length on protein efficiency ratio and net protein ratio values for animal protein meals. *Poult. Sci.,* **76**: 1722-1727.

Kidd, M.T., Kerr, B.J., Halpan, K.M., Mcward, G.W. and Quarles, C.L. (1998): Lysine levels in starter-finisher diets affect broiler performance and carcass traits. *J. Appl. Poult. Res.,* **7**: 351-358.

Leeson, S. and Summers, J. D. (2001): Nutrition of the chicken; 4th ed. Department of Animal and Poultry Science, University of Guelph, Ontario, Canada. Pp 84-514.

Lesson, S., Caston, L.T. and summer, J.D. (1988): Response of male and female broiler to diet protein. *Can. J. Anim. Sci.,* **68**: 882-889.

Liu, M. (2000): Nutritional Evaluation of High Ash Meat and Bone Meal for Poultry. MSc Thesis, the University OF Manitoba, Canada.

MAFRA (Ministry of Agriculture Food and Rural Affairs) (2008): Is feed efficiency still a useful measure of broiler performance? Government of Ontario, Queen`s printer for Ontario, E-mail*:* *ag.info.omafra@ontario.ca.*

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., and Morgan, C. A. (1995): Animal Nutrition. John Wiley and Sons, Inc, New York. 607Pp.

Milton, B. (2003): How do you measure feed conversion? Poultry International, Production, Processing and Marketing Worldwide, February 2003, Vol. **42**, No.2, Pp5-21.

Oluyemi, J.A. and Roberts, F.A. (2000): Poultry Production in Warm Wet Climate. Revised Edition, Ibadan Nigeria, Spectrum Book Limited.

Rezaei, M., Nassiri Moghaddam, H., Pour Reza, J. and Kermanshahi, H. (2004): The Effects of Dietary Protein and Lysine Levels on Broiler Performance, Carcass Characteristics and N Excretion. *Int. J. Poult. Sci.,* **3**: 148-152.

Salmon, R. E. (1977): Fish meal, meat and bone meal, fermentation byproducts& ingredient combinations in diets of young turkeys. *Can. J. Anim. Sci.,* **57**: 751-754.

Sibbald, J.R. (1975): The effect of level of feed intake on metabolizable energy values measured with adult roosters. *Poult. Sci.*, **54**: 1990-1997.

Sonaiya, E.B., Williams, A.R., Oni, S.A. (1986): A biological and economic appraisal of broiler production up to 16 weeks. *J. Anim. Sci. Res.*, **6**:115-125.

Speedy, A.W. (2004): Overview of world feed protein needs and supply. **I**n: Protein Sources For the Animal Feed Industry. FAO Animal Production and Health Proceedings, Bangkok, 29 April – 3 May 2002. Pp 9-28.

Statistical Packages for Social Sientistes (SPSS) (2006): SPSS release 15.0.0 (6 Sep, 2006). SPSS inc., 1989-2006.

Teguia, A. and Beynen, A. C. (2005): Alternative feedstuffs for broilers in Cameroon. *Livestock Research for Rural Development*, **17**: 45-53.

Ukachukwu, S.N. and Anugwa, F.O.I. (1995): Bio economics of feeding raw or heat-treated soyabeans to broiler chicken. Nig. J. Anim. Prod., 22: 137-140.

Upton, M. (1979): Farm Management in Africa: The Principle of Production and Planning. Oxford University Press, Great Britain. Pp 282-298.

Yashamita, C., Ishimoto, Y., Yamada, T., Medada, H.S. and Ebisava, S. (1975): Effect of dietary protein and energy levels on abdominal fat content and meat taste. *Japanese Poult. Sci.,* **12**: 78-84.

Waldroup, P. (2002). The future of poultry nutrition. *Poultry International*., **41**: 12-19.

Wang, X., and Parsons, C.M. (1998): Dietary formulation with meat and bone meal on a total versus a digestible or bioavailable amino acids basis. *Poult. Sci.,* **77**: 1010-1015.

Washburn, K.W. (1980): Genetic variation in efficiency of feed utilizetion and its relationship to carcass fat. Proc. 29th. National Breeders Roundtable, St. Louis, Missouri, USA. Pp 41-62.

Wiseman, J. (1987): Meeting nutritional requirement from available resources. In Feeding of non-ruminant animals. Translated and ed. By J. Wiseman. Butter worth and C. Ltd. Pp 9-15.

Assessment of origin and relative contributions of various plant species as honeybee (*a. Mellifera*) pollen sources

Desalegn Begna Rundassa

Holota Bee Research Center, P.O.Box 22, Holota, Ethiopia

Abstract

Survival of honeybee colony is totally linked to its ability to collect sufficient quantities of pollen and nectar from plants flower. This study analyzes the origin and relative contributions of various floral sources around Utrecht University, Netherlands through pollen collection from honeybees (*A.mellifera* L.) during seven months of 2003. The study identified 50 different plant families comprising 105 different species in the whole collections with an average of 10.3 species per collection week. There was a significant variations ($\chi2$ =6519.622, df=26, p<0.01) in the amount of pollen collected between the weeks with an average of 140.6g. Only 13 families contributed to more than 95% of the collection in which the four most important contributors Rosaceae (39.59%), Legumes (18.28%), Oleaceae (11.97%) and Compositae (8.08%)) accounted for more than 77%. Shannon Weiner index indicated low pollen source species diversity in the first weeks and at climax in the middle with subsequent declining as season advanced. Four different plant life forms (shrubs, herbs, trees and grasses) were identified in the total collections and shrubs and herbs alone contributed for 95% of the total pollen collections. Similarly, Pearson product-moment correlation coefficient showed a strong negative correlation (r= -532, n=27, P<0.05) between the amount of pollen and number of species collected, suggesting bee's pollen collection behavior is largely influenced by pollen availability than the species diversity.

Keywords: *Honeybees; pollen; herbs; diversity; trees*

Introduction

The ecological relationship between bees and the flowering plants (angiosperms) of the world is long lasting in that flowers provide different kinds of resources to bees and the bees provide pollination to the plants. Bees collect pollen and store it in the comb cell to provide as food for the brood and newly emerging bees. Including the full development of their hypopharyngeal glands, pollen provides bees with amino acids, fats and vitamins to achieve maturity (Ribbands 1953). Fresh pollen brought to the beehive stimulates brood rearing and hence, an average bee colony requires about 20 - 50kg pollen per year (Butler 1949, Winston 1987 and Seeley 1995). The number of plant species honeybee uses to collect food to make all hive products is enormous. In due course of collecting and transporting pollen as food sources, the types and amount transported by honeybees varies from place to place (Seeley 1995). It has been documented that honeybee forage choice is overruled by the variations in the date and duration of the flowering periods of plants, and these in turn depends on the season, the area in which an apiary is situated, its soil conditions and climates (Hodges 1984 and Roubik 1989). In other words, the origin and pollen amount contributed by each plant species varies according to different localities and it is difficult to draw conclusions based on the result recorded for one specific area. Owing to this, there is a large gap in our knowledge on the varieties and quantity of pollen collected from each plant species for a given area. Therefore, the main purpose of this study is to assess the pollen source plants and determine their relative pollen contributions as honeybee food sources around Utrecht University, The Netherlands.

Materials and Methods

The study was conducted at the Utrecht University, The Netherlands, Botanical Garden compound [(zero meter above sea level, Rainfall (236mm), Temperature (-4.4 to 35^{0}C)].

Pollen samples were collected from a strong honeybee colony (*A. mellifera* L.) housed in 40 framed langstroth hive placed under the roof. Pollen collections were performed once a week from April 2003 until October 2003 using conventional pollen trap (18% efficiency) fitted to the hive entrance. Until the date of the analysis, the collected pollen samples were stored in a deep freeze according to Doull (1966) and 24hrs before running the analysis; it was allowed to dry at room temperature. The total weights of the dried pollen were taken to obtain information on the foraging intensity of the bees and to infer the relative contribution of each botanical species. Subsequently, 20g bee collected pollen was randomly sampled from each collection round, weighed and sorted into homogeneous colour groups using standard colour charts according to Hodges (1984) and Krik (1994). From each homogeneously sorted pollen loads, 1-2 loads were placed on microscopic slide, mixed with distilled water, smeared across the slide, cover with rectangular coverslips (17x17mm), stain either side of the coverslips with coloured and uncoloured glycerine jelly to differentiate between the pollen components and make them more visible and carefully dried on a warm plate to evaporate extra water (Sawer 1981). Subsequently the identity of the pollen to its plant type and morphology were confirmed by measuring the pollen sizes using 40x magnification of compound microscope (Louveaux, *et al.*, 1978 and Sawer 1981). In addition, the identification processes were assisted with keys, diagrams and photographs in the books and other previous publications (Sawer 1988, Ricciardelli 1997, Van der Ham *et al,* 1999).

The contributions of each coloured sorted pollen loads in the 20g sample to the total collection were calculated from the total weight of weekly collected pollen. The levels of importance as honeybees' pollen source were determined based on their proportions in the total weight (Silveria, 1991). The relationships between the amount of pollen collected per week (measured as the weight of pollen collected) and number of species collected per week (measured as number of species occurring in the weeks sample) was investigated using Pearson product-moment correlation coefficient. The dominance of each taxon in the collection sample and hence in the whole collections were analyzed based on their relative weight in every sample. Shannon Wiener diversity index were run to estimate species diversity in each weekly-collections. Honeybee foraging intensity (amount of pollen collected) from each taxon was correlated over the week collections.

Results

Pollen spectrum and major pollen sources

The result indicated that the number of plant families and species of floral sources of pollen foraged by honeybees were diverse and varied during the collection periods (Figure 1). Totally, 50 families and 105 species pollen was represented in the collection as honeybee pollen sources. Even if the pollen collected spectrum is high, only limited families contributed largely to the total collections and about 95% of the collection came only from 13 families (Table 1). Honeybees collected pollen from an average of 23 plant families monthly, with highest species diversity in August (Figure 1). The collected pollen spectrum included entomophilous, anemophilous, native and introduced plant species (Table 1). Collections of pollen from introduced plants were evidenced, in June and July from Anacardium spp and in October from Palmeae. Likewise, it was recognized that bees included pollen from stimulant plant Canabiaceae (Canabis sativa) and fungus spore as a pollen sources into their collections. The identified anemophilous plants pollen (Avena sativa, Zea mays, and Dactylis glomerata) contributed nearly 3% of the total collection (Table 1).

Table-1. Plant families and their pollen weight collected in percent

Family	% collected	Plant family	% collected	Plant family	% collected
Rosaceae	39.59	Anacardiaceae	0,26	Lbiatae	0.05
Legunimosae	18.28	Corniaceae	0.26	Polmoniaceae	0.05
Oleaceae	11.95	Lociniceraceae	0.23	Rutaceae	0.05
Compositae	8.08	Liliaceae	0.21	Crassulaceae	0.04
Bracicaseae	2.92	Simarcubaceae	0.20	Fagaceae	0.04
Gramineae	2.85	Ericaceae	0.18	Canabiaceae	0.03
Aralianceae	2.53	Balsaminaceae	0.12	Nymphaeaceacae	0.03
Hippocastanaceae	1.95	Chenopodiaceae	0.12	Valerianaceae	0.02
Unidentified	1.76	Apiaceae	0.11	Cyperaceae	0.01
Plantaginaceae	1.66	Malvaceae	0.10	Hydrophyllaceae	0.01
Scrophalareacae	1.60	Graniaceae	0.08	Polygalaceae	0.01

Family	% collected	Plant family	% collected	Plant family	% collected
Ranunculaceae	1.31	Mangoliaceae	0.08	Saxiferagaeceae	0.01
Oenotheraceae	1.13	Onagraceae	0.08	Solanaceae	0.01
Cucurbitaceae	0.73	Palmeae	0.08	Tropeolaceae	0.01
Fungus	0.54	Crucuferae	0.07		
Polygonaceae	0.46	Papaveraceae	0.07		

The number of plant families and species identified in the collection varied over the collection periods and ranged from 4-22 and 6-33 with an average of 16.14 and 23.86, respectively (Figure-1). The diversity increased with season and reached maximum in August. More specifically, pollen from Compositae, Leguminosae and Rosaceae families were more divers and collected for long periods (for about six months).

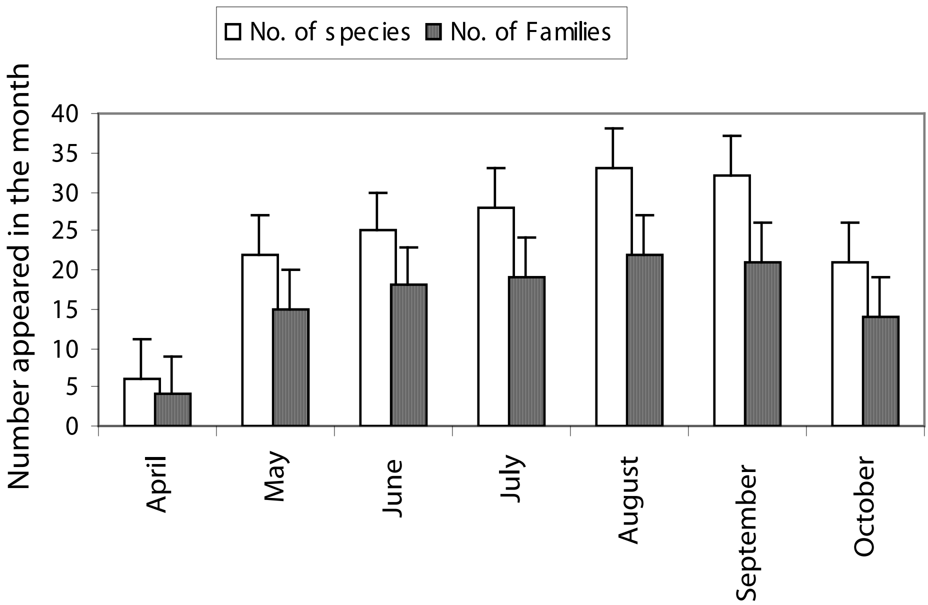


Figure 1. Number of plant families and species identified over the collection months

Pollen foraging intensity

With 18% efficiency pollen trap, a colony collected a total of 3794.52g of pollen during the whole collection periods and this averagely equals to about 21kg of pollen for the season without pollen trap. However, there is big variation in terms of the amount collected (16-668.6g) between the weeks ($\chi2$ =6519.622, df=26, p<0.01) with an average of 140.6g per collection week and bees have collected maximum amount in the first three weeks and minimum in the 21st and 22nd weeks (Figure 2).

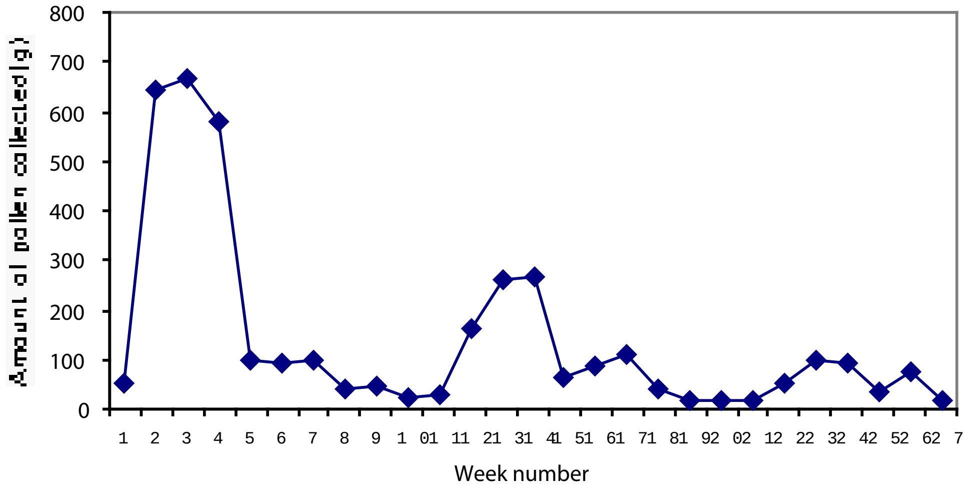


Figure 2. Amount of pollen collected by the honeybees over the collection weeks

Species diversity over the collection weeks were evaluated using Shannon Weiner diversity index and have shown low species diversity in the first weeks and increased as season advanced and attained climax at the middle of the season, and started to decline as season advanced (Figure 3). From the total 105 plant species identified during the collection periods, to the minimum one species is collected only once and to the maximum 12 with an average of 10.3 per collection week.

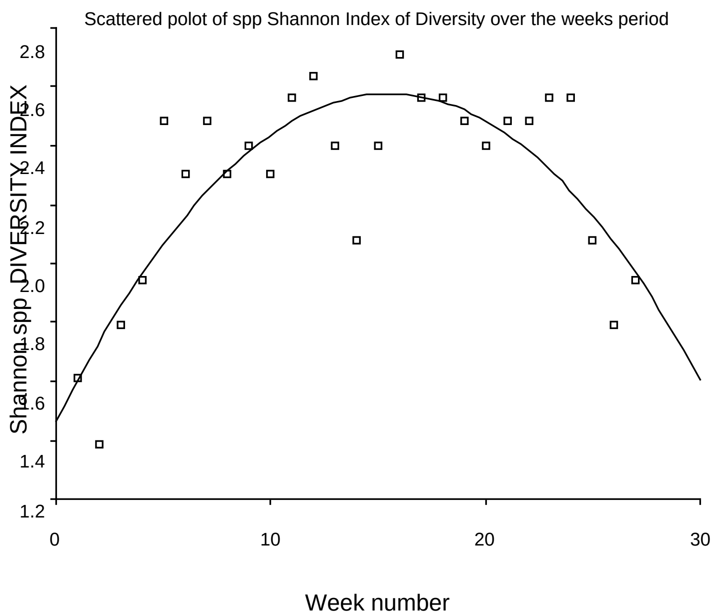


Figure 3. Shannon species diversity index over the collection weeks

Therefore, the species Diversity Index out put related to the collection periods (in this case week numbers) can be explained in a general equation of $A=d+am+bm^2$, where, A= Shannon Diversity Index out put; m= time in weeks, d, a and b, values of linear regression analysis. Hence, the relationship between the Shannon Diversity Index out put and the time of collection in this study case can be calculated as:

$A= 1.464+0.144m-1.005m^2$ (Figure 3)

Pollen amount versus species number

The relationships between the amount of pollen collected per week and the number of species collected were investigated using Pearson product-moment correlation coefficient. Accordingly, there was strong negative correlation between these two factors ($r = -532$, $n = 27$, $P< 0.05$), i.e., high pollen weight record associates with low species diversity (Figure 4).

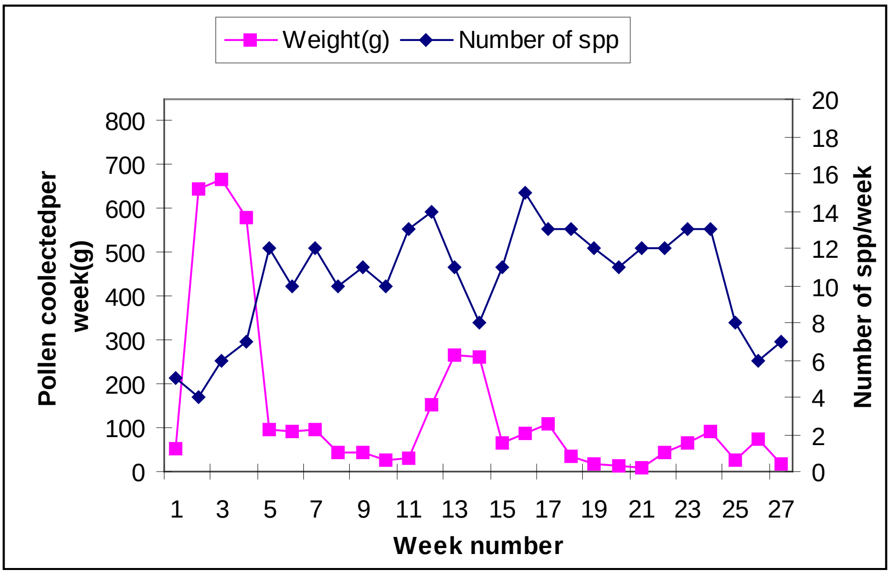


Figure 4. Amount of pollen collected and number of species over the collection weeks

Relative pollen contribution of plant forms

There were four different plant life forms (trees, shrubs, herbs and grasses) identified which contributed to the collected pollens. Comparing their species abundances and frequency of pollen collections from each life forms, there is significant variations ($\chi2 = 131.165$, df = 3, $p<0.01$) and ($\chi2 = 351.420$, df = 3, $p < 0.01$), respectively for trees, shrubs, herbs and grasses. Similarly, each plants life was evaluated in terms of pollen contribution to the total collection. Hence, there is significant difference between them

($\chi 2 = 3102.197$, df = 3, $p<0.01$) and large amounts of contribution were done from shrubs (54%) and herbs (41%). Whereas, the contributions from grasses and trees were very minimal and accounted for 3% and 2%, respectively (Figure 5).

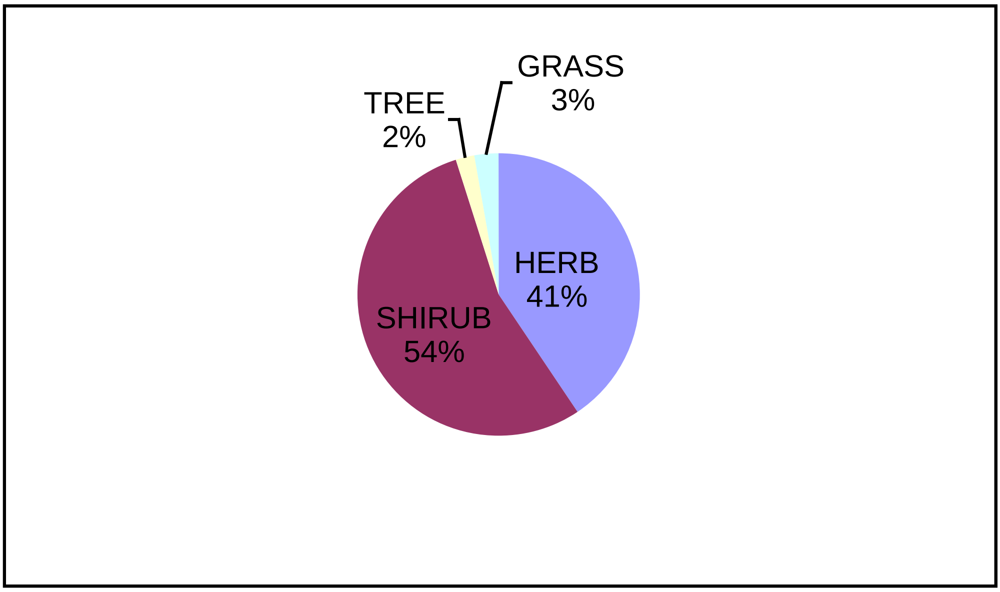


Figure 5. Relative pollen contributions of different plant life forms

Discussion

During the study period, honeybees collected pollen grains from 105 plant species under 50 plant families. However, only 13 plant families were found as main contributors in terms of pollen amount and pollen collection time span. The bees have collected about 21kg of pollen in the season and this accord with the previous records (Butler 1949, Winston 1987 and Seeley 1995). There is a considerable fluctuation in terms of the collected pollen amount over the months. This might be due to the interaction of the climatic and floral factors and the colony demand which in turn is governed by the amount of brood in the hive. Large amounts of pollen collections were done during the first weeks of the season. This might be because of large pollen requirement by the bees to initiate and enhance brood rearing that was suspended as a result of unfavorable winter season. However, the declining of the pollen collected after the third week might be attributed to the temporary pollen optimal collection by the bees and lack of storage space, which might insist the bees to shift their mind to collect nectar. Collections of large amounts of pollen from few species were done at the beginning of the season. This might be due to the fact these plant species were either preferred by the bees as pollen source or because they were the copious species, as pollen collection is often done from the most abundant species.

Contrarily, small pollen amounts were collected from relatively large variety of plant species towards the end of the active season. This most probably indicates the existences of diversified plant species but sparsely populated to be plenty pollen sources.

The anemophilous pollen collections were done by the honeybees in almost all the collection months and this fact is recorded (Soderstorm & Calderon 1971, Pojar 1973, Severson and Parry 1981, Cortopassi-Laurino and Ramalho 1989 and Suryanarayana et al 1992). Although the reason and its side effects were not stated, bees collection of pollen from stimulant plant Canabiaceae as a pollen source were also recorded in India (Suryanarayana et al. 1992). Similarly, honeybees' inclusion of fungal spores and other none pollen materials in their collection is also reported (Chapman 1964 and Roubik 1989). Even if the motive is not yet clear, it is speculated that bees collect fungus due to lack of sufficient or quality pollen (Roubik 1989). But, this speculation didn't hold true in this study as the bees did fungal collection when there are plenteous of natural pollen to collect. Collections of pollen by the bees from introduced plants of the adjacent green house suggests wide adaptations of honeybees to collect pollen from any available pollen sources regardless of their co-evolution/co-existences with pollen source species, as it is demonstrated on artificial bioassay (Pernal and Currie 2002).

Conclusions

The study identified 50 different plant families comprising 105 different species with an average of 10.3 species per week. Of the so different plant families occurring in the total collection, only 13 families contributed to more than 95% of the collection. Among these 13 families, the four most important plant families namely Rosaceae (39.59%), Legumes (18.28%), Oleaceae (11.97%), and Compositae (8.08%)) contributed more than 77% of total pollen collection. Four different plant life forms (trees, shrubs, herbs and grasses) were identified in the collected pollens and shrubs and herbs alone contributed 95% of the pollen. There was high foraging intensity at the beginning of the season as a sign of commencing brood rearing and colony build up after long time wintering. In addition to the origin and relative contributions of pollen source plants this study showed strong negative relation between the amount of pollen collected and the number of pollen source plant species and this suggests the largely influence of pollen availability on pollen collection behavior of the bee than the species diversity.

Finally, this study not only gave an insight into the origin and relative pollen contributions of the surrounding plants as honeybee food sources, but also highlighted major pollen source plants for further plantation, conservation and characterizations.

Acknowledgements

I would like to thank Drs. Frouke E. Hofstede, the supervisor of the Msc students and Dr. Marinus Sommeijer, the course coordinator, in Utrecht University, The Netherlands for their support, encouragement and wonderful ideas during this research work. My gratitude should also go to Dr. Jaap Kerkvliet, for his kind assistance in identifying some of the pollens that were beyond the capacity of Utrecht University laboratory.

References

Butler, C.G. 1949. The honeybee. An introduction to her sense physiology and behaviour. ***In***: The pollen loads of the honeybee (Dorothy Hodges, 1984).

Chapman, G.P 1964. Urediospore collections by honeybees from Puccinia psidii. Ann. Entomol. Soc. Amer. 57: 264

Cortopassi-Laurino, M and Ramalho, M 1989. Pollen harvest by Africanized Apis mellifera & Trigona species in Sao Paulo. Botanical & Ecological reviews. Apidologie 19: 1-24.

Doull, K.M 1966. The relative attractiveness of pollen collecting honeybees of some different pollen. JAR. 5:5-14.

Hodges, D. 1984. The Pollen Loads of the Honeybee: a Guide to their Identification by Color and Form. 1st ed. (reprinted). London: IBR.

Krik, W.D. 1994. A Color Guide to Pollen Loads of the Honeybee. Cardiff, New York: IBR.

Louveaux, J. Maurizio A. and Vorwohl G. 1978. Methods of melissopalynology. Bee World, 59 (4): 139-347

Pojar, J 1973. Pollination of typically anemophilous salt marsh plants by bumblebees, Bambus trrricola occidentalis Grine. Amer. Midl. Naturalist 89: 448-451.

Ribbands, R. 1953. The Behavior and Social Life of Honeybees. Bee Research Association Limited, London, UK

Ricciardelli D'albaore 1997. Textbook of Melissopalynology. Ed. Apimondia-Buchrest, 308 pp

Roubik David W. 1989. Ecology and natural history of tropical bees. Cambridge University press. Cambridge

Sawer, R 1981. Pollen identification for beekeepers. University college Cardiff Press. Cardiff, Uk, 111pp

Sawer, R 1988. Honey Identification. University college Cardiff Press. Cardiff, Uk, 115pp

Seeley, Thomas D. 1995. The wisdom of the hive. The social physiology of honeybee colonies. Harvard University press. Cambridge, Massachusetts. London, England

Severson DW. and Parry, JE 1981. A chronology of pollen collection by honeybees. JAR. 20: 97-103

Silveria da FA. 1991. Influence of pollen grain volume on the estimation of the relative importance of its source for bees. Apidologie (1991), 22: 495-502

Soderstorm, T.R. & Calderon C.E 1971. Insect pollination in tropical rain forest grasses. Biotropica 3: 1-6

Suryanarayana MC., G. Mohana Rao and TSMS Singh 1992. Studies on pollen sources for Apis cerena Fabr and Apis mellifera L bees at Muzaffarpur, Bihar, India. Apidologie 23: 33-46

Van der Ham R.W.J.M., Kaas I.P., Kerkvliet I.D., Neve A. Ruijter A.de. 1999. Pollenanalyse. Stuifmeelonderzoek van Honing voor Imkers, Scholen en Laboratoria.

Winston, M. L. 1987. The Biology of the Honey Bee. Cambridge, Massachusetts: Harvard University Press

Information for Contributors

General

Ethiopia is one of the countries endowed with a large number and diverse livestock resources. The spectacular land formation, ranging from mountain chains with peaks of over 4500 m asl to areas below sea level, has created diverse climatic conditions with variable agro-ecological zones and rich biodiversity. This unique variability has afforded the country for the evolution and development of different agricultural production systems. Different species and breeds of livestock have been domesticated and used for various purposes. The different production systems and the economic and social roles that livestock play in the livelihood of millions of smallholder farmers is substantial. The proper exploitation of this large number and diverse livestock resource in the country has remained a great challenge to all professionals engaged in livestock production. This has also afforded a number of national and international organizations a great opportunity to undertake research and development activities to ensure proper utilisation and conservation of these resources.

In order to co-ordinate such efforts and to streamline the research and development agenda, The Ethiopian Society of Animal Production (ESAP) has been operational since its establishment in 1985. ESAP has created opportunities for professionals and associates to present and discuss research results and other relevant issues on livestock. Currently, ESAP has a large number of memberships from research, academia, and the development sector. So far, ESAP has successfully organised about 10 annual conferences and the proceedings have been published. The ESAP Newsletter also provides opportunities to communicate recent developments and advancements in livestock production, news, views and feature articles. The General Assembly of the Ethiopian Society of Animal Production (ESAP), on it's 7th Annual Conference on May 14, 1999, has resolved that an Ethiopian Journal of Animal Production (EJAP) be established. The Journal is intended to be the official organ of ESAP.

The ***Ethiopian Journal of Animal Production (EJAP)*** welcomes reports of original research data or methodology concerning all aspects of animal science. Study areas include genetics and breeding, feed resources and nutrition, animal health, farmstead structure, shelter and environment, production (growth, reproduction, lactation, etc), products (meat, milk, eggs, etc), livestock economics, livestock production and natural resources management. In addition the journal publishes short communications, critical review articles, feature articles, technical notes and correspondence as deemed necessary.

Objectives

- To serve as an official organ of the Ethiopian Society of Animal Production (ESAP).
- Serve as a media for publication of original research results relevant to animal production in Ethiopia and similar countries and contribute to global knowledge
- To encourage and provide a forum for publication of research results to scientists, researchers and development workers in Ethiopia

Columns of the Journal

Each publication shall include some or all of the following columns.

Research articles

Research articles based on basic or applied research findings with relevance to tropical and sub-tropical livestock production.

Short communications

Short communications are open to short preliminary reports of important findings; normally not more than 2000 words. They may contain research results that are complete but characterized by a rather limited area or scope of investigation, description of new genetic materials, description of new or improved techniques including data on performance. They should contain only a few references, usually not more than five and a minimum number of illustrations (not more than one table or figure). Abstract should not be more than 50 words.

Review articles

Review papers will be welcomed. However, authors considering the submission of review papers are advised to consult the Editor-in-Chief in advance. Topical and timely short pieces, news items and view points, essays discussing critical issues can be considered for publication

Feature articles

Feature articles include views and news on the different aspects of education, curricula, environment, etc will be considered for publication after consulting the Editor-in-Chief. Areas for consideration include education, society, indigenous knowledge, etc.

Technical notes

Technical notes relate to techniques and methods of investigation (field and laboratory) relevant to livestock production. Notes should be short, brief and should not exceed one page.

Correspondence

Letters on topics relevant to the aims of the Journal will be considered for publication by the Editor-in-Chief, who may modify them.

Frequency of publication

Once a year (May)

Guidelines to Authors

General

The ***Ethiopian Journal of Animal Production (EJAP)*** publishes original articles of high scientific standard dealing with livestock and livestock related issues. Reviews on selected topics on livestock research and development appropriate to Ethiopia and other similar countries will also be considered for publication. Short communication and technical notes are also welcome.

Manuscripts should be written in English, double spaced throughout and should be on one side of an A4 sheet. Authors are advised to strictly stick to the format of the journal. Submit three copies of manuscript and each page should be numbered. An electronic form in Word format should also accompany the manuscript. The disk should be clean from viruses, and should be labelled clearly with the authors' names and disk file name. Manuscripts submitted to the Editorial Office will be duly acknowledged. All articles will be sent to at least two reviewers (within or outside the country) selected by the Editorial Board and will be reviewed for relevance to the journal, scientific value and technicality. Rejected papers will be returned to the author(s) immediately. Accepted papers will be returned to the author with the comments of the reviewer(s) for further improvement of the manuscript. EJAP has no page charge.

Proofs will be sent to the author. Typeset proofs are not checked for errors. Thus, it is the responsibility of the primary author of each paper to review page proofs carefully for accuracy of citations, formulae, etc. and to check for omissions in the text. It is imperative that the authors do a prompt, thorough job of reviewing the returned proofs to ensure timely publication. Authors are instructed to return the proofs to the Editorial Office within 15 (fifteen) days of receipt. Senior or corresponding authors will be provided with 25 (twenty-five) offprints free of charge for each published articles.

Format for Manuscripts

Research paper should be as concise as possible and should not exceed 6000 words or about 10 to 12 pages including illustrations and tables. Papers should be partitioned into sections including abstract, introduction, materials and methods, results, discussion, acknowledgements and references. Main text headings should be centered and typed in capitals. Sub-headings are typed in capitals and small letters starting from left hand margin.

Headings: Title of the paper should be in upper and lower case. Main headings should be in upper and lower case, centre.

Sub-headings: First sub-headings, flush left, separate line, capitalize main words; second sub-headings- flush left, same line as text, capitalize first word, followed by period; third sub-heading – flush left, same line as text, capitalize first word, italics followed by a dash.

Title: The title should be concise, specific and descriptive enough to contain key words or phrases including the contents of the article. A short running title of less than 50 characters should also be suggested.

Author and institution: The name(s) of author(s) and the institution(s) with which they are affiliated, along with the addresses, should be provided. Corresponding author should be identified in case of more than one author.

Abstract: Research or applied articles should have an abstract of no more than 300 words. The abstract should state concisely the goals, methods, principal results and major conclusions of the paper. Incomplete and uninformative descriptions should not be used. The use of acronyms is discouraged. Keywords of up to five words should be included.

Introduction: This part should be brief and limited to the statement of the problem or the aim of the experiment, justification and a review of the literature pertinent to the problem.

Materials and methods: The techniques and procedures of the research, the conditions under which the study was conducted and the experimental design are described under this heading. Relevant details about the animal should be given and the statistical design should be described briefly and clearly. Data should be analyzed and summarized by appropriate statistical methods; authors should examine closely their use of multiple comparison procedures. A measure of variability, e.g., standard deviation or standard error must be provided when reporting quantitative data. If standard methods of investigation and analysis are employed appropriate citation suffice.

Results: The summary of major findings and assessments of the investigation are given in this section. The results can be presented using tables, illustrations and diagrams.

Tables: Tables are numbered consecutively in arabic numerals (e.g., Table 1) and should bear a short, yet adequately descriptive caption. Avoid using vertical and/or horizontal grid lines to separate columns and/or rows. Metric units are clearly to be shown, abbreviated in accordance with international procedure. Footnotes to tables are designated by lower case which appear as superscripts in appropriate entries. Tables should be compatible with column width viz. 140 mm, and should be presented on separate sheets, and grouped together at the end of the manuscript. Their appropriate position in the text should be indicated and all tables should be referenced to in the text.

Illustrations and diagrams: These should be inserted into the text using any suitable graphics programmes. Freehand or typewritten lettering and lines are not acceptable. Authors are requested to pay attention to the proportions of the illustrations so that they can be accommodated in the paper without wastage of space.

Figures: Figures should be restricted to the display of results where a large number of values are presented and interpretation would be more difficult in a Table. Figures may not reproduce the same data as Tables. Originals of figures should preferably be A4 size, of good quality, drawn or produced on good quality printer and saved in a separate file. There should be no numbering or lettering on the originals. Numbering and lettering, which must be kept to an absolute minimum, should be legibly inserted on the copies. Vertical axes should be labelled vertically. A full legend, describing the figure and giving a key to all the symbols on it, should be typed on a separate sheet. The symbols preferred are: ▲,■ ○ □, but + and x signs should be avoided. Figures should be numbered consecutively in arabic numerals (e.g., Figure 1), and refer to all figures in the text.

Photographs: Should be original prints and suitable for reproduction. They should be unmounted with lettering clearly indicated on overlays or photocopies. For composites, photographs should be unmounted and a photocopy enclosed to indicate the required measurement. Magnification should be given in the legend or indicated by a scale or bar. They should be numbered as part of the sequence of Figures. If several plates or coloured photographs are submitted, the authors may be asked to the cost of reproducing them.

Discussion: The reliability of evidence (result), comparison with already recorded observations and the possible practical implication is discussed.

Conclusion: Authors are encouraged to forward conclusion (two to three brief statements) from the study summarising the main findings and indicating the practical implications of the findings.

Acknowledgements: Should be briefly stated following the conclusion.

References: Cite references by name and date. The abbreviation et al should be used in the text where more than two authors are quoted. Personal communications and unpublished work should be cited in the text only, giving the initials, name and date. They should not appear in the list of references. All references should be listed alphabetically. References should be selected based on their relevance and the numbers should be kept to a minimum. Journal names should be abbreviated according to the World list of Scientific Periodicals.

Ethiopian names should be in direct order, i.e., the full first name followed by the father's name and should not be abbreviated. E.g. Zinash Sileshi and not Sileshi, Z.
(Tesfu Kassa and Azage Tegegne, 1998).

(Alemu Yami and Kebede Abebe, 1992; Alemu Gebre Wold and Azage Tegegne, 1995; Zinash et al., 1996)
– Chronologically
According to Zinash Sileshi and Siyoum Bediye (1995)

Where more than two authors are quoted in the text: - Zinash Sileshi et al. (1990) or (Zinash Sileshi et al., 1990). However, all authors' names should be given in the Reference list.

Examples

Journal article:

Zerbini, E., Takele Gemeda, Azage Tegegne, Alemu Gebrewold and Franceschini, R. 1993. The effects of work and nutritional supplementation on postpartum reproductive activities and progesterone secretion in F_1 crossbred dairy cows in Ethiopia. Theriogenology 40(3):571-584.

Crosse, S., Umunna, N.N., Osuji, P.O., Azage Tegegne, Khalili, H. and Abate Tedla. 1998. Comparative yield and nutritive value of forages from two cereal-legume based cropping systems: 2. Milk production and reproductive performance of crossbred (*Bos taurus x Bos indicus*) cows. Tropical Agriculture 75 (4):415-421.

Book

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Chapter in a Book

Zerbini, E., Takele Gemeda, Alemu Gebre Wold and Azage Tegegne. 1995. Effect of draught work on the metabolism and reproduction of dairy cows. In: Philips, C.J.C. (ed.), Progress in Dairy Science. Chapter 8. CAB International. pp. 145-168.

Paper in Proceedings

Alemu Gebre Wold, Mengistu Alemayhu, Azage Tegegne, E. Zerbini and C. Larsen. 1998. On-farm performance of crossbred cows used as dairy-draught in Holetta area. Proceedings of the 6th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-15, 1998, Addis Ababa, Ethiopia, pp. 232-240.

Papers based on Theses

Papers based on theses should be presented with the thesis advisor as co-author and should indicate the institution, the year the work was done, and the full title of the thesis as a footnote.

Abbreviations

Follow standard procedures.

Units

All measurements should be reported in SI units. (e.g., g, kg, m, cm)

Table 1. The following are examples of SI units for use in *EJAP*

Quantity	Application	Unit	Symbol or expression of unit
Absorption	Balance trials	Grams per day	g d^{-1}
Activity	Enzyme	Micromoles per minute per gram	µmol min-1 g^{-1}
Area	Land	Hectare	ha
	Carcass	Square centimetre	cm^2
Backfat	Carcass	Millimetres	Mm
Concentration	Diet	Percent	%
	Blood	Gram per kilogram	g kg^{-1}
		International unites per kilogram	IU kg^{-1}
		Milligram per 100 mL	Mg dL^{-1}
		Milliequivalents per litre	Mequiv L^{-1}
Density	Feeds	Kilogram per hectolitre	Kg hL^{-1}
Flow	Digesta	Grams per day	g d^{-1}
	Blood	Milligrams per minute	mg min^{-1}
Growth rate	Animal	Kilogram per day	Kg d^{-1}
		Grams per day	g d^{-1}
Intake	Animal	Kilograms per day	Kg d^{-1}
		Grams per day	g d^{-1}
		Grams per day per kg bodyweight0.75	g d-1 $kg^{-0.75}$
Metabolic rate	Animal	Megajoules per day	MJ d^{-1}
		Watts per kg bodyweight	W kg^{-1}
Pressure	Atmosphere	Kilopascal	KPa
Temperature	Animal	Kelvin or degree Celsius	K or °C
Volume	Solutions	Litre	L
		Millilitre	ML
Yield	Milk production	Litres per day	L d^{-1}
Radioactivity	Metabolism	Curie or Becquerel	Ci (=37 GBq)

Units with two divisors should be written with negative indices (e.g., kg ha^{-1} yr^{-1}). The use of solidus (/) should be reserved for units written in full (e.g., mole/kilogram) or to separate a physical quantity and unit (e.g., yield/ha). Units should be chosen so that the numeric component falls between 1 and 10 or 1 and 100 when using one or two significant figures, respectively (e.g., use 31.2 mg than 0.0312 g).

Membership to the Ethiopian Society of Animal Production (ESAP)

Membership advantages

Some of the personal benefits afforded to active members of the Ethiopian Society of Animal Production (ESAP) include the following:

- A convenient means of keeping up-to-date on current scientific and production developments;
- An avenue for personal involvement in fostering high standards and professional developments in Animal Science;
- To receive a printed copy of the Ethiopian Journal of Animal Production (EJAP);
- Receiving copies of the Society's newsletter, Membership Directory, and advanced registration information for national meetings;
- Eligibility to present abstracts at national meetings and to submit manuscripts for publication in the Ethiopian Journal of Animal Production (EJAP);
- Eligibility to provide personal leadership to the field of animal science by serving on the Executive Committee of the society or by accepting other society assignments; and
- Eligibility to be selected for prestigious society-sponsored awards

Eligibility for membership

Membership is open to individuals interested in research, instruction or extension in Animal Science or associated with the production, processing, marketing and distribution of livestock and livestock products.

Application form for Membership

Application form for Membership

Ethiopian Society of Animal Production (ESAP)

Name ________________ ____________________ ______________

First Middle Last

Mailing Address: ____

Current Employment: ____

Company/Institution: ____

Phone: ____

Fax: ____

E-mail: ____

Type:

- ☐ Professional
- ☐ Student

Other___________ Specify:______________________________

Signature: ____________________Date:_____________________

Bank Account:	Commercial Bank of Ethiopia Andinet Branch Account Number 1369 Addis Ababa, Ethiopia

Mailing Address

Three copies of the manuscript along with an electronic form on a diskette (Word format) should be sent to:

The Editorial Office
Ethiopian Journal of Animal Production (EJAP)
C/o Ethiopian Society of Animal Production (ESAP)
P.O.Box 80019
Addis Ababa
Ethiopia
Tel: (+251-1) 15 83 39

The Editorial Office assumes no responsibility for the loss of the manuscript in the process of mailing. Authors are advised to retain copies of their submission.

Subscription and Communications

Information to Subscribers

Subscription rates for one year (one issue), including airmail, are as follows:

	Local	Foreign
Institution	50 (Birr)	25 (US$)
Individuals	25 (Birr)	10 (US$)

All business correspondences about subscriptions, back issues, single copies, change of address and claims for missing issues should be sent to:

The Editor-in-Chief
EJAP Editorial Office
C/o ESAP Office
P.O.Box 80019
Addis Ababa; Ethiopia;
Tel: (+251-1) 15 83 39

Members of the Executive Committee of ESAP