Multipurpose fodder trees in Ethiopia

Farmers' perception, constraints to adoption and effects of long-term supplementation on sheep performance

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DEDICATED

to

my beloved mother Yitayesh Workneh

Abstract

Many organizations in Ethiopia have promoted exotic multipurpose fodder tree species particularly *Sesbania sesban* for livestock feed and soil improvement. Despite the apparent benefits, the number of farmers planting these trees was low. Moreover, some farmers feeding *Sesbania sesban* reported reproduction problems in sheep. The latter was supported by a few short term reproduction studies conducted in Ethiopia. The present thesis was conducted to assess farmers' perceptions about multipurpose fodder trees and about constraints to adoption, and to study effects of long-term feeding of *Sesbania sesban* on sheep performance. The farmers' perception was studied by a field survey among 235 farm households from three districts with different dominant farming systems (wheat, teff or coffee as the major crop) and the sheep performance studies were a series of experiments at the International Livestock Research Centre in Debre Zeit, Ethiopia.

Farmers planted exotic multipurpose fodder trees for their feed value. The valuation for other purposes (soil and water conservation, use as fuel wood) depended on cropping system, vegetation cover and availability of alternative local fodder trees. Major constraints to adoption were agronomic problems, low multipurpose value, and land shortage. Farmers' decision making criteria to adopt multipurpose fodder trees encompassed multiple objectives: farmers preferred local fodder trees to exotics for biomass production, multi-functionality, life span, and compatibility to the cropping system. In terms of feed value, ease of propagation, and growth potential of local fodder trees were ranked lower than or comparable to exotics. A significant correlation was observed between farmers' feed value score of a fodder tree species and the crude protein content assessed in the laboratory. The number of *Sesbania sesban* trees currently planted on-farm was about 30% of the recommended number for meat or milk production. Despite some farmers (11.8% of users) reported reproduction problems in sheep, the feed value of *Sesbania sesban* was appreciated across farming systems. However, the feed value was appreciated more in the wheat- and the teff-based farming systems than in the coffee-based farming system. From the results of the series of on-station experiments conducted for one whole reproductive cycle from post-weaning up to the end of the first lactation it was observed that supplementation of *Sesbania sesban* at 30% of the ration (0.98% of body weight) improved basal and total feed intake and digestibility, growth rate and the overall reproductive performance of sheep. No observable adverse effects of possible anti-nutritional factors in *Sesbania sesban* were found in this long term study.

We conclude that the introduction of exotic multipurpose fodder trees need consideration of farmers multiple criteria, of local resources and knowledge and of the diversity of the farming systems. Introduction should be accompanied by practical training of farmers and of extension agents. The studies show that *Sesbania sesban* is a potential protein supplement that can be used to support the security of livestock or substitute commercial concentrates for smallholder farmers in the Ethiopian highlands.

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The thesis contents were the results of an on-farm survey, and a series of on-station animal experiments and of laboratory investigations conducted in Ethiopia. Undoubtedly, many people have contributed to this work. It is impossible to acknowledge all of you individually. In case I miss out your name, please know that I am very grateful.

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Contents

Chapter 1

General introduction

1 Introduction

In Ethiopia 85% of the population depends on agriculture for their livelihood. Agriculture is the basis for the entire socio-economic development, provides about 80% of total employment, and is the source of 85% of earnings from export (EEA, 2002). Livestock is an integral component for most of the agricultural activities in the country. The livestock sector has a share of 12-16% of the total Gross Domestic Product (GDP), and 30-35% of agricultural GDP (Ayele *et al.,* 2002, LMA, 1999).

Livestock contributes to the livelihoods of 60-70% of the Ethiopian population. Besides the well known contributions as source of food, income and employment, draught power, manure and transport, livestock serve as productive assets that allow households to be self-provisioning, as critical buffer against falling into what is usually unremitting poverty and as springboard that enable some households to advance to relative wealth by the standards of contemporary Ethiopia (Zinash and Tegegne, 2000; Ayele *et al*., 2002). Livestock also plays an important role in urban and peri-urban areas for the poor evoking a living out of it and for those involved in commercial activities (Ayele *et al.,* 2002; Halderman, 2005). For many years the export of livestock and livestock products (live animals, chilled carcasses from sheep and goats, and hides and skins) has been Ethiopia's most valuable source of foreign exchange, after coffee. Generally, the livestock sector is important in Ethiopia for economic development and for poverty reduction. Because of the potential of livestock, the current government has given great emphasis to a market-led livestock development policy and has allocated a large budget for this (MORAD, 2004).

1.1 Livestock production systems

Zinash *et al.* (2001) identified three types of livestock production systems in Ethiopia: mixed crop-livestock systems associated with growing annual and perennial crops mainly in the highlands, semi-extensive agro-pastoral systems that integrate animals with cropping in warm and semi-arid areas, and extensive pastoralism in arid and semi-arid rangelands.

The mixed-crop livestock system is characterized by varying degrees of crop-livestock integration, including use of crop residues, draught power and manure. A wide range of cereals, oil crops, food legumes and perennial crops are grown. Cattle are reared for draught, seasonal milk and meat production.

Small ruminants are the main source of cash and family consumption (Alemayehu, 2004).

The semi-extensive agro-pastoral system comprises a mix of former pastoralists who have taken up various forms of small-scale crop production as well as maintaining a less extensive form of pastoral livestock production. In the extensive pastoral systems, livestock rearing is the mainstay of people, and livestock and livestock products provide subsistence, either directly as milk, milk products, meat and blood, or indirectly to purchase cereals (Zinash *et al.*, 2001; Alemayehu, 2004).

The studies described in the present thesis deal with livestock in mixed farming systems. The latter will be described in more detail in the following sections.

1.1.1 Mixed crop-livestock systems in the Ethiopian highlands

Ethiopia accounts for about 50% of the highlands of the African continent (FAO, 1986). The Ethiopian highlands (above 1500 m a.s.l., receiving more than 700 mm annual rainfall, and have a mean daily temperature of less than 20^{o}C) occupy 44% of the total land area, and cover the central, western, southern and eastern parts of the country (Amare, 1978; Zinash *et al.*, 2001). About 88% of the human population, 70% of cattle and sheep, 30% of goats and 80% of equines are found in this region (Alemayehu, 2004). Amare (1978) identified three broad agro-ecologies in the mixed crop-livestock systems of the Ethiopian highlands:

- the high potential cereal crop-livestock (HPC) zone
- high potential perennial crop-livestock (HPP) zone
- and low potential cereal crop-livestock (LPC) zone

The high potential cereal crop-livestock zone is important in terms of human and livestock densities and the production of food crops (Chilot and Mohammed, 2001; de Leeuw and Getachew, 1992). This zone includes the central highlands, the north western and eastern highlands and the Lake Tana basin (Chilot and Mohammed, 2001). Animal traction and crop residues are the prominent binding elements between the crop and livestock sub-sectors. The major crops are wheat, teff (*Eragrostis tef*), barley and maize with pulses and oil crops as minor crops. Cattle, sheep and goats are important ruminant species (de Leeuw and Getachew, 1992). Marginalized communal pasture and crop residues are the predominant feed resources. Based on the major crop types grown, barley-based, wheat-based, teff-based and maize-based crop livestock sub-systems are identified in this zone (de Leeuw and Getachew, 1992; Chilot

and Mohammed, 2001). Two of the study districts of the present thesis (Lay-Armachuho and Debay-Tilatgen) represent a wheat-based and a teff-based sub-system, respectively.

The high potential perennial crop-livestock zone includes the southern highlands where districts in Sidama are included, south western and western highlands of Ethiopia. In this zone, the cropping system is coffee/enset (*Enset entricosum*)-based and highly diversified. Enset is the main staple food followed by maize. Coffee and fruit trees are the major sources of income. Crop-livestock integration is strong in such a way that farmers use crop residues as feed source, but also return the manure into the soil, applied mainly around the home garden (Amare, 1978; de Leeuw and Getachew, 1992). One of the study districts in the present thesis (Sidama) is found in this high potential perennial crop-livestock zone .

1.2 Feed resources and nutritional limitations

In the mixed crop-livestock systems of the Ethiopian highlands, the total feed resources available for livestock production come from permanent marginal pastures and transient pastures between cropping cycles, crop residues, and crop aftermath grazing. Forage obtained from crop thinning and defoliation from annual crops and perennial crops e.g. enset in the coffee/enset-based livestock system is also important for livestock feeding (Fekadu, 1996). However, these feed resources are high in fibre, with low to moderate digestibility and low levels of nitrogen (Preston, 1995; Tsige Yohanes, 2000). Their crude protein and neutral detergent fibre (NDF) content ranges between 2.5 to 7.5% and 72.6 to 77.8%, respectively. Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Hindrichsen *et al.,* 2004). The livelong low nutrient supply may affect reproductive performance of animals. Despite, these limitations marginal pastures and crop residues could provide a valuable source of energy for ruminant livestock if supplemented with protein-rich feeds.

1.3 Approaches to improve the utilization of crop residues

A number of authors (Alemu *et al.,* 1991; Leng, 1990; Oosting, 1993; Osuji *et al.,* 1995; Tsige Yohanes, 2000) have reported various options of improving the utilization of poor quality feed resources. Proposed means to achieve better utilization of fibrous feeds include chemical and mechanical treatment, use of

commercial protein supplements, and the cultivation and use of leguminous forage crops (herbaceous legumes and fodder trees).

The use of chemical treatments such as oxidizing agents, alkali-based agents and urea are less attractive methods because of cost implications and their difficulty to apply (Chensoet and Kayouli, 1995; McDonald *et al.,* 1995; Oosting 1993). Economic limitations as well hinder resource-poor farmers to have access to commercial concentrate supplements. Cultivated herbaceous forage legumes may not be a solution to smallholder livestock feeding owing to scarcity of land, competition with crops, inadequate supply of forage seeds, and labour shortages especially in the high- and mid-altitude areas of sub-Saharan Africa (Tothill, 1986). In this regard, cultivation of and supplementation with fodder trees (further often referred to as multipurpose fodder trees since they exhibit a wide array of functions) is perhaps the best-suited method for smallholder farmers (Devendra, 1992; Alemu *et al.,* 1991; Alemayehu, 1997; Sawe *et al.,* 1998; Norton 1994; Smith, 1992; Kaitho *et al., 1998*; Solomon, 2002). The use of multipurpose fodder trees can overcome the protein deficiency in the basal diet, complement crop production and stabilize the ecosystem to maximize food and feed from the same land (Tothill, 1986; Lambourne and Little, 1987; Said and Tolera, 1993; Bonsi et al., 1994; Alemayehu, 1997). The foliage of multipurpose fodder trees can also be a valuable green manure or mulch of high nitrogen content for improving the fertility of cropped soils, provide fuel wood and poles for various farm uses (Franzel and Scherr, 2002; Swinkles *et al.,* 1997). Investment costs, land and labour use and risk of failure are relatively low, which is essential for widespread adoption and use (Batz *et al.,* 2003).

1.4 Feed value of multipurpose fodder trees

The feed value of a forage is a function of its nutrient content, digestibility, its palatability and associative effects with other feeds. An example of the latter is the low protein content of low-quality tropical feeds that limits their digestion. This limitation can be overcome by supplementing a protein source e.g. fodder trees or shrubs. Sufficient literature exists on the nutrient content of several fodder trees and shrubs (Le Houerou, 1980; Topps, 1992; Siaw *et al.,* 1993). Though the reported crude protein (CP = 6.25 * the nitrogen (N) content) is variable, it is within the range of 12-30%, and several exceed alfalfa hay in protein content. Therefore, most fodder trees would be good protein supplements, provided they are degraded adequately in the rumen to make the protein available to the animal and non-toxic (Leng, 1997). Fodder trees contain significant fibre, but invitro digestion studies indicated that the fibre was as

digestible as that of alfalfa hay, and much better than that of cereal straws (El Hassan *et al.,* 2000). Macro- and micro- mineral content of fodder trees are usually adequate to cover animal requirements (Smith, 1992).

Even if fodder trees have important nutritional merits, there are also reports (McNabb *et al.,* 1993; Wang *et al.,* 1994; Silanikove *et al.,* 1996; Kaitho *et al.,* 1998; du Plessis *et al.,* 1999; Norton, 2000; Solomon, 2002) which indicate that anti-nutritional factors found in fodder trees such as tannins, saponins, non-protein amino acids, phyto-estrogens can affect growth, onset of puberty and reproductive functions via direct toxicity, interference in the metabolic process or reduction of nutrient availability or a combination of these pathways.

1.4.1 Effect of supplementation of Sesbania sesban

1.4.1.1 Feed intake, digestibility and body weight gain

An important multipurpose fodder tree is *S. sesban*. It is an exotic tree to Ethiopia and is originally from east Africa. The International Livestock Research Centre (ILRI) has conducted a selection program and has come forward with accessions of good agronomic performance and feed value. The most widely distributed commercial cultivars to smallholder farmers include, 15036, 15019 and 10865 (Jean Hanson, personal communication).

Reviewed reports (Reed *et al.,* 1990; Ebong, 1995) showed that supplementation of *S. sesban* increased significantly intake of the total dry matter consumed with concurrent increase in rumen fermentation rate of the basal roughage feed. This in turn promoted high levels of rumen ammonia, volatile fatty acids and minerals (Bonsi *et al.,* 1994, 1995) resulting in an increased efficiency of microbial protein synthesis and higher nitrogen retention by the animal (Umunna *et al.,* 1995; Woodward and Reed, 1997). Nevertheless, an improved intake and digestibility of basal feed was observed at lower (<30%) but not at higher levels of supplementation (Bonsi *et al.,* 1995; Bitende and Ledin, 1996; Solomon, 2002). At high supplementation levels intake of the supplement is substituting the basal diet intake (Kaitho, 1997).

The effect of *S. sesban* on intake and digestibility may in part be attributed to its low to moderate levels of tannins which bind to feed proteins and protect against excess protein degradation in the rumen, thus increasing the flow of amino acids to the small intestine (Bonsi *et al.,* 1995; Reed *et al.,* 1990; Woodward and Reed, 1995; Wiegand *et al.,* 1996). However, tannins at relatively high levels in the diet may make the feed protein unavailable to enzymes and

even bind to intestinal wall proteins thus affecting protein digestion and amino acid absorption from the gut. The positive and negative effects of secondary plant compounds from *S. sesban* on intake, digestibility and animal performance were also observed among accessions. In a sheep metabolism trial at ILRI, accession 15036 (cv Mount cotton) had the highest content of proanthocyanidins (condensed tannins) and the lowest protein digestibility compared to three other *S. sesban* accessions (10865, 15019, 15007) tested. Sheep fed accessions with high content of proanthocyanidins had the lowest intake of cereal crop residue and the lowest digestibility of protein, N retention and growth rate. Nevertheless, sheep fed accessions with a moderate content of proanthocyanidins had a higher growth rate and N-retention than sheep fed the lowest content (Wiegand *et al.,* 1995).

1.4.1.2 Reproductive performance

There are scarce reports on the effects of *S. sesban* on reproductive performance of ruminants. The available literature indicates that sheep and goats supplemented with *S. sesban* for 6 months showed reduced live weight gain and reduced scrotal circumference changes, which could be attributed to phytochemicals (Kaitho *et al.,* 1998). Although the probable reasons were not clearly described, Woldemeskel *et al.* (2001) reported that relatively low levels (200 g/day) of *S. sesban* resulted in tubular degeneration, interstitial fibrosis and focal Leydig cell proliferation in male reproductive organs of sheep and goats, to a lesser extent observed at higher levels (400 g/day) of Sesbania supplementation. Recent evidences from the long-term effects of supplementation (8 months supplementation) of *L. pallida, S. sesban*, *L. purpureus* on the reproductive performance of Menz ewes fed a basal diet of teff straw, at ILRI, showed that supplementation of *S. sesban* (accession 1198) had a negative effect on the reproduction of ewes by compromising manifestation of oestrus, abortion or death of pregnant ewes (Solomon, 2002). Anti-nutritional factors could reduce the physiological availability of protein and minerals to the animal system. A copper deficiency could, for example affect behavioural oestrus (Robinson, 1996; du Plessis *et al.,* 1999). Moreover, a mummified foetus and stillbirth were observed in ewes and birth to a lamb with paralyzed hind legs, which suggest toxicity to major organs like the liver and the heart (Solomon, 2002).

2 The study areas

Owing to the high human and livestock pressure associated with land degradation and feed shortage, the Ethiopian highlands where the study

districts in the present thesis are found, have been the central focus for most of the feed resource development and soil conservation programmes for many years. The districts selected for on-farm research are described in the following sections. Districts differ with regard to agro-ecology and type of crop-livestock system in order to study role and function of multipurpose fodder trees in different farming systems. An inclusion criterion for selection of districts was that introduction and utilization of multipurpose fodder trees had started more than 5 years ago. Three districts representing farming systems and three peasant associations (PAs, the smallest administrative unit in Ethiopia) per district were included for the present study.

2.1 Lay-Armachuho district (Wheat-based crop livestock system)

Lay-Armachuho district is located in the north western part of Ethiopia, North Gondar Zone of Amhara region. This district is situated between latitudes $12^{0}39'66''$ and $12^{0}42'45''$N, and longitudes $37^{0}26'99''$ and $37^{0}28'42''$E (Fig 1). With an estimated area of 1330 km^2, Lay-Armachuho district has a population of 158.0 thousand (30.8 thousand farm households), of which 97% reside in rural areas (CSA, 2005). The average family size was 5.1 persons per household (7.1 for the study PAs). The altitudes in this district range from 1500 to 2500 m a.s.l. (2200 to 2400 m in the study PAs), and the average annual rainfall was 1100 with a mono-modal pattern from July to September. The topography is characterized by a rugged mountain (44%) with undulating plateaus (30%). The vegetation cover is moderate and different species and types of trees are found scattered around homestead and in farm lands. Land holding was 1.29 ha per household (1.64 ha in the study PAs). The major crops grown are Duragn (a crop-type where barley and wheat are grown mixed on the same land) wheat, faba-bean and barley (BOAAR, 2005). Cattle, sheep and goats are the most important livestock components of the farming system. Because of the proximity to major urban centres, crossbred cattle were introduced since 1991 through the Austrian Integrated Livestock Development Project (ILDP) for small scale dairy production. Cattle are usually kept for draught purposes (local breeds), milk (from crossbreds) and manure. Sheep and goats are the main source of income with minor contribution from the sale of milk. Crop residues and marginalized natural pasture are the major feed resources, and contribute for about 60% to the feed resource base. Local fodder trees and sporadically commercial concentrates are used to supplement animals during the dry season and for fattening sheep and cattle. The dry season lasts from December to June with an occasional shower of rain from February to March (BOAAR, 2005).

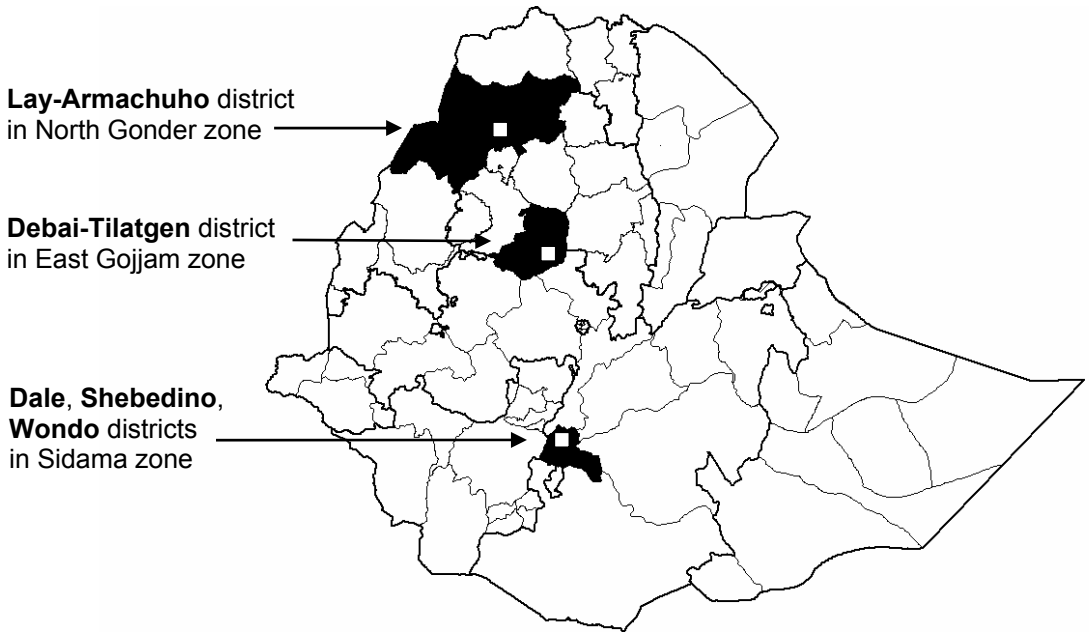

Fig. 1. The location of study districts (□) in Ethiopia (EMA, 2006)

The introduction of exotic multipurpose fodder trees started in the 1980s initially for soil and water conservation. But, later along with crossbred dairy cattle an extensive dissemination of seeds and seedlings of Sesbania, Tree Lucerne (in the extreme high altitudes), and perennial grasses like Napier grass has been carried out by the project (ILDP) to serve as supplementary feed for dairy animals around the milk-shed areas, for fattening of sheep and cattle in areas distant from urban centres and for soil conservation. A total of 3300 farm households were involved in growing multipurpose fodder trees since 1991, which is about 8.7% of the overall rural households of the district. The major plantation strategies were around backyards and on terraces of soil conservation structures in farmlands (ILDP, 2004).

2.2 Debay-Tilatgen district (Teff-based crop-livestock system)

Debay-Tilatgen district is located in the north western part of Ethiopia, East Gojjam Zone of Amhara region. This district is situated between latitudes $10^0$31'87" and $10^0$33'20"N, and longitudes $37^0$57'89" and $37^0$59'04"E (Fig 1). With an estimated area of 1160 km^2, Debay-Tilatgen district has a population of 132.6 thousand (27.1 thousand households) of which 98 % are rural (CSA, 2005). The average family size was 4.8 persons/household (5.7 persons per household in the study PAs). The altitudes range from 2000 to 3000 m a.s.l. (2300 to 2600 m in the study PAs). The average annual rainfall was 1200 mm with a mono-modal pattern from July to September. The average land holding was 1.21 ha

per household (1.38 ha in the study PAs) with a topography of undulating plateaus (67%) and mountain peaks (24%). Except with some eucalyptus trees planted around homesteads, the vegetation cover is poor and manure is used extensively for fuel. The principal crops are teff, faba-bean, wheat, and rough pea as major crops and oil crops as minor crops (BOAAR, 2005). Local cattle are kept for draught power, and sheep are the important sources of income. Due to the intensity of crop production grazing lands are scarce and feed shortage is critical during the dry (December to June) as well as during the rainy season (July to August). Livestock is dependent on crop residues most of the year and crop residues contribute for over 60% to the feed resource base. Multipurpose fodder trees (Sesbania and Tree Lucerne) in this district were introduced by government and non-governmental organizations for animal feed, soil conservation, and other farm functions such as fuel wood and live fences. About 2300 farm households (11.6% of the rural households) were involved in growing exotic fodder trees since 1995. Fodder trees are planted around backyards as live fence, in hedge rows and on terraces of soil conservation structures. Farmers usually supplement sheep followed by cattle in both the dry and rainy seasons using a cut and carry system (BOAAR, 2005).

2.3 Sidama district (Coffee-based crop-livestock systems)

Dale, Shebedino and Wondo districts (together referred to as Sidama district) are located in the southern part of Ethiopia, Sidama Zone of Southern region. This district is situated between latitudes $6^{0}27'46''$ and $6^{0}46'20''$N, and longitudes $34^{0}4'36.6''$ and $38^{0}12'54''$E (Fig 1). Sidama district has an estimated area of 3060 km^2, and a population of 1.1 million (212.3 thousand households) of which 98% are rural (CSA, 2005). The average family size was 5.4 persons per household (7.1 person per household in the study PAs). The altitude ranges from 1200 to 2600 m a.s.l. (1800 to 2200 m in the study PAs) and the average annual rainfall was 1320 mm with a bimodal pattern from March to April and June to September. The topography is characterized by undulating plateaus (70%), few mountain peaks (13%) and valleys (17%). Because of the perennial cropping system the vegetation cover in this district is good. The average land holding was 1.04 ha/per household (1.06 ha in the study PAs). Cattle (mainly local and few crossbreeds), sheep and goats are important livestock species. Coffee, enset (*Enset entricosum*) and maize are the major crops grown, and sweet potato, fruit trees, sugar cane and banana are minor crops (BOASNNP, 2005).

In Sidama district, enset is the main staple food followed by maize. Coffee and fruit trees are the major sources of income for farm households. Crop-livestock

integration is strong. Farmers use crop residues as feed source and return the manure into the soil for perennial crops. Livestock, therefore, play a critical role in the coffee-enset farming systems, as they provide manure for important perennial crops such as coffee and enset, food especially milk and occasionally meat for the family (McCabe and Lee, 1996). Because of the vicinity to urban markets, smallholder dairy production with crossbred cattle is emerging in this area. The consumption of milk, butter, and cottage cheese is common and make a critical contribution to an enset-based diet, which in itself is very low in protein (Shank and Ertiro, 1996; Pijls *et al.*, 1994). Stall feeding (tethering) is the principal means by which livestock are fed throughout the coffee-enset growing areas, and is a labour intensive activity. Enset leaves, maize stover and foliages from local multipurpose trees form an important part of the livestock diet (Fekadu, 1996). Exotic multipurpose trees (Sesbania, Calliandra and Leucaena) were introduced by the Ministry of Agriculture primarily for coffee shade and soil conservation. Since 1995, the Small-scale Dairy Development Project (SDDP) disseminated the exotic multipurpose fodder trees together with perennial grass species like Napier and Guatemala grass for animal feed and soil conservation. About 1120 farm households (0.5%) have participated in growing exotic multipurpose fodder trees around their homestead and farmlands (BOASNNP, 2005).

3 Rationale and objectives

In Ethiopia, the introduction of exotic multipurpose fodder trees such as Sesbania, Leucaena, Calliandra and Tree Lucerne in the mixed crop-livestock system started in the 1970s. The Ministry of Agriculture through the Fourth Livestock Development Project (FLDP) and the National Soil and Water Conservation Programme have been disseminating a huge amount of seeds and seedlings of exotic fodder trees particularly *S. sesban* for animal feed and soil conservation (Alemayehu, 1997; Betru, 2000). More recently, about 32 government and non-governmental organizations (Mekoya, unpublished report) in the Ethiopian highlands are involved in promoting multipurpose fodder trees especially *S. sesban* in an integrated rural development program. This fodder tree species (accessions 15019, 15036 and 10865) was extensively distributed in most parts of the country because of its adaptation for a wide range of soils, moisture regimens and its ease for establishment and fast growth rate.

Despite the significant research and development efforts in exotic multipurpose fodder trees development over the last three decades, the scale of fodder tree

planting and utilization undertaken by smallholder farmers have shown uneven success rates and did not meet the project goals. Very limited adoption rates and/or abandoning soon after adoption have been observed in most areas of sub-Saharan Africa (Thomas and Sumberg, 1995; Sumberg, 2002). In the Ethiopian highlands too, apart from their use in a limited number of specific situations, farmers have overwhelmingly chosen not to take advantage of the range of benefits multipurpose fodder trees can offer. In most cases farmers ceased growing fodder trees when the projects terminated from the area. Little is known about how smallholder farmers in sub-Saharan Africa and in Ethiopia value fodder trees, how they manage them and what they perceive as constraints to adoption and cultivation of fodder trees. In areas with relative adoption successes where Sesbania is being used as a supplementary feed, some farmers mentioned that *S. sesban* caused reproduction problems when fed to sheep. Farmers suspicions were supported by few short term (less than 7 months) on-station reproduction studies (Kaitho *et al.*, 1998: Woldemeskel *et al.*, 2001; Solomon, 2002) conducted in Ethiopia.

Since Sesbania is being introduced at a wider scale into the farming community and sheep are one of the most important animals to small holder farmers, there is need to investigate farmers' practices and perceptions about exotic multipurpose fodder trees at farm level and also to know the long-term supplementation effects of *S. sesban* under controlled environments. Our approaches will help understand issues related to multipurpose fodder trees both at the farming system and the animal level. Therefore, the present studies in this thesis were initiated with a general objective to explore farmers' motivations, their perceptions and constraints to adoption of exotic multipurpose fodder trees and effects of long-term feeding of *S. sesban* in sheep performance.

Specific objectives

1. Assess farmers' perception about use value, management practices, and constraints to adoption of exotic multipurpose fodder trees
2. Understand farmers' preference criteria, compare their preference between exotic and local multipurpose fodder trees, and evaluate the relationship of farmers' feed value assessment with laboratory indicators.
3. Get insight into farmers' feeding practices and their perception about the effects of *S. sesban* supplementation on sheep performance

4. Investigate the effects of long-term *S. sesban* accession 15019 supplementation on feed intake, post-weaning growth rate, and on-set of puberty of male and female lambs.
5. Investigate the long-term effects of supplementation of *S. sesban* accession 15019 on sexual activity and reproductive performance of male and female Menz sheep.
6. Investigate the effects of feeding *S. sesban* accession 15019 as a supplement to lactating ewes on milk production and growth rate of their lambs.

4 Thesis outline

- Chapter 1 gives an overview of the livestock production systems in the Ethiopian highlands, role and function of livestock, feed resources and nutritional limitations, role of multipurpose fodder trees in the crop-livestock production system, their positive and negative effects on feed intake, digestibility, body weight gain and reproduction, rationale and objectives of the thesis.

- In Chapter 2, the results of farmers' awareness, motivation to grow exotic multipurpose fodder trees, their perception about constraints to adoption are presented and options for future improvement are discussed.

- Chapter 3 examines farmers' decision making criteria in order to adopt multipurpose fodder trees, their preference in terms of the intended benefits and desired attributes of exotic and local fodder trees, the relationship between farmers assessment of feed value and laboratory indicators. The need to consider farmers decision making criteria and local resources during the research inception and development process, and how farmers' indigenous knowledge would help to complement scientific knowledge are described.

- Chapter 4 deals with farmers' feeding practise and perception about effects of *S. sesban* on sheep performance. The role of *S. sesban* in each farming system and its contribution to a year round supplementation to fulfil recommended protein requirement of animals for an optimal production is elaborated.

Based on results reported in Chapter 4 and reviewed literature on the adverse effects of *S. sesban*, a series of experiments was designed to assess the effects of

long-term supplementation of *S. sesban* on sheep performance (beginning from weaning age) for one whole reproductive cycle. These series of experiments are addressed in Chapters 5, 6 and 7.

- Chapter 5: Three levels of Sesbania supplements (0, 47.5 and 95% Sesbania in the supplement) were fed to post-weaned male and female lambs. The results of the effects of supplementation on feed intake, digestibility, post-weaning growth rate, sexual development and onset of puberty of ewe and ram-lambs are presented.

- Chapter 6: The same animals (rams up to the end of mating and ewes until the end of the pregnancy period) that were fed 0 and 95% levels of Sesbania in the supplement during the previous growth experiment in Chapter 5 were used in the study reported in Chapter 6. The results of long-term supplementation effects of Sesbania on the scrotum circumference change and semen quality of rams, and reproductive performance of ewes (oestrus behaviour, conception rate and pregnancy) are described.

- Chapter 7: Ewes that were fed 0 and 95% Sesbania during the pregnancy experiment of Chapter 6 continued to be fed at the same supplementation level and were monitored from lambing to weaning. In this Chapter, the results of the effects of supplementation of *S. sesban* to lactating ewes on milk yield and pre-weaning growth rate of lambs are explored.

- In Chapter 8, findings of previous chapters are interpreted and integrated, and it is discussed how the results of on-farm studies and the results of on-station experiments could be useful for farming systems. Recommendations for further research and development are presented.

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Chapter 2

Farmers' perceptions about exotic multipurpose fodder trees and constraints to their adoption

Mekoya, A., Oosting. S.J., Fernandez-Rivera, S. and Van der Zijpp, A.J. Farmers' perceptions about exotic multipurpose fodder trees and constraints to their adoption. Accepted by Agroforestry Systems

Abstract

Many organizations in Ethiopia have for many years promoted exotic multipurpose fodder trees (EMPFT) through their introduction for livestock feed and soil improvement. Despite the apparent benefits, the number of farmers planting these trees was low. The present research aimed to elucidate farmers' perceptions about their use value, management practices and constraints to adoption. It was carried out in three districts representing annual (one wheat-based and one teff-based) and perennial (coffee-based) crop-based livestock systems in the Ethiopian highlands. Data were collected from 235 farm households using a structured questionnaire. Most farmers (95.3% of respondents) had awareness of EMPFTs and the principal sources of information were development agents (75.3%). Over half of the farmers were motivated to plant EMPFTs for feed value. Motivation for other purposes depended on cropping system, vegetation cover and availability of alternative local fodder tree species in the area. Farmers had positive perceptions about EMPFTs for their feed value and contribution to soil and water conservation. The mean number of EMPFTs per farm where the trees were adopted was 587 (standard error 84). Major constraints to adoption of EMPFT were agronomic problems, low multipurpose value, and land shortage. Majority of farmers (89.8% of respondents) were interested to either continue or begin fodder tree development. Of the interested respondents, 44.5% preferred local fodder trees whereas 55.5% preferred EMPFTs. We conclude that farmers are aware of use values of the EMPFTs while perceived constraints suggest that introduction of EMPFTs need consideration of farmers multiple criteria, but also awareness of growing and feeding fodder trees and resource availability. Moreover, current approaches for development and delivery of technologies have to recognize the importance of involving the end-users at all stages through participatory approaches as a means to enhance relevance and adoption of technologies.

Key words: Ethiopian highlands; Development constraints; Adoption; Farm households; Awareness; Values

1 Introduction

Agriculture in the Ethiopian highlands (areas above 1500 m a.s.l, receiving >700mm annual rain fall and having a mean daily temperature of <20°C) is largely based on intensive cultivation of annual and perennial crops in mixed crop-livestock farming systems. The favourable climate and soil fertility allowed for high human and livestock population pressure on available land (Jahnke and Asamenew, 1983). The crop and livestock sub-sectors compete for scarce farm resources. As a result, the livestock productivity is generally low if compared to the apparent potential (EARO, 1998). Among contributing factors to low livestock productivity, the overriding constraint is inadequate feed supply, which comes mainly from marginal natural pastures and crop residues (Tsige Yohannes, 2000; Assefa, 2005). Two factors limit performance of animals fed on poor pastures and cereal straws: the amount consumed is restricted and the nutritive value per unit ingested feed is relatively low (Reed *et al.,* 1990; Tsige Yohannes, 2000). However, crop residues and natural pasture are still the principal feed sources and could provide a valuable source of energy if supplemented with protein rich feeds (Oosting, 1993). Several studies recommend supplementation with multipurpose fodder trees as perhaps the best-suited method for small-scale farmers' (Smith, 1992; Kaitho, 1997; Solomon, 2002).

Since the 1970s many organizations in Ethiopia promoted exotic multipurpose fodder tree (EMPFT) species such as *Sesbania sesban*, *Leucaena leucocephala*, *Calliandra calothyrsus* (here after referred to as Sesbania, Leucaena, and Calliandra) and Tree Lucerne, for supplementary feeding of livestock and soil improvement. Despite the significant development efforts and the apparent benefits, the number of farmers planting these trees was low. We hypothesized that understanding farmers' perception about values of fodder trees at the farm and constraints to introduction and growing of exotic multipurpose fodder trees will contribute to better understanding of how and which innovations should be introduced. The present research was conducted to assess the values of multipurpose fodder trees and to study farmers' practices of growing fodder trees and the constraints they perceive for introducing and growing exotic multipurpose fodder trees in the crop-livestock mixed farming system of the Ethiopian highlands.

2 Materials and methods

2.1 Conceptual framework

One's perception depends on ones frame of reference. According to Boogaard *et al.* (2006) four factors contribute to a frame of reference: knowledge, experience, values and interests.

Knowledge and experience: perception of an innovation is influenced by the household's knowledge, knowledge source, and how this knowledge is transferred into the community (Andrew and Rikoon, 1997). In the present study we assessed knowledge as awareness. Experience serves as a yardstick from which new practices are evaluated (Biggelaar and Gold, 1995; Andrew and Rikoon, 1997). The extent of constraints prevailing in the locality and the significant contribution of the innovation (values) to alleviate constraints may change farmers' perception (Napier *et al.,* 1986; Napier and Napier, 1991).

Values and interests: values can be defined as matter important to people in a collective or individual setting. Farmers' interests have a more individual nature and are related to family subsistence, farm economics but also to social-cultural issues. Values and interests are therefore partly overlapping. With regard to fodder trees, values and interests become explicit in the role and function of fodder trees in the farming system.

Since farming systems differ between agro-climatic zones, and resource availability at the farm also determines the farming system, the present study compares different districts (which represent different farming systems) and wealth groups within districts.

2.2 Regions and farming systems

This study was conducted from August to December 2004, in Lay-Armachuho and Debay-Tilatgen districts of Amhara region, in the north-western highlands, and in Dale, Shebedino and Wondo districts (here after called Sidama district) of Southern region, in the southern highlands of Ethiopia. The altitudes range from 2200 to 2400 m, 2300 to 2600 and 1800 to 2000 m a.s.l. for Lay-Armachuho, Debay-Tilatgen and Sidama districts respectively. Average annual rainfall for Lay-Armachuho and Debay-Tilatgen districts was 1100 and 1200 mm with a mono-modal pattern from July to September. The average annual rainfall for Sidama district was 1320 mm with a bi-modal distribution from March to April and June to September.

The agricultural production systems in Lay-Armachuho and Debay-Tilatgen district are annual crop-based livestock system respectively wheat-based and teff (*Eragrostis tef*)-based whereas a perennial (coffee) crop-based livestock system characterizes Sidama district (Jahnke and Asamenew, 1983). Average land holding was 1.64, 1.38 and 1.06 ha for Lay-Armachuho, Debay-Tilatgen and Sidama districts, respectively. In Lay-Armachuho and Debay-Tilatgen

districts about 98% of crop land was allocated for annual crops. While in Sidama district 75% of crop land was used to grow perennial crops. An extensive livestock production system (free grazing) dominates Lay-Armachuho and Debay-Tilatgen districts whereas in Sidama district tethering is the common practice. The average livestock number per farm was 4.1, 3.4 and 2.7 tropical livestock unit (TLU= tropical livestock unit is a hypothetical animal of 250 kg live weight, used to bring all animal types under a common denominator as applied by Gryseels, 1988) for Lay-Armachuho, Debay-Tilatgen and Sidama districts, respectively. The livestock species contributing most to farm income was cattle in Lay-Armachuho and Sidama and sheep in Debay-Tilatgen. A detailed description of the agro-ecology, farm and household characteristics of the study districts is presented in Table 1.

2.3 Survey methodology

Regions, districts and Peasant Associations (PAs) (the smallest administrative unit within a district) for this study were selected by employing multi-stage purposive sampling (beginning from regions to districts and PAs). Data from development organizations were used to select farms based on criteria: agro-ecology for region, more than five years of introduction of fodder trees and the type of crop-livestock system for districts, sufficient number of adopters (those who planted and utilized EMPFT) and non-adopter households (those who did not adopt EMPFT but use local fodder trees for feeding and other purposes) for PAs and presence of livestock for individual farms. Within each of the three study districts twelve PAs were selected and from the list of candidate farmers within each PA 7 or 8 non-adopting and 8 or 9 currently adopting farm households were randomly selected. However, for the group of discontinued adopters (those who abandoned using EMPFT) all available farmers were selected within the PAs included in the study due to the limited number of discontinued adopters. Two hundred thirty five farm households (98 adopters, 93 non-adopters and 44 discontinued adopters) from Lay-Armachuho, Debay-Tilatgen and Sidama districts were included in the present study. The distribution was 31, 34 and 33 for adopters, 30, 30 and 33 for non-adopters and 27, 5 and 12 for discontinued adopters in Lay-Armachuho, and Sidama districts, respectively. After selection, farmers were further classified into three wealth categories based on land size and livestock converted to tropical livestock unit (TLU) into poor (those who possess ≤1 ha land and ≤1.6 TLU), medium (those with 1 to 2 ha land and 1.7 to 4.0 TLU) and rich (those with ≥2 ha land and ≥4.0 TLU). The distribution of wealth groups was 23, 22 and 39 for poor farmers, 23,

Table 1 Agro-ecological and farm household characteristics of the study districts in the Ethiopian highlands

Descriptions	Districts		
	Lay-Armachuho	Debay-Tilatgen	Sidama
Geograph. coordinates	$12^0$39′66″ and $12^0$42′45″N	$10^0$31′87″ and $10^0$33′20″N	$6^0$27′46″ and $6^0$46′20″N
	$37^0$26′99″ and $37^0$28′42″E	$37^0$57′89″ and $37^0$59′04″E	$34^0$4′36.6′′ and $38^0$12′54″E
Altitude (m.a.s.l.)	2200-2400	2300-2600	1800-2000
Rainfall (mm)	1100	1200	1320
Rainy seasons, pattern	June- Sept., monomodal	June-Sept., monomodal	March-April, June-Sept., bimodal
Soils	Leptosols	Pellic vertisols	Nitosols
Vegetation cover	Poor	Medium	Good
Production system	Wheat-based crop-livestock	Teff-based crop-livestock	Coffee-based crop-livestock
Land use			
Avg land holding (ha)	1.64	1.38	1.06
Avg crop land (ha)	1.36	1.31	0.94
Avg grazing land (ha)	0.27	0.06	0.12
Area annual crops (%)	97.8	99.4	25.5
Major crops	Duragn*, Faba-bean, Wheat, Barley	Teff, Wheat, Faba-bean, Rough pea	Coffee, Enset, Maize, Sugar cane
Herd size (TLU)	4.1	3.4	2.7
Predominant livestock	Dairy (crossbr), draught (local), sheep, goats	Draught (local), sheep,	Dairy (crossbr + local), sheep, goats
Major feed resources	Grazing, crop residues	Grazing, crop residues	Perenn. crop leaves, local fodder trees
Feed shortage seasons	February to June	December to August	February to June
Age household head (y)	41.8	37.5	42.1
Mean family size	7.1	5.7	7.9
Education status (%)			
Illiteracy	31.8	30.4	14.1
Read and write	56.8	50.7	28.2
≥ Elementary education	11.4	18.8	57.7

* Duragn is a crop type where barley and wheat are grown mixed on the same land

28 and 27 for medium farmers, and 42, 19 and 12 for rich farmers in Lay-Armachuho, Debay-Tilatgen and Sidama districts, respectively.

2.4 Data collection and analysis

Data collection was by household interviews in local language by trained enumerators using a pre-tested, structured questionnaire. From each household farm land characteristics (farm size, allocation, ownership type), socio-economic characteristics (age, sex, education, economic activities engaged in), livestock characteristics (number, herd composition, purposes of keeping livestock, feed resources and feeding practices) and detailed information about fodder trees (farmers' awareness of, perception about and motives to plant EMPFT, tree number and EMPFT species available on-farm, use values, management practices, and constraints to adoption) were assessed.

Depending on the nature of data, chi-square tests, analysis of variance and regression analyses were employed to compare districts, wealth and adoption groups. The data on number of EMPFT owned was not normally distributed and mean comparisons were done on the log-transformed data. Data were analyzed using SPSS (2002) and SAS (2000) statistical packages.

3 Results

3.1 Awareness and experience

Most farmers (95.3%) had awareness about planting EMPFT. The sources for information about introduction and use of EMPFT were development agents (75.3%) and neighbouring farmers (17.4%) with a significant ($P<0.05$) difference between districts, adoption groups and wealth groups (Table 2).

Neighbouring farmers were an important information source for non-adopters. For more than 94% of adopters and discontinued adopters, development agents were the principal information source. Farmer-to-farmer information exchange was relatively high in Debay-Tilatgen and Sidama districts and for poor farmers (Table 2).

Current and discontinued adopters of EMPFT had experience of growing EMPFT from three to fifteen years. There was a significant ($P<0.05$) difference between districts. In Debay-Tilatgen district, a lower proportion of farmers had a long term experience, but a higher proportion had a medium term experience than in the other districts. There was no significant difference between wealth groups (Table 3).

Table 2 Awareness of adopters, non-adopters and discontinued (D-) adopters and major sources of information about EMPFTs in the Ethiopian highlands

	Awareness of EMPFTs (% responding "yes")	**Major information source (% respondents)**			
		Development agents	Neighbour farmers	Both	No source
Districts					
Lay-Armachuho	98.9	84.1	11.4	3.4	1.1
Debay-Tilatgen	98.6	75.4	21.7	1.4	1.4
Sidama	88.5	65.4	20.5	2.6	11.5
P	***0.00***		***0.01***		
Adoption groups					
Adopters	100	94.9	4.1	1.0	0.0
Non-adopters	88.2	45.2	37.6	5.4	11.8
D-adopters*	100	95.5	4.5	0.0	0.0
P	***0.00***		***0.00***		
Wealth groups					
Poor	96.4	61.9	31.0	3.6	3.6
Medium	96.2	84.6	9.0	2.6	3.8
Rich	93.2	80.8	11.0	1.4	6.8
P	***0.57***		***0.01***		
Overall (n=235)	95.0	75.3	17.4	2.6	4.7

*D-adopters are farmers discontinued from EMPFT development; **EMPFT= Exotic multipurpose fodder trees; P-values are chi-square probabilities

Table 3 Length of experience of growing EMPFTs and functions of EMPFTs as perceived by current and discontinued adopters in the Ethiopian highlands

	Experience of growing EMPFTs (% respondents)			**Functions**** **(% responses)**				
	Short ≤ 5 y	Medium 6-10 y	Long > 10 y	Coffee shade	Feed	Fence	Fuel	SWC*
Districts								
Armachuho	20.7	36.2	43.1	0.0	71.3	16.3	6.3	6.3
Debay	17.9	66.7	15.4	0.0	41.1	22.1	12.6	24.2
Sidama	15.6	40.0	44.4	30.9	47.9	4.3	5.3	11.7
P		***0.02***				***0.00***		
Wealth groups								
Poor	20.0	40.0	40.0	14.3	55.6	11.1	11.1	7.9
Medium	20.8	41.5	37.7	11.4	46.5	18.4	9.6	14.0
Rich	14.8	53.7	31.5	7.6	57.6	10.9	4.3	19.6
P		***0.68***				***0.17***		
Overall (n=142; n = 489)	18.3	45.8	35.9	10.8	52.4	14.1	8.2	8.2

*SWC= Soil and water conservation ** Farmers could select more functions; P-values are chi-square probabilities

3.2 Values and interests

Of the responses given by current and discontinued adopters (each respondent could choose more than one important use value of EMPFT on his farm), feed value as motivator for introducing and/or growing EMPFT represented 52.4%. A significant (P<0.05) difference was observed between districts: In Sidama, planting (fodder) trees for coffee shade was important, while in Debay-Tilatgen district soil fertility, live fence, and fuel-wood were relatively important motives. There was no significant association between wealth groups and EMPFT functions (Table 3).

Within the group of adopters 85.9% of respondents had positive response on the feed value of EMPFTs on animal productivity with a significantly (P<0.05) lower proportion of positive respondents for Sidama than for the other districts. Among important nutritional attributes of fodder trees "better body condition" got overall 47.4% of responses (farmers could select more than one attribute), followed by milk production (30.1% of responses) and improved straw intake (22.5% of responses). Ranking of attributes differed significantly (P<0.05, chi-square) between districts. Body condition score was highly ranked in Sidama, milk production got relatively few responses in Debay-Tilatgen and improved straw intake was unimportant in Sidama (Table 4).

Table 4 Current adopters' perception about values of exotic multipurpose fodder trees in the Ethiopian highlands

	Feed value (% resp. "yes")	**Productivity improvement** (% of responses)*			**Contribution to SWC** (% of resp.)			**Replace manure** (% resp. "yes")	**Contrib. to crop prod.** (% of resp.)	
		BBCO	BMP.	ISI	None	Little	Much		None	Little
Districts										
Armachuho	87.9	40.5	33.9	25.6	3.2	74.2	22.6	54.8	22.6	77.4
Debay	94.9	48.6	16.7	34.7	2.9	23.5	73.5	26.5	17.6	82.4
Sidama	75.6	60.7	39.3	0.0	18.2	60.6	21.2	9.1	33.3	66.7
P	***0.03***		***0.00***			***0.00***		***0.00***	***0.31***	
Wealth groups										
Poor	82.9	52.7	23.6	23.6	10.0	50.0	40.0	35.0	25.0	75.0
Medium	86.9	48.3	31.5	20.2	10.0	35.0	55.0	27.5	25.0	75.0
Rich	87.0	43.8	32.4	23.8	5.3	71.1	23.7	28.9	23.7	76.3
P	***0.75***		***0.75***			***0.04***		***0.83***	***0.99***	
Overall (n=98)	85.9	47.4	30.1	22.5	8.2	52.0	39.8	29.6	24.5	75.5

*Farmers could select more than one perceived productivity improvement option; SWC=Soil and water conservation; BBCO=Better body condition; BMP=Better milk production; ISI=Improved straw intake

Of the adopters 39.8% of respondents perceived the contribution of EMPFT to soil and water conservation as important, 52.0% as medium and 8.2% as unimportant. Relatively more adopters in Debay-Tilatgen valued EMPFT as important for soil and water conservation than in the other districts (chi-square, P< 0.05). Perception of importance of EMPFTs for soil and water conservation was also significantly (P<0.05) associated with wealth group (Table 4).

The majority (73.5%, not in table) of adopters perceived the importance of EMPFT for fuel wood as limited. The value of EMPFT to replace manure was relatively important in Lay-Armachuho (for 54.8% of adopters), less so in Debay-Tilatgen (26.5%) and very low in Sidama (9.1%) without significant (P<005) differences between wealth groups. Adopters valued the contribution of EMPFTs to crop production as absent (24.5%) or limited (75.5%) (Table 4).

3.3 Fodder tree resources and management practices

Across districts 88.8% of adopters planted Sesbania, 8.8% Calliandra, and 2.5% Leucaena. In Lay-Armachuho and Debay-Tilatgen districts Sesbania, was the sole EMPFT species grown by farmers whereas in Sidama district the majority of farmers grew more EMPFT species. The mean number of EMPFTs available on-farm by a current adopter household was 587 trees (Table 5). Current adopters in Sidama had significantly less trees than those in the other districts,

Table 5 Number of exotic multipurpose fodder trees available on current adopters' farms, seedling sources, plantation area in the Ethiopian highlands

Variables	Trees/household		Seedling source (% respondents)		Seedling raising (Prop. Respon. "yes")	Plantation area (% respondents)		
	No. ± (s.e)	Natural log ± (s.e)	Neighbour farmers	DOs*		Back yard	Farm land	Both
Districts								
Lay-Armachuho	1014±213	6.0±0.23[a]	1.5	98.5	29.0	94.8	1.7	3.4
Debay-Tilatgen	566±102	6.0±0.22[a]	0.0	100.0	23.5	94.9	2.6	2.6
Sidama	207±63	4.4±0.23[b]	15.2	84.8	33.3	11.1	57.8	31.1
P			***0.00***		***0.67***		***0.00***	
Wealth groups								
Poor	242±176	4.9±0.32[b]	14.0	86.1	25.0	65.7	20.0	14.3
Medium	405±124	5.3±0.22[b]	1.5	95.5	20.0	62.3	24.5	13.2
Rich	960±128	6.0±0.23[a]	1.6	98.4	39.5	75.9	14.8	9.3
P			***0.01***		***0.15***		***0.62***	
Overall (n=98)	587±84	5.5±0.15	4.6	95.4	28.6	68.3	19.7	12.0

Means in a column with different superscripts are significant at P<0.05; P-values are chi-square probabilities; *DOs: Development Organizations

while rich current adopters had more trees than adopters in the other wealth groups.

The initial sources of seeds and seedlings were development organizations (95.4%) either directly or via contract farmers. Farmer-to-farmer exchange of seeds and seedlings was very low (4.6%), though higher in Sidama than in the other districts ($P<0.05$) and higher for poor farmers than for the other wealth groups ($P<0.05$). After establishment of the parent stock 71.4% of current adopters continued to acquire freely from development organizations and contract farmers for replacement and expansion.

Backyard and farmland plantation were the two major development strategies exercised by 68.3% and 19.7% of the current adopters, respectively. Farmers in Sidama planted EMPFTs more often in farmland than farmers in the other districts ($P<0.05$) (Table 5).

The number of EMPFTs a household (current adopter) owned was positively ($P<0.05$) correlated with livestock number ($r=0.35$), number of crossbreds ($r=0.39$) and land size ($r=0.24$). Multiple regression analysis revealed land size and number of crossbreds as significant ($P<0.05$) factors (Regression: Trees number = -38 (s.e.84.1; ns) + 7 (s.e. 15.7; ns) * livestock number + 207.2 (s.e. 60, $P=0.001$)* crossbred number + 273 (s.e. 112.2; $P=0.017$) * land size (ha); $R^2=0.33$, n=98, rsd=478). Relationships within districts and wealth groups did not differ significantly from the overall regression.

The average age of cutting for feed and fuel wood among current adopters was 10.4 and 49.8 months respectively without significant effects of district and wealth group except for the age of initial cutting, which was 9.6 (s.e 0.38) months for rich farmers, significantly higher than for poor (11.1 (s.e. 0.48) months) and medium (10.9 (s.e. 0.42) months) farmers. The average annual frequency of cutting fodder trees was 2.6 times. There was significant difference ($P<0.05$) between districts. Farmers in Sidama district cut more frequently than those in the other districts. Among respondents, 37% of farmers cut during December to May, 28.7% of farmers during September to November and June to August, and 34.4% of farmers did not follow specific seasons. Seasonality of cutting was associated with district and wealth groups (Table 6).

Table 6 Harvesting parameters for exotic multipurpose fodder trees at current adopters' farms in the Ethiopian highlands

	Cutting frequency /y (mean±s.e)	Cutting seasons (% respondents)			
		Dec-May	Jun-Aug	Sep-Nov	Not specific
Districts					
Lay-Armachuho	2.6±0.1[b]	27.5	10.0	5.0	57.5
Debay-Tilatgen	2.5±0.1[b]	43.3	18.3	21.7	16.7
Sidama	3.0±0.2[a]	36.8	10.5	15.8	36.8
P				***0.00***	
Wealth groups					
Poor	2.8±0.2	47.1	8.8	17.6	26.5
Medium	2.6±0.1	34.8	21.7	15.9	27.5
Rich	2.8±0.1	33.3	5.6	13	48.1
P				***0.05***	
Over all (n=98)	2.6±0.07	36.9	13.4	15.3	34.4

Means in a column with different superscripts are significant at P<0.05; P-values are chi-square probabilities

3.4 Constraints to adoption, future interest and preference of farmers

Non-adopters, current and discontinued adopters were asked to select maximally 5 constraints they envisage or experienced for establishing and growing EMPFT (Table 7). The major constraints were related to agronomic problems (31.8% of responses; low biomass, short life, incompatibility to the cropping system, adaptability), low multipurpose value (20.6% of responses), and land shortage (18.2% of responses).

However, there was a significant (P<0.05) association between constraints and districts, adoption groups and wealth groups. Agronomic problems and low multipurpose value were important constraints for Lay-Armachuho and Sidama districts, whereas, land shortage was the major impediment of adoption for Debay-Tilatgen district. Non-adopters mentioned low multipurpose value of EMPFTs and land shortage as important constraints while current and discontinued adopters mentioned agronomic problems as an important constraint (Table 7).

Non-adopters, current and discontinued adopters were asked whether they were interested to either continue or (re)start growing of multipurpose fodder trees. Interest to do so was expressed by 89.8% of farmers (Table 8). Of those interested to begin or continue fodder tree growing, 44.5% preferred local multipurpose fodder tree species and 55.5% preferred EMPFTs. A majority

Table 7 Constraints perceived by current and discontinued (D-) adopters, non-adopters for adoption and growing of exotic multipurpose (mp) fodder trees (n=538)

Variables	**Perceived constraints (% of total responses)**							
	agro-nomic	low mp value	land shortage	lack util. awaren.	labour shortage	free grazing	harbour pest	others
Districts								
Armachuho	37.2	25.5	10.9	3.8	13.4	2.9	2.1	4.2
Debay	6.5	2.9	39.9	18.8	8.0	16.7	1.4	5.7
Sidama	45.3	28.6	10.6	8.7	3.1	0.0	0.0	1.9
P					***0.00***			
Adoption								
Adopters	38.3	12.1	20.3	10.2	5.1	8.6	1.2	4.3
N-Adopters	0.0	32.3	30.1	16.5	11.3	2.3	0.0	7.5
D-Adopters	49.0	24.8	4.0	0.7	13.4	3.4	2.7	2.0
P					***0.00***			
Wealth groups								
Poor	25.8	23.9	18.4	12.9	8.0	3.1	0.0	7.9
Medium	31.0	19.9	23.4	10.5	5.8	7.0	0.6	1.8
Rich	37.3	18.6	13.7	4.9	12.3	6.4	2.9	4.0
P					***0.00***			
Overall*	31.8	20.6	18.2	9.1	8.9	5.6	1.3	4.5

* Maximally 5 constraints per farmer; P-values are chi-square probabilities

Table 8 Future interest among current and discontinued adopters and non-adopters to continue or start growing fodder trees and preference for fodder tree species

	Future interest (Prop. farmers resp. "yes")	**Preferred fodder tree species** (% resp)	
		Local	Exotic
Districts			
Lay-Armachuho	100.0	64.8	35.2
Debay-Tilatgen	84.1	0	100
Sidama	83.3	56.9	43.1
P	***0.00***	***0.00***	
Adoption groups			
Adopters	92.9	9.9	90.1
Non Adopters	90.3	61.9	38.1
D-adopters	81.8	91.7	8.3
P	***0.13***	***0.00***	
Wealth groups			
Poor	86.9	54.8	45.2
Medium	85.9	35.8	64.2
Rich	97.3	42.3	57.7
P	***0.04***	***0.07***	
Overall (n=235*, 211)**	89.8	44.5	55.5

* Future interest; ** Preferred fodder tree type; P-values are chi-square probabilities)

of farmers in Lay-Armachuho and Sidama districts preferred local multipurpose fodder trees, while all farmers in Debay-Tilatgen district preferred EMPFTs. Current adopters preferred EMPFT whereas a majority of discontinued adopters (91.7%) and non-adopters preferred local multipurpose fodder trees (Table 8).

4 Discussion

4.1 Awareness and experience

The present study showed that most farmers were aware of the possibility of growing and utilizing EMPFTs and also of possible benefits. However, being aware about an innovation does not necessarily lead to adoption. As we observed in the present study, all discontinued adopters were well aware of and used EMPFTs for certain period whereas the majority of non-adopters (88.2%) had awareness of EMPFTs, but were reluctant to adopt. Decisions to adopt a given practice may require suitable bio-physical and socio-economic environments, in addition to adequate knowledge and favourable attitudes. When these factors are not in congruence, farmers' practices show divergence from their awareness and attitudes. Semgalawe (1998) and Tesfaye (2003) who studied adoption of soil and water conservation practices in Tanzania and Ethiopian highlands also reported that farmers' knowledge on and attitudes to soil and water conservation have a basic, but limited role in determining their practices, which may demonstrate as well that fodder development practices are affected by factors other than awareness and perception of values.

It was observed in the present study that farmers feed less of the fodder tree biomass than recommended. This could be a lack of awareness among farmers of an optimal feeding strategy for animal production, but it could also be related to other constraints e.g. a different farming objective than livestock (coffee in Sidama), resource availability (limited land and labour) or agronomic problems. The latter, however, relates to in part to knowledge of tree management.

The channel of information source in the present study was unidirectional, top-down from development agents to farmers. Information exchange among farmers was generally low, which may affect the extent of adoption since farmers could learn needs and practices from other farmers. Hence, build up of a farmer-to-farmer information exchange system through participatory approaches will help develop trust of farmers to adopt an innovation. In an adoption study in the highlands of central Kenya, Sinja *et al.*(2004) and

Wanyoike (2004) also reported that the spread of fodder legume technology was significantly enhanced by participatory, bottom-up methods especially farmer-to-farmer extension.

4.2 Values and interests

Values and interests with regard to EMPFTs are reflected in their functions at farms. The high importance given to the feed function of EMPFTs suggests prevalence of feed shortage with regard to quality and quantity in all districts and wealth groups. The importance of other functions depended on the farming system, and vegetation cover of the area. For instance, in Debay-Tilatgen district (due to intensive utilization of land for cropping) the vegetation cover was poor and availability of alternative local fodder trees on farmlands was scanty. Hence, important functions of EMPFTs here were soil and water conservation, live fence and fuel wood. On the other hand, coffee is the dominant perennial crop grown in Sidama district and growing EMPFTs for coffee shade was an important function. EMPFT-functions in the present study compare to those in reports of Franzel *et al.* (2003) and Poshiwa *et al.* (2006) in Kenya and Zimbabwe. The present study showed that farmers perceived EMPFTs positively for feeding value and contribution to soil and water conservation in line with results about utilization of multipurpose fodder trees in the Philippines where Calub (2003) concluded that farmers appreciated fodder trees and shrubs like Leucaena and *Glicirida sepium* for their role in bridging the gap in fodder supply during dry months and also to avoid soil degradation. The positive perception of farmers about feed value of EMPFTs in Lay-Armachuho was associated with a high fodder tree availability and importance of (crossbred) dairy cows in the farming system. While in Sidama, even though farmers had crossbred dairy cows, their perception about the feed value of EMPFTs was lower as compared to Lay-Armachuho district, which may be associated with the lower number of trees they had but also to the availability of local multipurpose fodder trees which they perceive better than or comparable to the exotics. Also Franzel *et al.* (2003) and Paterson *et al.* (1998) reported that farmers appreciated the feed value of fodder trees if they had sufficient fodder trees and experience of feeding dairy cows.

Furthermore, the difference in the ranking of attributes for productivity improvement could be attributed to the difference in the production objectives of each farming system as well as the extent of utilization of crop residues. In Debay-Tilatgen district, cattle are reared mainly for draught purpose and sheep served as a main source of income. Here, the nutritional attribute of fodder

trees was more for body condition improvement and increasing straw intake than milk production. Conversely, in Sidama the contribution of crop residues as a feed resource was lower compared to the other districts and consequently the attributes of fodder trees to increase straw intake were not recognized.

The difference in importance of the function of EMPFTs for soil and water conservation between districts could be explained by differences in vegetation cover and availability of alternative trees. Compared to other districts, Debay-Tilatgen district had poor vegetation cover and a low availability of local fodder trees, and farmers gave more importance to the function of soil and water conservation of EMPFTs. Our results agree with the reports of Roose and Ndayizigiye (1997) in Rwanda and McDonald *et al.* (1997) in Jamaica. Both studies described that in the mountains of Jamaica and Rwanda hedge rows of Calliandra and Leucaena have reduced run-off and soil erosion compared with conventional plots with a positive effect on crop production. The observation that farmers in the poor and medium wealth groups gave more importance to the soil and water conservation function of EMPFTs than rich farmers did could be related to the relevance of fodder trees for farmers that lack resources to purchase external inputs to maintain soil fertility.

Besides alleviating feed shortage, amongst the objectives of development organizations while introducing EMPFTs was to serve as fuel so that the manure would be saved from being used for fuel. However, in the present study their contribution to replace manure and their positive effect on crop production was insignificant in all districts and wealth groups. Similar results were reported by Neupane *et al.* (2002) in Nepal stating that only 18% of respondents perceived agro-forestry technologies improved crop yields. By the same token, Franzel *et al.* (2003) in central Kenya ascribed that the contribution of Calliandra for fuel wood was appreciated by only 24% of respondents, which was associated with the frequent pruning for feed that reduce the stem and trunk length and thickness that are important for burning qualities.

4.3. Fodder tree resources and management

Majority of respondents were dependent on external sources of seeds/seedlings to resume EMPFT development. Even after parent stock establishment, only a minority of respondents were capable of multiplying seedlings. The endeavour to rely on their own or community based seed and seedling exchange system was lower than in the Kenyan highlands reported by O'Neill *et al.* (2001) and Franzel *et al.* (2003), which may be attributed to the difference in the scale of

dairy development and extension approaches in the two countries. The average initial age of cutting and annual cutting frequency recorded was similar to on-farm study reports in Kenya (Paterson *et al.*, 1998; Franzel *et al.*, 2003). Rich farmers were able to cut and start feeding at earlier fodder tree age than other wealth groups. The reason could be their higher number of fodder trees and better fodder tree management. The difference among districts in frequency of cutting may be related to the difference in moisture regime and feeding practice.

4.4 Constraints to adoption and implications

In Lay-Armachuho and Sidama districts where local multipurpose fodder trees are available, the lower multi-functionality of and more agronomic problems associated with EMPFTs were important reasons for low adoption. Also the observation that a high proportion of non-adopters and discontinued adopters preferred local multipurpose fodder trees to EMPFTs could be associated with a lower appreciation of multifunctional values of EMPFTs if compared to the alternative local sources. Napier and Napier (1991) argued that rural farmers will tend to choose development activities that offer at least as much, in terms of socio-economic and environmental benefits as they get from alternative activities. Use of local multipurpose fodder trees, when available, could therefore be an option for development of fodder tree use at farms.

The success of technology transfer also depends on the compliance of the technology with farm objectives. Development organisations tend to work on technology transfer on assumption of market integration of farmers, which in turn implies a production orientation with specialized farms and farmers that reason and decide on basis of economics to maximize their farm output. From the present perception study it seems justified to conclude that farmers used fodder tree supplementation not with the aim to achieve maximal livestock output. As stated earlier, it remains unknown whether adoption and maximal utilization of EMPFTs for animal production is limited by farm characteristics as land size and perceived agronomic problems, by the fact that livestock output is not the principal farm objective or by lack of knowledge among farmers. The observation that number of crossbreds at a farm related to the number of trees indicates that farmers with income from milk supplement more fodder tree biomass. In addition, in Sidama livestock is only a secondary farm component besides the growing of coffee. Farmers there grow EMPFTs also for the purpose of shade for coffee and have fewer trees per farm. However, farmers express the interest to develop the growing of fodder trees, which

indicates that they do see beneficial effects for their farms, which relates to the appreciation they had for feed and soil and water conservation value of EMPFTs. Hence, farmers do take the effect on animal production into account which implies that perceived constraints as given in Table 7 could well be the limiting factors for adoption and growing more EMPFTs. Part of the constraints (agronomic problems, lack of utilization awareness) can potentially be overcome by participatory technology development and training and education of farmers. However, other constraints (low multipurpose values of EMPFTs, land and labour shortage, free grazing) are constraints that stem from the farming system itself and need to be approached through a problem analysis of the whole farm in which farmers should participate. The farm objective (whether subsistence, crop production or livestock output) will determine what farmers perceive as the most important problem to find a solution for. Only if exotic or local multipurpose fodder trees fit into the solution sustained adoption of fodder trees can be expected.

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Chapter 3

Multipurpose fodder trees in the Ethiopian highlands: Farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S. and Van der Zijpp, A.J. Multipurpose fodder trees in the Ethiopian highlands: Farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators. Accepted by Agricultural Systems

Abstract

In the tropics, numerous organizations have promoted multipurpose fodder trees (MPFT) with an emphasis on exotic species. These species have generally been selected and recommended by the research system through the conventional nutritional and agronomic experimentation for use as animal feed and soil conservation. In Ethiopia, the introduction of exotic MPFT started in the 1970s. However, despite its apparent benefits, the adoption of exotic MPFT by smallholder farmers has been slow and in some cases farmers ceased using exotic MPFT in their farming systems. The objectives of the present study were to assess farmers' preference criteria, compare their preference between exotic and local MPFT, and evaluate the relationship of farmers' knowledge of feed value assessment with laboratory indicators. Focus group discussions and preference ranking and scoring by a total of forty farmers were conducted in two districts representing two production systems (cereal and coffee-based livestock production systems) in the Ethiopian Highlands. The comparison between exotic and local MPFT for their benefits and desired tree characteristics showed that farmers preferred local MPFT to exotics for biomass production, multi-functionality, life span, and compatibility to the cropping system. In terms of feed value, ease of propagation, and growth potential local MPFT were ranked lower than or comparable to exotics. There was also a strong correlation between farmers' feed value score and laboratory results. Farmers were able to discriminate effectively MPFT species that had high and low protein and fibre content using their indigenous feed value indicator system for all pair wise comparisons. We concluded from this study that farmers' preference criteria encompass multiple objectives beyond feed value and soil rehabilitation. The different merits that farmers associate with exotic and local MPFT could provide an opportunity to use both MPFT types and to improve farm bio-diversity. Hence, incorporating locally available MPFT, farmers' indigenous knowledge and preference criteria at the research inception process is vital to maximize the likelihood of farmers' adopting and maintaining these technologies.

Key words: Farm households; Multipurpose fodder trees; Highlands; Indigenous knowledge; Preference ranking; Nutrient composition

1 Introduction

The conventional way of screening fodder tree species in the tropics involves on-station agronomic and feeding studies comparing biomass production and nutritive value of selected species under different management regimes (Roothaert and Franzel, 2001; Roothaert *et al.*, 2003). These studies usually focus on exotic species, such as *Sesbania sesban*, *Leucaena leucocephala*, *Chamacytisus palmensis*, *Calliandra calothyrsus*, because planting materials and information are readily available from international sources. Likewise, in the Ethiopian highlands, there has been considerable research and concerted development efforts on exotic MPFT since the 1970's, mainly for the purpose of animal feed and soil conservation (Alemayehu, 1997). However, the adoption of exotic MPFT has been limited. From the farmers' perspectives, the major constraints to adoption of exotic MPFT were related to technical and socio-economic factors such as agronomic problems, low multipurpose value, and limited resources of land and labour (Mekoya *et al.*, 2006).

A survey conducted in the Ethiopian highlands by the proponents of this study showed that farmers use many different local MPFT, besides the exotic MPFT, to feed their animals and for other farm purposes and a significant proportion of these farmers preferred local to exotic MPFT (Mekoya *et al.*, 2006). It is believed that farmers' preference of MPFT extends beyond the scientific interpretation of biomass production potential and nutritive value. Farmers might use complex criteria for evaluation of MPFT in the frame of their multiple farm objectives (Thapa *et al.*, 1997; Roothaert and Franzel, 2001; Roothaert *et al.*, 2003). Nevertheless, there is no detailed information available on the species used by farmers, preference between exotic and local MPFT and the reasons underlying preferences in the Ethiopian highlands. We also believe that farmers generally possess invaluable knowledge about local and exotic MPFT that can lead to the identification of pertinent research questions that help focus research and speed up the development process. Hence, the present study aimed at elucidating farmers' preference criteria, to use such criteria in a comparative assessment of exotic and local MPFT, and to assess the relationship between farmers' indigenous knowledge of MPFT feed value and laboratory-based indicators.

2 Materials and methods

2.1 Description of the study areas

This study was conducted from August to December 2004, in Lay-Armachuho district of Amhara region, in the north-western highlands of Ethiopia, and

Sidama district of Southern region, in the southern highlands of Ethiopia. Lay-Armachuho district is situated between $12^{0}39'66''$ and $12^{0}42'45''$N and between $37^{0}26'99''$ and $37^{0}28'42''$E. Sidama district is situated between $6^{0}27'46''$ and $6^{0}46'20''$N and $34^{0}4'36.6''$ and $38^{0}12'54''$E. The altitudes range from 2200 to 2400 m and from 1800 to 2000 m a.s.l. for Lay-Armachuho and Sidama districts respectively. The climate in all study districts represents ''Dega'' (Dega is a local classification and represent the climate in areas above 1500 m above sea level) (Jahnke and Asamenew, 1983). Average annual rainfall for Lay-Armachuho was 1100 mm with a mono-modal rainfall from July to September. The average annual rainfall for Sidama district was 1320 mm with a reliable bi-modal rainfall from March to April and June to September. The vegetation cover in Lay-Armachuho district is poor and consequently soil nutrient depletion and environmental degradation are typical characteristics of the area whereas in Sidama district the vegetation cover is good and land degradation is mild.

Low input-output subsistence, rain-fed agriculture is the main stay in both study districts. Sales from crops (annual crops for Lay-Armachuho, and perennial crops such as coffee and fruits for Sidama district) animals, animal products and off-farm activities are the major income sources. The agricultural production system in Lay-Armachuho district is dominated by a cereal-based mixed crop livestock production system whereas a coffee-based mixed crop-livestock system characterizes Sidama district (Amare, 1978; Jahnke and Asamenew, 1983). The average family size per household in Lay-Armachuho and Sidama districts was 7 and 8 heads respectively. Average land holding for farmers included in the study was 1.64 (±0.07 s.e) ha for Lay-Armachuho district and 1.06 (±0.08 s.e) ha for Sidama district. In Lay-Armachuho district 97.8% of cropland was allocated for the cultivation of annual crops, while in Sidama district 74.5% of cropland was used to grow perennial crops. Livestock (mainly cattle, sheep and goats) is an integral component of the subsistence crop-livestock production system in both areas. An extensive livestock production system (free grazing) dominates Lay-Armachuho district. In Sidama district, on the other hand, animals are tethered year round and an in-door/out-door stall-feeding system is practised. The average livestock number was 4.1 and 2.7 TLU (TLU = tropical livestock unit is a hypothetical animal of 250 kg live weight, used to bring all animal types under a common denominator as applied by Gryseels, 1988) per household for Lay-Armachuho and Sidama districts respectively. Pasture and hay from communal and private grazing land and crop residues make up over 60% of the feed resource base in Lay-Armachuho district. In Sidama district, perennial crop leaves and MPFT

(mainly local) contribute about 40% of the feed resource base for livestock. Feed shortage, particularly from February to June, is one of the major impediments of livestock production in both districts (Mekoya *et al.,* 2006).

2.2 Survey methodology and data collection

From the two districts (Lay-Armachuho and Sidama), 40 farmers (20 from each district) residing in adjacent peasant associations were purposely selected because of their experience and knowledge in the development and utilization of exotic and local MPFT. A group discussion with 20 farmers in each district was carried out to list the most important and commonly used MPFT, the benefits they perceive, and the tree characteristics they desire in the respective district. This step was important for selecting the most preferred MPFT and in defining criteria for assessing individual trees during evaluation of different tree species.

The ranking exercise was undertaken on an individual basis by a total of 40 farmers (20 farmers from each district involved in the group discussion as mentioned above). Scoring was done on a scale from 1 (poor performance) to 4 (excellent performance). For the laboratory analysis, fodder tree samples from leaves and soft twigs of the selected MPFT were collected from each district. Samples from different trees within species and within location were treated as replicates and three replicates per location were collected for each species. The samples were air dried and taken to the laboratory for analysis. Dry matter and CP were determined according to AOAC (1990) procedures. Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and lignin were analyzed using the method of Van Soest and Robertson (1985). Condensed tannins (CT) were determined by heating 2 mg NDF samples at 95^{o}C for one hour in n-butanol containing 5% concentrated HCL and the absorbance was read at 550 nm (Reed *et al.,* 1982). Results were expressed as absorbance per gram NDF. Soluble tannins (ST) were determined by precipitation with trivalent ytterbium (Reed *et al.,* 1985).

2.3 Statistical analysis

The scores of preference ranking were treated as quantities measured on a continuous scale (Kuntashula and Mafongoya, 2005). Due to the difference in the types of MPFT available in each district, means were calculated and analysis of variance (ANOVA) tests were conducted within districts. Cross tabulations were used to identify the proportion of respondents for each MPFT ranking exercise. To establish the relationships that exist, if any, between farmers'

assessment of MPFT feed value scores with the relative assessments derived from laboratory-based indications of feed quality, Spearman's rank correlation analysis was carried out independently for each district. Data were analyzed using SPSS (2002) and SAS (2000) statistical packages.

3 Results

3.1 Farmers' preference criteria and most preferred multipurpose fodder trees

Based on the group discussion consensus, in each district commonly agreed criteria were set to rank each MPFT. The parameters used to rate MPFT by farmers during the ranking exercise for each of the desired attributes are shown in Table 1.

Besides the exotic MPFT such as *Sesbania* and *Calliandra,* over 95% of farmers in each district use different local MPFT and shrubs for various purposes. Among the local MPFT available in the two districts, 16 species (six species from Lay-Armachuho and ten species from Sidama district) were most preferred and frequently used for feeding animals and other farm functions. The list of local MPFT kept by farmers and exotic MPFT introduced by development organizations selected for appraisal is presented in Table 2.

Table 1. Farmers' criteria used to rate multipurpose fodder trees (MPFT) for different benefits in Lay-Armachuho and Sidama districts of Ethiopia highlands

Major criterion for benefits and desired tree attributes	**Sub-parameters within a criterion**
Biomass yield	Amount of leaves and soft twigs per cutting
Adaptability	Easy to grow on wide range of soil types, fertilities and moisture regimes; Drought resistance
Feed value	Palatability by animals; Improvement of body condition, growth and milk production; Improvement of intake of straw diets; Improved health of animals
Ease of propagation	Easy to propagate by seeds, seedlings, and cuttings; Easy to collect seeds and raise seedlings; Labour requirement
Growth and re-growth potential	Growth rate after establishment; Re-growth potential after frequent cutting or looping
Multi-functionality	Use for Timber, poles and other constructions; Fuel wood; Fence; Medicinal value; Shade tree; Source of honey; Farm implements
Life span of the tree	Ability to stay for many years after planted under recurrent cutting
Compatibility	Do not compete with crops on available soil nutrients and moisture; Improve soil fertility; Improve growth of below canopy annual and perennial crops

Table 2 List of most preferred MPFT in the two districts*`

Districts			
Lay-Armachuho		Sidama	
Local name	Botanical name	Local name	Botanical name
Atat	*Maytenus undata*	Berbra	*Millettia spp*
Chibaha	*Ficus thonningii*	Calliandra	*Calliandra calothyrsus***
Donga	*Apodytes dimidiata*	Game	*Ehretia cymosa*
Girar	*Acacia spp*	Girar	*Acacia spp*
Sesbania	*Sesbania sesban***	Girawa	*Vernonia amygdalina*
Wanza	*Cordia africana*	Guancho	*Sapium ellipticum*
Wulkfa	*Dombeya bruceana*	Olencho	*Ekebergia capensis*
		Sesbania	*Sesbania sesban***
		Setamo	*Olea capensis*
		Shesho	*Typha angustifolia*
		Soyama	*Grewa bicolar*
		Wanza	*Cordia africana*

* Botanical names are used throughout the text; ** Exotic MPFT

3.2.1 Biomass yield

In Lay-Armachuho district, *F.thonningii* followed by *A. dimidiata*, *Acacia spp* and *C. africana* were rated highest for biomass yield. More than 75% of farmers gave *F. thonningii* a maximum four score for its biomass yield. Farmers' rating for the exotic MPFT *S. sesban* was very low and the maximum rank given to *S. sesban* was two by 75% of respondents. In Sidama district, *E. cymosa* was rated highly for biomass yield. *Vernonia amygdalina*, *G. bicolar*, *Millettia spp* and *C. africana* were rated next to *E. cymosa*. *Ehretia cymosa* was given rank three and four by 75 and 15% of respondents. Among exotic MPFT, *C. calothyrsus* was intermediate in mean score and about 45% of the respondents gave rank three whereas *S. sesban* was the lowest (80% of respondents gave rank two) in biomass yield than most of the local MPFT. In both districts, most of the local MPFT were superior in biomass yield to exotic MPFT (Table 3).

3.2.2 Adaptability

In the comparison for adaptability in Lay-Armachuho district, *F. thonningii* and *Acacia spp* had a higher mean score compared to the rest of local MPFT and *S. sesban*. About 85% and 60% of respondents gave score four for *F. thonningii* and *Acacia spp* respectively. The exotic MPFT *S. sesban* had a lower mean score than the rest of the trees and was given rank two by 55% of the respondents. While in Sidama district, five of 12 local and exotic MPFT types were ranked highest. Unlike Lay-Armachuho district, the exotic MPFT found in Sidama district were comparable with local MPFT in mean score for adaptability (Table 3).

Table 3 Production and use characteristics comparison of exotic and local MPFT in Lay-Armachuho and Sidama districts of the Ethiopian highlands

Species/District	Biomass	Adaptability	Feed value	Ease propagation	Growth potential	Multifunction	Life Span	Compatibility
Lay-Armachuho								
M. undata	1.7^{d}	2.9^{c}	1.3^{d}	1.6^{e}	2.3^{b}	2.3^{c}	2.9^{c}	2.7^{e}
F. thonningii	3.8^{a}	3.9^{a}	3.5^{ab}	3.8^{a}	3.4^{a}	2.2^{c}	3.2^{b}	3.1^{cd}
A. dimidiata	2.8^{b}	3.2^{bc}	1.4^{d}	2.3^{cd}	2.4^{b}	2.7^{b}	2.9^{c}	2.8^{de}
Acacia spp	2.7^{b}	3.6^{a}	3.6^{ab}	2.4^{c}	2.3^{b}	2.8^{b}	3.8^{a}	3.9^{a}
*S. sesban**	1.8^{cd}	2.5^{d}	3.7^{a}	2.7^{b}	3.4^{a}	1.4^{d}	1.3^{d}	3.1^{cd}
C. africana	2.4^{b}	3.2^{bc}	3.0^{c}	2.2^{cd}	2.3^{b}	3.5^{a}	3.6^{a}	3.6^{b}
D. bruceana	2.1^{c}	3.3^{b}	3.4^{b}	2.0^{d}	1.9^{c}	2.8^{b}	3.2^{b}	3.2^{c}
Mean ± s.e	2.4±0.07	3.2±0.05	2.8±0.09	2.4±0.06	2.5±0.06	2.5±0.07	2.9±0.07	2.7±0.03
Sidama								
Millettia spp	3.0^{ab}	3.3^{abc}	3.4^{a}	2.7^{cd}	2.6^{bc}	2.8^{bc}	3.3^{b}	2.8^{b}
E. cymosa	3.1^{a}	3.6^{a}	3.0^{b}	3.3^{a}	3.3^{a}	2.6^{bcd}	3.3^{b}	2.9^{b}
S. ellipticum	2.7^{bc}	2.9^{d}	1.8^{d}	1.7^{f}	1.9^{d}	2.9^{b}	3.0^{bcd}	2.7^{b}
Acacia spp	2.3^{de}	3.6^{a}	3.2^{ab}	2.3^{e}	2.5^{c}	2.4^{de}	3.7^{a}	3.0^{b}
V. amygdalina	3.0^{ab}	3.6^{a}	2.5^{c}	3.3^{ab}	2.9^{b}	2.5^{ef}	2.1^{e}	3.5^{a}
E. capensis	2.8^{abc}	3.1^{cd}	1.4^{e}	1.8^{f}	1.8^{d}	2.7^{bcd}	3.1^{bc}	2.7^{b}
*S. sesban**	2.0^{ef}	3.2^{bcd}	3.3^{ab}	3.2^{ab}	3.4^{a}	1.5^{h}	1.5^{f}	1.2^{d}
O. capensis	2.2^{def}	3.0^{d}	1.7^{de}	1.7^{f}	1.8^{d}	1.8^{gh}	1.9^{e}	2.7^{b}
T. angustifolia	1.9^{f}	2.9^{d}	1.5^{de}	1.8^{f}	1.7^{d}	1.9^{fg}	2.9^{cd}	2.8^{b}
G. bicolar	3.0^{ab}	3.6^{a}	3.4^{a}	2.4^{de}	2.6^{bc}	2.9^{b}	3.2^{bc}	3.0^{b}
C. Africana	2.9^{ab}	3.6^{a}	3.2^{ab}	2.7^{c}	2.6^{bc}	3.6^{a}	3.8^{a}	3.8^{a}
*C. calothyrsus**	2.5^{dc}	3.4^{ab}	3.3^{ab}	3.0^{bc}	3.5^{a}	2.5^{cd}	2.8^{d}	1.7^{c}
Mean ± s.e	2.6±0.04	3.2±0.03	2.6±0.06	2.5±0.05	2.5±0.05	2.5±0.05	2.8±0.05	2.7±0.05

Means in a column and within district with different superscripts are significant at P<0.05; * Exotic MPFT

3.2.3 Feed value

In Lay-Armachuho district, *S. sesban*, *Acacia spp*, *F. thonningii* and *D. bruceana* were highly preferred and were significantly different (P<0.05) from the rest of MPFT for their feed value. Farmers gave the highest preference rate for *S. sesban* (70% of respondents rank four). In Sidama district, *G. bicolar* and *Millettia spp* scored highest followed by *C. calothyrsus*, *S. sesban*, *Acacia spp* and *C. africana*. However, the preference rating of farmers among local MPFT was not significantly different. Multipurpose fodder trees with lowest preference for feed value were *O. capensis*, *S. ellipticum*, *T. angustifolia* and *E. capensis* (Table 3). In both districts exotic MPFT were either superior or comparable to local MPFT.

3.2.4 Ease of propagation

Ficus thonningii was ranked highest followed by *S. sesban* for ease of propagation in Lay-Armachuho district. According to respondents, *F. thonningii* could be propagated by seed, seedlings and cuttings, and could grow in a wide range of soil types, fertility statuses, and at any place at farm (back yard, farmlands, soil and water conservation structures) as compared to other MPFT. Farmers mentioned that seeds from *S. sesban* could be collected easily, grown in nurseries and transplanted in backyards. Self-propagated seedlings shattered from mature trees were additional merits of *S. sesban*. In Sidama district, *E. cymosa*, *V. amygdalina* and *S. sesban* had the highest mean score followed by *C. calothyrsus*, *C. africana* and *Millettia spp*. Farmers in Sidama district also mentioned similar attributes like the farmers in Lay-Armachuho district for *E. cymosa* and *S. sesban* for ease of propagation. The other MPFT types need either treatment of seeds or higher labour to take care of seedlings in nurseries (Table 3).

3.2.5 Growth potential

In Lay-Armachuho district, *F. thonningii*, and *S. sesban* were ranked highest for fast growth rate and re-growth potential after cutting and were significantly different (P<0.05) from the rest of MPFT. In Sidama district, farmers gave a higher score for *C. calothyrsus*, *S. sesban* and *E. cymosa* than for other MPFT. In Sidama district also, the exotic MPFT *C. calothyrsus* and *S. sesban* were most preferred by farmers compared to the rest of local MPFT with regard to growth rate and re-growth potential (Table 3).

3.2.6 Multi-functionality

For their multiple function, *C. africana* followed by *D. bruceana*, *Acacia spp* and *A. dimidiata* had the highest mean score in Lay-Armachuho district whereas *S. sesban* was given the lowest mean score (65% of respondents gave the lowest rank one). Similarly in Sidama district, *C. africana* ranked highest followed by *G. bicolar* and *S. ellipticum*. *Sesbania sesban* was the lowest and *C. calothyrsus* was intermediate in mean score. About 55% of respondents gave the lowest score one for *S. sesban* (Table 3).

3.2.7 Life span

In Lay-Armachuho district, with respect to the life span of the tree *Acacia spp* and *C. africana* were ranked highest and *S. sesban* was given the lowest score (70% of respondents scored one) than the other MPFT. Similarly, in Sidama district, *C. africana* and *Acacia spp* were ranked highest and *S. sesban* was ranked lowest. Despite the largely different MPFT types that were compared, the highest and lowest ranked species were similar in both districts (Table 3).

3.2.8 Compatibility

In Lay-Armachuho district, *Acacia spp* followed by *C. africana* had the highest mean score and were significantly different ($P<0.05$) from the rest of MPFT for their compatibility with the cropping system. About 85 and 60% of the respondents gave the highest rank four for *Acacia spp* and *C. africana*. The lowest ranked MPFT type was *M. undata* by 65% of respondents. On the other hand, *C. africana* and *V. amygdalina* were ranked highest in Sidama district. *Sesbania sesban* and *C. calothyrsus* had a lower score compared to other local MPFT for compatibility (Table 3). In both districts the preference of farmers for *C. africana* was similar and the exotic MPFT were less preferred in Sidama than in Lay-Armachuho District.

3.3 Laboratory evaluation of exotic and local MPFT preferred by farmers

The average nutrient composition profile of exotic and local MPFT derived from laboratory analysis is shown in Table 4. The crude protein (CP) content of individual samples of MPFT for Lay-Armachuho and Sidama districts ranged from 110 to 328 g kg^{-1} DM and from 116 to 274 g kg^{-1} DM respectively. In Lay-Armachuho district, the highest CP content was found in *S. sesban* followed by *D. bruceana* and *Acacia spp* and the lowest was recorded in *M. undata* and *A. dimidiata*. In Sidama district, *G. bicolar* and *Millettia spp* followed by *C. calothyrsus*, *V. amygdalina* and *S. sesban* had the highest CP content whereas *T. angustifolia*, *O. capensis* and *E. capensis* had the lowest CP content (Table 4).

Table 4 Nutrient composition (%) of exotic and local MPFT in Lay-Armachuho and Sidama districts of the Ethiopian highlands

Species	DM	OM	CP	NDF	ADF	ADL	CT	ST
Lay-Armachuho								
M. undata	913^{b}	919^{a}	132^{f}	388^{d}	317^{c}	98^{d}	15.1^{c}	26.9^{a}
F. thonningii	909^{bc}	857^{c}	183^{e}	420^{c}	316^{c}	86^{e}	38.7^{a}	14.5^{c}
A. dimidiata	903^{d}	917^{a}	116^{g}	555^{a}	441^{a}	213^{a}	16.9^{c}	14.5^{c}
Acacia spp	914^{b}	890^{b}	251^{c}	411^{cd}	258^{d}	117^{c}	14.0^{c}	18.4^{b}
S. sesban	922^{a}	892^{b}	317^{a}	214^{e}	172^{e}	57^{f}	14.4^{c}	19.0^{b}
C. africana	907^{d}	858^{c}	234^{d}	523^{b}	401^{b}	136^{b}	25.1^{b}	14.33^{c}
D. bruceana	909^{c}	854^{c}	258^{b}	422^{c}	256^{d}	33^{g}	15.5^{c}	9.7^{d}
Mean ±s.e	911±0.8	884±2.4	213±5.8	419±9.3	309±7.7	106±4.7	20±0.8	17±0.6
Sidama								
Millettia spp	920^{b}	911^{c}	268^{a}	623^{a}	433^{a}	215^{a}	34.0^{d}	14.5^{ef}
E. cymosa	910^{e}	856^{gh}	202^{e}	301^{f}	208^{fg}	49^{fg}	21.7^{e}	22.1^{b}
S. ellipticum	908^{e}	914^{bc}	145^{f}	346^{e}	250^{e}	55^{f}	9.9^{g}	21.3^{b}
Acacia spp	903^{f}	860^{fg}	230^{d}	482^{b}	304^{d}	160^{b}	21.6^{e}	18.8^{c}
V. amygdalina	912^{cde}	863^{f}	240^{c}	366^{d}	249^{e}	79^{e}	7.5^{g}	18.2^{cd}
E. capensis	916^{c}	920^{b}	122^{h}	300^{f}	212^{f}	75^{e}	77.8^{a}	24.8^{a}
S. sesban	894^{g}	891^{d}	238^{c}	255^{g}	166^{i}	51^{f}	17.5^{f}	13.9^{f}
O. capensis	931^{a}	938^{a}	126^{gh}	442^{c}	330^{c}	98^{d}	9.7^{g}	6.8^{g}
T. angustifolia	915^{cde}	839^{i}	128^{g}	334^{e}	183^{h}	40^{gh}	39.5^{c}	18.5^{cd}
G. bicolar	910^{c}	856^{gh}	270^{a}	269^{g}	199^{g}	35^{h}	7.3^{g}	16.5^{de}
C. Africana	914de	852^{h}	231^{d}	444^{c}	421^{b}	127^{c}	6.4^{g}	15.9^{ef}
C. calothyrsus	912^{cd}	876^{e}	255^{b}	307^{f}	218^{f}	91^{d}	66.1^{b}	21.9^{b}
Mean ±s.e	912±0.7	881±2.0	205±3.6	372±6.8	264±5.6	89±3.4	27±1.5	18±0.4

Means in a column and with in a district with different superscripts are significant at P<0.05; DM=dry matter (g kg^{-1}); OM=organic matter (g kg^{-1} DM); CP=crude protein (g kg^{-1} DM); NDF=neutral detergent fibre (g kg^{-1} DM); ADF=acid detergent fibre (g kg^{-1} DM); ADL=acid detergent lignin (g kg^{-1} DM); CT=condensed tannins (Absorbance g^{-1} NDF); ST=soluble tannins (% DM)

The NDF and ADF content of individual samples of MPFT ranged from 183 to 735 and from 152 to 586 g kg^{-1} DM in that order for Lay-Armachuho district. In Sidama district, the NDF content ranged from 248 to 685 g kg^{-1} DM and the ADF content from 157 to 464 g kg^{-1} DM. *Apodytes dimidiate* and *C. Africana* were the highest and *S. sesban* was the lowest in both NDF and ADF contents in Lay-Armachuho district. On the other hand, *Millettia spp* was the highest and *S. sesban* and *G. bicolar* were the lowest in both NDF and ADF content in Sidama district. Generally, the exotic MPFT were low in fibre content in both districts (Table 4).

The acid detergent lignin (ADL) content of each MPFT from Lay-Armachuho district ranged between 28 and 236 g kg^{-1} DM. *Sesbania sesban* and *D. bruceana*

were the lowest whereas *A. dimidiata* followed by *C. africana* and *Acacia spp* were the highest in lignin content. In Sidama district, the range of ADL content of MPFT varied from 26 to 246 g kg^{-1} DM. The lowest lignin content was found in *G. bicolar*, *T. angustifolia* and *E. cymosa* (Table 4). *Millettia spp* followed by *Acacia spp* and *C. africana* had high lignin content. In both districts, the exotic MPFT lignin content was below the mean value.

The condensed tannins (CT) and soluble tannins (ST) content of MPFT in Lay-Armachuho district ranged from 7.5 to 40.2 Abs g^{-1} NDF and from 6.8 to 39.1% of DM. *Ficus thonningii* followed by *C. africana* contained high CT content whereas *M. undata* had the highest and *D. bruceana* the lowest ST content. In Sidama district, the CT and ST content of MPFT ranged from 3.3 to 86.2 Abs g^{-1} NDF and from 3.6 and 34.7% of DM respectively. *Ekebergia capensis* followed by *C. calothyrsus* had high CT and ST content (Table 4).

3.4 Relationship between farmers' feed value assessment and laboratory based nutritive value indicators

The comparison for nutrition content profiles with farmers' feed value score among MPFT in this study focused on crude protein, fibre, and tannin contents of each MPFT which may help to explain tree fodder quality.

3.4.1 Correlation analysis

The rank correlation analysis between individual laboratory indicators of nutritive value with farmers' ranking of fodder trees for feed value is presented in Table 5. Farmers' rankings for feed value of MPFT was significantly correlated ($P<0.05$) with some individual nutrient composition laboratory indicators, notably with CP. In Lay-Armachuho district, the CP content of MPFT was positively ($P<0.05$) correlated with farmers' feed value score. As farmers' ranking for feed value increases there was an increasing trend in CP content of MPFT whereas, the ADF and ST content of MPFT were negatively ($P<0.05$) correlated. The higher the feed value score the lower the ADF and ST content of MPFT. In Sidama district and in the overall combined analysis, on the other hand, only the CP content of MPFT were positively ($P<0.05$) correlated with farmers' feed value score. The other compositional parameters did not correlate significantly ($P>0.05$) with the farmers' assessment of feed value. The combined and district stepwise regression analysis of all laboratory parameters on farmers' feed value score corroborates a significant relationship ($P<0.0001$) only on the CP content of MPFT.

Table 5. Rank correlations of farmers feed value score with individual laboratory indicators of nutritive value

Feed value score	Laboratory parameters					
	CP	**NDF**	**ADF**	**ADL**	**CT**	**ST**
Lay-Armachuho	0.729 ***	-0.263	-0.591**	-0.280	-0.311	-0.377*
Sidama	0.860 ***	-0.013	0.125	0.199	-0.134	-0.243
Overall	0.814 ***	-0.081	-0.095	0.069	-0.146	-0.229

* Significant at P<0.05, ** P<0.01, *** P<0.001

The combined and district regression equations for the relationship of feed value score (Y) and laboratory results for CP (X) were (SE in parenthesis);

Y = 3.92(2.2) + 0.73 (0.07) X; (R^2=0.53, P<0.0001) for Lay-Armachuho district
Y = 2.62(1.9) + 0.86 (0.08) X; (R^2=0.74, P<0.0001) for Sidama district and
Y = 2.92(1.4) + 0.83 (0.07) X; (R^2=0.68, P<0.0001) for the overall districts

3.4.2 Complementarities between indigenous knowledge and laboratory assessment

Examples of farmers' feed value ranks and their corresponding laboratory assessed nutrient composition values of both districts MPFT are presented in Fig. 1 and 2.

With the exception of *F. thonningii* in Lay-Armachuho district and *V. amygdalina* in Sidama district, farmers were able to discriminate effectively MPFT species that had high and low protein content using their indigenous feed value indicator system for all pair wise comparisons. The CP laboratory results of MPFT in each district apparently confirmed the observation of farmers. The complementarities between rankings used by farmers and the CP laboratory nutrient values of MPFT species correlated with these are shown in Fig. 1.

The NDF and ADF contents of MPFT collected from Lay-Armachuho district showed a decreasing trend as the crude protein content and farmers' feed value score increase (Fig. 2). However, this trend was not consistent for ADL, CT and ST contents. In Sidama district, similar trend of association was observed only between farmers' feed value score and the CP content of individual MPFT species. As it is shown in Fig. 2, for NDF, the correspondence of farmers' ranking with other nutrient compositions (ADF, ADL, CT and ST) of MPFT was unable to discriminate individual MPFT and did not support the complementarities of the two knowledge systems.

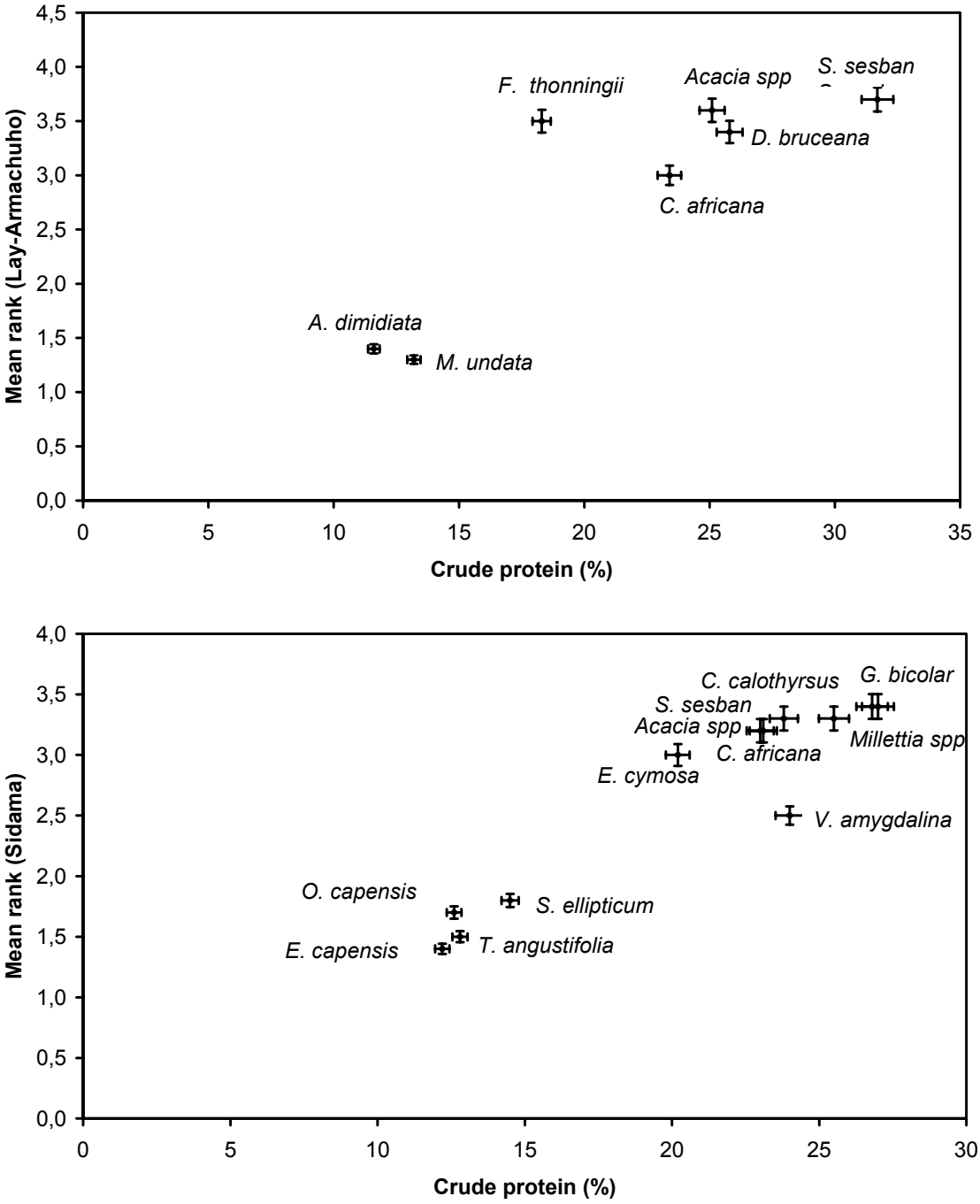

Fig. 1 Complementarities between farmers' rankings for feed value and correlated laboratory crude protein contents of multipurpose trees in the two districts

4 Discussion

4.1 Farmers' preference criteria and rating of multipurpose fodder trees

In this study, farmers' criteria of evaluating MPFT broadly combine the intended purposes to meet different farming objectives and agronomic characteristics they wish from trees, which suggest farmers' preference criteria for MPFT are more complex. Our result is in agreement with the works carried

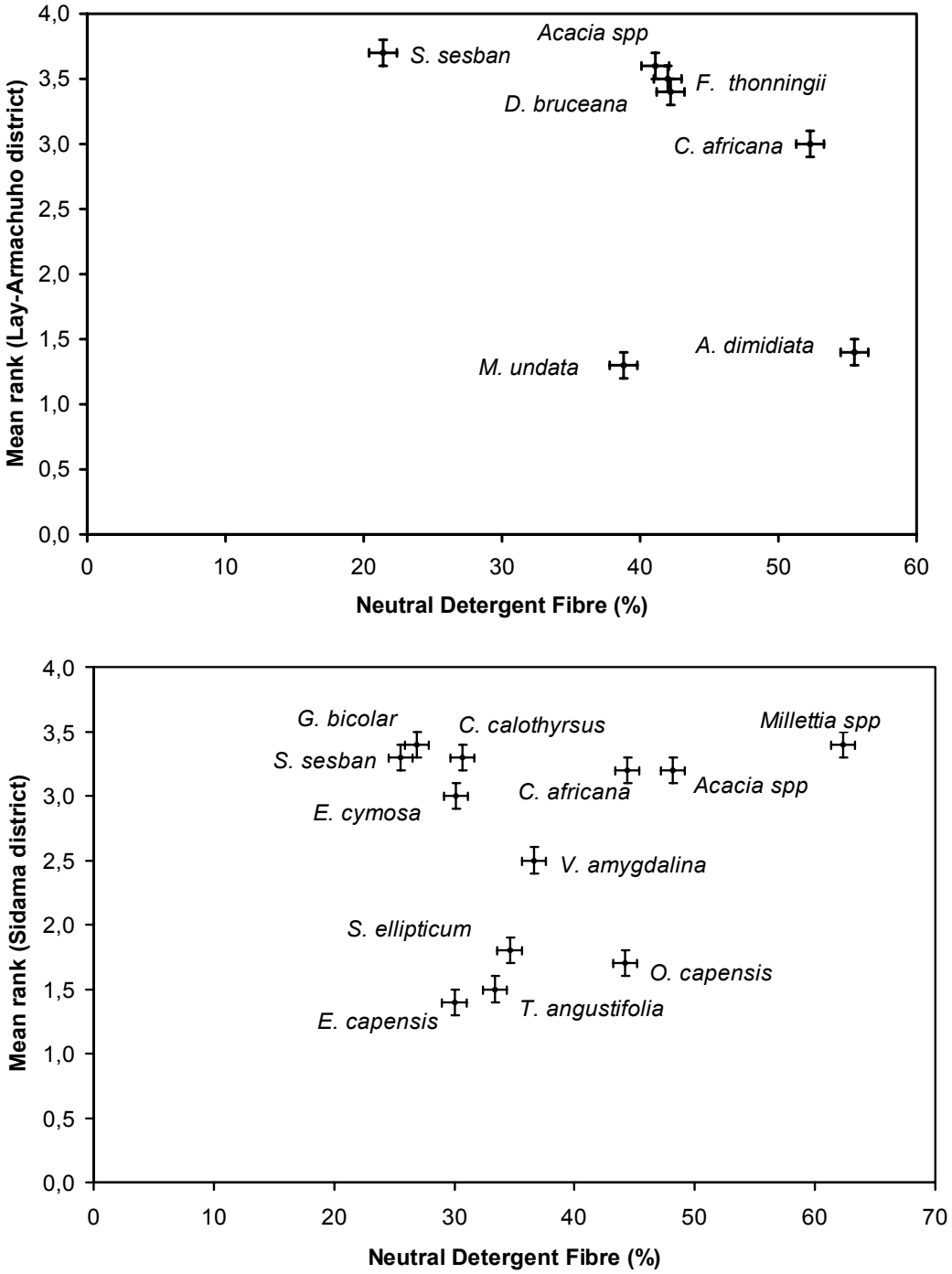

Fig. 2 Complementarities between farmers' rankings for feed value and correlated laboratory neutral detergent fibre contents of multipurpose trees in the two districts

out in Nepal (Thapa *et al.,*1997; Thorne *et al.,* 1999) and Kenya (Roothaert and Franzel, 2001) who reported that farmers' appreciation of fodder trees in both countries extends beyond the conventional researchers' view of nutritive value, biomass production and soil fertility improvement.

Among the stated comparison criteria in Table 2, farmers' preference ranking of MPFTs for biomass production, multi-functionality, life span of the tree, and compatibility to the cropping system showed that local MPFT were superior and more preferred by farmers than the exotic MPFT *S. sesban* and *C. calothyrsus*. The low preference of farmers for exotic MPFT for compatibility with the cropping system, particularly in Sidama district, was associated with competition with coffee and other perennial crops for available soil moisture. Schroth (1999) in his review on belowground interactions in agroforestry systems reported similar observations in Malawi where coffee suffers from competition of the shade trees *Albizia lebbeck* and *Gravillea robusta* for soil water. On the other hand, on parameters of feed value, ease of propagation, growth and re-growth potential *S. sesban* and *C. calothyrsus* were higher than most or comparable to few of the local MPFT. The exceptions were *F. thonningii* and *E. cymosa* that had higher mean scores for ease of establishment, growth and re-growth potential than *S. sesban* and *C. calothyrsus*. This was in agreement with the studies of Roothaert *et al.* (2003) on his comparison of selected local and introduced MPFT preferred by farmers in central Kenya for survival, growth and re-growth potential and feed value. In terms of adaptability, however, farmers' comparison between exotic and local MPFT was not consistent. For instance, in Lay-Armachuho district, the exotic MPFT *S. sesban* was inferior according to farmers' preference ratings when compared to the local MPFT, whereas in Sidama district, *C. calothyrsus* was comparable with those that had the highest score and *S. sesban* was similar with those local MPFT that had low mean score. This could be due to the difference in soil type, fertility status and moisture regimes of each district.

For MPFT species that had similar agronomic characteristics such as *F. thonningii* and *E. cymosa*, and for those species common to both districts such as *S. sesban*, *Acacia spp* and *C. Africana*, farmers' scoring in most of the parameters that were compared were alike. This shows that farmers' evaluation techniques for a particular tree attribute were consistent regardless of the difference in agro-ecology of the two districts.

4.2 Laboratory evaluation of MPFT

One limitation of this study was that the samples taken from MPFT found in each district were not uniform in stage of growth, cutting frequency, soil type and fertility status. Hence, the nutrient composition data for each of MPFT species may not be conclusive. Despite the limitations, the comparison among MPFT found in each district showed impressive differences in nutrient

composition among MPFT. The ranges and individual CP content laboratory results of farmers' preferred MPFT samples from the two districts were nearly similar. One exception was the very high CP content of *S. sesban* in Lay-Armachuho district, which may have been attributed to differences in accessions, soil fertility, harvesting regimen or stage of growth of the plant. Similar disparities in CP content of *S. sesban* grown even in the same locality were also reported due to the variation in accessions (Wigand *et al.,* 1995; Kaitho, 1997; El hassan *et al.,* 2000).

Aside from two species in Lay-Armachuho district and four species in Sidama district, the rest of MPFT crude protein contents in the present study were within the ranges of several reports in the tropics (Kaitho, 1997; Thorne *et al.*, 1999; Walker *et al.,* 1999; Solomon, 2002). Therefore, they could serve as potential protein supplements to enhance the intake and utilization of fibrous crop residues for ruminant diets. This shows that there are indeed possibilities of improving farmers' feed resource base and other farm objectives from local resources available in each district that combine most of farmers' preference criteria which is in agreement with the reports of Roothaert and Franzel (2001) on local fodder trees and shrubs in Kenya.

The NDF, ADF and ADL content of exotic MPFT in both districts was lower than the value of local MPFT compared. However, the fibre content of most MPFT in this study was in agreement and within the range of reports for tree fodder in the tropics (Norton, 1994a; Kaitho, 1997; Solomon, 2002). Multipurpose fodder trees that had NDF and ADF content below 30 and 40% respectively are believed to have high digestibility (Norton, 1994b; Kaitho, 1997; Solomon, 2002). This also holds true for most MPFT found in both districts as their chemical composition falls with in these ranges. Nevertheless, chemical composition alone is an inadequate indicator of nutritive value since the availability of nutrients from fodder trees is variable and their digestibility could also be affected due to anti-nutritional factors (Norton, 1994b). Hence, more information on the NDF, ADF, lignin content and secondary plant compounds along with animal performance trials of these MPFT is needed if a comprehensive assessment of their nutritive value is to be made. Unlike the other nutritional parameters, the ranges of CT contents of MPFT showed wide variations between districts, which could also affect the values of fibre components (NDF ADF, ADL) due to formation of tannin-protein/cell-wall carbohydrate complexes (Reed *et al.,* 1986; Miller and Ehlke, 1996).

4.3 Complementarities between farmers' feed value score and laboratory assessment

The correlation analysis between farmers' feed value score and CP, ADF and Tannin contents of MPFT, particularly in Lay-Armachuho district, showed that there was strong correspondence between farmers' indigenous feed value indicators and the derived laboratory results. The strong relationship of farmers' feed value score and the CP content of MPFT in both districts confirms that farmers through their accumulated indigenous knowledge are capable of differentiating MPFT that had high CP content and are useful in supplementing animal diets. The aggregated and district regression estimates also showed that the CP content of each MPFT could effectively be discriminated by farmers' feed value scoring. This is in agreement with the studies of Thorne *et al.* (1999) in Nepal who reported that significant complementarities were found between farmers' assessment of tree fodder quality and the relative assessments derived from laboratory information. Besides the pair wise comparisons of farmers' feed value score and individual MPFT species fibre contents, the negative correlation coefficients observed in Lay-Armachuho district, although the relationships were not significant ($P>0.05$), further support the importance of farmers' indigenous knowledge to discriminate MPFT that had high and low fibre content. However, in Sidama district, pair wise correspondence of farmers' feed value score with individual tree species laboratory based NDF and ADF results were inconsistent and did not show a trend, which could confirm the complementarities of the two knowledge systems as in Lay-Armachuho district.

4.4 Conclusion

From this study, it was observed that farmers' preference criteria encompass multiple interests beyond the anticipated MPFT development objectives of the actors involved. MPFT dissemination parameters such as nutritive value and significance to soil and water conservation are just some of the many indicators of the preference of farmers for a particular MPFT. Depending upon the agricultural production system of the study areas, factors related to agronomic characteristics, and other farm functions might be equally or more worthy as well. Thus, consideration of farmers' selection criteria through participatory approaches in MPFT research and development programs would help in explicit selection of species that may be compatible with requirements for incorporation of MPFT in to local farming systems.

The availability of local MPFT preferred by farmers to exotics in each district implies better prospects for improving farmers' feed resource base and other

farm objectives from local resources. However, the present scientific knowledge of these species is too limited to support promotion at farm level and some of the species could be unfamiliar to researchers and development professionals. Given the dearth of information, it may be sensible in the short term to focus on a limited number of species considered by farmers to have broader desirable attributes for detailed investigation.

The complementarities between the two knowledge systems would appear encouraging too for a more integrated approach to assessing and selecting fodder tree species that are most suited to their requirements. Integration of the two knowledge systems is of paramount importance because it is neither feasible nor useful to collect, routinely, data on the chemical composition of MPFT because of the range of trees used by farmers and the extent to which their nutritive value varies as a result of seasonal and other bio-physical factors. Nevertheless, a more detailed knowledge of the biological basis of farmers' feed value assessment and the extent to which they can supplement and improve laboratory nutritive value evaluation of fodder quality is needed, which will allow laboratory nutritive evaluations to be concentrated more effectively on farmers' objectives and to deliver results to them in ways they can understand. Hence, we conclude that incorporating locally available resources, farmers' preference criteria and indigenous knowledge at the research inception process is vital to offer a wider dimension of opportunities for the development and acceptability of a technology by farmers.

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Chapter 4

Farmers' feeding practices of *Sesbania sesban* and their perception about supplementation effects on sheep performance

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S. and Van der Zijpp, A.J. Farmers' feeding practices of *Sesbania sesban* and their perception about supplementation effects on sheep performance. Submitted to Animal Feed Science and Technology

Abstract

Sesbania sesban is one of the exotic multipurpose fodder trees introduced in the Ethiopian highlands for livestock feed and soil conservation. Several on-station studies showed that supplementation with Sesbania improved intake and digestibility of basal diet and growth rate of animals. However, there is limited information about how farmers utilize Sesbania and how they perceive the effect of Sesbania supplementation on animal performance. The present study was conducted to assess farmers' feeding practices and their perception about effects of *S. sesban* supplementation on sheep performance in annual (one wheat-based and one teff-based) and perennial (coffee-based) crop-based livestock systems of the Ethiopian Highlands. Data were collected from 98 households by interviews using a structured questionnaire. Farmers had on average 6.9 (±0.26) years of experience using Sesbania as a cut and carry supplementary feed. Sixty nine percent of respondents supplemented during specific seasons and 31.5% when available. Frequency of feeding was either daily or every other day (49% of respondents) and once or twice weekly (51% of respondents). Both frequency and amount of supplementation were significantly different ($P<0.05$) among farming systems. With the currently available Sesbania trees on-farm, farmers could only cover about 30% of the requirements for meat or milk production. Farmers were not aware of about the amount and frequency of offer to cover animal requirements. Most farmers' reported increased birth and body weight gain, earlier onset of puberty and improved pregnancy rate of sheep while some farmers (11.8%) reported reproduction problems such as abortion, delayed puberty and low conception rate due to feeding of Sesbania. The number of Sesbania trees primarily influenced the frequency and amount of supplement, which in turn affected the extent of weight gain, puberty age, and pregnancy rate of ewes. We conclude that the feed value of Sesbania was appreciated across farming systems. However, the feed value fitted better into the wheat-based and the teff-based farming systems than in the coffee-based farming system. Development actors should realise the diversity of farming systems when promoting Sesbania. Sesbania should not be introduced as a tree alone, but should be accompanied by practical training of farmers when and how much to supplement either for maintenance or for optimal production coupled with growing of sufficient Sesbania trees. Furthermore, long-term on-station studies to probe the possible toxic compounds, and on-farm studies to measure actual performance of sheep under farmers' management to exploit the nutritional value of Sesbania.

Key words: *Sesbania sesban*; Farmers' practices; Supplementation; Sheep productivity; Ethiopia.

1 Introduction

Fodder trees and shrubs offer considerable potential for use in mixed crop-livestock production systems to alleviate and complement the low feeding value of crop residues and natural pastures that constrain livestock production in sub-Saharan Africa (Devendra, 1992; Gutteridge and Shelton, 1994). For a large part of the dry season, the forage of fodder trees may maintain a crude protein content of more than 9%. As a result, animals with access to fodder trees perform better than those kept on natural pasture in milk yield, weight gain, reproductive performances and survival rates (Norton, 1994b; Mohammed-Saleem and de Leeuw, 1994; Elbasha *et al.,* 1999).

S. sesban is one of the exotic multipurpose fodder tree (EMPFT) species that have been introduced in the Ethiopian highlands to alleviate feed shortages, maintain soil fertility and prevent land degradation. In a survey conducted in Ethiopia (Mekoya, unpublished) it was observed that 30 out of 32 governmental and non-governmental organizations engaged in agricultural development activities were promoting various accessions of *S. sesban* to the farming community. The most widely distributed commercial cultivars to smallholder farmers from the International Livestock Research Institute (ILRI) collections were accession 15036, 15019, and 10865 (Jean Hanson, personal communication). They were selected on the basis of good agronomic performance in terms of adaptability, vigour of growth, dry season survival, growth response to cutting, biomass yield, and related factors.

Several Sesbania species are reported to be outstanding livestock feeds both as fodder and hay (Onim and Dzowela, 1988). Nitrogen contents of Sesbania forage are quite high compared to other forage legumes. The crude protein (CP) content of the genus Sesbania ranges from 18.8% to 32% with a mean of 27.1%. The mean crude fibre content is low (13%) and the mean calcium to phosphorus ratio is high (3:8) (Evans and Rotar, 1987; Onim and Dzowela, 1988; Smith, 1992). In feeding studies conducted at ILRI in Ethiopia and in other sub-Saharan countries, body growth rate of animals receiving supplementation of straw diets with *S. sesban* was by far superior to that of animals supplemented with other legumes (Nsahlai *et al.,* 1995; Woodward and Reed, 1997; Osuji and Odenyo, 1997; Kaitho *et al.,* 1998; Solomon, 2002). In a recent on-farm survey study in the Ethiopian highlands (Mekoya *et al.,* 2006) 88.8% of the respondents used to grow and feed S. sesban, and appreciated its feed value. However, some experiments have shown that prolonged and uninterrupted intake of fodder trees such as *S. sesban* may have a negative effect on live weight gain and

reproductive performance of small ruminants (Kaitho *et al.,* 1998; Woldemeskel *et al.,* 2001; Solomon, 2002). Although no documented knowledge is available, farmers that fed Sesbania also reported reproduction problems in small ruminants which might substantiate these experimental results (Mekoya, personal observation).

Despite the excellent nutritional attributes of *S. sesban* (including the reported drawbacks) that has spurred interest by research and development organizations for a large-scale promotion in to the farming community, there is limited information on how farmers utilize this tree and how they perceive the effect of Sesbania supplementation on animal productivity. We hypothesize that the importance and utilization of *S. sesban* in smallholder farmers depends on the farming system. Hence, the present study was carried out to gather insights into the feeding practices of farmers' and their perceptions of the effects of *S. sesban* supplementation on production and reproductive performance of sheep in three farming systems.

2 Materials and methods

2.1 Description of the study areas and farming systems

This study was conducted from August to December 2004, in Lay-Armachuho and Debay-Tilatgen districts of Amhara region, in the north-western highlands of Ethiopia, and in Sidama district of Southern region in the southern highlands of Ethiopia. A detailed description of the agro-ecology as well as a description of the predominant farming system of the study districts is presented in Table 1.

In Lay-Armachuho and Debay-Tilatgen districts, 98% of crop land was allocated for annual crops, while in Sidama district, 75% of crop land was used to grow perennial crops. Livestock (mainly cattle, sheep and goats) are an integral component of the farming system in all districts. An extensive livestock production system (free grazing) dominates Lay-Armachuho and Debay-Tilatgen districts while in Sidama district tethering is the common practice. In Lay-Armachuho and Sidama districts, small scale dairy production using crossbreds was introduced by development organizations and is becoming a source of income whereas in Debay-Tilatgen district cattle are mainly used for draught purposes and sheep are the main source of income for the household. Pasture and hay from communal and private grazing land and crop residues make up over 60% of feed resource in Lay-Armachuho and Debay-Tilatgen districts. In Sidama district, permanent crop leaves and multipurpose fodder trees (mainly local) comprise about 40% of the feed resource base.

Table 1 Farming system description of the study districts in the Ethiopian highlands

Descriptions	Districts		
	Lay-Armachuho	**Debay-Tilatgen**	**Sidama**
Altitude (m.a.s.l.)	2200-2400	2300-2600	1800-2000
Rainfall (mm)	1100	1200	1320
Rainfall pattern	Mono-modal	Mono-modal	Bi-modal
Rainy seasons	June-Sept.	June-Sept.	March-April, June-Sept.
Vegetation cover	Poor	Medium	Good
Production system	Wheat-based-livestock system	Teff-based-livestock system	Coffee-based livestock system
Land use			
Avg land holding (ha)	1.64	1.38	1.06
Avg crop land (ha)	1.36	1.31	0.94
Avg grazing land (ha)	0.27	0.06	0.12
Area annual crops (%)	97.8	99.4	25.5
Major crops	Duragn*, Wheat, Faba-been, Barley, Teff	Teff (*E. tef)*, Wheat, Faba-been, Rough pea	Coffee, Enset *(E. entricosum)*, Maize, Sugar cane
Herd size (TLU**)	4.1	3.4	2.7
Small ruminants (TLU)	0.8	0.9	0.4
Major livestock (ruminants)	Dairy (crossbreds), draught (local cattle), sheep, goats	Draught (local cattle), sheep	Dairy (crossbreds + local), sheep, goats
Major feed resources	Communal and private grazing, crop residues	Communal and private grazing, crop residues	Perennial crop leaves, local fodder trees
Feed shortage seasons	February to June	January to August	February to June
Family size (n)	7.1	5.7	7.9

* Duragn is a crop type where barley and wheat are grown mixed on the same land; ;**TLU = tropical livestock unit is a hypothetical animal of 250 kg live weight, used to bring all animal types under a common denominator as applied by Gryseels (1988)

In the study districts, Sesbania was introduced by development organizations since the 1990s mainly for animal feed and soil conservation but in Lay-Armachuho and Sidama districts it was also associated with the introduction of crossbred dairy cattle.

2.2 Survey methodology, data collection and analysis

From the three districts and twelve peasant associations (the smallest administrative unit within a district) included in the study, 98 adopters (farmers' currently growing and feeding *S. sesban*) were selected randomly. The distribution of adopters was 31, 34 and 33 for Lay-Armachuho, Debay-Tilatgen and Sidama districts in that order.

Data were collected using a structured questionnaire about length of feeding experience, seasons, frequency, amount, systems of feeding and farmers' perception of the Sesbania supplementation effect on weight gain, reproductive performance and adverse effects encountered, if any, when feeding *S. sesban*. Ten farmers from each district were asked to show the armful of Sesbania they offer at a given feeding time. After the edible parts (leaves and soft twigs) were selected and air dried separately, samples from each farmer were taken to the laboratory for dry matter determination. The samples were oven dried for 16 h at 105^{o}C and the average amount of offer of edible Sesbania parts was calculated. Depending on the nature of data, chi-square tests, ANOVA and logistic regression were employed to compare farming systems (districts) and relationships between parameters. Data were analyzed using SPSS (2002) and SAS (2000) statistical packages.

3 Results

3.1 Farmers' experiences using *S. sesban* as feed

The experience of farmers using *S. sesban* as a supplementary feed ranged from 2 to 10 years. A significant difference ($P<0.05$) was observed in the length of feeding experience of farmers among districts (Table 2). Farmers in Debay-Tilatgen district had more years experience than those in Lay-Armachuho and Sidama districts.

3.2 Farmers' feeding practices of *S. sesban*

3.2.1 Season, frequency and amount of feeding S. sesban to animals

The majority of farmers in Lay-Armachuho (87.1% of respondents) and Debay-Tilatgen (85.3% of respondents) supplemented Sesbania during feed shortage seasons whereas most farmers in Sidama (66.7% of respondents) did not follow

Table 2 Farmers' experience (years) of utilizing *S. sesban* as feed

Variables	Experience of feeding Sesbania (years)	
	Growing experience	Feeding experience
Districts*		
Lay-Armachuho (wheat-based LS)	6.8[b]	6.2[b]
Debay-Tilatgen (teff-based LS)	8.1[a]	7.9[a]
Sidama (coffee-based LS)	6.9[b]	6.5[b]
Overall (n=98)	7.2±0.22	6.9±0.26

Means in a column with different superscripts were significantly different (P<0.05); LS=Livestock system

specific seasons and supplemented when there was sufficient herbage from Sesbania available on-farm. The average length of feeding was 5.7 months per year but differed among districts (P<0.05). Farmers in Lay-Armachuho and Debay-Tilatgen districts supplemented Sesbania for over 6 months compared to 3.7 months yearly in Sidama (Table 3).

Forty nine percent of respondents supplemented their animals either daily or every other day, and 51% of respondents once or twice in a week. The frequency of supplementation of Sesbania differed significantly (P<0.0001) among districts (Table 3). A higher proportion of farmers in Debay-Tilatgen and Lay-Armachuho districts fed Sesbania more frequently (daily or every other day) than of farmers in Sidama district (61.3 and 64.7% vs. 21.2% of respondents).

Farmers offered usually one to two armful cuttings of Sesbania in a feeding. The average amount of Sesbania offered was 1.4±0.08 kg dry matter (n=30) and ranged between 1.0 kg and 2.4 kg. There was a significant difference (P<0.05) among districts in the amount of Sesbania given as supplement. Per feeding, farmers in Lay-Armachuho and Debay-Tilatgen districts supplemented more Sesbania than those in Sidama district (Table 3).

Farmers' priority rank among animal species for Sesbania supplementation is shown in Table 3. The feeding priority among animal species for *S. sesban* differed significantly (P<0.05) between districts. Farmers in Lay-Armachuho and Sidama districts gave priority to cattle whereas farmers in Debay-Tilatgen district gave priority to sheep. In all districts, farmers gave lowest priority to goats for Sesbania supplementation. Within the same species of animals, farmers gave priority to lactating ewes or cows followed by oxen and younger animals for feeding Sesbania.

Table 3 Season, frequency, amount and animal feeding priority of *S. sesban* in the study districts (n=98)

Districts	Feeding seasons (% resp.)	Length of feeding (months)	Feeding frequency (%)		Feeding amount (kg/ feeding)	Feeding priority (mean score)		
			Daily*	Weekly*		Cattle	Sheep	Goat
Armachuho	Jan-June (87.1)	6.3[a]	61.3	38.7	1.63[a]	2.9[x]	2.1[y]	1.2[z]
Debay	Dec-Aug (85.3)	7.9[a]	64.7	35.3	1.70[a]	2.3[y]	2.7[x]	1.1[z]
Sidama	Not specific (66.7)	3.7[b]	21.2	78.8	0.98[b]	2.8[x]	1.8[y]	1.3[z]
Overall		5.7±0.41	49.0	51.0	1.4±0.08	2.7	2.2	1.2

* P=0.0001 (Chi square probabilities); Priority ranking was done in a 1 to 3 scale where 1 meant low and 3 meant high; Means in a column (a, b) and row (x, y, z) with different superscripts are significant at P<0.

The number of Sesbania trees was positively (P<0.05) correlated with the length of feeding period and the amount of supplement. Herd size and length of feeding were negatively correlated (P <0.05). The correlation coefficients of number of Sesbania trees owned with the amount of offer and length of feeding period were r=0.76 (P=0.0001), r=0.68 (P=0.0001) and the correlation coefficient of herd size with the amount of offer was r= -0.20 (P=0.043). Farmers that had higher numbers of Sesbania trees supplemented more for a longer period whereas farmers that had a larger herd size supplemented Sesbania for short periods and vice versa.

3.2.2 Forms of feeding S. sesban to animals

Farmers in the study districts usually follow two forms of feeding. About 44.3% of respondents supplemented freshly cut and 55.7% of respondents wilted Sesbania prior to feeding. Forms of feeding Sesbania differed significantly (P<0.05) among districts (Table 4). A higher proportion of farmers (70.3%) in Debay-Tilatgen district predominantly fed freshly cut Sesbania than of farmers in Lay-Armachuho and Sidama districts. Farmers' reasons for feeding wilted Sesbania were to remove insects or fungi that may cause bloating or diarrhoea on animals when ingested, and to allow more retention time in the rumen. On the other hand, increasing the intake of Sesbania and crop residues, and to feed according to animal preference were farmers' common explanations for feeding freshly cut Sesbania.

Respondents in the study districts practiced mixed (feeding of the leaves and edible soft twigs detached from the harvested branches after mixing with crop

Table 4 Forms of feeding, feeding modes and basal feeds used to mix with Sesbania (% respondents) in the study districts

Districts	Forms of feeding		Feeding modes		Mixture feed types		
	Wilted	Freshly cut	Mixed feeding	Sole feeding	Straws	Hay	Perennial crop leaves
Lay-Armachuho	63.9	36.1	71.0	29.0	58.5	41.5	0
Debay-Tilatgen	29.7	70.3	44.1	55.9	88.9	11.1	0
Sidama	69.4	30.6	57.6	42.4	13.3	60.0	26.7
P	0.00		0.09			0.00	
Overall	55.7	44.3	57.1	42.9	45.2	41.6	9.0

P values are chi-square probabilities

residues, hay or any other feed) and sole (the entire pollard of Sesbania offered separately and animals are allowed to lop) feeding modes of the supplement. Depending on the major feed resources available in each district, Sesbania served as supplement mixed with crop residues, hay, and perennial crop leaves. Hay and perennial crop leaves (86.7% of respondents) in Sidama and crop residues in Debay-Tilatgen district (88.9% of respondents) were the major basal feeds mixed and fed with Sesbania. In Lay-Armachuho district, on the other hand, farmers used to mix both crop residues (58.5% of respondents) and hay (41.5% of respondents) with Sesbania when feeding their animals (Table 4). In the annual crop-based livestock systems (Lay-Armachuho and Debay-Tilatgen districts) animals are supplemented when they are back home after grazing. In the coffee-based livestock system (Sidama district) where animals are fed tethered Sesbania was supplemented any time of the day.

3.3 Farmers' perceptions about effects of feeding *S. sesban* on sheep performance

3.3.1 Sheep body weight gain and lambs birth weight

Farmers in all districts had a similar perception about the effects of feeding Sesbania on body weight gain of sheep and birth weight of lambs born from ewes fed Sesbania during pregnancy. Improved birth weight of lambs and body weight gain of sheep were farmers' observations while supplementing Sesbania. Only 7.1% of farmers did not see any change in birth or in body weight (Table 5). Among the respondents who had a positive perception about the supplementation effects of Sesbania, 73.6% and 68.1% of the farmers noticed much increment whereas 26.4% and 31.9% of the respondents experienced little increment in body weight gain and birth weight of lambs, respectively. Farmers response differed significantly ($P<0.05$) among districts with regard to the extent of weight change in lambs birth weight. In Debay-Tilatgen district, relatively more farmers (87.5%) observed much birth weight increment in lambs

Table 5 Farmers' response (% of respondents) about the feeding effects of *S. sesban* on body weight gain and birth weight of sheep

Districts	Body/birth weight change	Extent of body weight increment		Extent of birth weight increment	
	Farmers responding "yes"	Little	Much	Little	Much
Lay-Armachuho	96.8	33.3	66.7	43.3	56.7
Debay-Tilatgen	94.1	15.6	84.4	12.5	87.5
Sidama	87.9	31.0	69.0	41.4	58.6
P	0.36	0.23		0.01	
Overall	92.9	26.4	73.6	31.9	68.1

P values are chi-square probabilities

born from ewes supplemented with Sesbania during pregnancy compared to farmers in Lay-Armachuho (56.7%) and Sidama (58.6%) (Table 5).

3.3.2 On-set of puberty, oestrus cycle and pregnancy rate of sheep

Most respondents (86.7%) interviewed in the present study could recall the age at which ewe and ram lambs attain puberty. Among farmers who had the knowledge of puberty age, 63.5% noticed an effect of feeding Sesbania on puberty age of sheep; there was no significant difference ($P>0.05$) among districts. The types of effects described by farmers were early (85.2% of respondents) or delayed (14.8% of respondents) onset of puberty of over three months either before or after the anticipated time. The number of farmers that reported delayed onset of puberty was higher in Sidama district than in the two other districts (Table 6).

Most respondents (69.4%) had knowledge about the duration of ewes' oestrus cycle. The oestrus cycle of ewes as mentioned by farmers ranged from 15 to 28 days. About 11.8% of respondents recognized either irregular cycling days or a longer period of anoestrus in ewes as a result of feeding Sesbania, and the majority were from Sidama district. From all districts, about 45.9% of respondents observed increased pregnancy rate for ewes supplemented with Sesbania and 54.1% of respondents did not see changes (Table 6).

The response of farmers for the effects of feeding Sesbania on ewes pregnancy rate was significantly different ($P<0.05$) between districts. Most farmers (71.0% of respondents) in Lay-Armachuho district observed increased pregnancy rates whereas 55.9% and 75.8% of farmers in Debay-Tilatgen and Sidama districts did not recognize improvements in pregnancy rate of ewes. Most farmers (93%)

Table 6 Farmers' response about the feeding effects of *S. sesban* on puberty age, oestrus cycle, pregnancy rate of ewes and libido of rams (% respondents) (n=98)

Districts	Effect on puberty age	Type of effects (n=54)		Effect on oestr cycle (n=68)	Effect on pregnancy rate	Effect on fertility of rams
	Prop. resp. "yes"	Delayed age	Early age	Prop. resp. "yes"	Prop. resp. "improv."	Prop. resp. "improv."
Lay-Armachuho	71.4	5.0	95.0	4.5	71.0	58.1
Debay-Tilatgen	72.4	4.8	95.2	3.8	44.1	32.4
Sidama	46.4	46.2	53.8	30.0	24.2	0
P	0.07	0.00		0.01	0.00	<0.00
Overall	63.5	14.8	85.2	11.8	45.9	29.6

P values are chi-square probabilities

were not able to precisely estimate the proportion of ewes that showed increased or unchanged pregnancy rates since they did not recall the actual number of ewes that were pregnant**.** Moreover, 29.6% of respondents reported improved libido and fertility of rams due to feeding of Sesbania (Table 6).

3.3.3. Relationship of frequency and amount of offer with body weight gain, onset of puberty and pregnancy rate of ewes

Table 7 shows the relationship of farmers' perception of the effects of frequency and amount of Sesbania supplementation on weight gain of sheep, onset of puberty and pregnancy rate of ewes. The extent of weight gain observed due to feeding of Sesbania was positively related (P<0.05) with the amount of supplement. Farmers that supplemented higher amounts of Sesbania observed higher body weight gain in sheep and higher birth weight in lambs than those that supplemented the lower amount . On the other hand, both frequency and

Table 7 Maximum likelihood estimates for the effects of frequency and amount of offer on weight gain, onset of puberty and pregnancy rate of sheep

Parameter	Body weight gain		Onset of puberty		Pregnancy rate	
	Estimate	Pr> X2	Estimate	Pr> X2	Estimate	Pr> X2
Intercept	0.494	0.599	-4.430	<0.0001	-3.722	0.0004
Feeding frequency	0.872	0.273	1.493	0.002	0.827	0.045
Feeding amount	1.469	0.012	0.984	0.011	0.704	0.026

Dependent variables for body weight gain: Y1 = lower body weight gain and Y2 = higher body weight gain (0 = low, 1= high); For the onset of puberty: Y1 = no change and Y2= improved onset of puberty (0= no, 1=yes); for pregnancy rate: Y1 =no change and Y2 = improved pregnancy rate(0=no, 1=Yes); The reference category for birth weight, on-set of puberty and pregnancy rate were the higher levels (high weight gain, improved onset of puberty and pregnancy rate)

amount of supplement affected positively (P<0.05) puberty age and pregnancy rate of ewes. Farmers that supplemented higher amount of Sesbania more frequently (daily or every other day) observed onset of puberty at younger age in ewe- and ram-lambs and increased pregnancy rate in ewes than those that supplemented a lower amount of Sesbania less frequently (once or twice in a week).

3.3.4 Adverse effects of feeding S. sesban on sheep performance

Among the respondents, 12 farmers encountered palatability problems while feeding Sesbania (Table 8). The number of farmers in Lay-Armachuho and Sidama districts that reported low palatability of Sesbania was higher (each 5 farmers) than the number of farmers in Debay-Tilatgen district (2 farmers). However, farmers have developed strategies to improve palatability of Sesbania by animals such as mixed feeding, gradual adaptation, wilting, and addition of or soaking in salt.

A few farmers (n=11) reported suspected adverse effects such as abortion, delayed onset of puberty and low conception rate in ewes, and birth defects and paralysis in newborn lambs due to feeding of Sesbania. Nevertheless, farmers were not certain whether the problems they mentioned were related to feeding of Sesbania or to any other cause. Among eight farmers that reported reproduction problems (delayed onset of puberty and low conception rate), four (all from Sidama district) attempted to avoid the incidence through reducing the amount and frequency of Sesbania offer.

Table 8 Problems mentioned by farmers related to Sesbania feeding (number of respondents)

Sesbania related problems	Districts			
	Lay-Armachuho (n=31)	Debay-Tilatgen (n=34)	Sidama (n=33)	Total (n=98)
Low palatability	5	2	5	12
Abortion	0	1	0	1
Birth defects	0	1	0	1
Delayed puberty age / low conception rate	1	1	6	8
Paralysis	0	1	0	1

4 Discussion

4.1 Experiences of feeding Sesbania and animal feeding priority

Farmers need to have sufficient length of experience of feeding Sesbania to observe improvement in animal performance. The years (on average around 7

years) of feeding experience recorded in the present study revealed that farmers in each district had enough time to evaluate the feed value of Sesbania. The variation among districts in length of growing and feeding experience of Sesbania could be ascribed to farmers' exposure to development interventions.
The difference in supplementation priority among animal species among districts could be attributed to the economic importance farmers attach to each animal species and the need for cash income in each farming system. For instance in Lay-Armachuho and Sidama districts, due to the introduction of crossbred dairy cows, farmers tend to give first priority to cattle whereas in Debay-Tilatgen district sheep serve as an immediate source of family income and was given the priority for supplementation. The priority given to suckling animals and younger ages shows the farmers' awareness of different physiological nutrient requirements for different age groups. The least priority given to goats by farmers could be associated to their better scavenging abilities and access to browses if compared to the other species.

4.2 Season, frequency, amount and feeding systems of Sesbania

The difference in the duration of feeding seasons among districts could be attributed to the number of Sesbania trees available on-farm, extent of feed scarcity and importance of crop residues as livestock feed in each farming system. Farmers in Lay-Armachuho district (87%) fed Sesbania specifically during the dry season to supplement crop residues when other feed resources are deficient both in quantity and quality. In Debay-Tilatgen district due to the extensive utilization of land for crop production, grazing lands and other alternative feed resources are scarce even during the rainy season (June-September). Animals rely on crop residues most of the year and cannot fulfil maintenance level feed requirements without supplementation. Consequently, farmers (65% of respondents) used to feed Sesbania during the dry as well as the rainy seasons. On the other hand, the majority of farmers (67%) in Sidama district did not follow specific seasons to supplement Sesbania, which may be associated primarily to the few Sesbania trees they had, a lower contribution of crop residues as a feed resource and the availability of alternative fodder trees as compared to Lay-Armachuho and Debay-Tilatgen districts. Adoption constraints such as low biomass, low multifunctionality, and land shortage were reported by Mekoya *et al.* (2006). Yet, in each district, the strategic utilization of Sesbania to supplement the nitrogen deficiency and improve the utilization of straw diets during feed shortage seasons, in Lay-Armachuho and Debay-Tilatgen districts, in contrast to farmers in Sidama district shows that

Sesbania fits well to these farming systems where crop residues serve as the major feed resources for ruminant livestock.

The difference in the length of feeding period among farmers as a function of the number of Sesbania trees may be associated with the wealth status of farmers. Mekoya *et al.* (2006) assumed that land size and herd size determined the wealth status of farmers, which in turn influenced the number of trees available on-farm. Rich farmers had larger land (>2 ha cropping and grazing land) and herd size (> 4.0 TLU) and this was associated with more Sesbania trees (>500 trees) per farm. The larger land size of rich farmers enables them to have more grazing area, produce more hay, and may afford the access to alternative feed resources to support their animals other than the dry season. Hence, the choice of farmers with more trees (rich farmers) and herd size for dry season (January to June) supplementation could be to strategically utilize Sesbania during critical periods probably as a production supplement. Alternatively, poor farmers have a small area of land (≤1 ha cropping and grazing), lower herd size (≤1.6 TLU) and a lower number of Sesbania trees (≤ 250 trees) coupled with limited opportunity to alternative feed resources. As a result, poor farmers could be more dependent on crop residues and would prefer to feed Sesbania to their animals as a maintenance supplement for the large part of the year. This shows that for poor farmers that have marginal access to resources (land and capital) Sesbania could be a useful and affordable alternative source of protein to avert animals from starvation while also fulfilling to some extent other farm objectives. Our arguments on the importance of Sesbania and other fodder trees for poor farmers agrees with the reports of several studies that recommend multipurpose fodder trees for resource poor farmers (Devendra, 1992; Norton 1994a; Alemayehu, 1997; Sawe *et al.*, 1998; Franzel and Scherr, 2002) in the tropics.

Similarly, the frequency and amount of Sesbania supplementation in the present study was a function of the number of trees available in the back-yard of a household, and the extent of utilization of straw diets in each district. For instance, farmers in Sidama district had a low number of Sesbania trees (on average 210 trees household^{-1}) and the contribution of crop residues from annual crops, because of the perennial crop-based farming system, was also lower compared to other districts. Farmers depended largely on hay, perennial crop leaves and local fodder trees to meet the feed requirement of their animals. Thus, they supplemented Sesbania less frequently (once or twice in a week) and in a lower amount (0.98 kg of dry matter) per feeding. In addition, agronomic

problems, land size and the availability of alternative local fodder trees in Sidama district (Mekoya *et al.,* 2006) could as well constrain farmers' motivation to grow more trees to supplement more frequently and increase the amount of offer. In Lay-Armachuho and Debay-Tilatgen districts, on the other hand, due to the higher number of Sesbania trees available on-farm (on average over 500 trees household^{-1}) and the contribution of crop residues to over 60% of the feed resource base for ruminant livestock, farmers supplemented a higher mass of Sesbania (over 1.6 kg) more frequently (daily or ever other day), which shows also the significance of Sesbania in these farming systems.

Besides improving other husbandry practices, farmers' awareness of the amount of Sesbania they should supplement for an optimum level of productivity is vital to realize the feeding effects of Sesbania. In the present study, the majority of farmers (87%) were aware of the amount they offer at a given feeding frequency. Nevertheless, farmers in all districts did not have training/awareness on the optimum number of Sesbania trees they ought to have and a rough estimate of how much to supplement either to keep their animals at maintenance level or for an optimal production (weight gain, milk production and reproduction). Devendra (1988) generally recommended that, when used as supplements, the optimum dietary level of fodder trees for an optimal output should be 30 to 45% of the ration dry matter or 0.75 to 1.125 kg 100 kg^{-1} body weight day^{-1}. The average livestock holding in the study districts was 3.65 TLU. Assuming that 30% of the ration (0.75 kg of supplement 100 kg^{-1} body weight) as the optimum level and with no differential treatment among ruminant species, the average amount of supplementary Sesbania required for the whole ruminant livestock was 5.6 kg day^{-1} for a household. However, the amount offered by farmers was 1.43 kg day^{-1} with a feed deficit of 4.2 kg day^{-1} to attain the recommended level. The recommended amount of supplement required for production as compared to the average number of Sesbania trees available per household would reveal that the contribution of Sesbania to fulfil protein requirements was low and could only cover the supplementary protein demand for about three months in a year. The observed wide supplementary feed deficit suggests that it is unlikely for farmers to fully exploit the nutritional value of Sesbania and envisage improvement in production. Growing more trees to cover the recommended requirements for production, on the other hand, may not be a feasible option particularly for farmers constrained with land, family labour and market access. Thus, with the available number of trees on-farm, farmers with limited resources may supplement Sesbania only during critical feed shortage periods or implement differential feeding within the herd

for strategic gains or production. Moreover, cutting frequency and biomass (edible parts) yield of Sesbania could be variable as influenced by moisture regimen and cutting stage (Heering *et al.,* 1995; Mekoya *et al.,* 2006) which consequently affect the amount and length of the feeding period. Encouraging farmers to harvest Sesbania during seasons where they can get the maximum herbage and DM yield, and store it as hay for later use would be an option to reduce the gap. This type of strategy could to help produce a larger amount of herbage annually and enable farmers to supplement more animals for longer periods.

Farmers' lack of awareness on appropriate feeding practices and the gap in availability and demand for supplementation as well shows the weak extension service delivery system to demonstrate the suitable utilization techniques. Mohammed-Saleem and Von Kaufmann (1995) and Franzel and Scherr (2002) also reported lack of and/or incomplete extension information as constraints to adoption of multipurpose fodder trees in Africa where farmers are unaware of the fodder technology utilization techniques.

Farmers feeding forms of Sesbania (freshly cut or wilted) could be attributed to individual differences in choosing one of the feeding modes. However, the reasons mentioned by farmers (removal of insects and fungi and longer retention in the gut) that fed wilted Sesbania may show their experience on health problems associated with feeding the fresh cut, and their knowledge of how to protect the nutrients in Sesbania from rapid fermentation in the rumen. Farmers' interpretation with regard to the rapid fermentation of Sesbania when the fresh cut is fed to animals agrees with the on-station studies of Nsahlai *et al.* (1998) and Wiegand *et al. (*1996) who reported that freshly cut *S. sesban* undergoes rapid rumen fermentation associated with high urinary nitrogen losses when eaten by sheep. The difference in the type of basal feeds used to be mixed with Sesbania observed among districts was associated with the types of crops grown in each farming system and individual differences among farmers on the size of grazing land they had for hay collection.

4.3 Farmers perception of feeding Sesbania on productivity of sheep

4.3.1 Body weight gain and lambs birth weight

Irrespective of the farming system and individual management difference that exist, the high proportion of respondents with similar positive perception about effects of Sesbania supplementation on body weight gain and birth weight of lambs would imply that the feeding value of Sesbania for sheep was equally

appreciated by farmers across districts. Farmers' observation agreed with the findings of Reed *et al. (*1990), Umunna *et al. (*1995), Wiegand *et al. (*1996), Nsahlai and Umunna (1996), Kaitho *et al. (*1998) and Solomon (2002) who reported increased live weight of sheep and goats fed straw diets and supplemented with graded levels of multipurpose fodder trees due to a substantial increase of basal feed intake and digestibility. The implications of the agreements between farmers response and the reported findings imply that in the study districts, especially in the annual crop-livestock systems where crop residues contribute to over 60% of the feed resource base and are still the major basal feeds for ruminant livestock, Sesbania could be used as potential protein supplement to improve reproductive rate and marketable weights in sheep. The difference between districts on the extent of increment achieved in body weight of sheep and birth weight of lambs due to feeding of Sesbania could be attributed to the extent of supplementation (frequency and amount), which was a function of the number of Sesbania trees available on-farm in each district.

4.3.2 Puberty age, oestrus and pregnancy rate

In spite of the reproductive problems (delayed puberty age, irregularities in oestrus cycle and low conception rate) reported by farmers, the positive perception of most respondents about the reproductive performance of sheep (early onset of puberty, increased pregnancy rate and fertility of rams) confirms the potential feed value of Sesbania as a protein supplement to low quality feeds for subsistence farmers. On-station supplementation studies conducted on *S. sesban* and *L. leucocephala* on the reproductive performance of sheep (Kaitho *et al.,* 1998; Negussie *et al*., 2000; Akingbade *et al.,* 2001; Solomon, 2002) corroborate the importance of multipurpose fodder trees to improve reproductive efficiency. However, the potential production improvement will only be achieved when sheep will be supplemented the recommended level (25-30% of the ration on dry matter basis) of *S. sesban* (Kaitho *et al.,* 1998; Solomon, 2002). Analogous to weight gain and birth weight, the positive perception of farmers about the effects of Sesbania supplementation on puberty age and pregnancy rate of ewes were associated with the amount of offer and frequency of feeding. Farmers that supplemented their sheep higher amounts of Sesbania more frequently observed onset of puberty earlier than three months before the anticipated age (except few farmers who reported a delayed onset of puberty) and higher pregnancy rates. Conversely, farmers that supplemented higher amount of Sesbania but less frequently or a lower amount of Sesbania more frequently were unlikely to observe improvement in puberty age and

pregnancy rates of sheep. Hence, the present study shows that the synergy of the optimum amount and frequency of supplementation are quite indispensable in order to attain better performance and acknowledge the role of Sesbania as a protein supplement in the farming system.

4.4 Palatability and suspected reproduction problems of Sesbania feeding

Palatability is a complex phenomenon influenced by animal, plant and environmental factors. It is also related to choices and alternatives an animal has for feeding and adaptation to a particular feed type. The higher proportion of farmers who reported palatability problems in Lay-Armachuho and Sidama districts could be attributed to the availability and adaptation to alternative local fodder trees. When animals had the chance of selection, they tend to consume what they are accustomed to earlier or which gives relish condition by sensory impulse, and the problem of palatability could be observed until animals adapt to the new feed type. While in areas with no alternatives, initial reluctance of animals may gradually fade and improve their intake which was noticed from farmers' response in Debay-Tilatgen district.

The higher number of farmers from Sidama district that encountered delayed onset of puberty, irregular oestrus cycles and low conception rate may not be necessarily associated to feeding of Sesbania. As many farmers in this district use different types of multipurpose fodder trees to supplement their animals, the problem could be confounded with other multipurpose fodder trees as well since they may have anti-nutritional factors which could adversely affect reproduction. Moreover, the abortion and abnormal births in Debay-Tilatgen district could be caused by many management factors other than feeding Sesbania. Thus, it is difficult to presume from farmers' observation and the extent of daily offer (since most farmers supplement below requirement) that the reported reproductive problems could exclusively be associated to feeding of Sesbania. However, the distrust of farmers in both districts deserves further studies.

4.5 Conclusion

- The positive perception of farmers about the feed value of *S. sesban*, when used as supplement, would appear to confirm its value for improving the utilization of fibrous feeds and alleviate protein deficiency during the dry season.

- From the present study it can be deduced that *S. sesban* fit better in the cereal-based livestock production systems than in the coffee-based production systems. Hence, more development focus to the system where it suits would be more fruitful.

- The majority of farmers have insufficient number of trees to supplement according to production requirements. Among other factors, land size will influence farmers' willingness to grow more trees. Hence, for farmer where land is a constraint maintaining productive animals or differential feeding among animal species and physiological stages corresponding to the available herbage would be an option.

- The transfer of fodder technologies lacked complete information particularly on appropriate feeding techniques. Thus, practical training of farmers when to feed and how much to feed either for maintenance or for different production objectives is a paramount importance to realize the feed value.

- Despite the appreciation to improve animal productivity, farmers' scepticism of Sesbania about reproductive problems warrant further long-term feeding experimentation under controlled environment to probe the possible toxic or inhibitory compounds which affect reproduction.

- Continue on-farm research with farmers to assess the feed value of Sesbania and other feed inputs and to understand the actual growth rate and reproductive performance of sheep under farmers' management conditions.

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Chapter 5

Effect of supplementation of *Sesbania sesban* on post-weaning growth performance and sexual development of Menz sheep (Ethiopia)

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S., Tamminga, S., Tegegne, A. and Van der Zijpp, A.J. Effect of supplementation of *Sesbania sesban* on post-weaning growth performance and sexual development of Menz sheep (Ethiopia). Submitted to Livestock Science.

Abstract

Most supplementation experiments with fodder trees including *S. sesban* have been of short duration and focused mainly on feed intake and growth rate. Long-term studies regarding the effects of feeding *S. sesban* on reproductive performance of small ruminants particularly in both sexes are scanty. We conducted a series of experiments to assess the long-term effects of supplementation with *S. sesban* on sheep performance fed a basal diet of 70% teff straw and 30% supplement. This study was part of a successive series of experiments to investigate the effects of *S. sesban* on feed intake, post-weaning growth rate, and onset of puberty of male and female lambs. Sixty weaned female and 60 male Ethiopian highland sheep in weight and age ranging between 7.2-11.8 kg and 4-5 months respectively were evaluated for a period of 9 months in a Completely Randomized Design with factorial arrangement of two sex (male and female) and three levels of *S. sesban* (0, 47.5 and 95% of supplementary protein provided by *S. sesban* and the rest being provided by a mix of concentrates). Between sex groups male sheep, and among treatments animals fed with 47.5 and 95% Sesbania in the supplement had significantly ($P<0.05$) higher basal feed, supplement, and total feed intake than those supplemented with concentrate alone. Supplementation with Sesbania resulted in significantly ($P<0.05$) higher DM, OM and N digestibility than supplementation with sole concentrates. Incremental levels of Sesbania enhanced teff straw intake by 14 and 21% compared to sole concentrate supplements. Average live weight gain was 31(±6) g^{-d}. Supplementation with 95% Sesbania elicited higher daily weight gain than those fed with 47.5% Sesbania and sole concentrates over the growth period. The onset of puberty was at 265 (± 36) and 342 (± 45) days of age and puberty weight was 15.2 and 14.6 kg for ram and ewe-lambs in that order. Ram-lambs fed with 47.5% and 95% Sesbania in the supplement reached puberty by 34 and 21 days earlier and were 1.4 kg heavier ($P<0.05$) than those fed concentrates. Ewe-lambs supplemented with 47.5 and 95% Sesbania were faster ($P<0.05$) to attain puberty by 43 and 37 days than those supplemented with sole concentrate but without significant variation ($P>0.05$) in body weight at first behavioural oestrus. The average scrotum circumference gain until the onset of puberty was 0.5 (±0.1) mm^{-d}. Mean P_4 concentrations during the first behavioural oestrus ranged from non-detectable levels to a peak of 4.32 ng/ml at mid-cycle but with no difference ($P>0.05$) among treatments. Therefore, it can be concluded that inclusion of *S. sesban* as a supplement up to 30% of the ration improved feed intake, growth rate, onset of puberty and sexual development of male and female sheep without adverse effects.

Key words: *Sesbania sesban*; growth; onset of puberty; Teff straw; Menz sheep

1 Introduction

Residues from cereal crops and pulses combined with post-harvest stubble grazing account for over 90% of all available feed in the Ethiopian highlands (de Leeuw, 1997). Such feed resources are high in fibre, with low to moderate digestibility and low levels of nitrogen. Consequently, they cannot sustain a maintenance level ration (Preston, 1995) of most animals. Nitrogen has been identified as the primary limiting nutrient in crop residues (Oosting, 1993; Devendra and Thomas, 2002). Feeding of supplementary nitrogen/protein has been recommended to improve utilization of poor-quality roughages by ruminants (O'Donovan, 1983; Devendra and Thomas, 2002; Leene, *et al.,* 2003). One way of mitigating protein deficiency in crop residues is through strategic supplementation of multipurpose fodder trees (MPFT) like *S. sesban* during periods of feed scarcity.

Reviewed reports have demonstrated that supplementation of *S. sesban* increased significantly intake of dry matter, digestible organic matter, efficiency of microbial protein synthesis, nitrogen retention and body weight gain, which may be attributed to its high levels of nitrogen and low levels of tannins and fibre fractions (Reed *et al.,* 1990; Bonsi *et al.,* 1994,1995; Nsahlai *et al.,* 1995; Umunna *et al.,* 1995; Woodward and Reed, 1995; Wiegand *et al.,* 1996; Nsahlai and Umunna, 1996; Woodward and Reed, 1997; Kaitho *et al.,* 1998; Solomon, 2002). Despite the multifaceted nature of farmers' decision making criteria to adopt a MPFT, in a recent on-farm study to assess farmers' preference between local and exotic MPFT for their benefits and desired tree characteristics, farmers preferred the exotic MPFT *S. sesban* and *C. calothyrsus* for feed value (Mekoya *et al.,* 2007a). Furthermore, farmers that supplemented *S. sesban* reported improved body weight gain, puberty age and pregnancy rate of sheep (Mekoya *et al.,* 2007b). Conversely, *S. sesban* might be toxic to the microbes and/or host animals (Woodward and Reed, 1989; Reed *et al.,* 1990) which may reduce feed intake, affect growth rate and pose deleterious effects on sexual development and reproduction of animals (Kaitho *et al.,* 1998; Woldemeskel *et al.,* 2001; Solomon, 2002). For instance, feeding *S. sesban* was observed to cause retarded growth rate and decrease development of the scrotum (Kaitho *et al.,* 1998; Woldemeskel *et al.,* 2001), affected spermatogenesis (Woldemeskel *et al.,* 2001) and was spermicidal (Brown *et al.,* 1987; Dorsaz *et al.,* 1988; Shquier *et al.,* 1989). There are also unconfirmed reports from farmers that *S. sesban* causes reproduction problems in small ruminants (Mekoya *et al.,* 2007b).

Most supplementation experiments with fodder trees including *S. sesban* have been of short duration and focused mainly on feed intake, feed conversion and growth rate. Long-term studies on the effects of feeding *S. sesban* on reproductive performance of small ruminants particularly in both sexes are scanty. We, therefore, proposed and conducted a series of experiments to assess the long-term supplementation effects of *S. sesban* on sheep performance at different physiological stages for one whole reproductive cycle, which makes it unique compared to other studies conducted elsewhere. Hence, the present study was the first of a series of experiments designed to investigate the effects of supplementation of *S. sesban* on feed intake, post-weaning growth rate, sexual organs development and on-set of puberty in male and female lambs.

2 Materials and Methods

2.1 The study area

The study was carried out at the International Livestock Research Institute (ILRI), Debre Zeit Research Station, situated in the central highlands of Ethiopia (1850 m above sea level; annual rainfall 800 mm).

2.2 Experimental animals

Sheep used in this experiment belonged to the Menz breed, a breed predominantly found in the central highlands of Ethiopia between 39-40^{o} E longitude and 10-11^{o} N latitude. The breed is characterized as small to medium-sized fat tail. Mature live weight ranges between 25-35 kg in ewes and 35-45 kg in rams (Galal, 1983). Sixty weaned female and 60 male Ethiopian highland sheep were purchased from local farmers that reared their sheep traditionally (free grazing system) and were involved in an on-farm monitoring study by Sheno Agricultural Research Centre. Animals were transported to the Debre Zeit research station, kept in quarantine for one month, treated for internal and external parasites and vaccinated against common diseases before the commencement of the experiment. The experimental animals ranged in weight and age between 7.2-11.8 kg and 4-5 months respectively at the start.

2.3 Feeds and feeding

Teff straw (*Eragrostis tef*) was used as basal feed and provided 70% of dry matter (DM) intake. It was purchased from the surrounding area and stored for subsequent feeding. *S. sesban* (accession 15019) was harvested from two cuttings grown in the research centre. It was air dried, mixed and packed in sacks for later use. Unchopped teff straw supplemented with three levels of *S. sesban* (0, 47.5 and 95% of supplementary protein provided by *S. sesban* and the rest being

provided by a mix of noug cake (*Guizotia abyssinica*), maize husk and maize grain, the mixture having the same level of protein as *S. sesban* were used in this study (Annex 1). The concentrate feeds served as a positive control and to fulfil the 12% crude protein (CP) requirement of animals when the *S. sesban (*accession 15019*)* supplement was 0 and 47.5%. Samples of treatment feeds were analyzed for DM and CP before the commencement of the study to formulate the experimental ration. The supplementary feeds were formulated to be iso-nitrogenous, iso-caloric and equal levels of Ca and P in the dry matter (Annex 1). Di-ammonium phosphate and limestone were used to correct the phosphorous and calcium levels of *S. sesban* and concentrate feeds. Animals were housed in individual pens on slatted floors, fed the basal diet and supplements individually with free access to water. They were allowed to adapt to the experimental feeds and pens for 15 days before the commencement of data collection. Teff straw was given *ad libitum* by adjusting the level of offer every two days to allow a refusal of approximately 20% of the teff straw offered. To ensure that every animal was getting the 30% supplementary feed in the diet, supplements of *S. sesban* and concentrate feeds were offered using the following formula: SPOF = ESPDMI / DMSP , where

SPOF= Daily supplement offer

ESPDMI = Estimated supplement dry matter intake

DMSP = Dry matter of supplement

ESPDMI was calculated from the estimated total dry matter intake (ETDMI) by multiplying with an offer of supplement factor (0.3) and ETDMI was calculated from dry matter intake of teff straw (DMI Teff) divided by an offer of teff straw factor (0.7). Supplements were given at 9:00h and teff straw at 11:00h. Unconsumed supplements during the offer of teff straw were transferred into buckets, and left to be consumed later in the day. Quantities offered and refused were recorded daily to determine intake. Refusals were collected and weighed daily before the morning feeding. Samples from the offer and refusals of teff straw and supplement feeds were collected and at the end of the experiment pooled per animal and sub-sampled for chemical analysis.

2.4 Digestibility trial

Towards the end of the feeding study, eight animals (males) from each level of *S. sesban* were kept in metabolic crates for a 10-day digestibility trial. They were allowed to adapt to the metabolic crates and carrying of the faecal collection bags for three days followed by a daily total collection of faeces for seven consecutive days. Feeds offered and refused were sampled daily for the determination of DM and N. Faeces was collected in faecal bags. Ten percent of

voided faeces were sampled and pooled for each animal over the collection period, stored at -20 ^{0}C, dried under forced air at 60 ^{0}C and analyzed for DM, OM, NDF and N.

2.5 Body weight and reproductive parameters

Animals were weighed at the beginning of the experiment and fortnightly afterwards for three consecutive days until the end of the experimental period and the average weight was recorded. The scrotum and testis development of ram-lambs was monitored and recorded fortnightly. When ram-lambs attained over 15 cm scrotum circumference, semen was collected fortnightly by electro ejaculator for semen analysis. Puberty was defined as the age at first collection of an ejaculate with at least 50 x 10^6 sperm cells and 10% motility as mentioned by Mukasa and Ezaz (1992) for the same breed. The percentage of motile spermatozoa (motility percent) was estimated immediately after ejaculation by microscopic examination (10 x) of a drop of semen placed between a slide and a 22x32 mm cover slip in a warm (34-37^{O}C) condition (Hafez, 1994). From the ejaculates, 100 µl of semen sub-samples were dropped into tubes containing 2.9% PBS-glutaraldehyde solution for subsequent determination of sperm concentration. Semen concentration was analyzed by spectrophotometer in duplicate. Ewe-lambs were monitored from 7 months of age until all females showed at least the first oestrus cycle (period between the first oestrus behaviour and subsequent oestrus). The oestrus behaviour was checked daily from 15:00 to 18:00 hours with the aid of teaser rams. Oestrus was noted if the female stood willing for the teaser rams to mount her. In order to verify the luteal function, blood samples were taken twice weekly by jugular venipuncture in 5 ml heparinized vacutainers. Samples were centrifuged (1500 x g for 15 min) immediately after blood collection and plasma was stored at -20 ^{0}C until assayed for progesterone concentrations (P_4). P_4 was evaluated by ELISA (Enzyme-Linked ImmunoSorbent Assay). The intra and inter-assay coefficients were 10 and 14% respectively. The sensitivity of the assay was 0.1 ng/ml. A concentration of 1.0 ng/ml was taken to indicate the presence of a functional corpus luteum (Mukasa and Ezaz, 1992). The age at puberty was considered as the date of the first oestrus behaviour followed by luteal function.

2.6 Feed analysis

Feed offers, refusals and faeces were ground to pass a 1-mm screen using a Wiley mill. Dry matter (DM), nitrogen and ash in feed offers, refusals and faeces were determined according to AOAC (1990) standard procedures. Organic matter (OM) was calculated as 1000-ash. NDF (neutral detergent fibre), ADF

(acid detergent fibre) and lignin in feed offers and refusals, and faeces were analyzed using the method of Van Soest and Robertson (1985). Condensed tannins (CT) were determined by heating 2 mg NDF samples at 95 ^{o}C for one hour in n-butanol containing 5% concentrated HCl and the absorbance was read at 550 nm (Reed *et al.,* 1982). Results were expressed as absorbance g^{-1} NDF. Soluble tannins (ST) were determined by precipitation with trivalent ytterbium (Reed *et al.,* 1985).

2.7 Experimental design and data analysis

The experimental design was a Completely Randomized Design in a factorial arrangement of two sex (male and female) and three levels of Sesbania (0, 47.5 and 95% of supplementary protein provided by *S. sesban* and the rest being provided by a mix of concentrates). Animals in each sex group were ranked in order of initial weight and were allocated to the three diet levels on the basis of weight. For each sex and diet level 20 animals were assigned per treatment. The duration of this study was 9 months. The following model was used for data analysis.

$\mathbf{Y_{ijk}=\mu + T_i + S_j + (T_iS_j) + e_{ijk}}$

Where

μ = Overall mean, $\mathbf{T_i}$ = Treatment effect, $\mathbf{S_j}$ = Effect of sex, $\mathbf{T_iSj}$= Interaction of Treatment and Sex, and $\mathbf{e_{ijk}}$= Random error.

Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000). When there were no interactions and terms that were not significant in the full model, the reduced model was employed for analysis. The terms indicating the effects of sex and its interaction with level of Sesbania were not included in the statistical analysis of the digestibility trial.

3 Results

Chemical composition of the basal feed and experimental diets used during the growth study is show in Table 1. The crude protein content of the three levels of experimental diets was similar. The NDF and ADF content of the sole concentrate supplement (0% Sesbania) were higher than 47.5% and 95% Sesbania supplements. On the other hand, the CT and ST contents of 47.5 and 95% Sesbania supplements were higher than the sole concentrate supplement.

3.1 Feed and nutrients intake

Table 2 shows the average feed nutrients intake for sex and treatments. Male sheep had significantly ($P < 0.05$) higher basal feed, supplement, total feed and

Table 1 Chemical composition of treatment feeds offered to growing Menz sheep

Treatment feeds	Chemical composition									
	DM	OM	Ash	CP	NDF	NDF-N	ADF	ADL	CT	ST
Basal feed (Teff straw)	926	925	75	37	795	3.1	440	44	nd	nd
Supplement 1 (0% SS)	908	926	74	280	451	1.8	278	54	nd	nd
Supplement 2 (47.5% SS)	909	905	95	283	323	4.1	223	53	52.4	4.5
Supplement 3 (95 % SS)	901	885	115	287	207	5.7	168	41	77.2	12.2

SS=*Sesbania sesban*; DM=Dry matter (g kg^{-1}); OM=Organic matter (g kg^{-1} DM); Ash (g kg^{-1} DM); CP=Crude protein (g kg^{-1} DM); NDF=Neutral detergent fibre (g kg^{-1} DM); NDF-N= Nitrogen in NDF (g kg^{-1} DM); ADF=Acid detergent fibre (g kg^{-1} DM); ADL=Acid detergent lignin (g kg^{-1} DM); CT=Condensed tannins (Absorbance g^{-1} NDF); ST=Soluble tannins(%DM); nd=not determined

Table 2 Feed nutrients intake (g/day) of Menz sheep during the growth trial

Variables	DM			DOM	CP	NDF	ADF	CT	ST
	TS	SP	TF						
Sex									
Female	279^{b}	115^{b}	394^{b}	173^{b}	45^{b}	288^{b}	163^{b}	8.0^{b}	0.62^{b}
Male	349^{a}	143^{a}	492^{a}	212^{a}	59^{a}	352^{a}	200^{a}	9.8^{a}	0.76^{a}
Level of SS									
0%	263^{b}	106^{b}	369^{b}	137^{b}	44^{c}	284^{b}	159^{b}	nd	nd
47.5%	325^{a}	134^{a}	459^{a}	219^{a}	55^{b}	332^{a}	187^{a}	6.8^{b}	0.79^{b}
95.0%	355^{a}	146^{a}	501^{a}	227^{a}	61^{a}	345^{a}	196^{a}	20.1^{a}	1.28^{a}
Overall	314	129	443	193	53	321	181	8.9	1.03

Means in a column with different superscripts are significant at P<0.05; SS= Level of *S. sesban* in the supplement; TS= Teff straw; SP=Supplements; TF=Total feed; DM=Dry matter; DOM=Digestible organic matter based on digestibility trial; CP=Crude protein; NDF=Neutral detergent fibre; ADF=Acid detergent fibre; CT= Condensed tannins; ST=Soluble tannins; nd=Not determined

nutrients intake than females. Among treatments, animals fed with 47.5 and 95% Sesbania in the supplement had significantly higher (P<0.05) intake of DM, DOM, CP, NDF, ADF and tannins than those supplemented with concentrate alone throughout the experimental period. However, with the exception of CP and tannins there was no significant difference (P>0.05) in nutrients intake between animals fed with 47.5 and 95% Sesbania in the supplement. The low and high levels of Sesbania supplements enhanced intake of teff straw compared to sole concentrates by 14 and 21% respectively. Daily total feed DM intake increased linearly with length of feeding period, the highest being for those supplemented with 95% Sesbania (Fig 1).

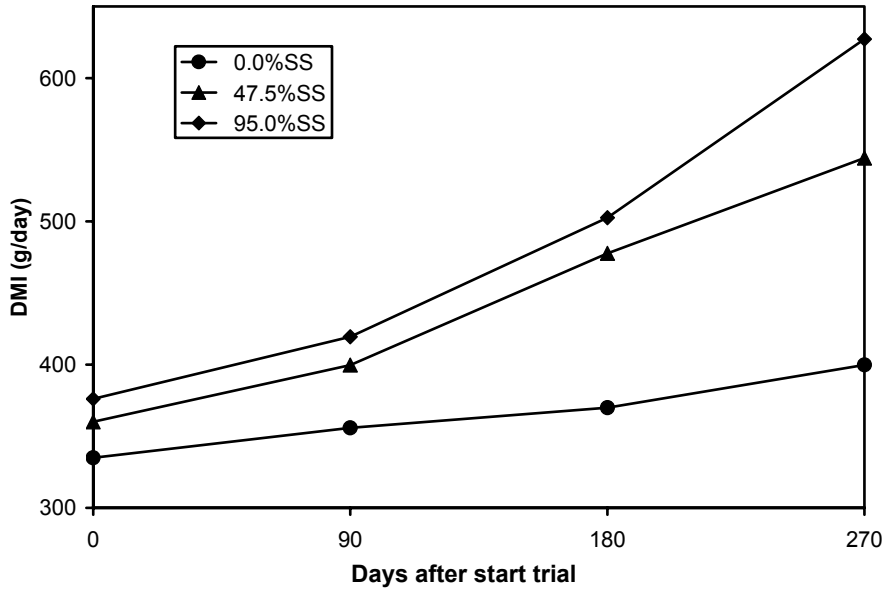


Fig 1 Development of daily dry matter intake (DMI) of sheep fed different levels of *Sesbania sesban* (SS) in the supplement during the growth trial

3.2 Body weight gain and feed conversion efficiency

The average live weight gain was 31(±6 se) g/d and ranged from 11 to 55 g/d. Significant differences (P<0.05) were observed between sex groups, among treatments and for the interaction of sex and diet in average daily live weight gain and final live weight (Table 3). Supplementation with 95% Sesbania elicited higher daily weight gain than supplementation with 47.5% Sesbania and sole concentrates over the growth period. During the 9 months experimental period, growth rate of both sex groups and those supplemented with 47.5 and 95% Sesbania increased up to the 6th month of the feeding period

Table 3 Post-weaning body weight gain and feed conversion efficiency of Menz sheep during the growth trial

Variables	IWT (kg)	FWT (kg)	Live weight gain (g/day)				FCE
			P1	P2	P3	Overall	(g WT gain/kg DM)
Sex							
Female	9.9^{b}	16.8^{b}	24^{b}	27^{b}	27^{b}	26^{b}	47^{b}
Male	10.6^{a}	20.1^{a}	34^{a}	39^{a}	34^{a}	36^{a}	63^{a}
Level of SS							
0	10.2	17.0^{b}	25^{b}	26^{c}	27^{b}	26^{c}	55^{b}
47.5	10.5	18.9^{a}	31^{a}	34^{b}	30^{b}	32^{b}	61^{a}
95.0	10.1	19.4^{a}	32^{a}	38^{a}	35^{a}	35^{a}	62^{a}
Sex*LSS		***	ns	ns	ns	***	***
Overall	10.3	18.4	29	33	31	31	58.0

Means in a column with different superscripts are significant at P<0.05; *** Significant for interactions; IWT= Initial weight; FWT = Final weight; ns=Not significant; P1=Period from 1-90 days; P2=90-180 d; P3=180-270 d; FCE=Feed conversion efficiency; WT=Weight; SS= *S. sesban*

at an increasing rate compared to the last 3 months. On the other hand, the growth rate of animals supplemented with sole concentrate feeds remained constantly increasing, though very small, throughout the growth period**.** Supplementation with Sesbania improved efficiency of use of teff straw better than supplementation of concentrates. Moreover, males were more efficient than females in feed conversion (Table 3). About 16 kg of feed was used per kg of weight gain over the experimental period. After the initial 3 months feeding period, feed conversion efficiency differed significantly ($P<0.05$) between sex groups and among treatments. The amount of gram body weight gain per kg of DM intake was highest during the 1st three months as compared to the next and last three months feeding period for all sex groups and treatments (Fig 2).

Over the experimental period, there was strong and positive correlation($P<0.05$) between intake of DM, DOM and average daily weight gain ($r = 0.72$, $r = 0.71$ for DM and DOM intake respectively)**.** Animals that had higher feed DM and DOM intake had higher body weight gain. The regression estimates for the relationship of DOM intake with daily body weight gain is shown in Fig 3.

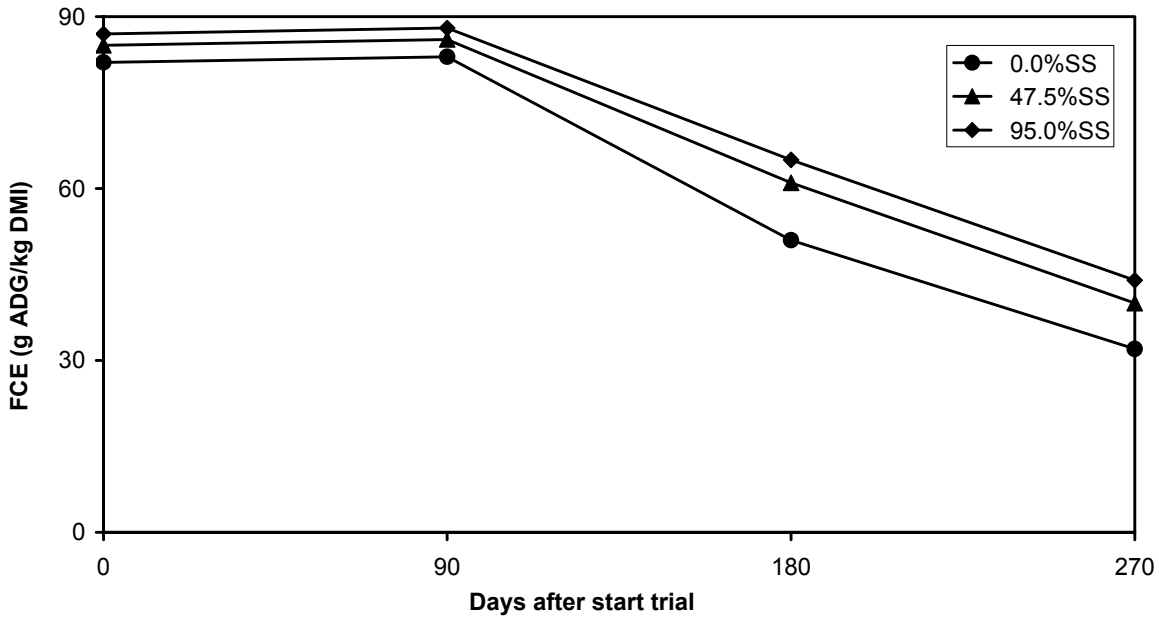


Fig 2 Feed conversion efficiency (FCE, g average daily gain (ADG)/kg dry matter intake (DMI)) for treatment groups during the growth trial

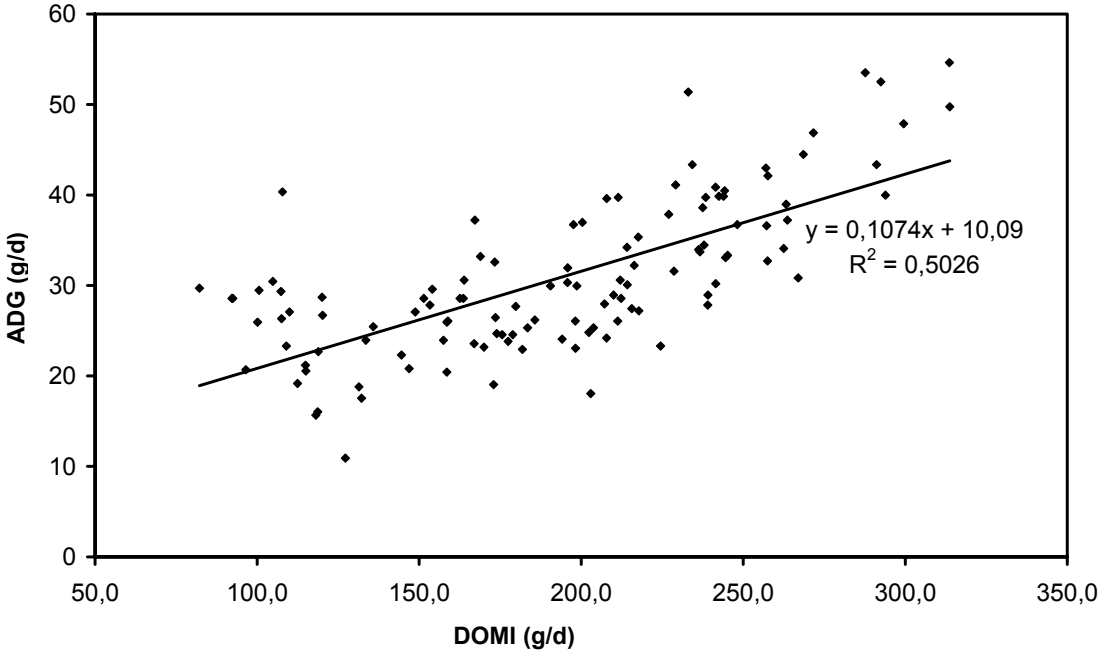


Fig 3 Relationship between average daily gain (ADG, g/day) and digestible organic matter intake (DOMI, g/day)

3.3 Digestibility trial

3.3.1 Feed and nutrients digestibility

Voluntary intake and nutrients digestibility during the metabolism trial are given in Table 4. Animals fed with 47.5 and 95% Sesbania in the supplement showed significantly higher ($P < 0.05$) voluntary feed DM and N intake compared to animals that received concentrate alone**.** Supplementation with Sesbania promoted significantly higher ($P < 0.05$) DM, OM and N digestibility than supplementation with sole concentrates but there was no statistical difference ($P > 0.05$) between 47.5 and 95% levels of Sesbania. Besides, digestibility of NDF and ADF were not significantly different ($P > 0.05$) between animals supplemented with 95% Sesbania and sole concentrates.

Table 4 Least square means of intake and digestibility of nutrients for yearling Menz sheep supplemented with different levels of *Sesbania sesban*

Variables	**DM intake (g kgW$^{-0.75}$)**			**OM**	**N**	**Digestibility (g/kg DM)**				
	TS	SP	Total			DM	OM	N	NDF	ADF
Level of SS										
0	35.5	13.8^{b}	49.3^{b}	49.4	8.3^{b}	344^{b}	345^{b}	426^{b}	261^{b}	142^{b}
47.5	40.3	16.8^{a}	57.1^{a}	56.8	10.4^{a}	468^{a}	471^{a}	638^{a}	315^{a}	175^{a}
95.0	40.4	16.9^{a}	57.2^{a}	56.8	10.1^{a}	447^{a}	452^{a}	596^{a}	281^{ab}	163^{ab}
Overall	38.7	15.8	54.5	54.3	9.6	420	423	553	286	160

Means in a column with different superscripts are significant at $P < 0.05$; TS=teff straw; SP=supplement;DM=Dry matter (g kg^{-1}); OM=Organic matter (g kg^{-1} DM); N=Nitrogen (g kg^{-1} DM); NDF=Neutral detergent fibre (g kg^{-1} DM); ADF=Acid detergent fibre (g kg^{-1} DM)

3.4 Onset of puberty

The onset of puberty was 265 (± 36 sd, n=60) and 342 (± 45 sd, n=59) days for ram and ewe-lambs respectively (Table 5). Puberty age ranged from 260 to 438 days for ewe-lambs, and from 194 to 339 days for ram-lambs. Onset of puberty was significantly different (P<0.05) among treatments in each sex group. Males attained puberty earlier than females, and puberty age in both sexes was reduced due to supplementation with Sesbania but without significant difference (P>0.05) between ram-lambs supplemented with 95% Sesbania and those supplemented with concentrates. Ewe and ram-lambs reached puberty at14.6 and 15.2 kg respectively. Puberty weight differed significantly (P<0.05) among treatments for ram-lambs but not for ewe-lambs. Ram-lambs fed with 47.5% and 95% Sesbania in the supplement reached puberty by 34 and 21 days earlier and were 1.4 kg heavier than those supplemented with sole concentrate. Ewe-lambs supplemented with 47.5 and 95% Sesbania were faster to attain puberty by 43 and 37 days respectively compared to those supplemented with sole concentrates without significant difference in body weight at first behavioural oestrus.

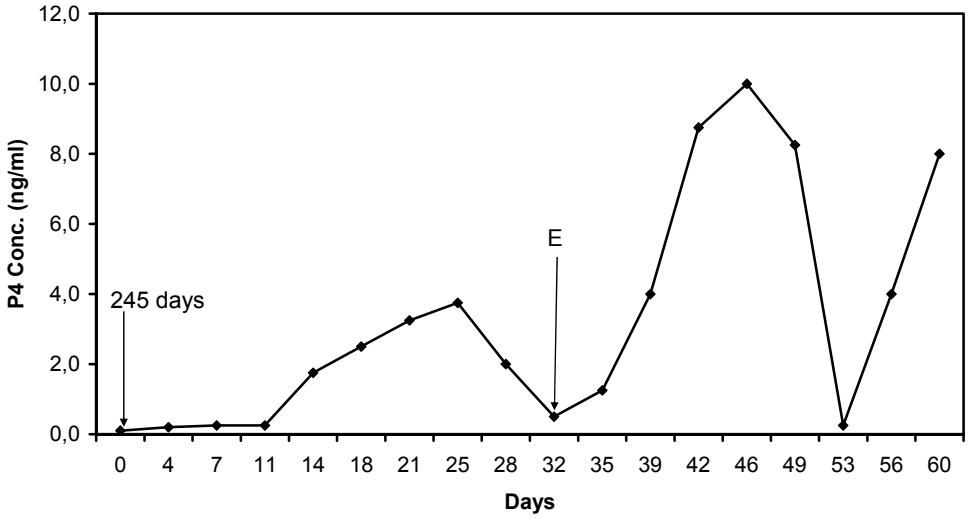
The average daily scrotum circumference (SCF) gain until the onset of puberty was 0.51mm (±0.11 se). Supplementation with Sesbania improved SCF gain but was not statistically significant (P>0.05) among treatments. Mean plasma progesterone concentrations ranged from non-detectable levels to a peak of 4.32 ng/ml at mid-cycle. In 36% of ewe-lambs, initial behavioural oestrus was associated with luteal function. Forty four percent of ewe-lambs showed at least one period of luteal function not preceded by oestrus and 20% of ewe-lambs showed at least one oestrus not followed by luteal function, but no significant differences were observed among treatments. Examples of progesterone profiles for the three oestrus behaviours are given in Fig 6.

Table 5 Onset of puberty parameters in Menz sheep supplemented with different levels of *S. sesban*

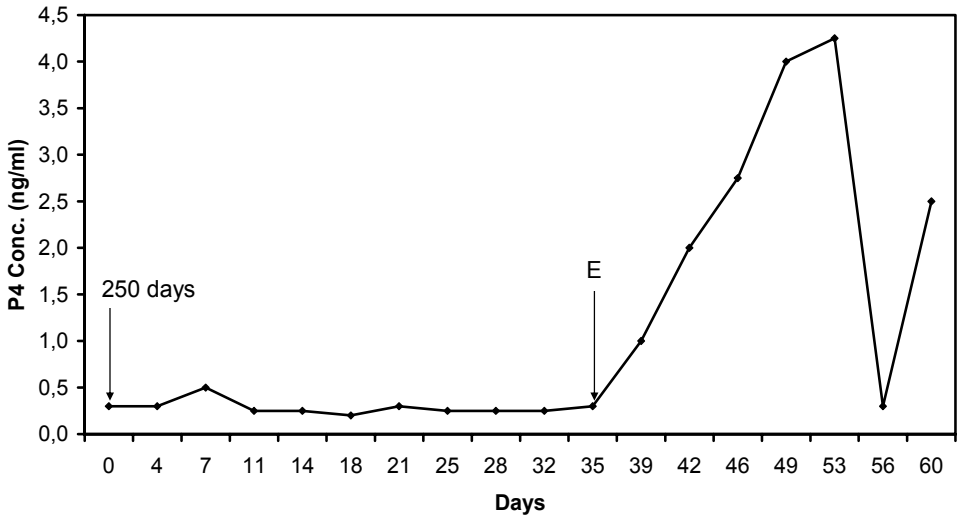
Level of SS	Males					Females	
	PAge (days)	PWT (kg)	ISCF (cm)	SCFP (cm)	DSCFG (mm/day)	AFE (days)	WTAFE (kg)
0%	283^{a}	14.4^{b}	11.6	15.9	0.48	368^{a}	14.7
47.5%	249^{b}	15.8^{a}	12.2	15.9	0.52	325^{b}	14.4
95.0%	262^{ab}	15.7^{a}	11.7	15.7	0.54	331^{b}	14.8
Overall	265	15.2	11.8	15.8	0.51	342	14.6

Means in a column with different superscripts are significant at P<0.05;PAge=Puberty age; PWT=Puberty weight; ISCF= Initial scrotum circumference; SCFP=Final scrotum circumference at on-set of puberty; DSCFG= Daily scrotum circumference gain; AFE=Age at first behavioural oestrus; WTAFE= Weight at first behavioural oestrus.

A. Oestrus after luteal function



B. Oestrus followed by luteal function



C.Oestrus before luteal function

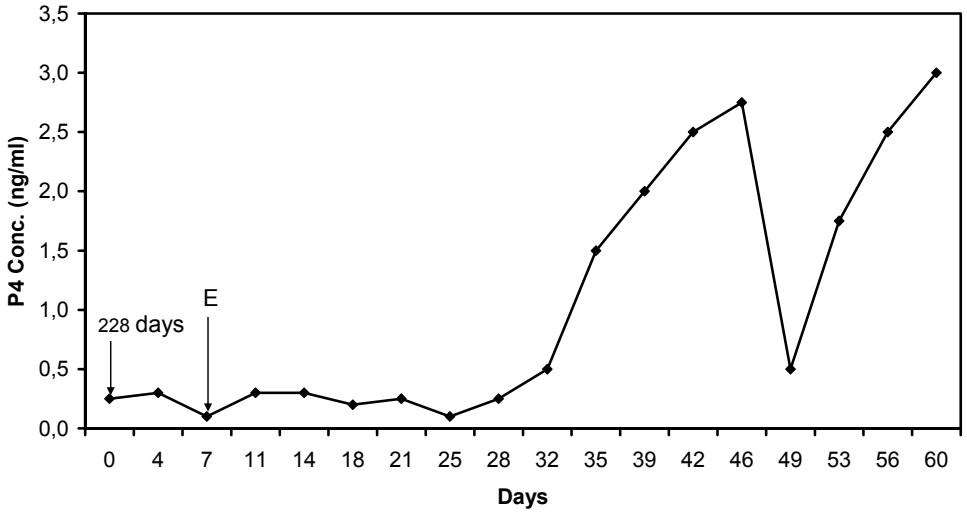


Fig 6 Examples of different relationships between moment of observed behavioural oestrus (E) of Menz ewe-lambs fed different levels of *S. sesban* and the P4-concentration (progesterone) in their blood (ng/ml)

3.5 Relationship between on-set of puberty, body weight gain and feed intake

In ram lambs, puberty age was negatively correlated ($P<0.05$) with daily body weight gain ($r = -0.35$), and feed DM intake ($r = -0.57$). The relationship between puberty age and scrotum circumference gain was also negative ($r = -0.15$) but was not statistically significant ($P>0.05$). Ram-lambs that had higher body weight gain and total feed DM intake attained puberty earlier than those with lower values. Similarly, ewe lambs that had higher daily weight gain and total feed DM intake reached puberty at younger age ($P<0.05$) than those with lower body weight, daily weight gain and feed DM intake ($r = -0.18$ and $r = -0.34$ for daily weight gain and DMI in that order).

4 Discussion

4.1 Feed nutrients intake and digestibility

Lower intakes of DM, OM, and N in concentrate supplemented sheep than in those supplemented with 47.5 and 95% Sesbania was mainly a reflection of the higher NDF and ADF contents in the concentrate mixture. The high fibre content of the concentrate supplement as compared to Sesbania supplements may have caused lower digestibility of basal and total feeds DM, OM and Nitrogen,, which subsequently may have decreased the availability of energy and nitrogen to the rumen microbes. Nsahlai *et al.* (1999) reported that diets supplemented with oil seed cakes had lower dry matter intake than those supplemented with mixtures of Sesbania and Acacia diets due to fast degradation rates of oil seed cakes which may cause a shorter retention time with subsequent excretion of nutrients in the faeces. In the present study, although rumen degradation rates of supplements were not determined, the lower DM, OM, N intake and digestibility of sole concentrate supplements could probably be associated with their degradation rates being faster than that of Sesbania (since 60% of the concentrate mix was composed of oil seed cakes). Bonsi *et al.* (1995) also ascribed that bulkiness of supplementary feeds could depress roughage intake when fed as supplements. The diet of animals fed with sole concentrates was composed of 33% maize husk in the supplement. Because of its bulkiness, the maize husk may have depressed basal, total feed DM and OM intake and digestibility in concentrate supplemented animals.

Conversely, animals supplemented with Sesbania had higher DM, OM and CP intake, which could be attributed primarily to the lower NDF and ADF contents in Sesbania diets. The lower fibre contents associated with high N and OM

intake and digestibility may have increased the efficiency of Sesbania to deliver adequate energy and nitrogen for microbial bacteria that would enable rumen microbes to efficiently digest the fibre. This in turn may have promoted high levels of rumen ammonia, volatile fatty acids, increased efficiency of microbial nitrogen supply and higher nitrogen retention, which probably improved microbial growth and proliferation with concurrent improvement in feed conversion efficiency and live weight gain of animals. Reviewed reports on *S. sesban* and other fodder trees (Reed *et al.,* 1990; Bonsi *et al.,* 1995; Woodward and Reed, 1995; Wiegand *et al.,* 1996; Kaitho *et al.,* 1998, Negussie *et al.,* 2000; Solomon, 2002) as well support our results.

During the growth period, animals supplemented with 47.5 and 95% Sesbania were significantly higher in basal feed DM intake than animals supplemented with concentrates alone. However, this result was not repeated in the metabolism trial which may be due to the shortness of the feeding period. High digestibility of DM, OM, N and fibre in 47.5% Sesbania supplemented animals, even if not significantly different from sheep supplemented with 95% Sesbania, could probably demonstrate the complementarities of mixing concentrates and Sesbania to trap the high rate of degradation of concentrate feeds and the beneficial effects of low levels of tannins in Sesbania (accession 15019) to reduce the rate of N degradability in the rumen, and thus leading to synchronization of the release of nitrogen and availability of energy. Our results are in line with the studies of Nsahlai *et al.* (1999) who reported that a moderate content of tannins in a ration or a combination of rapidly degradable concentrates with forage legumes that had moderate levels of tannins may provide adequate levels of both rumen degradable protein and by-pass protein to ruminants.

4.2 Body weight gain

The daily live weight gain of animals fed different levels of Sesbania in the supplement in the present study agreed with the reports of other studies (Bonsi *et al.,* 1994; Wiegand *et al.,* 1996, Kaitho *et al.,* 1998; Solomon 2002) that used similar levels of Sesbania supplementation. Farmers' response of improved body weight gain while supplementing their sheep with Sesbania (Mekoya, *et al.,* 2007b) further confirms our on-station results. Differences in daily live weight gain between treatments more or less reflected the differences in daily DM, OM and N intake and digestibility of DM, OM, N and fibre. The linear increase in daily body weight gain with increasing levels of Sesbania in the supplement is probably the result of increased OM and N intake and/or efficient use of the basal feed. In general, higher feed intakes as well as higher

digestibilities and body weight gain in Sesbania supplemented diets compared to animals supplemented with sole concentrates observed in our study showed that Sesbania could serve as a protein supplement substituting fully or partially commercial concentrates to improve body growth, intake and digestibility of fibrous feeds. Besides, the moderate levels of tannins found in animals supplemented with 47.5 and 95% Sesbania in the supplement did not depress voluntary intake of basal feed or supplements, and did not prevail adverse effects in post weaning growth of ewe and ram-lambs even when fed for long-term periods. Devendra (1988), Kaitho *et al.* (1998) and Solomon (2002) suggested that, when used as supplements, the optimum dietary levels of fodder trees should be about 30-50% of the ration on DM basis or 0.9 to 1.5 kg per 100 kg body weight. Results from the present study also confirm that supplementation of Sesbania at a rate of 30% in the DM was effective to improve feed intake, feed conversion efficiency and growth of animals fed with fibrous basal feeds.

4.3 Onset of puberty

Puberty is a function of live weight rather than of age which is evident both in ram and ewe-lambs. In other words, a rapid achievement of body size and weight are pre-requisites for the prompt onset of puberty. In sub-Saharan countries, puberty is usually delayed in grazing animals because pastures and crop residues, most commonly used feed resources for livestock, do not provide enough protein and other nutrients which lead to insufficient production of rumen microbial protein to support optimum growth rate. There are several studies on the effects of offering high and low energy and protein diets on the on-set of puberty (Mukasa *et al*., 1991; Mukasa and Ezaz, 1992; Boulanouar *et al.,* 1995; Abi Saab *et al.,* 1997; Waldron *et al.,* 1999; Freitas *et al.,* 2004; Robinson *et al.,* 2006). These reports generally indicate that the onset of puberty seems to be determined by weight gain achieved during the post-weaning period. In our study, post-weaning weight gain, puberty age and weight are within the ranges of most reports for tropical breeds and other studies done on the same Menz sheep but with different feed ingredients used as a supplement in Ethiopia (Mukasa *et al.,* 1991; Mukasa and Ezaz, 1992; Mukasa and Lahlou-Kassi,1995). An inverse relationship was observed in both males and females between growth rate and age at puberty in our experiment. This agrees with the reports of Mukasa and Lahlou-Kassi (1995) who reported that ewe and ram lambs fed different levels of supplementary protein had different growth rates and it had inverse relationship with onset of puberty.

The age at which puberty occurs in both sexes in the present study ranged from 194 to 339 and 260 to 438 days for ram and ewe-lambs respectively, which agrees with the reports of Mukasa *et al.* (1991) and Mukasa and Ezaz (1992) for the same breed in Ethiopia. Both sex groups supplemented with 47.5 and 95% Sesbania were earlier in the onset of puberty, heavier in body weight, and ram-lambs had higher scrotum circumference compared to animals supplemented with concentrates, which could be the function of higher feed intake and body weight gain. The inverse relationship of daily weight gain with DM and OM intake supports studies conducted on the same breed (Mukasa and Lahlou-Kassi, 1995) and other tropical breeds. Several studies show that rapidly growing animals attained puberty earlier compared to animals that grew at a slower rate (Mukasa and Lahlou-Kassi, 1995; Boulanouar *et al.*, 1995; Freitas *et al.,* 2004). In our study also supplementation with Sesbania resulted in a faster growth rate with a subsequent attainment of puberty at younger age.

The attainment of puberty in ewe-lambs is associated with a large discrepancy between oestrus and luteal function, which is useful information in order to understand some failures in fertilization that occur in sheep mated close to the time of puberty. Mukasa and Ezaz (1992) found that in ewe-lambs supplemented with a growing ration composed of 152 g/kg DM digestible protein and 2.5 Mcal/kg DM metabolizable energy, 23% of the initial behavioural period was not associated with luteal function and 17% of the first detected period of luteal function was not associated with oestrus. These observations were numerically different from our results which showed 44 % of the first oestrus not associated with luteal function and 20 % of the first detected period of luteal function not associated with oestrus. The lack of significance in oestrus behaviour during the onset of puberty among treatments may indicate that the anti-nutritional factors in Sesbania (accession 15019) did not cause noticeable interference on folliculogenesis as follicles in the last stage of development are responsible for the release of high levels of oestrogen that triggers behavioural heat or oestrus (Robinson *et al.*, 2006), and supplementation with Sesbania at least could improve sexual development of ewe-lambs as concentrate feeds. From the response of most farmers in our on-farm study on the effects of Sesbania supplementation (although majority of them supplemented far below the optimum level) on the onset of puberty of sheep (Mekoya *et al.*, 2007b) and the results of this experiment, it can be concluded that inclusion of *S. sesban* for long-term feeding as a supplement up to 30% of the ration (on DM basis) promoted improvement in puberty age,

puberty weight and semen characteristics such as motility and concentration in growing male and female sheep and did not show any adverse effects.

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Annex 1. Composition of basal feed and supplements in the ration

Ingredients	**% DM in the ration**		
	95% SS	**47.5% SS**	**0% SS**
Teff straw	70.00	70.00	70.00
Sesbania sesban	28.52	14.26	0.00
Noug cake	0.00	9.95	18.22
Maize husk	0.00	4.69	9.68
DAP	0.48	0.23	0.03
Lime stone	0.00	0.21	0.45
Urea	0.00	0.33	0.81
Maize (grounded)	0.85	0.18	0.66
Salt	0.15	0.15	0.15
CP in diet (%)	12.02	12.02	12.02
ME in diet (MJ/kg DM)	7.87	7.87	7.87
Ca in diet (%)	0.59	0.59	0.59
P in diet (%)	0.30	0.30	0.30

DAP=Di-Ammonium Phosphate

Chapter 6

Effect of supplementation of *Sesbania sesban* on reproductive performance of sheep

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S., Tamminga, S., Tegegne, A. and Van der Zijpp, A.J., 2007. Effect of supplementation of *Sesbania sesban* on reproductive performance of sheep. Submitted to Livestock Science

Abstract

Two successive experiments were conducted on the same animals that had been fed concentrates alone (0% Sesbania) or 95% of supplementary protein provided by *S. sesban* in the first growth experiment to investigate the long-term effects of supplementation of *S. sesban* on reproductive performance of Ethiopian Menz sheep. Forty ewes and 40 rams ranging in weight and age between 16-20 kg and 14-15 months respectively were fed a teff straw basal diet and supplemented with two levels of Sesbania (0, and 95% of supplementary protein provided by Sesbania and the rest being provided by concentrates) for 7 months. In experiment 1 (mating period), 4 paired female-male groups (diet of the male with or without Sesbania, and diet of the female with or without Sesbania) consisting of 20 animals each were formed and assigned for mating. Ewes that were mated and did not return to heat in subsequent cycles during the 70 days mating period continued in experiment 2 receiving similar supplementary diets (concentrate alone or Sesbania) for the study of pregnancy and lambing. During the mating period, males and animals supplemented with Sesbania were superior ($P<0.05$) in daily feed nutrients intake, whereas daily body weight gain (ADG) was significantly different ($P<0.05$) between treatments but not between sex groups. During pregnancy a significant difference ($P<0.05$) was observed only in nitrogen intake, and ADG of ewes did not differ ($P>0.05$) between treatments. Supplementation with Sesbania promoted an increase in testicular size by 13%. Except semen concentration, the other seminal characteristics were not significant ($P<0.05$) between treatments. The average oestrus cycle length was 19±5 days. Mean progesterone profile for cycling ewes on the day of oestrus was 0.4±0.04 and ranged between undetectable levels to 0.75 ng/ml followed by a rise starting on day 4 (1.7±0.16 ng/ml) through day 7 (2.5±0.0.29 ng/ml) and day 10 (3.6±0.47 ng/ml) to a peak of 3.9±0.45 ng/ml (plateau phase) on day 14. Supplementation with Sesbania improved the proportion of ewes conceived by 17% over supplementation with concentrates. The average birth weight of lambs, and post partum dam weight of ewes was 1.97 kg and 18.6 kg respectively and differed significantly ($P<0.05$) between treatments. We concluded that inclusion of Sesbania up to 30% in the diet of sheep as supplement before and during the period of mating and pregnancy improved testicular growth and semen quality in rams or reproductive performance of ewes with out showing negative effects.

Key words: Scrotal circumference; Semen quality; Oestrus; Progesterone; Conception rate; Menz sheep

1 Introduction

The productivity of ruminants is closely associated with the provision of optimum energy and protein required by the animal tissues for different productive states. The available feed resources (marginal pasture and crop residues) in the Ethiopian highlands cannot meet the energy and protein requirements of animals for low to medium productivity (Tsige Yohannes, 2000). The nutritional limitations of animals fed on marginal pasture and crop residues, which cannot sustain maintenance level ration, are associated with low body weight gain, retarded sexual organs development, low reproductive performance and increased non-productive life of animals (Abi Saab *et al.,* 1997; O'Callaghan and Boland, 1999; Negussie *et al.,* 2000). Crop residues could be a valuable source of energy for ruminants if supplemented with multipurpose fodder trees (MPFT) such as *S. sesban* that contain high levels of protein, which could enhance the utilization of crop residues (O'Donovan, 1983).

Several studies (Reed *et al.,* 1990; Umunna *et al.,* 1995a, b; Nsahlai *et al.,* 1995; Wiegand *et al.,* 1996; Kaitho *et al.,* 1998; Solomon, 2002) have illustrated that supplementation with *S. sesban* improved significantly intake and digestibility of basal feeds and consequently live weight gain of the animals. On the other hand, like many other fodder trees, *S. sesban* contains anti-nutritional components that may have detrimental effects on growth and reproduction, which may limit its extensive utilization. Secondary plant compounds in *S. sesban* have shown to cause tubular degeneration, interstitial fibrosis and focal Leydig cell proliferation in male reproductive organs of sheep and goats (Woldemeskel *et al.,* 2001). Kaitho *et al. (*1998) found that prolonged and uninterrupted intake of *S. sesban* had a negative effect on live weight gain and scrotal circumference changes in sheep and goats, which could be attributed to unidentified phytochemicals such as saponins. Recently evidence (Solomon, 2002) was provided that supplementation of *S. sesban* had adverse effects on reproduction of ewes by compromising manifestation of oestrus and termination of pregnancy due to abortion or death of pregnant ewes. A mummified foetus, giving birth to a lamb with paralyzed hind legs and stillbirth were observed in ewes supplemented with *S. sesban*, most likely due to the interference of some anti-nutritional factors.

A recent survey conducted in selected agro-ecological zones of the Ethiopian highlands, showed that there is increased interest by many Government and Non-Government organizations to include MPFT like *S. sesban* in their integrated rural development programs for livestock feed and other agricultural

purposes (Mekoya, unpublished report). Despite the growing interest of development organizations and farmers to adopt MPFT, only limited information is available on the effect of long-term feeding of *S. sesban* on the reproduction of sheep. If MPFT have to have an impact on animal production, the need for them to support high fertility and prolificacy are desirable as these parameters of reproduction are pre-requisites for increased animal productivity and sustainable utilization of fodder trees in the farming community. To understand the implications of the reviewed literatures also necessitate the need for further long-term investigation. This study was a continuation of a post-weaning growth and onset of puberty experiment with the objective to elucidate the long-term effects of supplementation of *S. sesban* on the scrotal growth and semen quality of rams, and reproductive performance of ewes.

2 Materials and Methods

2.1 The study area

Two successive experiments were conducted at the International Livestock Research Institute (ILRI), Debre Zeit Research Station, situated in the central highlands of Ethiopia at 38^0 58'E, 8^0 44'N at an elevation of 1850 m above sea level.

2.2 Feeds and feeding

Teff straw (*Eragrostis tef*) used as basal feed was purchased from the surrounding area and stored for subsequent feeding. *S. sesban* (accession 15019) was grown and harvested in the research centre. It was air dried, mixed and packed in sacks for later use. Unchopped teff straw supplemented with two levels of Sesbania (0, or 95% of supplementary protein provided by *S. sesban* and the rest being provided by a mix made of noug cake (*Guizotia abyssinica*), maize husk and maize grain with the same level of protein as *S. sesban*) were used for both experiment 1 and 2 (Annex 1). The concentrate feeds served as a positive control. Samples of treatment feeds were analyzed for DM and CP before the commencement of the study to formulate the experimental ration. The supplementary feeds contained 10.5% CP and 7.82 MJ/kg DM metabolisable energy and were iso-nitrogenous, iso-caloric and had equal levels of Ca and P in the dry matter (Annex 1). Di-ammonium phosphate and limestone were used to correct the phosphorous and calcium levels of *S. sesban* and concentrate feeds. Animals were housed in individual pens on slatted floor, fed the basal diet and supplements individually with free access to water. Teff straw was given *ad libitum* by adjusting the level of offer every two days to allow a refusal of approximately 20% of the offer. To ensure that every animal

was getting the 30% supplementary feed in the diet, supplements of *S. sesban* and concentrate feeds were offered using the formula indicated in the growth experiment (Mekoya *et al.,* 2007). Supplements were given at 9:00 h and teff straw at 11:00 h. Unconsumed supplements during the offer of teff straw were transferred into buckets, and left to be consumed later in the day. Quantities offered and refused were recorded daily to determine intake. Refusals were collected and weighed daily before the morning feeding. Samples from the offer and refusals of teff straw and supplement feeds were collected and at the end of the experiment pooled per animal and sub-sampled for chemical analysis.

2.2.1 Feed analysis

Feed offers and refusals were ground to pass a 1-mm screen using a Wiley mill. Dry matter (DM), nitrogen and ash of feed offers and refusals were determined according to AOAC (1990) standard procedures. Organic matter (OM) was calculated as 1000-ash. NDF (neutral detergent fibre), ADF (acid detergent fibre) and lignin in feed offers and refusals were analyzed using the method of Van Soest and Robertson (1985). Condensed tannins (CT) were determined by heating 2 mg NDF samples at 95^{o}C for one hour in n-butanol containing 5% concentrated HCl and the absorbance was read at 550 nm (Reed *et al.,* 1982). Results were expressed as Absorbance g^{-1} NDF. Soluble tannins (ST) were determined by precipitation with trivalent ytterbium (Reed *et al.,* 1985).

2.3 Experimental animals, data collection, design and analysis

Experiment 1 (mating period)

Forty ewes and 40 rams (a total of 80 animals) of Ethiopian highland Menz sheep which had been fed concentrates alone (0% Sesbania) or 95% of supplementary protein provided by *S. sesban* in the first growth experiment (Mekoya *et al.,* 2007) were used for this study. The live weight and age of experimental animals ranged from 16 to 20 kg and 14 to 15 months respectively. Animals from each sex and Sesbania level were randomly divided into four groups. Thereafter, 4 paired female-male groups (diet of the male with or without *Sesbania,* and diet of the female with or without *Sesbania)* consisting of 20 animals each were formed and assigned for mating. The feeding treatments for both ewes and rams were similar to the previous growth experiment (concentrates alone or 95% Sesbania in the supplement) throughout the mating and pregnancy period.

Rams were allowed to join ewes in the morning and afternoon (10:00-11:30 AM and 4:00-5:30 PM) by dismantling the inner partition of pens for three hours

daily throughout the mating period. One ram served one ewe and mating was restricted to 70 days. Ewes were monitored daily by visual observation and data were collected on oestrus behaviour of ewes for oestrus cycle length (days between two oestrus cycles), heat symptoms during oestrus, number of estruses observed per ewe and number of services until the end of the mating period. Blood samples from the jugular veins were collected from ewes twice weekly throughout the mating period and analyzed for plasma progesterone concentrations as described in the growth experiment (Mekoya *et al.,* 2007) to assess luteal function and silent estruses.

Beginning from the onset of puberty until the end of the mating period, the scrotal circumference of rams was measured using a metal scrotal measuring tape, and semen was collected fortnightly using an electro-ejaculator for semen quality. Ejaculate volume was determined by collecting semen into graduated tubes. The percentage of motile spermatozoa (motility percent), and wave motion (motility score, scored from 1 to 5) were estimated immediately after ejaculation by microscopic examination (10x) of a drop of semen placed between a slide and 22x32 mm cover slip in a warm (34-37^{o}C) condition (Hafez, 1994). The wave motion (motility score) was defined as good when the sperm cells showed a vigorous straightforward movement and poor when a weak, slow and spasmodic movement of the sperm cells was noted (Kemp *et al.,* 1989). From the ejaculates, 100 µl of semen samples were dropped into tubes containing 2.9% PBS-glutaraldehyde solution for subsequent determination of sperm concentration and evaluation of sperm morphology. Semen concentration was analyzed by spectrophotometer in duplicates. The percentage of morphologically abnormal spermatozoa was determined adopting the classification scheme proposed by Hafez (1994). Spermatozoa were examined microscopically on an unstained smear of each semen sample, and the percentage of defective sperm cells was determined from a count of 300 cells per smear. Animals were weighed and live weights were recorded for three consecutive days at the beginning and fortnightly afterwards until the end of the experimental period.

The experimental design was a completely randomized design with two sexes (male and female) and two diets (concentrates or *S. sesban*). The experimental unit was a pair female-male. The model for analysis of conception rate was

$$\mathbf{y_{ijk} = \mu + F_i + M_j + F_iM_j + e_{ijk}}$$

Where μ=Overall mean; F_i=Diet of female animals; M_j=Diet of male animals; F_iM_j =Interaction of diet of female with diet of male and e_{ijk}= Random error.

For feed intake and body weight gain during the mating period, the model used for analysis was

$\mathbf{y_{ijk} = \mu + T_i + S_j + T_iS_j + e_{ijk}}$

Where μ= Overall mean; $\mathbf{T_i}$ = Treatment effect; $\mathbf{S_j}$ = Sex of the animal; $\mathbf{T_iS_j}$ = Interaction of treatment and sex of the animal and $\mathbf{e_{ijk}}$= Random error.

Scrotum circumference, gain, semen characteristics and oestrus behaviour were analyzed using only treatment effects in the model. Data was analyzed using the General Linear Model (GLM) procedures of SAS (2000). Initial live weight of animals at the beginning of mating was used as a covariate to daily body weight gain for the period of mating and pregnancy in identifying differences between treatment groups but was not significant and not included in the results.

Experiment 2 (Pregnancy)

Ewes which had been supplemented one of the alternative treatment diets (concentrate or 95% Sesbania in the supplement) during the 70 days mating period in experiment one, and that were considered to be pregnant (ewes that were mated and did not return to heat in subsequent cycles) continued to be used to assess the effect of Sesbania supplementation for the period of pregnancy and lambing. Length of pregnancy was estimated from the difference between the last successful mating and parturition dates. Abortions and/or any other adverse effects during pregnancy and parturition, litter size, lamb birth weight, ewe weight at birth, placenta weight, and stillbirths at lambing were recorded. Parameters of reproductive performance were estimated as defined by Gatenby (1986). Live weight of ewes was recorded for three consecutive days at the beginning and fortnightly afterwards until the end of the experimental period. The study took 5 months.

The experimental design was a completely randomized design with two diet levels (0, or 95% of supplementary protein provided by *S. sesban* and the rest being provided by a mix of concentrates). The experimental unit in this study was an animal/pen. The model employed for the analysis of feed intake and body weight gain during pregnancy and reproductive performance of ewes was

$\mathbf{y_{ij} = \mu + T_i + e_{ij}}$

Where μ = Overall mean; $\mathbf{T_i}$ = Treatment effect; $\mathbf{e_{ij}}$ = Random error.

Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000).

3 Results

3.1 Feed and nutrients intake

The chemical composition of treatment feeds used in both experiments is presented in Table 1. The crude protein content of the two of experimental diets was similar. The NDF and ADF content of the sole concentrate supplement (0% Sesbania), however, was higher than the 95% Sesbania supplements. The 95% Sesbania supplement contained moderate levels of tannins.

The average nutrients intake during the mating and pregnancy period for sex and treatment groups is shown in Tables 2 and 3. Supplementation with Sesbania resulted in a significantly (P<0.05) higher intake of total feed DM, OM and nitrogen compared to supplementation with concentrates. During the

Table 1 Chemical composition of experimental feeds offered to ewes and rams of Menz sheep during the mating and pregnancy period

Treatment feeds	Chemical composition									
	DM	OM	Ash	CP	NDF	NDF-N	ADF	ADL	CT	ST
Basal feed (Teff straw)	923	923	77	38	793	2.2	443	42	nd	nd
Supplement 1 (0% SS)	911	918	82	241	440	2.0	287	55	nd	nd
Supplement 2 (95%SS)	906	881	119	243	213	3.6	171	57	75.1	12.4

SS=*Sesbania sesban*; DM=Dry matter (g kg^{-1}); OM=Organic matter (g kg^{-1} DM); Ash (g kg^{-1} DM); CP=Crude protein (g kg^{-1} DM); NDF=Neutral detergent fibre (g kg^{-1} DM); NDF-N= Nitrogen in NDF (g kg^{-1} DM); ADF=Acid detergent fibre (g kg^{-1} DM); ADL=Acid detergent lignin (g kg^{-1} DM); CT=Condensed tannins (Absorbance g^{-1} NDF); ST=Soluble tannins(%DM); nd=not determined

Table 2 Feed intake (g/day), body weight (kg) and daily weight gain (g/day) of Menz sheep during the period of mating

	Feed intake (g/day)							Body weight (kg)		ADG (g/day)
	DM	OM	CP	NDF	ADF	CT	ST	IW	FW	
Sex										
Female	442^{b}	431^{b}	49^{b}	320^{b}	180^{b}	11.8	0.97	16.7^{b}	18.3^{b}	23
Male	531^{a}	525^{a}	58^{a}	383^{a}	216^{a}	13.7	1.12	19.6^{a}	21.4^{a}	25
Level of SS										
0%	446^{b}	441^{b}	48^{b}	374^{a}	205	nd	nd	17.0^{b}	18.6^{b}	23^{b}
95%	528^{a}	523^{a}	59^{a}	356^{b}	192	25.5	2.09	19.3^{a}	21.1^{a}	26^{a}
Overall	488	482	54	351	198	12.8	1.05	18.2	19.9	24

Means in a column with different superscripts are significant at P<0.05;SS=Levels of *Sesbania sesban*; DM=dry matter; OM=organic matter; CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; CT=condensed tannins; ST=soluble tannins; IW= Initial weight at the beginning of mating; FW=Final weight at the end of mating; ADG=Average daily weight gain; nd=not determined

mating period, males and animals supplemented with Sesbania were superior in daily feed and nutrients intake.

During pregnancy, significant difference (P<0.05) was observed only in nitrogen intake, and supplementation with Sesbania did not result in significant differences (P>0.05) in daily feed DM and OM intake compared to supplementation with concentrates (Table 3). On the other hand, excluding data on males, feed intake of ewes supplemented with concentrates increased linearly beginning from mating towards the advancement of pregnancy whereas feed intake of ewes supplemented with Sesbania decreased towards the advancement of pregnancy (Fig 1).

Table 3 Feed intake (g/day), body weight (kg) and daily weight gain (g/day) of Menz sheep during pregnancy

Level of SS	**Feed intake (g/day)**							**Body weight (kg)**		**ADG (g/day)**
	DM	**OM**	**CP**	**NDF**	**ADF**	**CT**	**ST**	**IW**	**FW**	
0%	448	437	48[b]	345	195	nd	nd	18.6[b]	20.6[b]	29
95%	506	501	57[a]	338	189	25.1	2.06	21.1[a]	22.4[a]	30
Overall	476	472	53	341	192	25.1	2.06	19.9	21.5	30

Means in a column with different superscripts are significant at P<0.05; SS=*Sesbania sesban*; DM=dry matter; OM=organic matter; CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; CT=condensed tannins ; ST=soluble tannins; IW= Initial weight at the beginning of pregnancy; FW=Final weight at the end of pregnancy; ADG=Average daily weight gain; nd=not determined

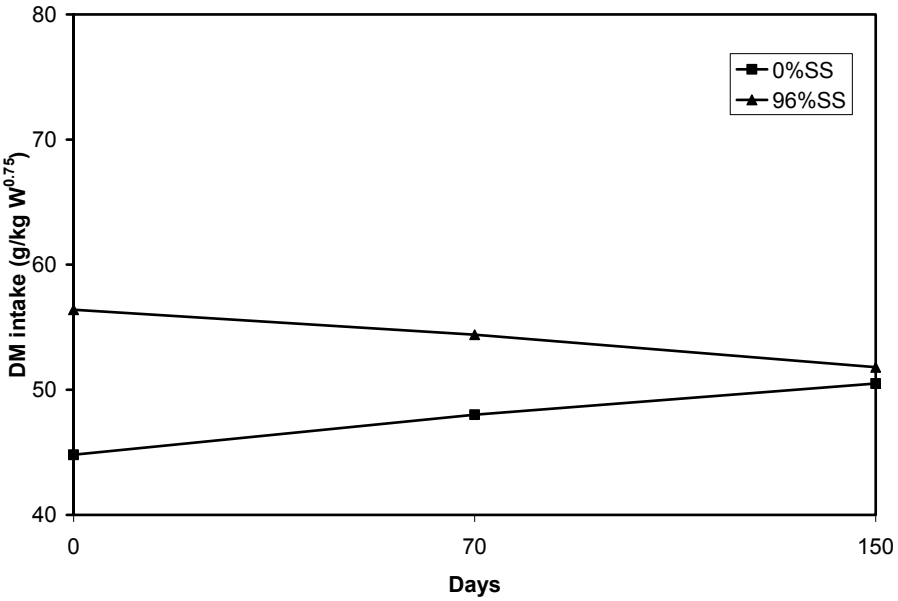

Fig 1 Dry matter (DM) intake of ewes supplemented with Sesbania or concentrates during the mating and pregnancy period

3.2 Body weight gain

The average body weight gain (ADG) for sex groups and treatments during the period of mating and for ewes during the period of pregnancy was 24.3 and 30 g/day respectively (Tables 2 and 3). At the period of mating (Table 2), initial and final live weight of animals were significantly different (P<0.05) between sex groups and treatments. However, daily body weight gain was significantly different (P<0.05) only between treatments but not between sex groups. Final live weight of ewes at the end of pregnancy was significantly different (P<0.05) whereas daily body weight gain of ewes during the period of pregnancy did not differ statistically (P>0.05) between treatments (Table 3). Supplementation with Sesbania did not improve daily body weight gain of pregnant ewes better than those supplemented with concentrates.

3.3 Reproductive performance

3.3.1 Scrotal circumference

The scrotum circumference (SCF), SCF gain and seminal characteristics of animals supplemented with Sesbania and concentrates are shown in Table 4. Supplementation with Sesbania resulted in significantly (P<0.05) higher SCF gain compared to supplementation with concentrates. Animals supplemented with Sesbania showed an increase in testicular size by 13% compared to animals supplemented with concentrates. The SCF gain after puberty increased linearly in all treatment groups until the commencement of the mating period. However, during the mating period SCF gain was negative without showing statistically significant differences (P>0.05) between treatment groups (Table 4). The correlation between SCF gain and body weight gain from the onset of puberty to the beginning of mating period was positive and highly significant

Table 4 Scrotal circumference, daily scrotal circumference gain and semen characteristics of Menz sheep

Level of SS	ISCF (cm)	SCF1 (cm)	SCF2 (cm)	SCFG (mm/d)			Semen characteristics				
				P0	P1	P2	Vol. (ml)	Motility		Conc. (x 10^9 ml^{-1})	Morph defects (%)
								score	(%)		
0%	15.9	19.3[b]	19.0[b]	0.21[b]	-0.05	0.14[b]	0.87	2.91	68.6	1.06[b]	12.3
95%	15.9	22.2[a]	21.3[a]	0.37[a]	-0.15	0.23[a]	0.90	3.10	70.9	1.24[a]	17.6
Overall	15.9	20.8	20.2	0.29	-0.10	0.19	0.89	3.01	69.8	1.15	14.7

Means in a column with different superscripts are significant at P<0.05; SS=*Sesbania sesban*; ISCF= scrotal circumference at the onset of puberty; SCF1=scrotal circumference at the beginning of mating; SCF2= scrotal circumference at the end of mating; P0=scrotal circumference gain from puberty to mating; P1=scrotal circumference gain during mating; P2= over all scrotal circumference gain from puberty to end of mating

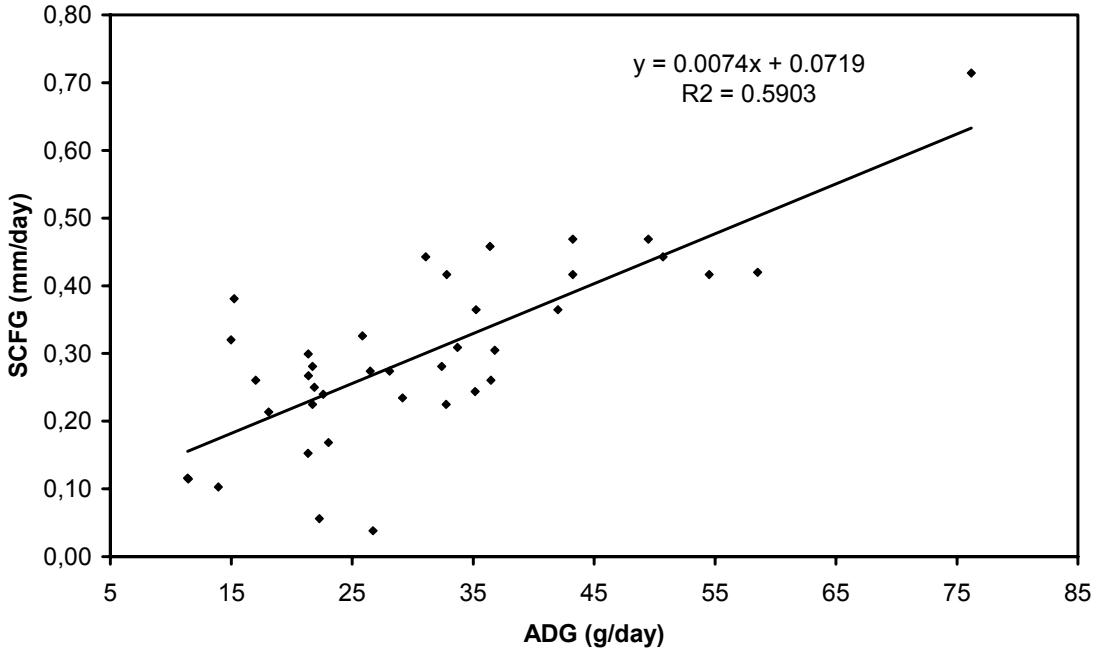

Fig 2 Relationship between scrotum circumference gain (SCFG) and average daily gain (ADG) of Menz rams

(r=0.71, P<0.0001). The regression estimates for the relationship of daily body weight gain with scrotal circumference gain is presented in Fig 2.

3.3.2 Seminal characteristics

With the exception of semen concentration, the seminal characteristics of the ejaculates of rams supplemented with Sesbania and concentrate feeds did not show statistically significant differences in semen volume, progressive forward movement and morphological defects (Table 4). Supplementation with Sesbania elicited higher semen concentration than supplementation with concentrates. Semen volume, motility and concentration were positively and significantly (P<0.05) correlated to SCF. The correlation coefficients for the relationship of semen volume, motility and concentration with SCF were r=0.37 (P=0.03),r=0.54 (P<0.001) and r=0.62 (P<0.001) in that order. The quantity of morphologically abnormal spermatozoa in the ejaculates did not increase significantly (P> 0.05) due to supplementation of Sesbania. However, animals supplemented with Sesbania showed numerically a higher proportion of morphological abnormalities than those supplemented with concentrates (Table 4).

3.3.3 Oestrus behaviour

The average oestrus cycle length of ewes was 19±5 days (Table 5). The percentage of ewes showing oestrus at least once a month was very high (96%). Ten percent of the cycles were short (≤14 days), 61% normal (15-20 days), 13%

Table 5 Cycling days (% of ewes) and average (mean ±s.e) length of oestrus cycle and Progesterone (P_4) concentrations at two levels of *S. Sesban* (SS) supplementation

Level of SS	**Cycling days**					**Oestrus cycle length (d)**	**P_4 Concentration (ng/ml)**	
	≤14	15-19	20-27	28-40	>40		Follicular phase	Plateau phase
0%	9.1	65.5	9.1	10.9	5.5	19.0	0.4	3.9
95%	10.9	57.8	15.6	12.5	3.1	19.3	0.5	4.3
Overall	10.1	61.3	12.6	11.8	4.2	19.2 ± 4.62	0.4±0.04	3.9±0.45

long (21-27 days), 12% silent or missed (28-40 days) and 4% represented anoestrus (>40 days) with no statistically significant difference due to supplementation of Sesbania in oestrus behaviour.

The mean progesterone profile for cycling ewes on the day of oestrus was 0.4±0.04 and ranged between undetectable levels to 0.8 ng/ml followed by a rise starting on day 4 (1.7±0.16) through day 7 (2.5±0.29 ng/ml) and day 10 (3.6±0.47 ng/ml) to a peak of 3.9±0.45 (plateau phase) on day 14. A rapid decline was then observed from day 15 until the next follicular phase or oestrus. Mean progesterone (P_4) concentration differed significantly ($P<0.05$) between treatments on the day of the cycle. Animals supplemented with Sesbania showed higher progesterone concentration on the 4th, 7th, and 10th days of the cycle than those not supplemented with concentrates. However, the progesterone concentration on the days of follicular and plateau phase were not different ($P>0.05$). Examples of P4 profiles for a period of two oestrus cycles for the treatment groups are given in Fig 3.

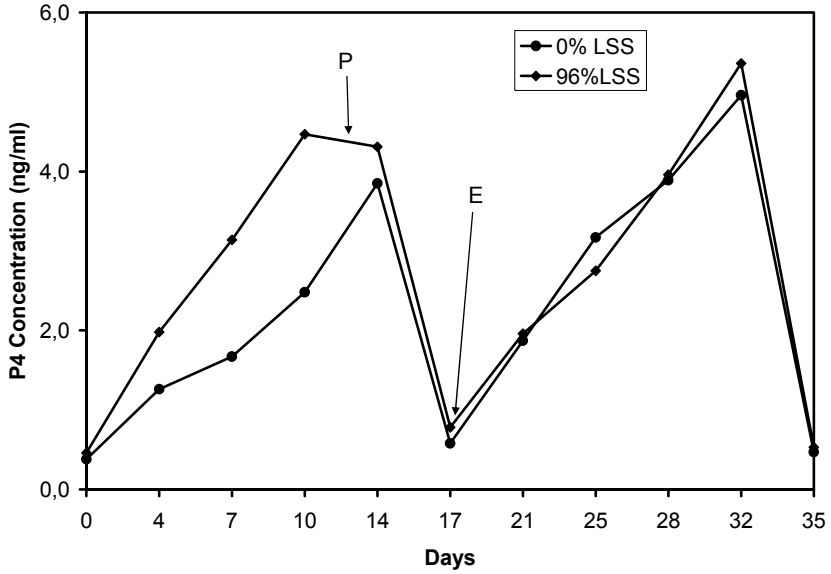

Fig 3 Progesterone concentrations of Menz ewes during follicular and luteal phase of the oestrus cycle. P=Plateau phase; E=Follicular phase

3.3.4 Conception rate

The overall proportion of ewes conceived to 1st, 2nd, and 3rd oestrus during the 70 days mating period was 64.1, 10.3 and 2.6% respectively while 23% of the ewes did not conceive when mated with rams in three consecutive estruses (Table 6). No significant differences (P>0.05) were observed between treatments in conception to consecutive estruses. Supplementation with Sesbania improved the overall proportion of ewes conceived by 17% over the animals supplemented with concentrates.

Treatment effects on the number of services per conception and conception rates are given in Table 7. The mean number of services per conception was 1.2±0.18 and no significant difference was observed between treatments. However, ewes mated with rams that were fed similar type of supplement (Sesbania or concentrate) had a higher number of services per conception than those ewes mated with rams supplemented with the alternative diet. The overall average conception rate was 0.77 and ranged from 0.60 to 0.90. Conception rate was significantly lower (P<0.05) for pairs of which both animals (ewes and rams) were without Sesbania supplement than for pairs where at least one received Sesbania. Conception rates did not differ significantly (P<0.05) between pairs where one received Sesbania and pairs of which both animals (ewes and rams) were with Sesbania supplement. Number of services per conception was not affected by the diet of rams.

Table 6 Proportion (%) and number of Menz ewes conceived to consecutive oestruses at two levels of *S. Sesban* (SS) supplementation

Level of SS	Conception to			Ewes conceived
	1st	2nd	3rd	
0%	60.0 (12)	5.0 (1)	5.0 (1)	70.0 (14)
95%	68.4 (13)	15.8 (3)	0.0	84.3 (16)
Overall	64.1 (25)	10.3 (4)	2.6 (1)	77.0 (30)

*Numbers in parenthesis are the number of ewes

Table 7 Conception rate and services per conception of Menz ewes

Treatments*	Conception rate	Services per conception
$F_0 \times M_0$	0.6 ± 0.13 [b]	1.5
$F_{95} \times M_{95}$	0.9 ± 0.06 [a]	1.6
$F_0 \times M_{95}$	0.8 ± 0.11 [a]	1.0
$F_{95} \times M_0$	0.8 ± 0.12 [a]	1.2
Overall	**0.8** ± 0.07	**1.2**±0.18

Means in a column with different superscripts are significant at P<0.05; * F=females, M=males, receiving 0 or 95% *S. sesban* in diet indicated by subscript

3.3.5 Gestation length, litter size and lambs birth weight

Mean gestation length was 152±5 days and ranged between 147 and 169 days. The average litter size, birth weight of lambs, and post partum weight (PPW) of ewes was 1.0 and 2.0±0.24 kg and 18.7±1.21 kg respectively (Table 8). Birth weight of lambs ranged from 1.3 to 2.4 kg. A significant difference ($P<0.05$) was observed between treatments in birth weight of lambs and PPW of ewes. Ewes supplemented with Sesbania were superior in PPW than those supplemented with concentrates. Supplementation with Sesbania before and during pregnancy improved birth weight of lambs by 26% compared to supplementation with concentrates. Gestation length and litter size of ewes did not differ significantly ($P>0.05$) between treatments. The relationship of ewes live weight at the beginning of mating and the end of pregnancy with lambs birth weight was significant ($P<0.05$) and positively correlated. Ewes that had higher initial and final live weight gave birth to heavier lambs. The correlation coefficients of initial and final live weight at the beginning and end of pregnancy with lambs birth weight were r = 0.47 (P = 0.008) and r=0.49 (P=0.006) respectively.

Table 8 Gestation length and parturition parameters of Menz ewes at two levels of *S. Sesban* (SS) supplementation

Level of SS	Gestation length (d)	Litter size	Litter weight (kg)	PPW (kg)	Placenta weight (g)
0%	151.8	1.0	1.8^{b}	17.9^{b}	164^{b}
95%	152.0	1.0	2.1^{a}	19.4^{a}	206^{a}
Overall	152± 5	1.0	2.0±0.24	18.7±1.21	187±45

Means in a column with different superscripts are significant at $P<0.05$; PPW= Post partum dam weight

4 Discussion

4.1 Feed intake and body weight gain

Like was observed in the growth experiment (Mekoya, *et al.*, 2007), animals supplemented with Sesbania sustained higher DM, OM and CP intake, which was primarily a reflection of higher intake of basal feed and supplements. The lower intake recorded in animals supplemented with concentrates could be associated with the higher concentration of fibre in the supplement. During pregnancy animals supplemented with Sesbania were not significantly higher in daily body weight gain than those supplemented with concentrates, which could probably be associated with the mobilization of nutrients from the dams for the development of the foetus and later translated to higher birth weight of lambs.

In the present study, the amount of tannins and its long-term intake in Sesbania supplemented animals did not show any observable adverse effects on feed intake and body weight gain of the animals. Rather, a positive effect was noted which could probably be due to the moderate levels of tannins contained in this accession (15019) of Sesbania. Our observations confirm earlier reports (Reed *et al.,* 1990; Bonsi *et al.,* 1995; Woodward and Reed, 1995; Wiegand *et al.,* 1996) which state that the importance of Sesbania on intake and digestibility and body weight gain may be attributed to its low to moderate levels of tannins and fibre fractions. The moderate levels of tannins in *S. sesban* have beneficial effects since tannins in low to moderate concentrations increase the flow of non-ammonia nitrogen and essential amino acids from the rumen (Waghorn *et al.,* 1987; McNabb *et al.,* 1993). However, the reduction in feed intake of ewes supplemented with Sesbania with the advancement of pregnancy as observed in our experiment, may also indicate that although Sesbania contained moderate levels of tannins, the beneficial effects on intake and digestibility may tend to diminish over a long period of feeding.

4.2 Sexual development and reproductive performance

4.2.1 Scrotal circumference

The results of the present study showed that supplementation with Sesbania could enhance testicular growth in rams better than supplementation with concentrates as indicated by scrotal circumference. This is in agreement with the findings of Negussie *et al.* (2000) on Leucaena supplemented animals who described that rams supplemented with the lower or equivalent amount of Leucaena as in the present experiment were significantly higher in testicular size and daily scrotal circumference gain than those supplemented with similar amount of concentrate mixtures composed of wheat bran, noug cake (*Guizotia abyssinica*) and molasses . Furthermore, Solomon (2002) reported that animals supplemented with *Sesbania* alone or a mixture of Sesbania (Accession 15019) and Leucaena were superior in scrotal circumference gain as compared to animals supplemented with *Acacia Angustissima* or wheat bran. On the other hand, in a supplementation study of *L. pallida* and *S.* sesban on body growth and scrotal circumference of Ethiopian highland sheep and goats fed teff straw basal diet for 6 months, *Kaitho et al.* (1988) mentioned that prolonged and un interrupted supplementation of *S. sesban* showed negative effect on live weight and scrotal circumference gain of sheep and goats. Although different accessions of Sesbania may have different effects because of differences in tannin contents, our study did not show adverse effects in testicular size and scrotal circumference gain on animals supplemented with Sesbania. Rather,

Sesbania supplementation promoted higher testicular size and scrotal circumference gain. The reduction in testicular size during the period of mating, which may be attributed to loss of fat in the scrotal tissue owing to frequent ejaculations, still does not show evidence that this is caused by adverse effects of Sesbania since it was noted on both treatment groups but with a higher magnitude on Sesbania supplemented rams. Therefore, it appears that long-term supplementation of sheep with *S. sesban* improved reproductive performance as deduced from the correlation between SCF and semen volume, motility and concentration which agrees with the reports of Rege *et al.* (2000) that described testicular size is correlated with semen qualities responsible for effective fertilization.

4.2.2 Seminal characteristics

The average ejaculate volume recorded was within the range of 0.8-1.2 ml suggested by Foote (1980) and Rege *et al.* (2000) for the same breed. Acquisition of progressive motility is considered to be one of the strong evidences for sperm maturation and a useful determinant of conception. The range in the proportions of actively motile spermatozoa observed in our study was 50-83% which were within the standard range (60-80%) set for mature rams (Foote 1980) and agrees with the reports of studies conducted on the same breed (Rege *et al.*, 2000) as well as other breeds in Ethiopia (Negussie *et al.*, 2000).

In spite of the difference between treatments, sperm cell concentration was lower (1.2×10^9 ml^{-1}) compared to the normal ranges of $1.6\text{-}6 \times 10^9$ and $2\text{-}3 \times 10^9$ ml^{-1} of semen as reported by Foote (1980) and Hafez (1994) respectively, for mature rams. It was also lower than the sperm cell concentration $2.8\text{-}7.1 \times 10^9$ ml^{-1} and 2.4×10^{12} ml^{-1} reported by Negussie *et al.* (2000) on Arsi breeds and Rege *et al.* (2000) for the same breed in Ethiopia. But, our results are in line with the values 0.9×10^9 ml^{-1} reported by Chiboka (1980) in the semen of west African dwarf rams under grazing conditions in Nigeria. Sperm cell concentration is a highly variable trait of semen quality (Hafez, 1994) and the disparities between the results of the present and other studies for the same and/or different breeds in Ethiopia and in Africa are supposed to be normal. High sperm cell concentration is generally considered to be beneficial because during natural mating it ensures the entry of more spermatozoa into the cervical reservoir and then into the oviduct, consequently increasing the chance of fertilization (Hafez, 1994). Our results suggest that supplementation with Sesbania enabled rams to have significantly higher sperm concentrations which will increase the chance of fertilization of rams and conception rate of ewes.

The morphological abnormalities varied from 7.4 to 20.6% which are in agreement with the findings of Rege *et al.* (2000) for the same breed. The percentage of abnormal cells was higher on rams supplemented with Sesbania compared to animals supplemented with concentrates. Woldemeskel *et al.* (2001) reported that more pronounced tubular degeneration, interstitial fibrosis and focal Leydig cells proliferation were observed in sheep and goats supplemented with 200 g *S. sesban*, which could lead to testicular degeneration associated with acquired infertility and lowered seminal quality. In the present study, the daily intake of Sesbania ranged from 160 to 230 g/day and was similar to the intake of sheep reported by Woldemeskel *et al.* (2001). However, the high conception rates recorded in ewes that were serviced by rams supplemented with Sesbania did not support the suggestions of Woldemeskel *et al.* (2001) which also show that the morphological defects were not harmful enough to result in poor semen fertility and low conception.

With the exception of semen concentration, the absence of significant responses on semen volume, motility score, progressive forward movement and morphological defects between rams supplemented with Sesbania and concentrates most likely indicates that inclusion of up to 30% of Sesbania (accession 15019) as a supplement in the diet of ruminants would have no adverse effects on the accessory sex glands nor on fertility and libido of rams. The higher ($P<0.05$) concentration of semen in Sesbania supplemented animals further supports the beneficial effect of Sesbania supplementation for the development of sex glands with subsequent improvement in fertility of rams. Our results are in agreement with the findings of Negussie *et al.* (2000) in that supplementation of incremental levels of Leucaena to Ethiopian highland sheep did not reduce, but were superior in motility percentage, motility score, and concentration with low proportion of morphological defects. Akingbade *et al.* (2002) also reported that feeding Leucaena to mature male goats was not detrimental to semen quality and fertility of bucks and to conception among females mated by the bucks fed the forage Leucaena.

4.2.3 Oestrus behaviour

The oestrus cycle length of ewes recorded in the present study is within the range of 16-19 days for the same breed reported by Mukasa and Lahlou-Kassi (1995) and Solomon (2002). The percentage of ewes showing short, normal, long and silent oestrus, and mean progesterone concentrations from the day one of oestrus to the next follicular phase/oestrus was in agreement with the reports

of Mukasa and Lahlou-Kassi (1995) for the same breed kept under concentrate supplements.

Solomon (2002) found that ewes supplemented with Sesbania at 0.9 and 1.2% of their body weight (25-30% of the ration), were significantly higher in manifestation of oestrus compared to ewes supplemented with Sesbania at 1.5% of their body weight (>30% of the diet). In the present study the level of Sesbania supplementation was 30% of the diet (0.98% of body weight of animals) and the oestrus behaviour (oestrus cycle length, duration of oestrus and heat symptoms during oestrus) observed in ewes agreed with the reports of Solomon (2002). The lack of difference in oestrus behaviour and progesterone concentrations between animals supplemented with Sesbania and concentrates would suggest that long-term and uninterrupted supplementation of *S. sesban* did not have any visible negative effects on sexual development and activity of female sheep. However, supplementation of Sesbania beyond 30% of the diet may probably reduce manifestation of oestrus in cycling ewes (Solomon, 2002) and may need further investigation.

4.2.4 Conception and parturition

The average conception rates to 1st, 2nd, and 3rd estruses recorded in our study (77%) was comparable to the results (79.5%) of Mukasa *et al.* (2002) kept under concentrate supplementation. Conception rates to first mating only was lower than the values of conception rates reported by Solomon (2002) while it was nearly similar to the values (64 vs. 69%) reported by Mukasa and Lahlou-Kassi (1995) for Menz sheep that received concentrate supplements, which may be attributed to the difference in the mating practice followed in each study. Although statistically not significant, the proportion of ewes conceived to 1st, 2nd and 3rd estruses between treatments in general showed that supplementation with Sesbania promoted higher conception rates than those supplemented with concentrates. Robinson (1990) and Solomon (2002) described that some anti-nutritional factors in multipurpose fodder trees may interfere on folliculogenesis, as follicles in the last stage of development are responsible for the release of high levels of oestrogen that triggers behavioural heat or oestrus. When ewes were supplemented with *S. sesban* (accession 1198) at 0.9 and 1.2% of their body weight (≤ 30 % of the diet) no adverse effects on oestrus and conception rates were detected (Solomon, 2002). Suspected interference of anti-nutritional factors was perceived in ewes supplemented with Sesbania at 1.5% of their body weight or >30% of the diet. In our results also no visible indications were noticed that compromise behavioural oestrus

and conception as a result of inclusion of Sesbania (accession 15019) as a supplement up to 30% of the diet. Besides, conception rate could be improved by supplementing either rams or ewes in a comparable rate achieved through supplementing both sexes, which suggests that in the absence of sufficient number of Sesbania trees on-farm, farmers could use one of the alternative feeding systems.

The mean gestation length of ewes of the present study was 152 days which was similar to the mean gestation length of 150 and 151 days reported by Mukasa and Viviani (1992) and Solomon (2002) for the same breed supplemented with concentrates, *L. pallida* and *S. sesban*. Ewes on the different levels of Sesbania gave birth to only single lambs and prolificacy was 1.0. This value was slightly lower than the values of 1.02-1.08 recorded for Menz sheep (Gautsch, 1992) kept under experimental conditions and fed with concentrate supplements, which could probably be associated to the small sample size used in our experiment. The increased reproductive efficiency (number of services per conception, conception rate, and lamb birth weight) of ewes supplemented with Sesbania compared to those supplemented with concentrates may suggest that the effect could probably be mediated by the presence of moderate levels of tannins in *S. sesban*. This could be associated with reduced proteolysis of forage protein in the rumen (Min *et al.*, 1999 and 2001), reduced rumen plasma ammonia concentration, reduced blood plasma concentrations (Min *et al.,* 1999 and 2001) and increased net absorption of essential amino acids (Waghorn *et al.*, 1987; and Min *et al.,* 1999) from the small intestine. These metabolic changes may promote events such as folliculogenesis, conception, attachment, embryo survival, foetal growth and lamb survival (Ramire-Restrepo *et al.*, 2005). Rodriguez *et al.* (1998) ascribed as well that the incorporation of leguminous browses as a supplement could improve growth and reproductive output of ruminants, by enhancing male fertility and female fecundity via improved nutrition.

During the pregnancy period no incidences of still birth, abortion and mortality of pregnant ewes or any other physical abnormalities were detected on ewes supplemented with Sesbania. Our results are different from the reports of Solomon (2002) for the same level of Sesbania supplementation in the diet. Solomon (2002) described termination of pregnancy due to abortion or death of pregnant ewes, a mummified foetus, stillbirth and birth to a lamb with paralyzed hind legs for ewes supplemented with Sesbania at 0.9, 1.2 and 1.5% of their body weight. Higher nutrients intake in ewes supplemented with *S.*

sesban promoted higher ewes live weight at lambing, which in turn positively influenced birth weight of lambs. This agrees with the findings of Solomon (2002) and Akingbade *et al.* (2002), who reported that lambs/kids birth weight was influenced by dam weight during gestation in sheep and goats. The average weight of lambs (2.0±0.24 kg) recorded was comparable to values of 2.1 kg (Gautsch, 1992), and higher than 1.76 kg (Solomon, 2002) reported for Menz sheep. The higher body weight of lambs born from ewes supplemented with *S. sesban* indicates that better nourishment was obtained from Sesbania by the dams that could enhance development of the foetus, which agrees with the reports of Solomon (2002) who described that lambs born from ewes supplemented with Sesbania were superior in birth weight.

4.3 Conclusion

The major conclusion that can be drawn from the results of the present study is that inclusion of *S. sesban (accession 15019)* up to 30% of the diet as supplement improved the testicular growth, semen quality of rams and reproductive performance of rams and ewes via improvement in the intake and digestibility of basal feed and nutrients which as well shows that it can safely be fed to sheep without adverse effects. Furthermore, under farming systems context when there is shortage of Sesbania to supplement the whole flock, farmers could practice differential feeding of Sesbania either for rams or ewes to improve conception rate in ewes.

5 Acknowledgements

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Annex 1 Composition of basal feed and supplements in the ration at two levels of *S. Sesban* (SS) supplementation

Ingredients	% DM in the ration	
	95% SS	**0% SS**
Teff straw	70.00	70.00
Sesbania sesban	28.93	0.00
Noug cake	0.00	13.84
Maize husk	0.00	11.59
DAP*	0.76	0.32
Lime stone	0.00	0.54
Urea	0.00	0.56
Maize (grounded)	0.17	0.00
Wheat bran	0.00	3.01
Salt	0.15	0.15
CP in diet %	10.5	10.5
ME in diet (MJ/kg DM)	7.82	7.82
Ca in diet	0.0060	0.0060
P in diet	0.0036	0.0036

*Di- Ammonium Phosphate

Chapter 7

Effect of supplementation of *Sesbania sesban* to lactating ewes on milk yield and growth rate of lambs

Mekoya, A., Oosting, S.J., Fernandez-Rivera, S., Tamminga, S. and Van der Zijpp, A.J. Effect of supplementation of *Sesbania sesban* to lactating ewes on milk yield and growth rate of lambs. Submitted to Livestock Science

Abstract

The present experiment was conducted to study the effects of supplementation of *S. sesban* on the milk yield of ewes and growth rate of their lambs. The experiment was done with animals that had been fed for 16 months on a basal diet of teff straw supplemented with concentrates alone (0% Sesbania) or 95% of supplementary protein provided by *S. sesban*. The animals received the experimental diet from the age of 4.5 months onwards. Thirty lactating ewes and their single lambs of Ethiopian highland Menz sheep were used in this study. The post partum weight of ewes and birth weight of their lambs ranged between 16-22 kg and 1.3-2.4 kg. The ewes continued to be fed a teff straw basal diet and supplemented with two levels of *S. sesban* (0, and 95% of supplementary protein provided by Sesbania and the rest being provided by concentrates) for 3 months. Three weeks after birth lambs were offered a succulent green grass-legume mixture ad libitum. DM and OM intake of basal feed and total feed, live weight at weaning and post partum daily body weight gain of ewes were not significantly different ($P>0.05$) between treatments. The overall lactation milk yield of ewes was 19 ±1.9 kg. The milk yield of ewes was significantly affected ($P<0.05$) by dietary treatments. Ewes supplemented with *S. sesban* showed a 13% increase in milk production over ewes supplemented with concentrates. The peak lactation for ewes supplemented with *S. sesban* was higher and persisted longer than for ewes supplemented with concentrates. Lambs born from ewes supplemented with *S. sesban* had a significantly higher pre-weaning growth rate and were heavier at weaning ($P<0.05$) than lambs born from ewes supplemented with concentrates. Supplementation with *S. sesban* improved significantly ($P<0.05$) post natal survival rate of lambs than supplementation with concentrates. We concluded that supplementation of *S. sesban* at 30% of the ration (0.98% of their body weight) during lactation improved milk yield of ewes, lambs growth rate and survival, and the overall reproductive performance of ewes.

Key words: Milk yield; Survival rate; *Sesbania sesban*; Lactation; Menz sheep

1 Introduction

In sheep, inadequate, excess or imbalanced intake of nutrients may delay age at first lambing, result in poor lactation, lengthen post-partum anoestrus and lambing interval, and reduce pre-weaning growth and survival of lambs (Smith and Somade, 1994, Robinson, 1996; O'Callaghan and Boland, 1999). Therefore, the provision of adequate energy and protein during pregnancy and parturition will enhance reproductive efficiency of ewes and growth rate of lambs. Unfortunately, the available feed resources in the Ethiopian highlands cannot meet these requirements (de Leeuw, 1997; Tsige Yohanes, 2000).

The productivity of lactating animals in smallholder farmers could be improved through supplementation with locally available feed resources (Lambourne and Little, 1987; Devendra, 1988; Osuji and Odenyo, 1997). Potential protein supplements for ruminants in Ethiopia are industrial by-products like oil seed cakes and multipurpose fodder trees (MPFT) like Sesbania, Leucaena and Calliandra. Sesbania is one of the most widely promoted MPFT to smallholder farmers in the Ethiopian highlands. Sesbania is rich in nitrogen and has the potential for use as protein supplement to poor quality roughages or as substitute for commercial protein supplements (Norton, 1994; Paterson *et al*., 1996; Dzowela *et al.,* 1997). However, like many species of MPFT it contains anti-nutritional factors which may bind protein, making it unavailable to the animal, and may have negative effects on palatability, digestibility, productivity and reproduction of animals (Woodward and Reed, 1995; Kaitho *et al*., 1998; Solomon, 2002). Most studies on multipurpose fodder trees particularly those on Sesbania as a supplement, focused on feed intake, digestibility and body weight gain of small ruminants. Information on the effects of feeding of *S. sesban* on milk yield and lambs growth rate in Ethiopia is scarce. Hence, the objective of this study was to assess the effect of feeding *S. sesban* as a supplement to lactating ewes on milk production and growth rate of their lambs.

2 Materials and Methods

2.1 The study area

This study was carried out at the International Livestock Research Institute (ILRI), Debre Zeit Research Station, situated in the central highlands of Ethiopia (1850 m above seal level; annual rainfall 800 mm).

2.2 Experimental animals

Thirty lactating ewes and their single lambs of Ethiopian highland Menz sheep, which in an earlier pregnancy study had been supplemented one of the

alternative treatment diets (concentrate or 95% Sesbania in the supplement) continued to be used to assess the effects of Sesbania supplementation for a 3 months lactation period. Lactating ewes had a post partum live weight ranging between 16 and 22 kg, and lambs had a birth weight ranging between 1.3-2.4 kg at the beginning of the experiment. The experimental ewes used in the present study had received similar experimental diets (concentrates alone or 95% Sesbania in the supplement) from an age of 4.5 months onwards during the growth, mating and pregnancy experiments. Thus, they were already 16 months on the diets.

2.3 Experimental feeds and feeding

Teff straw (*Eragrostis tef*) purchased from the surrounding area was used as basal feed in this study. *Sesbania sesban* (accession 15019) was grown and harvested at the Debre Zeit research station. It was air dried, mixed and packed in sacks for later use. The treatment feeds used for lactating ewes were concentrates (0%Sesbania, positive control) and *S. sesban* leaves (95%Sesbania). The concentrate supplement was composed of a mix made of noug cake (*Guizotia abyssinica*), maize husk and maize grain with the same level of protein as *S. sesban* (Annex 1). Samples of treatment feeds were analyzed for DM and CP before the start of the study to formulate the experimental rations. The supplementary feeds were calculated to contain 10.5% CP and 7.82 MJ/kg DM metabolizable energy and were iso-nitrogenous, iso-caloric and had equal levels of Ca and P in the dry matter (Annex 1). Di-ammonium phosphate and Limestone were used to correct the phosphorous and calcium levels of *S. sesban* and concentrate feeds, respectively. Animals were housed in individual pens on slatted floor, fed the basal diet and supplements individually with free access to tap water. Teff straw was given *ad libitum* by adjusting the level of offer every two days to allow a refusal of approximately 20% of the offer. To ensure that every animal was getting the 30% supplementary feed in the diet, supplements of *S. sesban* and concentrate feeds were offered using the formula indicated in the pregnancy experiment (Mekoya *et al.,* 2007). Supplements to lactating ewes were given at 9:00h and teff straw at 11:00h. Quantities offered and refused were recorded daily to determine feed intake of the lactating ewes. Refusals were collected and weighed daily before the morning feeding. Samples from the offer and refusals of teff straw and supplement feeds were collected and at the end of the experiment pooled per animal and sub-sampled for chemical analysis. Starting 3 weeks from birth all lambs were fed a succulent green grass-legume mixture *ad libitum*.

2.4 Data collection

The assessment of milk production started after the first three days of lactation to enable lambs to learn to suckle colostrum. Milk production was measured twice a week by the ''weigh-suckle-weigh'' technique using a sensitive balance. This method assesses milk intake of lambs after a fasting period (Banda *et al*., 1992; Njwe and Manjeli, 1992; Mousa and Shetaewi, 1995). Lambs were removed from their dams at 18:00 on the evening proceeding the recording day. They were then weighed at 07:00 h in the morning of the following day and allowed to suckle their dams for a 30 minute period. The lambs' body weights were then recorded and they were removed again until 18:00 h, at which time the procedure was repeated. The difference in the weights of the lambs before and after suckling represented the amount of milk consumed by the lamb. The daily milk yield was estimated by summing the milk suckled by the lamb during the two suckling periods. The total yield for 12 weeks of lactation was thus estimated. Ewes were considered dried off when the amount of milk produced weighed less than 75 g/day. The body weights of the ewes were monitored every fortnight whereas the kids were weighed twice a week.

2.5 Chemical analysis

Feed offers and refusals were ground to pass a 1-mm screen using a Wiley mill. Dry matter (DM), organic matter (OM), nitrogen and ash on feed offers and refusals were determined according to AOAC (1990) standard procedures. NDF (neutral detergent fibre), ADF (acid detergent fibre) and lignin in feed offers and refusals were analyzed using the method of Van Soest and Robertson (1985). Condensed tannins (CT) were determined by heating 2 mg NDF samples at 95^{o}C for one hour in n-butanol containing 5% concentrated HCL and the absorbance was read at 550 nm (Reed *et al*., 1982). Results were expressed as absorbance per gram NDF. Soluble tannins (ST) were determined by precipitation with trivalent ytterbium (Reed *et al*., 1985).

2.6 Experimental design and data analysis

The experimental design was a completely randomized design with two diet levels (0, and 95% of supplementary protein provided by *S. sesban*). The experimental unit in this study was an individual animal. Post partum weight of ewes was used as a covariate in the statistical models for analysis of feed intake, final live weight, and milk yield of ewes, and pre-weaning growth rate of lambs to correct for initial weight differences. For the same reason both post partum weight of ewes and birth weight of lambs were used as a covariate to

the 30, 60 and 90 days live weight of lambs. The model employed for the analysis of feed intake, body weight gain and milk yield of ewes was

$\mathbf{y_{ijk} = \mu + T_i + b_j*PPW + e_{ijk}}$

with μ = Overall mean; $\mathbf{T_i}$ = Treatment effect; **PPW** = post partum weight; $\mathbf{e_{ijk}}$ = Random error,

and the model for pre-weaning growth rate of lambs was

$\mathbf{y_{ijkl} = \mu + T_i + b_j*PPW + b_k*LBW + e_{ijkl}}$

with μ = Overall mean; $\mathbf{T_i}$ = Treatment effect; **PPW** = post partum weight; **LBW** = lamb birth weight $\mathbf{e_{ijk}}$ = Random error

Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000).

3 Results

3.1 Post partum feed intake and body weight gain of ewes

The chemical composition of treatment feeds used during the period of lactation is presented in Table 1. The crude protein content of the two levels of experimental diets was similar. The NDF and ADF content of the concentrate supplement (0% Sesbania), however, was higher than the 95% Sesbania supplements. The 95% Sesbania supplement contained moderate levels of tannins.

Tables 2 and 3 show the feed intake, post partum weight and daily body weight gain of lactating ewes. A significant difference ($P < 0.05$) was observed between treatment means adjusted for PPW only in supplement DMI and CP intake. PPW had no significant contribution to the full model for any of the feed components. Unadjusted mean intake was significantly higher ($P < 0.05$) for Sesbania supplemented diets than for concentrate supplemented diets for all feed components except NDF and ADF.

Ewes supplemented with *S. sesban* had significantly higher ($P < 0.05$) body weight at parturition. However, live weight at weaning and post partum daily body weight gain of ewes were not significantly different ($P > 0.05$) between treatments when adjusted for PPW ($b = 0.93$, $P < 0.05$). Actual, unadjusted, live weights of ewes are presented in Figure 1. Live weight decreased after parturition and revived 4 weeks post partum (Fig 1).

Table 1 Chemical composition of experimental feeds during the period of lactation

Ingredients	Nutrient composition									
	DM	Ash	OM	CP	NDF	NDF-N	ADF	ADL	CT	ST
Basal feed (Teff straw)	923	77	923	38	793	2.2	443	42	nd	nd
Supplement 1 (0% SS)	911	82	918	241	440	2.0	287	55	nd	nd
Supplement 2 (95% SS)	906	119	881	243	213	3.6	171	57	75.1	12.4

SS=*Sesbania sesban*; DM=Dry matter (g kg^{-1}); OM=Organic matter (g kg^{-1} DM); Ash (g kg^{-1} DM); CP=Crude protein (g kg^{-1} DM); NDF=Neutral detergent fibre (g kg^{-1} DM); NDF-N= Nitrogen in NDF (g kg^{-1} DM); ADF=Acid detergent fibre (g kg^{-1} DM); ADL=Acid detergent lignin (g kg^{-1} DM); CT=Condensed tannins (Absorbance g^{-1} NDF); ST=Soluble tannins(%DM); nd=not determined

Table 2 Intake (g/day) of feed components by lactating Menz ewes supplemented with concentrates or *S. Sesban* (SS) (means adjusted for post partum weight)

Level of SS	DMI			OMI			CPI	NDFI	ADFI	CTI	STI
	TSI	SPI	FI	TSI	SPI	FI					
0%	424	179^{b}	599	422	176^{b}	594	65.5^{b}	464	254	nd	nd
95%	470	201^{a}	672	468	196^{a}	664	75.4^{a}	448	258	34.0	2.8
Overall	449	189	638	447	186	634	70.8	455	256	34.0	2.8

Means in a column with different superscripts are significant at P<0.05. DMI=dry matter intake; OMI=organic matter intake; CPI=crude protein intake; NDFI=neutral detergent fiber intake; ADFI=acid detergent fiber intake; CTI=condensed tannins intake; STI=soluble tannins intake; TSI=Teff straw intake; SPI=Supplement intake; FI=Total feed intake

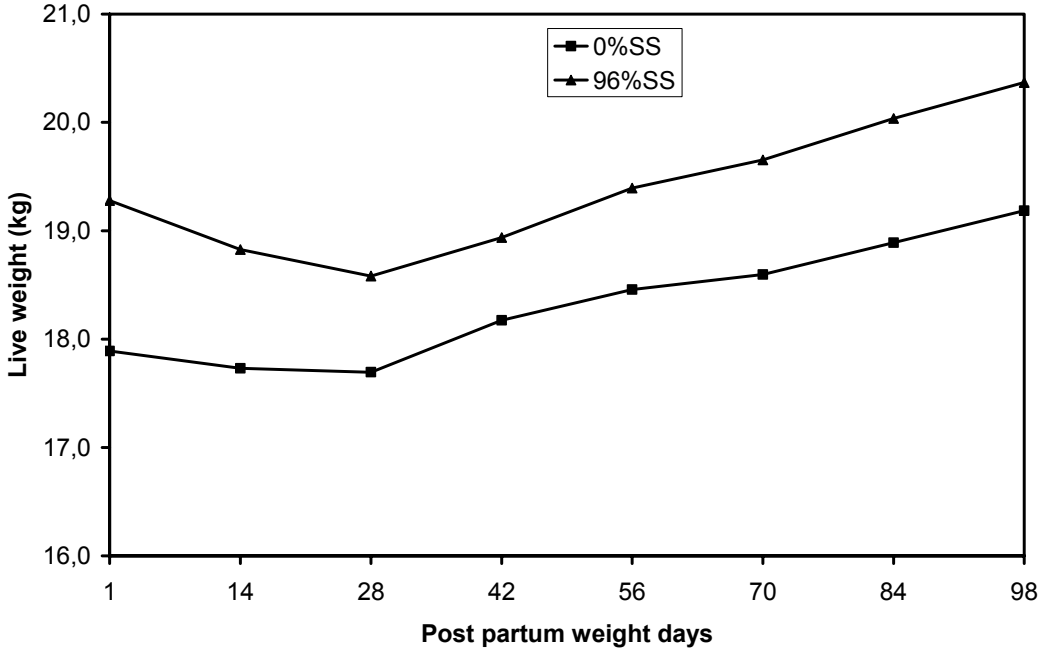

Fig 1 Post partum live weight of ewes over the lactation period

Table 3 Effect of supplementing *S. sesban* (SS) on lactating Menz ewe weight (post partum and at weaning of lambs) and weight gain

Level of SS	PPW	FWT*	PPADG (g/day)*
0%	17.9[b]	19.4	12.7
95%	19.3[a]	19.8	11.6
Overall	18.6	19.8	12.4

*Adjusted least square means. Means in a column with different superscripts are significant at P<0.05. PPW= Post partum weight; FWT= Final weight at weaning; PPADG= Post partum daily body weight gain.

3.2 Milk yield

The average daily milk yield of ewes during the 12 weeks lactation period was 210±6.0 g/day. The overall lactation milk yield of ewes was 18.9 ±1.9 kg (Table 4) and ranged between 11.4 and 27.0 kg. The milk yield of ewes was significantly affected (P < 0.05) by dietary treatments (Table 4, adjusted means). Milk yield of ewes increased progressively from week 1 to week 3 of lactation, and declined thereafter. Sesbania supplemented ewes produced more milk (P < 0.05) through all weeks of lactation than concentrate supplemented ewes. PPW of ewes significantly affected milk yield (b=1.28).

The peak lactation for ewes supplemented with Sesbania was higher and persisted longer from week 1 to 5 whereas for ewes supplemented with concentrates the peak lactation was higher from week 1 to 3 and persisted shorter (Fig 2).

Table 4 Effect of supplementing *S. sesban* on milk yield of Menz ewes (adjusted for PPW) and weight parameters and growth rate of their lambs (adjusted for both LBW and PPW)

Level of SS	Milk yield* (kg)	LBW (kg)	Lambs body weight (kg)*			PWADG (g/day*)			
			30d	60d	Weaning	P1	P2	P3	Overall
0	17.4[b]	1.84[b]	3.5	5.0	6.8[b]	75	64	54	66[b]
95%	20.2[a]	2.09[a]	3.8	5.5	7.7[a]	87	73	61	73[a]
Overall	18.9	1.97	3.7	5.3	7.3	80	68	64	70

* Adjusted least square means; LBW=Lambs birth weight; PWADG=Pre-weaning average daily gain; P1= from birth to 30 days; P2= 30-60 days; P3= 60-90 days; Means in a column with different superscripts are significantly different at P<0.05

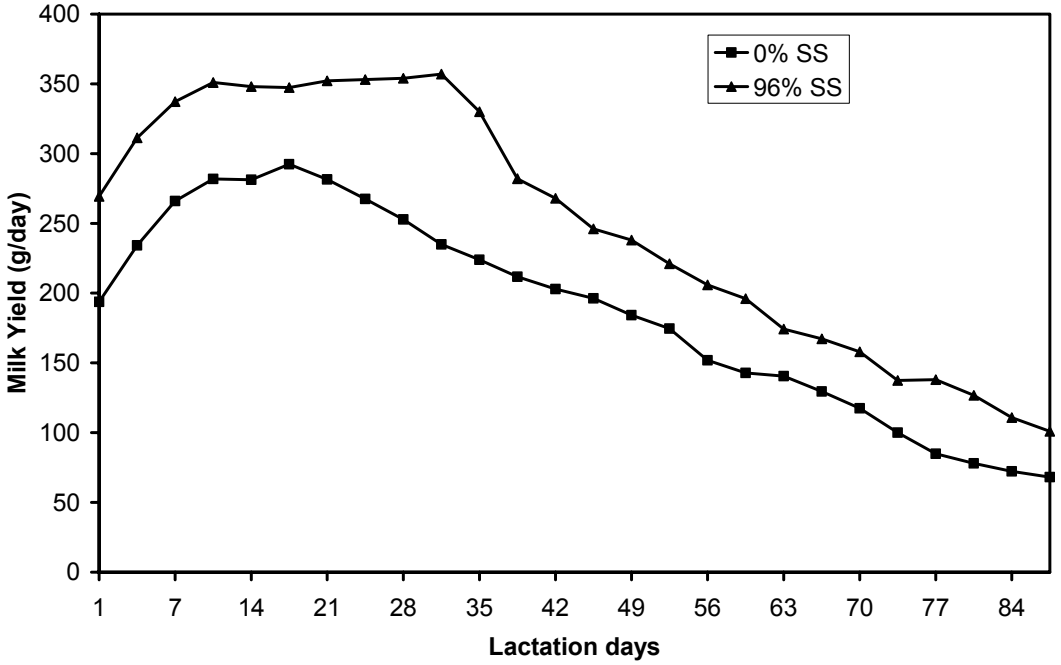

Fig 2 Milk yield of ewes (unadjusted) over the 12 weeks lactation period

3.3. Lambs growth rate

Lambs live weight and growth rate at 30, 60 and 90 days after birth for treatment groups is shown in Table 4. Means for 30d, 60d and weaning weight and growth rates in Table 4 are adjusted for PPW and LBW. PPW was significant ($P < 0.05$) for all lamb weight and growth data except for weight at 60 days, while LBW contributed significantly ($P < 0.05$) to the 30d weight and the weaning weight. The average live weight and growth rate of lambs at weaning was 7.3 ± 1.2 kg and 67 ± 3.0 grams per day respectively. Lambs live weight and growth rate was highest during the first 30 days (80 ± 4.3 g/day) after birth and then declined. Live weight of lambs at 30 and 60 days of age after birth was not significantly different ($P>0.05$) between treatments. However, the overall pre-weaning growth rate differed significantly ($P<0.05$) between treatments. Lambs born from ewes supplemented with Sesbania had a significantly higher pre-weaning growth rate ($P<0.05$) and were heavier numerically at weaning than those lambs born from ewes supplemented with concentrates (Table 4). Ewes milk yield and lambs growth rate were positively and significantly correlated ($r=0.78$, $P<0.0001$). The regression estimates for the relationship of ewes milk yield with pre-weaning growth rate of lambs are given in Fig 3.

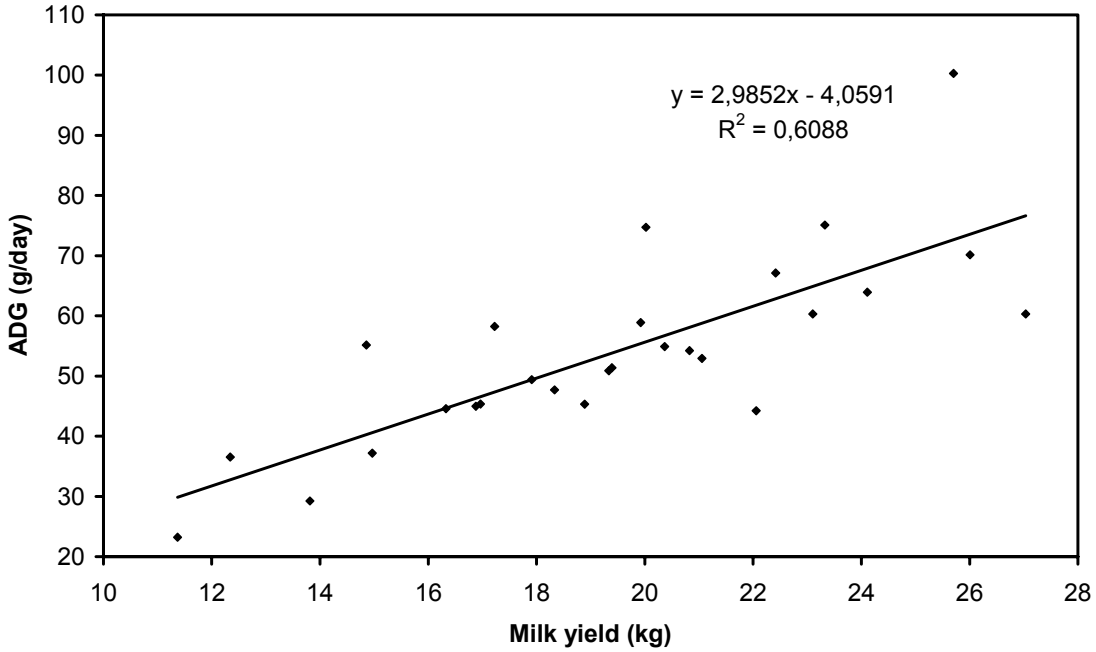

Fig 3 Relationship between milk yield of ewe and average daily body weight gain of lambs

3.4 Lambs survival rate

Post natal survival of lambs (the percentage of lambs born alive that were weaned) and the number or weight of lambs weaned per ewe bred differed significantly (P<0.05) between treatments (Table 5). Supplementation with Sesbania improved significantly (P<0.05) post natal survival rate of lambs, the number and weight of lambs weaned than supplementation with concentrates (Table 5).

Table 5 Effect of the dietary treatments on the postnatal survival of the lambs and the overall reproductive performance of ewes

	Treatments	
	Concentrates	**Sesbania**
No. of ewes bred	20	19
No. ewes lambed	14	16
No. of lambs weaned	11	16
No. of lambs weaned/ewe bred	0.55^{b}	0.84^{a}
No of lambs weaned/ ewe lambed	0.79^{b}	1.00^{a}
Lambs weaned/lambs born alive	78.6^{b}	100^{a}
Wt (kg) of lambs weaned/ewe bred	3.1^{b}	4.3^{a}
Wt (kg) of lambs weaned/ewe lambed	4.43	5.06

Means in a row with different superscripts are significant at P<0.05

4 Discussion

4.1 Lactating ewes feed intake and body weight gain

The ewes in the present experiment had a different feeding history before the experiment since each animal received the experimental diet already from an average age of 4.5 months onwards. Because the Sesbania-supplemented animals had a better intake and digestion during growth and pregnancy (Mekoya *et al.,* 2007) they had a higher post-partum weight than the animals that were receiving the concentrate supplement. To discriminate between the effect of higher post-partum weight and supplementation effects we included post-partum weight as a covariate in the statistical models. Differences between dietary treatments with regard to intake and ewe growth rate during lactation were to a large extent attributable to post-partum weight. Ewe milk yield, however, was even after correction for post-partum weight higher for Sesbania supplemented animals and had, consequently, a positive effect on growth of lambs.

Lactating animals' performance depends on intake of nutrients and their digestibility. Provided that there are no nutritional limitations and anti-nutritional factors that can affect feed intake and digestibility of nutrients, any increase in forage intake will ultimately improve productivity of animals. The mean DM intake of ewes during lactation was higher than the intake during pregnancy (638 vs. 476 g/day) and had the same trend for both treatments, which is associated to the higher nutrient requirements during lactation than during pregnancy. In addition, the increase in foetal size with the advancement of pregnancy occupies most of the abdominal cavity, limiting rumen space, which in turn limits the voluntary feed intake of the pregnant ewe. Our results are in line with the reports of Shetaewi *et al.* (2001) who described that the mean dry matter intake of lactating Damascus goats supplemented with *Acacia saligna* was higher than in the period of pregnancy.

The increment in body weight of ewes in both treatment groups, although very low, indicated that the nutrition of both treatment groups was fairly adequate to supply the required nutrients during lactation since there was no overall body weight loss over the three months lactation period. Conversely, there was weight loss during the first month of lactation and a weight gain towards weaning in both treatments. The former could be associated with lambing stress and the latter could be attributed to utilization of nutrients for body recovery with subsequent body weight gain. Muinga *et al.* (1992a) in crossbred dairy cows and Shetawari *et al.* (2001) in lactating goats reported that body weight of

lactating animals decreases following parturition thereafter increases if they are supplemented with optimum amount of feed with the required nutrients.

4.2 Lambs growth rate

The mean live weight of lambs at 30, 60 and 90 days of age for both treatment groups was comparable to those reported for Menz lambs by Mukasa *et al.* (2000) and Gautsch, (1987) supplemented with a growing concentrate ration and those reported by Mekoya (2000) and Niftalem (2000) managed under traditional (free grazing system) husbandry systems. Lambs born from ewes supplemented with *S. sesban* (Accession 1198) at 0.9 and 1.2% of their body weight (25-30% of the diet) had a live weight of 3.1 and 3.4 kg and a growth rate of 47 and 38 g/day respectively at 30 days after birth (Solomon, 2002). Our results are higher (3.8 and 80 g/day) than those reported by Solomon (2002) for the same age of lambs born from ewes supplemented with Sesbania (accession 15019) composed of 30% of the ration (0.98% of their body weight), which could be attributed to the difference in post partum weight of ewes.

The differences between treatments in growth rate and weaning weight of lambs in the present study could be associated with the differences in the capacity of the supplements to offer the required nutrients to ewes during pregnancy and lactation which might lead to differences in their capacity to produce more colostrum and milk. This shows that supplementation with *S. sesban* enabled ewes to produce more milk and thereby elicited higher live weight and growth rate of lambs, which agrees with the observations of Solomon (2002), Tedonkeng *et al.*, (2006), Abu-Zanat and Tabbaa (2006). They reported that supplementation of lactating ewes and does with multipurpose fodder trees improved growth rate of their lambs/kids.

4.3 Milk yield

Although there is no literature available on the milk yield of Menz ewes, the average milk yield registered in the present study was comparable to those reported (Gemeda *et al.*, 1997) for Horro sheep breeds in Ethiopia (19.2 kg/head/lactation) but was lower than those reported by Banda *et al.* (1992) for non-dairy sheep in Malawi, and the Dwarf Blackbelly sheep in Cameroun (Njwe and Manjeli, 1992) which could be associated to breed differences in terms of body weight and milking ability.

In an experiment to evaluate the effects of supplementation with fodder trees on milk production of crossbred dairy heifers, Khalili and Varvikko (1992)

substituted concentrate (a mix made of noug cake and wheat middling) with *S. sesban* (accession not mentioned) and observed linear decreases in total dry-matter intake and milk yield and concluded that *S. sesban* was inferior to concentrates. However, S. *sesban* has been shown, in terms of milk yield and live weight change, to be as effective a supplement as cottonseed cake, when fed to lactating crossbred cows given a Napier grass basal diet (ILCA, 1990). Muinga *et al.* (1992a,b) supplemented graded levels of Leucaena to lactating crossbred cows fed Napier grass basal diet, and described that supplementation with Leucaena increased total dry matter intake, milk yield and reduced live weight loss in early lactation maybe due to increased supply of nutrients. Furthermore, a significant increase in milk production in dairy cows was reported when the leaves of *L. leucocephala, S. sesban o*r *C. calothyrsus* were incorporated in the feeding regime of ruminants (Paterson *et al.,* 1996; Maasdorpa *et al.,* 1999). Our results also confirmed that supplementation with *S. sesban* resulted in more than a 13% increase in milk production (after adjustment for the difference in PPW) compared to supplementation with concentrates. The lower milk yield of ewes supplemented with concentrates could be associated primarily with the higher content of fibre contained in the dry matter with subsequent lower organic matter digestibility and lower energy availability. This may also show that the concentrate supplements used in our experiments were not of high quality. The increased milk production observed in the groups supplemented with Sesbania further validate the nutritional quality of Sesbania to offer adequate nutrients for body maintenance and production of lactating ewes. The anti-nutritional factors contained in Sesbania did not show observable negative effects on the milk yield of lactating ewes.

4.4 Lambs survival rate and ewes reproductive performance

The overall survival rate of lambs for treatment groups in our study agrees with the reports of Mukasa *et al.* (2000) for the same Menz breed but supplemented with commercial concentrates. The higher survival rate observed in lambs born from ewes supplemented with Sesbania could be related to the heavier birth weight of lambs and higher milk yield of their dams with a subsequent improvement in lambs' growth and survival rate. Tedonkeng *et al.* (2006) in his observation on the supplementation effect of multipurpose leguminous tree leaves found out that does with higher milk yield and supplemented with *L. leucocephala* and *C. calothyrsus* leaves during the dry season were able to produce more milk and weaned more lambs. The mean weight of lambs weaned per ewe lambed is considered to be a good indicator of the overall

reproductive performance. The present study also showed that supplementary feeding of *S. sesban* during pregnancy and lactation improved the overall reproductive performance of Menz ewes.

4.5 Conclusion

From the results of our study it can be concluded that supplementation of *S. sesban* at 30% of the ration (0.98% of their body weight) during pregnancy and lactation resulted in higher milk yield of ewes, higher lambs growth rate and survival compared to supplementation with concentrates. Hence, S. *sesban* has the potential of improving the traditional sheep husbandry by serving as a substitute ration to commercial concentrates for poor farmers who lack the resources to purchase and supplement their animals.

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Annex 1. Composition of basal feed and supplements in the ration at two levels of *S. Sesban* (SS) supplementation

Ingredients	% DM in the ration	
	95% SS	**0% SS**
Teff straw	70.00	70.00
Sesbania sesban	28.93	0.00
Noug cake	0.00	13.84
Maize husk	0.00	11.59
DAP	0.76	0.32
Lime stone	0.00	0.54
Urea	0.00	0.56
Maize (ground)	0.17	0.00
Wheat bran	0.00	3.01
Salt	0.15	0.15
CP in diet %	10.5	10.5
ME in diet (MJ/kg DM)	7.82	7.82
Ca in diet	0.0060	0.0060
P in diet	0.0036	0.0036

DAP=Di-Ammonium phosphate

Chapter 8

General discussion

1 Introduction

Livestock is essential to the livelihood of rural poor people in developing countries. It is an important source of cash income, and one of the few assets available to the poor. But most importantly it provides manure and draught power that are vital to the preservation of soil fertility and the sustainability of mixed farming systems in many developing areas. Thus, livestock is vital to ensure food security and to reduce poverty (Delgado *et al.,* 1999). The contribution of the livestock sector is, however, constrained by many technical, socio-economic and institutional factors. General consensus is that a major technical limitation to increased productivity of ruminant livestock in sub-Saharan Africa is poor nutrition in terms of quantity and quality.

Introduction of fodder trees is one of the many technological innovations that have been identified to alleviate feed shortage and improve the utilization of crop residues. Added benefits are that they reduce soil erosion, enhance land productivity, and serve as a source of fuel wood to smallholder farmers in sub-Saharan Africa. Despite the apparent benefits, the overall extent of adoption of fodder trees at farm level is too low and the innovation did not generally appear to be successful (Neupane *et al.,* 2002; Sumberg, 2002). Reasons underlying the lack of impact of much of the fodder tree technologies in sub-Saharan Africa in general and in the Ethiopian highlands in particular are undoubtedly complex and include technological, bio-physical and socio-economic factors (Thomas and Sumberg, 1995; EARO, 2002; Kassie *et al.,* 1999; Gebremedhin *et al.,* 2003). Technologies intended for better management and utilization of multipurpose fodder trees should address these inter-linked bio-physical and socio-economic factors. They should be treated as inherent attributes of the farming systems because agro-ecologies, socio-economic conditions and farmers interests are diverse. The notion of a fodder tree having ''value'' can only be meaningful in relation to a defined farming system and its context. The sense of absolute goodness associated with multipurpose fodder trees from a technical point of view such as nutritive value and role in soil conservation is not sufficient to justify the introduction of multipurpose fodder trees. Research and development organizations need to examine the potential role of fodder trees much more critically in a farming systems context. Bio-physical conditions, resource endowments and access to markets and institutions will differ within and between farming systems (Pender *et al.,* 1999; Assefa, 2005). Finding an answer to the questions of why farmers in the Ethiopian highlands have been so hesitant to grow and use exotic multipurpose fodder trees is essential if future fodder tree research and development is to

make a positive contribution to the livelihood of smallholder farmers and the environment. The present thesis aims to understand farmers' perception about the development and utilization of exotic multipurpose fodder trees, to identify their decision making criteria for adoption, and to elucidate the importance of local knowledge and resources to set up pertinent research questions in a farming systems context. Also it assesses the nutritional value of the most widely disseminated exotic multipurpose fodder tree ''*Sesbania sesban*'' from the farmers perspective, and in a series of experiments. The latter series of experiments was actually one long-term feeding experiment and was executed to answer the question whether Sesbania could be used safely for supplementation of ruminants.

The following sections discuss the implications of the research findings and address the potential benefits of exotic and local multipurpose fodder trees, by subsequently analysing farmers' decision making processes, local knowledge and resources, and the role that *S. sesban* and other multipurpose fodder trees could play under various crop-livestock systems. It deals also with the question of how results from the series of on-station experiments carried out on the feeding values of *S. sesban* could be made useful in practice. We conclude with a discussion of areas that need further research and development.

2 Adoption constraints

Batz *et al*. (2003) showed on the basis of a study in Kenya that speed and ceiling of adoption of dairy technologies was influenced by the relative investment, the relative risk and the relative complexity of the technology. Exotic multipurpose fodder trees as a technology was not included in their studies. We assume that investment, risk and complexity of introducing exotic fodder trees into farming systems that already contain local multipurpose fodder trees are relatively low. Hence, we conclude that constraints relate to farming system specific conditions, either bio-physical or socio-economic.

With a few exceptions in the mixed crop-livestock systems of the Ethiopian highlands, exotic multipurpose fodder trees were introduced either in association with improved dairy cattle and/or with soil and water conservation (SWC) programmes (Gebremedhin *et al.,* 2003). In two of our study districts the dissemination of exotic multipurpose fodder trees by development projects was linked with small scale dairy development. Growing exotic multipurpose fodder trees around the backyard and on soil conservation structures in farm lands was thought to improve the nutritive value of crop residue-based diets,

and to be beneficial to soil conservation (Chapter 2). The dissemination objectives did neither include assessment of farmers' criteria of adoption nor study of the potential of local resources. Contrarily, they generally lacked recognition and solving of the production constraints and farmers multiple objectives occurring to specific farming systems (Chapters 2 and 3).

Factors that affect adoption of fodder trees in the mixed crop-livestock systems emanate from interactions among system components and between the system and its external environment. For a farmer's family the adoption of fodder technologies is affected by

- supply and demand for livestock feed
- household production factors such as land and tenure type, labour and capital that determine the household's capability to integrate forage production into the farming system or to purchase feed from the market
- the extent of integration/participation and proximity to markets of inputs and outputs of the household
- and the presence and effectiveness of institutional services such as extension

All have been described in literature as principal factors explaining household adoption behaviour (Feder *et al.*, 1985; Batz *et al.,* 2003; Franzel *et al.,* 2003; Gebremedhin *et al.,* 2003).

The present thesis (Chapters 2, 3 and 4) also shows that adoption constraints originate from bio-physical, socio-economic and institutional factors. Although farmers in all farming systems pursue multipurpose fodder tree development for diverse objectives, the degree and importance of the constraints varied across farming systems (Table 1).

Table 1 Importance of adoption constraints for different farming systems in the Ethiopian highlands

Adoption constraints	**Farming systems***		
	Lay-Armachuho (Wheat based)	Debay-Tilatgen (Teff based)	Sidama (Coffee based)
Agronomic problems	+++	+	+++
Multifunctionality	+++	+	+++
Compatibility	+	+	+++
Land shortage	++	+++	++
Labour shortage	++	++	+
Utilization awareness	+	++	+
Others	++	++	++

+ Lowest importance; +++ Highest importance (Chapter 2); *In the wheat and coffee-based systems cattle (small scale dairy) and in the teff-based system sheep are important sources of income.

For instance, in Lay-Armachuho and Sidama bio-physical factors such as agronomic problems and multifunctionality are significant whereas in Debay-Tilatgen household resource base, institutional factors such as lack of land and labour, and lack of utilization awareness are important factors affecting adoption. Furthermore, the use of crop residues may increase the demand for supplementary feed in Lay-Armachuho and Debay-Tilatgen districts and consequently stimulate the adoption of fodder trees more than in Sidama. Plantation strategies (around the backyard and on soil conservation structures in farm lands) promoted in each district may also influence adoption. Growing on soil conservation structures in farm lands needs high labour to protect from free-grazing animals and was important constraint in Lay-Armachuho and Debay-Tilatgen whereas competition with perennial crops for the available moisture and nutrients such as coffee was the drawback to plant in farmlands in Sidama. However, in all farming systems it was the backyard plantation strategy that was acceptable by farmers (Chapter 2). The implication of the difference in the degree and types of constraints for adoption among districts/farming systems shows that a detailed site and system analysis is vital in complex production systems.

Farmers seek information from organisations and people whom they perceive to be credible, reliable and relevant to their context. In essence, farmers will prefer to liaise directly with state agencies, non-governmental organisations, their neighbours, or with a combination of these. Even when seeking information and advice from 'outsiders', they invariably verify such information through in-depth discussions with local farmers making informal or formal local networks important (Anandajayasekeram *et al.,* 2002). Farmers' major source of information and inputs for fodder development technologies were development organizations. It is unknown why farmer-to-farmer information exchange on the issue of fodder trees was relatively limited and whether informal local networks exist for exchange of information on other farm issues. If farmers do exchange information in such networks, but not on the issue of fodder trees might indicate that fodder trees are not perceived as very important in the farm practise.

Irrespective of the difference in farming systems and farmers wealth status 72% of respondents continued to depend on external sources for seeds or seedlings, and the effort for self-reliance was limited as well (Chapter 2). This implies that a change in the extension approaches is needed to enable farmers or farmer groups to access information and inputs for new practices. We can talk of

meaningful adoption when a farmer has experimented with a species or a fodder technology, and subsequently expands his plantation area with that technology using his own resources. Development partners should not see their role as simply transferring technology and information to farmers. Rather, they should focus on assisting farmers to mobilise their own resources and enhance their ability to obtain information on improved practices from in and outside their villages through strengthening farmer-to-farmer linkages, to make the flows of information and germplasm self-sustaining. Poor farmers relied more on farmer-to-farmer contact than rich ones for information (Chapter 2). This may show that the extension approach has preference to those privileged in resources and hence there is, to some extent, exclusion of poor farmers from extension services.

Farmers' evaluation is a prerequisite for adoption, and the success of introducing exotic multipurpose fodder trees depends on how well the new fodder tree fits into the existing farming system. Farmers decision making criteria for adopting a fodder tree comprises the following factors:

- its compatibility with other crops,
- its agronomic characteristics,
- its contribution to soil fertility improvement and protection of natural resources,
- its multiple function for a wide array of farm household objectives,
- its land and labour requirements, and
- its effects on the productivity of animals (Chapter 3).

In addition, the severity of feed scarcity and the importance of crop residues as livestock feed in each farming system influenced the introduction and adoption of fodder trees (Chapter 4). Generation and dissemination of fodder technologies that can comply with these highly complex and inter-twined multiple interests is essential, but it may be difficult in practice to find a multipurpose fodder tree that can suit all of the farmers' selection criteria. Nevertheless, some degree of compromise has to be found while taking into account farmers multiple interests as much as possible. Furthermore, specific consideration of the characteristics of each farming system or even farming households before introducing fodder development technologies is indispensable for a successful adoption. In Sidama (coffee-based livestock system) districts, farmers usually plant a variety of multipurpose fodder trees in order to cover a wide array of functions. In this farming system, the new fodder technology would be acceptable only if it has comparative advantages over the

local resources farmers already have. Conversely, in Debay-Tilatgen district (teff-based livestock system) where there are no alternative local fodder trees (Chapter 2), constraints related to agronomic characteristics and multifunctionality had less importance as compared to the other two districts (Table 1). Under such circumstances, the introduction of exotic multipurpose fodder trees will be more valuable and the degree of adoption would probably be higher.

It has been argued that the demand and the opportunities for farm innovations such as development of fodder trees may be poor if livestock production is for subsistence of the farming household only (although fodder adoption in Lay-Armachuho district does not support fully this argument) or if livestock productivity and response to innovations are low. The potential for adoption may be high when livestock productivity is high, when livestock respond to the innovation and when profitability is high due to market-oriented production systems, such as dairying in the highlands of Kenya and Uganda (Franzel *et al.*, 1996; Franzel *et al.,* 2003; Gebremedhin *et al.,* 2003). Similarly in the Ethiopian highlands, linking fodder tree utilization to a market-oriented production such as dairying with crossbreds or improved breeds, and fattening of cattle and small ruminants is believed to enhance adoption of fodder technologies particularly in peri-urban areas (Alemayehu, 1997; Gebremedhin *et al.,* 2003). The involvement of more farmers in adopting exotic multi purpose fodder trees in Lay-Armachuho district (Chapter 2) could be a reflection of the linkage between fodder development and market-orientated dairying. However, the existence of crossbred dairy cows and market orientation of livestock production does not necessarily lead to adoption of exotic multipurpose fodder trees. For instance, in Sidama district crossbred dairy cattle were introduced along with improved fodders such as Sesbania, Calliandra and Napier grass. Farmers had relatively better access to markets because of their proximity to major urban centres but adoption of exotic multipurpose fodder trees was lower than in the other districts as an effect of the availability of many useful local fodder trees and the secondary importance of livestock when compared to coffee. This shows that despite the potential benefits that could be achieved in feeding dairy animals through introducing exotic multipurpose fodder trees (assuming that their feeding value is higher than that of local multipurpose

fodder trees), the adoption decision can not be based only on one parameter but also on other farm functions.

3 Exploiting local knowledge and resources

3.1 Local knowledge

Whether local knowledge systems should be differentiated from scientific knowledge has been a source of debate since long (Long, 1992; Agrawal, 1995). Nevertheless, there must be a real coexistence between the different forms of knowledge for sustainable development (Long, 1992; Saidou, 2006). The study in the present thesis (Chapter 3) did not attempt to validate local perception against the standards of science. The emphasis, by contrast, is to indicate the importance of considering local knowledge to substantiate the existing knowledge developed by scientists. It gives scope for alternative, combined approaches from the perspectives of both farmers and scientists. And joint experimentation and co-production of new knowledge could minimize gaps between both approaches.

Farmers in our study districts (Chapter 3) and in other parts of the world have practical knowledge about the quality of fodder trees (Thapa *et al.,* 1997; Walker *et al.*, 1999; Thorne *et al.,* 1999; Roothaert, 2000). Tapping this knowledge would be much faster and cheaper than carrying out elaborate analysis in laboratories for the purpose of screening the nutritive value of browses. For instance, the complexity of anti-nutritional factors which influence nutritive value makes screening of fodder tree species difficult, and the only reliable information seems to be long-term feeding trials with different animal species under a range of conditions. It is therefore logical to obtain as much information as possible from farmers who have fed local tree and shrub species to their animals on a routine basis for a long time. In this case, farmers' and scientists' knowledge will be of complementary rather than exclusive nature in helping to design future studies that are more focused and that can be realised in the short term.

There were strong relationships between farmers' assessments of the feeding value of multipurpose fodder trees and laboratory analysis of crude protein. However, some species such as *F. thonningii* and *E. cymosa* deviated from the general relationship and showed relatively low crude protein contents in laboratory analysis but were appreciated by farmers for factors like multifunctionality, compatibility or ease of growing (Chapter 3). It is imperative to identify these outlying species, because they are important for farmers for other reasons than their crude protein content. They could easily be overlooked

in selection programmes if only laboratory tests were used as criteria. In this case integration of the two knowledge systems will help to make wise decisions to combat the drawbacks of one knowledge system over the other. If we combine the two knowledge systems and make the best of it, it is possible to select species that can meet farmers' requirements in most cases. On the other hand, farmers can differentiate bad fodder trees from good ones. However, their knowledge may not reach as far as determining which amounts of feed have to be mixed for the appropriate animal ration. Optimising ruminant livestock production still requires accurate information about the available feed resources and the quantity and quality of energy and protein in these feed resources. In this regard, scientists' knowledge would be complementary and necessary to generate the required information.

3.2 Local fodder tree resources

Indigenous species are hardly considered for on-station experiments since little is known about them in the first place and they are thought to have low fodder biomass production potential, one of the most important nutritionists' criteria. The development of technologies with indigenous multipurpose fodder trees contributes to increased bio-diversity on-farm, therefore, reducing the risk of depending on a few exotic species. Farmers scoring showed that most local multipurpose fodder trees could produce a biomass better than or comparable to exotics (Chapter 3). However, it needs to be supported by further investigation whether, under recurrent cutting, local multipurpose fodder trees produce similar to exotic species in terms of useful fodder per unit land area. Even if local fodder trees would produce less, growing them does not necessarily cause a loss of opportunity. As local fodder trees are highly integrated in the farming system, lower biomass production of these trees may probably be compensated by their importance for other farm functions. Among farmers' selection criteria, local multipurpose fodder trees were preferred to exotics in biomass, multifunctionality, compatibility with the cropping system and life span of the tree but were comparable or lower in the other parameters (Chapter 3). This shows that in farming systems like Sidama district, local multipurpose fodder trees do have abundant functional niches for the broad farm objectives. Thus, focusing initially on local resources would be more useful than the indiscriminate introduction of exotic species, particularly in farming systems where there are alternative local multipurpose fodder trees that farmers have grown and used for centuries. The advantages of exploiting local resources is not only beneficial to the specific farming systems they are found in, but also for other farming systems that lack the resources as an

alternative to introducing exotic species. Furthermore, the proximate analysis of local multipurpose fodder trees nutritive value reported in Chapter 3 shows that their crude protein content ranged between 110 and 270 g/kg dry matter and most of them were over 150 g/kg dry matter. Although variation in nutrient composition in different seasons will exist, these values are high enough to formulate productive rations with grass and crop residues that compare to rations that include exotic multipurpose fodder trees or commercial concentrate supplements. This shows the existence of more local opportunities for researchers, development organizations and for resource-poor farmers that can potentially serve as protein supplements.

4 Potential of *S. sesban* and contribution to year round supplementation

Sesbania is mainly recommended to the highland zones of sub-Saharan Africa where the mean daily temperature during the growing period is below 20^{o}C (ILCA, 1989) as supplement to low quality feeds (Heering, 1995). Nevertheless, the role of Sesbania in the farming systems should be assessed in terms of farmers' response to its feed value, contribution for year round supplementation and role for other farm functions. Farmers' perceptions on the positive attributes and drawbacks of *S. sesban* with respect to their farming systems were explored in Chapters 2, 3 and 4. The response to the attributes of Sesbania differed depending on the farming system, and depended on system components e.g. the types of crops grown, the extent of utilization of crop residues, the availability of alternative multipurpose fodder trees for feed and other purposes, and the extent of land scarcity (Chapter 4). Among the farming systems, the potential use and role of Sesbania for feed and other farm purposes was more noteworthy for the annual crop-based livestock systems than for the perennial crop-livestock production systems since the former are more reliant on crop residues most of the year (Table 2).

Table 2 Importance of *S. sesban* among farming systems in the Ethiopian highlands

	Farming systems		
	Lay-Armachuho (Wheat-based)	Debay-Tilatgen (Teff-based)	Sidama (Coffee-based)
Feed value	+++	+++	++
Year round feeding	++	+++	+
Other farm purposes*	+	++	+

+ Lowest importance; +++ Highest importance; * Role for other farm purposes include: soil conservation, live fence, fuel wood, construction; *In the wheat and coffee-based systems cattle (small scale dairy) and in the teff-based systems sheep are important sources of income.

On the other hand, in the coffee-based farming systems (Sidama district) the availability of alternative local multipurpose fodder trees, the lower contribution of crop residues as feed, and farmers' higher dependence on coffee for cash makes Sesbania less valuable than in the other districts. This implies that the level of importance of Sesbania varied between farming systems, and the approaches for introducing exotic multipurpose fodder trees such as Sesbania should be evaluated in terms of the specific features of the farming systems.

Irrespective of the difference among farming systems, farmers' perceptions about the supplementation effects of Sesbania in general were increased milk production, improved body weight gain and improved reproductive performance (Chapter 4). Farmers' perceptions were supported by our results in Chapters 5, 6 and 7. Farmers have at least four strategies to supplement fodder trees to livestock:

1) Strategic supplementation in the sense that they supplement just enough to supply the nutrients that limit intake, digestion and metabolic utilization of the crop residue in the diet. This effect is found at low supplementation levels (< 15% of total diet; Kaitho, 1997).

2) Strategic supplementation in the sense that they supplement the fodder tree during periods of low feed availability and low feed quality

3) Strategic supplementation in the sense that they supplement only those animals that benefit most from it. (In Chapter 6 it was observed that pregnancy rate was improved by Sesbania supplementation during the mating period, but that the effect was similar for supplementing either ewe or ram. The sex ratio was 1 in the experiment, while in practise one ram may serve 30 ewes. It would be very efficient then when supplementation of one ram would have the same effect as supplementing 30 ewes, but is doubtful whether this effect will be achieved. Further research of the effect of ram supplementation during the mating period on herd fertility is recommended).

4) Continues supplementation of all animals in the herd to achieve a high production output in terms of milk, meat and animals.

Sustainable use of Sesbania could only be achieved when farmers are well aware of the optimum amount, frequency and duration of feeding required for

each of the supplementation strategies. This could be ensured if farmers have the adequate number of fodder trees to supplement their animals either strategically or on a more continues basis

From the reviewed literature (Devendra, 1992; Kaitho *et al.*, 1998; Solomon, 2002) and the results of our own studies (Chapters 5, 6 and 7), supplementation of Sesbania at 30% of the ration on DM basis or 0.75 kg per 100 kg body weight per day seems a recommendable level for continued supplementation. The daily supplementation level of the three farming systems in our study was 1.4 kg per day per farm, which is 4.2 kg per day per farm below the recommended quantity to exploit the full potential production capacity of the farm animals (Chapter 4). The optimum number of fodder trees farmers should grow to fulfil the recommended daily requirements for an optimal body growth and production for different length of periods in a year is presented in Table 3. The calculated dry matter yield of the available Sesbania trees on-farm could supplement in Sidama for about 2 months and in Lay-Armachuho and Debay-Tilatgen districts for about 5 months. Taking into consideration the dry period (Mid December to June) all districts does not have sufficient number of trees for strategic dry season supplementation of their animals and the problem being more pronounced in Sidama district. For dry season supplementation targeted to include 30% fodder trees in the diet, farmers in Lay-Armachuho, Debay-Tilatgen and Sidama districts need to grow 180, 165 and 400 additional fodder trees, respectively, which will demand from 0.02 to 0.04 ha of land. Alternatively, most farms in the study districts are subsistence farms with some cash crop production (coffee) in Sidama and marginal milk marketing in Lay-Armachuho. Livestock in such systems is important for manure production to serve as fertilizer for crops, draught and transport and a means of savings. Farmers' interest to supplement their animals in such subsistence systems is to help them survive through the dry season and to give some production, especially of offspring. It seems justified to conclude that the current Sesbania trees available on-farm could be sufficient for strategic supplementation for subsistence in Lay-Armachuho and Debay-Tilatgen districts even year-round while the tree availability in Sidama could supplement only the dry season. This implies that the supplementation effect is for a major part to be attributed to the effect of the supplement on intake, digestion and utilization of the crop residue, while the actual amount of energy provided by the supplement is relatively low.

Table 3 Feed balance and annual projection for number of Sesbania trees required for an optimal production in the three farming systems

Districts	**Herd Size (TLU)**	**Trees / farm**	DM yield /farm /y	**Req. /farm (kg/d)**	**Days to be fed**	Feeding months req (kg)			Balance /farm						**Total No. trees required**		
									6		9		12				
						6	9	12	kg	No. of trees	kg	No. of trees	kg	No. of trees	6 mth	9 mth	12 mth
Lay-Armachuho	4.3	790*	1185	8.06	147	1451	2177	2903	-266	-178	-992	-661	-1718	-1145	968	1451	1935
Debay-Tilatgen	3.4	570	900	6.38	141	1148	1721	2295	-248	-165	-821	-548	-1395	-930	735	1118	1500
Sidama	2.7	210	315	5.06	62	911	1367	1823	-596	-398	-1052	-701	-1508	608 -1005		911	1215

Assumptions: 1 TLU= 250kg; Number of Sesbania trees that can be grown/ha=10,000; DM yield of Sesbania /ha=15 tones;

Daily animals requirement/100 kg body weight=0.75 kg

* The average number of trees in Lay-Armachuho district was calculated by excluding outliers (2 respondents)

Livestock in Lay-Armachuho and Debay-Tilatgen get part of their basal diet from grazing natural pastures. Though quality and quantity of such pastures is low during the dry season, young shoots that emerge in the beginning stage of the rainy season may be of good quality with regard to energy and protein (Assefa, 2005). Hence, grazing might at least during the start of the rainy season reduce the need for supplementation.

The difference between farmers with regard of the goal of livestock keeping determines whether they supplement continuously at a high level or strategically at a much lower level will determine their choice between growing or not growing more trees. However, even if farmers are willing to grow more trees, land and labour requirements (Chapter 2) will remain knotty. In the annual crop-livestock systems, most of the land is occupied by extensive crop production, especially in Debay-Tilatgen district, and growing more fodder trees may be unacceptable for farmers. In this farming system strategic utilization of *S. sesban* during critical feed shortage periods or differential treatment of animals depending upon the intended production objectives might be more worthwhile. In the coffee-based livestock systems (Sidama district) most farmers had alternative local fodder trees and could be reluctant to allocate extra land. Growing an additional number of trees would be acceptable only because of the relative advantages of Sesbania compared to local multipurpose fodder trees.

As mentioned before, farming systems in the Ethiopian highlands are predominantly subsistence systems. Livestock is kept for many purposes but its value is often perceived more in terms of number of animals rather than production potential. Farmers would rather choose to feed a high number of animals just above maintenance level from a given quantity of feed than to selectively feed the best diet ingredients to a limited number of animals to get maximum herd output (Zemmelink *et al.,* 2003). Hence, improved Sesbania availability might have the effect that farmers increase their livestock number for other benefits such as manure and not for increased animal protein output. This indicates a conflict of interests between farmers on the one hand and development organizations and the government on the other hand.

Nevertheless, with the existing fragile ecosystems, pressure on land resources and the relatively increasing demand for livestock products, livestock producers need to become more market-oriented. Market-oriented production might motivate farmers to have fewer but more productive animals. In this

case, the available number of Sesbania trees is insufficient to supplement the recommended amount, and farmers should be encouraged to grow more trees. Then the role of Sesbania as feed would be more significant.

5 Browses as supplements to low quality roughages

5.1 Effects on feed intake and digestibility

Most investigations of feed intake, digestibility, and performance of animals in response to protein supplementation of roughage and crop residue-based diets have been conducted with concentrates. Commercial concentrates, herbaceous legumes and fodder trees usually improve the supply of protein which is limited in fibrous feeds and this in turn will raise animal productivity through improving the intake, digestion and utilization of carbohydrates, energy and other nutrients from fibrous feeds. However, economic limitations hinder resource-poor farmers in the Ethiopian highlands to have access to commercial concentrate supplements. Moreover, commercial concentrates may be very variable with regard to composition and quality. The concentrate used in our experiments (Chapters 5, 6 and 7) was supposed to be iso-caloric with the Sesbania supplement, but appeared to have a high NDF-content and a low digestibility because of lower quality of the ingredients than expected.

Correcting dietary protein deficiency increases the microbial degradation of food in the rumen and consequently improves the animals' metabolic energy and protein supply, both of which lead to an increase in voluntary intake of digestible organic matter and in animal performance (Kaitho, 1997). This was clearly evident in the higher intake and digestibility of organic matter and live weight gain of the animals supplemented with Sesbania irrespective of the levels of Sesbania (Chapter 5). The high N content, digestibility, and moderate levels of tannins (Kaitho, 1997) of *S. sesban* makes it a good protein supplement, and when fed daily at levels of 30% of the ration on dry matter basis, could supply moderate levels of rumen-available N that could effectively be trapped for microbial synthesis. Hence, it can be concluded that an alternative to commercial concentrate is the use of multipurpose fodder trees as protein supplement and as a low cost strategy for smallholder farmers in the tropics.

5.2 Tannins in *S. sesban*

S. sesban could potentially contain the whole array of anti-nutritional factors, which are not identified in our studies, but the presence of low to high levels of tannins in different *S. sesban* accessions is well documented. Despite the difference within and among accessions in tannin content (Wiegand *et al.*, 1995)

owing to factors such as plant age, plant part, harvesting regimen, season and location, *S. sesban* (accession 15019) used in the feeding studies of Chapter 5, 6 and 7 of the present thesis contained moderate levels of tannins and fibre fractions (Kaitho, 1997; Reed *et al.,* 1990; Wiegand *et al.,* 1995). It is hypothesised that in species with moderate levels of tannins part of the feed protein will escape from ruminal degradation as a result of the tannin-protein binding. Such so-called by-pass protein will become available for digestion in the duodenum together with the microbial protein synthesized in the rumen. Hence, more protein will become available to the animal than in diets without tannin (Osuji *et al.,* 1993; Richards *et al.,* 1994; Nsahlai *et al.,* 1995; Melaku *et al.,* 2004a). In our experiments, due to relatively low quality of the concentrate, increased tannin-concentration in the diets was confounded with increased digestibility of the diet. For that reason it cannot be concluded whether the effects of increased Sesbania levels in the supplement were related to either more by-pass protein, or extra energy supply or both. However, literature showed that sheep fed accessions that had a high content of pro-anthocyanidins (condensed tannins) had the lowest intake of cereal crop residues and the lowest digestibility of protein, N retention and growth rate. Conversely, sheep fed accessions with a moderate content of condensed tannins had a higher growth rate and N retention than sheep fed the lowest content (Wiegand *et al.,* 1995). Browse species with low tannins and high N degradability provide high levels of rumen ammonia, much of which was wasted by excretion as urinary urea (Kaitho, 1997).

5.3 Effects on production and reproduction

The better reproductive performance of animals supplemented with Sesbania (Chapters 5, 6 and 7) or a mixture of Sesbania and concentrates (Chapter 5) suggest that the protein and energy concentration were adequate to supply the required nutrients for body growth, sexual development and reproductive performance of sheep. The existence of significant association between plane of nutrition and body weight, puberty age, sperm quality, and reproductive performance of ewes (Chapters 5, 6 and 7) further shows the nutritional quality of Sesbania to improve reproductive efficiency. Reviewed reports also indicate that protein concentration and level of feeding significantly influenced body growth, sexual development and reproductive performance of animals (Mukasa *et al.,* 1993; Preston, 1995; Abi Saab *et al.,* 1997).

In sheep, inadequate, excess or imbalanced nutrients intake may lengthen onset of puberty, reduce conception rate, embryonic or foetal survival and litter size,

result in poor lactation and lengthen post-partum anoestrus and lambing interval in females (Smith and Somade, 1994; Robinson, 1996; O'Callaghan and Boland, 1999). In male animals nutritional imbalances can cause low testicular size and scrotal growth, sperm production and fertility (Thwaites, 1995; Negussie *et al.,* 2000). The reproductive neuro-endocrine system of male and female lambs that leads to puberty is sensitive to dietary energy and protein levels (Kinder *et al.,* 1987; Wood *et al.,* 1991; Wood and Foster, 1998). Ewe- and ram-lambs under optimum feeding condition grow faster and will exhibit early onset of puberty (Mukasa *et al.,* 1993; Abi Saab *et al.,* 1997). Furthermore, protein levels higher than those required for maintenance and growth are needed to improve semen volume, sperm characteristics and fertility in rams and bucks (Foster and Olster, 1985; Abi Saab *et al.,* 1997). Adequate feeding of dietary protein and energy improves onset of puberty by enhancing pulsatile release of LH, a mode of action that probably triggers luteinizing hormone releasing hormone (LHRH) secretion by the hypothalamus (Foster and Olster, 1985) which at the ovarian level increase follicular development (Bergfeld *et al.,* 1994).

The level of Sesbania supplement in the studies reported in Chapters 5, 6 and 7 was 30% of the ration on DM basis, which confirmed earlier reports that have indicated the optimum levels of supplementation for better reproduction performance to be with in the range of 20 to 40% (Devendra, 1988; Ash, 1990; Kimambo *et al.,* 1992). The improvement in reproductive performance (puberty age of both sex groups, scrotal growth and semen quality in rams, conception rate, litter weight and milk yield of ewes) observed in Chapters 5, 6 and 7 corroborate earlier reports that have suggested improvements in reproduction parameters (Hamilton *et al.,* 1971; Akingbade *et al.,* 2001; Negussie *et al.,* 2000; Solomon, 2002) and wool production (Min *et al.,* 2001) from feeding fodder trees.

The results in the present thesis (Chapters 5, 6 and 7) showed that supplementation of Sesbania up to 30% of the ration on DM basis improved body growth and reproductive performance of sheep equivalent to or better than the local concentrate supplements. And at the levels of Sesbania tested (47.5 and 95% Sesbania in the supplement), no clinical symptoms of adverse effects were apparent that supported earlier reports and no effects on the onset of puberty, oestrus behaviour, conception rate of ewes, sperm quality and scrotum growth of rams, and fertility of both sexes were observed. On the other hand, other studies showed that supplementation with *S. sesban* reduced testicular growth (Kaitho *et al.,* 1998), resulted in tubular degeneration,

interstitial fibrosis and focal Leydig cell proliferation in male sheep and goats (Woldemeskel *et al.,* 2001). Supplementation of ewes with *S. sesban* (Accession 1198) over 30% of the ration resulted in the lowest expression of behavioural oestrus whereas supplementation levels below 30% of the ration (0.9 and 1.2% of live weight) caused termination of pregnancy due to abortion or death of pregnant ewes (Melaku *et al.,* 2004b) probably due to anti-nutritional components like tannins contained in *S. sesban*. However, the influence of inclusion of Sesbania (accession 15019) over 30% of the ration should be assessed in order to ensure the safety.

6 Implications of on-station experiments to the farming systems

Numerous on-station experiments have been carried out in sub-Saharan Africa to evaluate the feed value of multipurpose fodder trees. In many occasions these research results remain shelved without benefiting the end users and those disseminated often lack the appropriate packages that can be useful for farmers (EARO, 2002). Generation and dissemination of technologies is not an end by itself but a means to achieve improved livestock productivity. It has to be supported by complete delivery of the technological packages such as appropriate feeding practices for different production objectives, and health management coupled with rigorous practical training of extension agents and the end users in order to recognize the value of and adopt the technology in question. In addition, delivery of whole packages will not be effective if the packages do not give solutions to farm problems as perceived by the household. To be able to work with participatory approaches for problem definition and farmer-to-farmer learning (e.g. in farmers' field schools) should therefore also be competences of extension agents.

In our studies, the experimental animals were fed continuously *S. sesban* (accession 15019) as supplement for 19 months (9 months for growth and puberty study, and 10 months during the period of mating, pregnancy and lactation). Hence, we proved that inclusion of *S. sesban* up to 30% of the ration on dry matter basis will improve body growth and reproductive performance of sheep (Chapters 5, 6 and 7) better than locally available concentrates without visible adverse effects (Table 4). The on-station experiments further point out that even for farmers who had the opportunity to purchase and feed commercial concentrates, Sesbania could also partially be mixed with concentrates with similar effects in the productivity of sheep as feeding Sesbania or concentrates alone. The synergy between Sesbania and concentrates on animal performance will enable farmers to rely partly on feed resources

Table 4 Effect of supplementing (30% of dietary intake) *S. sesban* compared to concentrates on sheep performance

Measured parameters	Improvements Sesbania over concentrates (%)
Basal feed intake	21
Weight gain	25
Puberty age	43 days early
Scrotum growth	13
Pregnancy rate	17
Lambs birth weight	12
Milk Yield	13

grown in their backyards. The findings in the present thesis (Chapters 5, 6 and 7) would be useful particularly in the annual crop-based farming systems for different production objectives such as for maintenance, dairying, fattening of large and small ruminants.

It is a common practice of farmers in the Ethiopian highlands to fatten male sheep targeting holidays and festivals. They usually supplement their animals for about 4 or more months using weeds from crop lands, household wastes and sporadically commercial concentrates (Mekoya, 2000). In our studies (Chapter 5) a daily body weight gain ranging from 30 to 60 grams per day was achieved in males in the first six months of the growth experiment by supplementing *S. sesban* with a daily amount of 140 to 230 grams (average 180 grams per day). Our on-station results will not be similar to those obtained on-farm, because of the fact that our experiments were carried out under controlled environmental conditions. However, if farmers could supplement similar amounts of Sesbania as in our experiments along with improved management practices, they would attain body weight increments ranging from 3.6 to 7.2 kg in 4 months. This shows that supplementation with Sesbania accompanied with improved health care could probably fit into and complement the traditional fattening practices of farmers either alone or as a substitute to commercial concentrates. This implies stronger market integration of farmers. Information on market opportunities and threats is limited, which in turn makes economic evaluation of livestock production in the Ethiopian context necessary. Market fluctuations caused by extensive religious fasting periods, access to markets and credit facilities are among those factors that determine the importance of

Sesbania and other fodder trees in future livestock systems in the Ethiopian highlands.

7 Conclusions

- Farmers' perception about exotic multipurpose fodder trees and their constraints to adoption have been investigated between farming systems and wealth groups. The values and constraints of multipurpose fodder trees differ among farming systems. Although our studies are limited to exploring technical constraints, reviewed literature and the results of the present thesis suggest that adoption constraints stem from bio-physical, socio-economic and institutional factors of the system properties. Research on the development of fodder technologies should shift from constraints-oriented analysis that assumes a set of few objectives (e.g. maximal output of meat and milk) to address the whole system through using participatory approaches for problem definition, ideas for problem solutions combined with on-farm experiments and on-station experiments.

- Farmers value multipurpose fodder trees (local and exotic species) for their feed characteristics. Only few studies about local multipurpose fodder trees have been carried out in the Ethiopian highlands, because of inclination to exotic ones at extension services and development agents. Hence, a lack of readily available information on local species exists. The present thesis highlights that there are potential local resources that can serve farmers multiple functions. Furthermore, a significant proportion of farmers have shown interest and preferred to grow local fodder trees. Hence, further studies should generate data about the socio-economic and cultural values and of bio-physical performance of local multipurpose fodder trees. Such studies should among others look at farmers' species use, management, niches and ways of establishment and effects on biodiversity.

- A more detailed knowledge of the biological basis of farmers' feed value assessment and the extent to which they can supplement and improve laboratory nutritive value evaluation of fodder quality is needed, which will complement and allow laboratory nutritive evaluations to concentrate more effectively on farmers' objectives and to deliver results to them in ways they can understand.

- The feeding studies attest that *S. sesban* improves performance of animals and could be used to substitute locally available concentrate feeds for farmers that lack the resources to purchase external inputs. But, the on-station experiments were carried out under controlled environments and by feeding for longer periods. This has to be substantiated by on-farm feeding and economic evaluations. In that case the virtues of growing fodder trees, local and exotic ones, could be verified in terms of biological and economic impacts. Such type of studies will help increase the opportunities for technology transfer and convince farmers with different resource endowments.

- Our studies showed no evidence of reproductive problems in sheep receiving Sesbania as a supplement at a level of 30% of total dry matter intake.

- The development of multipurpose fodder trees need to be linked with market-oriented livestock production, which may encourage farmers in the Ethiopian highlands to adopt fodder technologies. And this has to be substantiated by giving due attention to investments that improve access to input- and output-markets, credit, efficient extension programs towards livestock, livestock health and artificial insemination services and natural resource improvement.

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Summary

Summary

Owing to the high human and livestock pressure associated with land degradation and feed shortage, the Ethiopian highlands were the central focus for many feed resource development and soil conservation programmes. About 32 government and non-governmental organizations are involved in promoting multipurpose fodder trees especially *Sesbania sesban* (accessions 15019, 15036 and 10865) for animal feed and soil conservation. In spite of the extensive development efforts and the apparent benefits of growing fodder trees, farmers adoption is limited and in some cases farmers ceased using exotic multipurpose fodder trees. In areas where *Sesbania sesban* is being used as feed, farmers reported that *Sesbania sesban* caused reproduction problems when fed to sheep. Farmers suspicions were supported by few short term on-station reproduction studies conducted in Ethiopia.

The overall objective of the present thesis was to explore farmers' motivations of and their perceptions about the use of multipurpose fodder trees and their constraints to adoption and to assess the effects of long-term feeding of *Sesbania sesban* on sheep performance. The results reported in the present thesis are from an on-farm survey including a total of 235 farm households in three different crop-livestock systems in the Ethiopian highlands, and a series of on-station experiments.

The on-farm study took place in Lay-Armachuho and Debay-Tilatgen districts of Amhara region, in the north-western highlands, and in Sidama district of Southern region, in the southern highlands of Ethiopia. The former two districts represent a wheat-based and a teff-based crop-livestock systems, respectively, whereas the latter district represents a coffee-based crop-livestock system. The on-station experiments were carried out at the International Livestock Research Institute (ILRI), Debre Zeit Research Station, in Ethiopia. The sheep breed used for the series of studies was Ethiopian highland Menz sheep, a breed predominantly found in the central highlands of Ethiopia.

The most important motivation of farmers to plant exotic multipurpose fodder trees was for their feed value (Chapter 2). The valuation for other purposes depended on cropping system, vegetation cover and availability of alternative local fodder tree species in the area. Farmers' perceptions about exotic multipurpose fodder trees were positive in terms of their feed value and their contribution to soil conservation. Major constraints to adoption of exotic multipurpose fodder trees were agronomic problems, low multipurpose value,

and land shortage. A majority of farmers (89.8% of respondents) was interested to either continue or to begin fodder tree development. Of the interested respondents, 44.5% preferred local fodder trees whereas 55.5% preferred exotic multipurpose fodder trees. The observation that values of exotic multipurpose fodder trees matched with the farming systems in combination with and the nature of constraints suggests that introduction of exotic multipurpose fodder trees need consideration of farmers multiple criteria. Moreover, current approaches for development and delivery of technologies have to recognize the importance of involving the end-users at all stages through participatory approaches.

Farmers' decision making criteria to adopt multipurpose fodder trees and to choose between exotic and local fodder trees, and the relationship between farmers' perception of feed value and laboratory indicators was described in Chapter 3. Results were obtained from focus group discussions and preference scoring techniques. Farmers preferred local multipurpose fodder trees to exotics for biomass production, multi-functionality, life span, and compatibility to the cropping system. In terms of feed value, ease of propagation, and growth potential local multipurpose fodder trees were ranked lower than or comparable to exotics. A strong correlation was found between farmers' feed value score and laboratory results. Farmers' preference criteria encompass multiple objectives beyond feed value and soil rehabilitation. Hence, incorporating locally available multipurpose fodder trees, farmers' indigenous knowledge and their preference criteria in the research inception process is important to maximize the likelihood of farmers' adopting and maintaining these technologies.

Farmers' feeding practices and their perception of the effect of *Sesbania sesban* supplementation on animal performance was assessed (Chapter 4) in the three farming systems (wheat-based, teff-based and coffee-based farming systems). Sixty eight percent of respondents supplemented during specific seasons and 32% when available. Frequency of feeding was either daily or every other day (49% of respondents) and once or twice weekly (51% of respondents). With the average currently available number of Sesbania trees on-farm, farmers could only cover about 30% of the requirements for meat or milk production. Despite the fact that some farmers report of (11.8%) reproduction problems in sheep, it was recognized that the feed value of Sesbania was appreciated across farming systems. However, the feed value fitted better into the wheat-based and the teff-based farming systems than in the coffee-based farming system. Development

actors should realise the diversity of farming systems when promoting *Sesbania sesban*. *Sesbania sesban* should not be introduced as a tree alone, but should be accompanied by training of farmers on appropriate feeding practices.

Most supplementation experiments with fodder trees including *Sesbania sesban* have been of short duration and focused mainly on feed intake and growth rate. Long-term studies regarding the effects of feeding *Sesbania sesban* on reproductive performance of small ruminants particularly in both sexes are scanty. A series of three experiments were conducted to assess the long-term effects of supplementation with *Sesbania sesban* on sheep performance fed a diet of 70% teff straw and 30% supplement. In the first study (growth and onset of puberty), three levels of *Sesbania sesban* (0, 47.5 and 95% of supplementary protein provided by *Sesbania sesban* and the rest being provided by a concentrate mixture were evaluated on male and female lambs for a 9 months growth period. In the second study (mating and pregnancy), animals that received concentrate alone and that received 95 % of supplementary protein from *Sesbania sesban* during the growth experiment continued and were evaluated for 7 months. The males were excluded from the experiment after the end of the mating period and the pregnant ewes remained for the pregnancy experiment. In the third study, the same ewes were given the same experimental diets after parturition during lactation, and the milk yield of ewes and the growth rate of lambs up to weaning were assessed.

The first study (Chapter 5) assessed the effects of *Sesbania sesban* on feed intake, post-weaning growth rate, and onset of puberty of 60 male and 60 female lambs ranging in weight and age between 7.2 to 11.8 kg and 4 to 5 months respectively. Supplementation with *Sesbania sesban* resulted in significantly ($P<0.05$) higher intake and digestibility of dry matter, organic matter and nitrogen, higher body weight and scrotal circumference gain than supplementation with sole concentrates. Incremental levels of *Sesbania sesban* enhanced teff straw intake by 14 and 21% compared to the sole concentrate supplement. Ram-lambs fed the 47.5% and 95% *Sesbania sesban* protein supplements reached puberty by 34 and 21 days earlier and were 1.4 kg heavier ($P<0.05$) than those fed concentrates. Supplementation with *Sesbania sesban* promoted an increase in testicular size by 13%. Ewe-lambs fed the 47.5% and 95% *Sesbania sesban* protein supplements reached puberty by 43 and 37 days earlier than those supplemented with sole concentrates but without significant variation ($P>0.05$) in body weight at first behavioural oestrus.

The second study, described in Chapter 6, investigated the effects of supplementation of *Sesbania sesban* on reproductive performance of sheep. Forty ewes and 40 rams ranging in weight and age between 16 to 20 kg and 14 to 15 months respectively were used for 7 months. During the mating period, 4 paired female-male groups (diet of the male with or without *Sesbania sesban*, and diet of the female with or without *Sesbania sesban*) consisting of 20 animals each were formed and assigned for mating. Only the ewes that were mated and did not return to heat in subsequent cycles during the 70 days mating period continued in the experiment and received similar supplementary diets (concentrate alone or *Sesbania sesban*) for the study of pregnancy and lambing. Except semen concentration, the other seminal characteristics did not vary significantly ($P<0.05$) between treatments. Supplementation with *Sesbania sesban* improved the proportion of ewes conceived by 17% and birth weight of lambs by 12% over the diet with concentrates.

The third study (Chapter 7) was conducted to assess the effects of supplementation of *Sesbania sesban* on the milk yield of ewes and on the growth rate of their lambs. Thirty lactating ewes and their single lambs were used in this study. The post partum weight of ewes and birth weight of their lambs ranged between 16 to 22 kg and 1.3 to 2.4 kg. The ewes continued to be fed same experimental diet as in the earlier experiments for 3 months. The overall lactation milk yield of ewes was 19 ±1.9 kg. Ewes supplemented with *Sesbania sesban* showed a 13% increase in milk production over ewes supplemented with concentrates. Lambs born from ewes supplemented with *Sesbania sesban* had a significantly higher pre-weaning growth rate ($P<0.05$) and were heavier at weaning than those lambs born from ewes supplemented with concentrates. From the results of the series of experiments that were conducted for one whole reproductive cycle (19 months) it can be concluded that supplementation of *Sesbania sesban* at 30% of the ration (0.98% of their body weight) improved feed intake and digestibility, growth rate and the overall reproductive performance of sheep. The anti-nutritional factors contained in Sesbania did not show any observable adverse effects.

We conclude that values of the exotic multipurpose fodder trees match with the farming systems. However, the constraints perceived by farmers suggest that introduction of exotic multipurpose fodder trees need consideration of farmers multiple criteria, local resources and knowledge and the diversity of the farming systems. Multipurpose fodder trees such as *Sesbania sesban* should not be introduced as a tree alone, but should be accompanied by practical training

of farmers and extension agents on appropriate feeding practices. Furthermore, the improvements in sheep performance as a result of feeding *Sesbania* sesban shows that it is a potential protein supplement that can be used to substitute commercial concentrates for smallholder farmers in the Ethiopian highlands.

Samenvatting

Samenvatting

Door de hoge bevolkingsdruk en veedichtheid die samengaan met bodemdegradatie en veevoedertekorten werden de Ethiopische hooglanden een proeftuin voor veel programma's gericht op verbetering van de veevoersituatie en van de bodemvruchtbaarheid. Ongeveer 32 overheids- en semi-overheidsinstellingen zijn betrokken bij de promotie van multifunctionele voederbomen. Dit zijn bomen en struiken die als ruwvoer voor herkauwers kunnen dienen maar ook andere functies binnen de boerderijen vervullen. Vooral *Sesbania sesban* (cultivars 15019, 15036 and 10865) wordt op grote schaal aanbevolen voor ruwvoerproductie en bodemverbetering. Ondanks de grote inspanningen om de teelt van voederbomen te ontwikkelen en ondanks de aantoonbare voordelen is de adoptie door boeren beperkt en in een aantal gevallen stopten boeren weer met het gebruik van geïntroduceerde exotische multifunctionele voederbomen. In gebieden waar *Sesbania sesban* op beperkte schaal voor voerproductie gebruikt werd rapporteerden boeren dat *Sesbania sesban* reproductieproblemen veroorzaakte als het aan schapen gevoerd werd. De verdenkingen van de boeren werden versterkt door resultaten van een paar korte termijn reproductiestudies op onderzoekscentra in Ethiopië.

De doelstelling van dit proefschrift was om het bij boeren in kaart brengen van de motivatie voor en de beleving van het gebruik van exotische multifunctionele voederbomen en de door hen ervaren belemmeringen voor adoptie en voorts om de effecten van langdurig voederen van *Sesbania sesban* op productie en reproductie van schapen vast te stellen. De resultaten in dit proefschrift komen van een enquête op in totaal 235 boerderijen in drie verschillende gemengde (vee en gewas) systemen in de Ethiopische hooglanden en van een serie van experimenten op een onderzoekscentrum.

De enquête werd afgenomen op boerderijen in de districten Lay-Armachuho en Debay-Tilatgen in de provincie Amhara, in the noordwestelijke hooglanden en in het district Sidama van de Zuidelijke provincie, in de zuidelijke hooglanden van Ethiopië. De eerste twee districten zijn representatief voor respectievelijk een tarwe- en teff-producerend gemengd bedrijfssysteem, terwijl de bedrijfssystemen in het laatste district veelal op koffieproductie gebaseerd zijn. De experimenten met schapen werden uitgevoerd op het onderzoekscentrum Debre Zeit van het "International Livestock Research Institute (ILRI)" in Ethiopië. Het schapenras Menz dat gebruikt werd in deze experimenten is een ras dat voornamelijk in de Ethiopische hooglanden wordt aangetroffen.

Het belangrijkste motief van boeren om exotische multifunctionele voederbomen aan te planten was voor de waarde als veevoeder (Hoofdstuk 2). De waardering van de overige functies van de exotische multifunctionele voederbomen hing af van het gewassysteem, vegetatie en de aanwezigheid van alternatieve lokale voederboomsoorten in de omgeving. Boeren waardeerden exotische multifunctionele voederbomen positief wat betreft hun voederwaarde en hun bijdrage aan bodemverbetering. De belangrijkste belemmeringen voor adoptie van exotische multifunctionele voederbomen waren teeltproblemen, een lage multifunctionele waarde en landschaarste. De meerderheid van de boeren (89,8% van de respondenten) had interesse om of de teelt van voederbomen voort te zetten of om die te starten. Van de geïnteresseerde boeren prefereerde 44,5 % locale voederbomen, terwijl 55,4 % de voorkeur gaf aan exotische multifunctionele voederbomen. De observatie dat de waarden van exotische multifunctionele voederbomen pasten binnen de bedrijfssystemen in combinatie met de aard van de beperkingen voor adoptie suggereert het belang van het laatste en daarmee dat het mee laten tellen van de meervoudige doelstellingen van boeren belangrijk is bij de introductie van exotische multifunctionele voederbomen. Bovendien, projecten gericht op ontwikkeling en overdracht van technologieën zouden de eindgebruikers in alle stadia van ontwikkeling moeten betrekken door middel van participatieve processen.

De beslissingscriteria van boeren voor adoptie van multifunctionele voederbomen en voor de keuze tussen exotische en lokale voederbomen en de relatie tussen de voederwaardering door boeren en die op basis van laboratoriumgegevens zijn weergegeven in Hoofdstuk 3. De resultaten waren verkregen uit focusgroepdiscussies en met behulp van technieken om voorkeurrangorde vast te stellen.
Boeren gaven de voorkeur aan lokale multifunctionele voederbomen boven exotische voor productie van biomassa, multifunctionaliteit, levensduur en compatibiliteit met het gewassysteem. Wat betreft voederwaarde, gemak van vermeerderen en groei werden de lokale multifunctionele voederbomen lager dan of gelijk aan exotische voederbomen gerangschikt. Een sterke correlatie werd gevonden tussen de beoordeling van de voederwaarde door boeren en laboratorium resultaten. Criteria van boeren die de voorkeur voor een bepaalde boom bepalen omvatten meervoudige doelstellingen naast die van voederwaarde en bodemverbetering. Het meenemen van lokaal beschikbare multifunctionele voederbomen, de kennis van boeren en hun voorkeurcriteria in het proces van het opzetten van onderzoek is belangrijk om de kans op

adoptie door boeren en het volhouden van het gebruik van technologieën te maximeren.

De praktijk van voeren en de perceptie van boeren van de effecten van *Sesbania sesban*-supplementatie op de productie en reproductie van dieren werd vastgesteld (Hoofdstuk 4) in de drie bedrijfssystemen (met tarwe, teff en koffie als hoofdgewas). Achtenzestig procent van de respondenten supplementeerde voederbomen gedurende specifieke seizoenen en 32 % wanneer er voer beschikbaar was. De frequentie van het voeren van voederbomen was of dagelijks of om de dag (49% van de respondenten) of eens of tweemaal per week (51% van de respondenten). Met de gemiddelde hoeveelheid bomen die op dit moment op de boerderijen aanwezig is kunnen de boeren slechts 30% van de voederbehoefte voor vlees- of melkproductie dekken. Ondanks het feit dat een deel van de respondenten (11.8%) reproductieproblemen bij schapen rapporteerde kon toch gesteld worden dat, over bedrijfssystemen heen, *Sesbania sesban* als voeder werd gewaardeerd. Echter, de waarde als voeder paste beter in de systemen met tarwe en teff als belangrijkste gewas dan in het systeem met koffieproductie. Actoren op het gebied van landbouwontwikkeling zouden zich de diversiteit van bedrijfssystemen moeten realiseren bij de introductie van *Sesbania sesban*. *Sesbania sesban* zou niet als boom alleen geïntroduceerd moeten worden, maar in combinatie met training van boeren op het gebied van geschikte voederpraktijken.

De meeste supplementatie-experimenten met voederbomen inclusief *Sesbania sesban* waren kortdurend en richtten zich voornamelijk op voeropname en groeisnelheid. Langdurende studies naar de effecten van het voeren van *Sesbania sesban* op reproductie van kleine herkauwers, zeker als het beide seksen betreft, zijn schaars. Een serie van drie experimenten werd uitgevoerd om de effecten vast te stellen van het langdurig supplementeren van *Sesbania sesban* aan schapen die een rantsoen kregen met 70% teffstro en 30% van een supplement. In het eerste experiment (groei en start puberteit) werden drie supplementatieniveaus (0%, 47,5% en 95% van het gesupplementeerde eiwit afkomstig van *Sesbania sesban*, de rest van een krachtvoermengsel) vergeleken bij ram- en ooilammeren gedurende een groeiperiode van 9 maanden. In het tweede experiment (conceptie en dracht) werden die dieren uit het eerste experiment aangehouden die of 0% of 95% van het gesupplementeerde eiwit uit *Sesbania sesban* kregen en gedurende 7 maanden gevolgd. De rammen werden na het dekken uit de proef verwijderd, terwijl de drachtige ooien bleven. In het derde experiment werden deze ooien gevolgd na de partus tijdens de lactatie

waarbij ze hun lammeren zoogden. De ooien hielden hun experimentele rantsoen. De melkproductie tijdens de lactatie en de groei van de lammeren werd gemeten tot aan het moment van spenen.

Het eerste experiment (Hoofdstuk 5) stelde de effecten van *Sesbania sesban* op voeropname, groei na spenen en het moment van het begin van puberteit vast bij 60 ram- en 60 ooilammeren, die in gewicht en leeftijd varieerden van respectievelijk 7.2 tot 11.8 kg en van 4 tot 5 maanden. Supplementatie met *Sesbania sesban* resulteerde in een significante ($P<0.05$) verhoging van de opname en verteerbaarheid van droge stof, organische stof en stikstof, een hogere groei en een snellere toename van de scrotumomvang dan supplementatie met het krachtvoermengsel. De oplopende niveaus van *Sesbania sesban* in het supplement (47,5 % en 95% van het supplement eiwit uit *Sesbania sesban*) resulteerden in een 14% en 21 % hogere opname van teffstro vergeleken met het krachtvoersupplement. Ramlammeren die gevoerd werden met de 47,5% and 95% *Sesbania sesban*-eiwitsupplementen bereiken hun puberteit 34 en 21 dagen eerder en waren 1,4 kg zwaarder dan de dieren die krachtvoer als supplement kregen. Supplementatie met *Sesbania sesban* bewerkstelligde een toename in de testikelomvang van 13%. Ooilammeren die gevoerd werden met de 47,5% and 95% *Sesbania sesban*-eiwitsupplementen bereiken hun puberteit 43 en 37 dagen eerder dan de dieren die met het krachtvoermengsel gevoerd werden, zonder significant verschil in lichaamsgewicht op het moment van het eerste bronstgedrag.

Het tweede experiment, in Hoofdstuk 6 beschreven, onderzocht de effecten van supplementatie met *Sesbania sesban* op de voortplanting van de schapen. Veertig van de ooien en 40 van de rammen uit het eerste experiment werden gedurende 7 maanden op hun experimentele dieet gehouden. Bij aanvang van het tweede experiment varieerden de dieren in gewicht en leeftijd respectievelijk van 16 tot 20 kg en van 14 tot 15 maanden. Gedurende het dekken werden 4 verschillende gepaarde ram-ooi-groepen gevormd (rantsoen van de ram met en zonder *Sesbania sesban*, rantsoen van de ooi met en zonder *Sesbania sesban*), iedere groep bestaand uit 20 dieren. Ooien die gedekt werden en niet opnieuw bronstig werden gedurende de 70 dagen durende dekperiode bleven in het experiment gedurende dracht en aflammeren en kregen hetzelfde experimentele dieet als in het eerste experiment. Behalve de concentratie van zaadcellen waren er geen significante verschillen in spermakarakteristieken tussen de rantsoenen. Supplementatie met *Sesbania sesban* verbeterde het bevruchtingspercentage van

de ooien met 17% en het geboortegewicht van de lammeren met 12% in vergelijking met het rantsoen met krachtvoersupplementatie.

Het derde experiment (Hoofdstuk 7) werd uitgevoerd om de effecten van supplementatie met *Sesbania sesban* op de melkgift van ooien en de groei van hun lammeren vast te stellen. Dertig lacterende ooien en hun lammeren (1 per ooi) werden in dit experiment gebruikt. Het post partum gewicht van de ooien en het geboortegewicht van hun lammeren varieerde van respectievelijk 16 tot 22 kg en van 1,3 tot 2,4 kg. De ooien bleven op hetzelfde rantsoen als in de eerste twee experimenten gedurende 3 maanden. De melkgift van de ooien was gemiddeld 19 kg (±1,9 kg) voor de gehele lactatie. Ooien die met *Sesbania sesban* gesupplementeerd werden lieten een 13% hogere melkproductie zien dan ooien gesupplementeerd met krachtvoer. Lammeren geboren uit ooien die met *Sesbania sesban* gesupplementeerd werden hadden een hogere groeisnelheid tot aan spenen ($P<0.05$) en waren zwaarder op het moment van spenen dan de lammeren die uit ooien geboren waren die krachtvoer als supplement ontvingen. Uit de resultaten van de serie experimenten die en volledige voortplantingscyclus (19 maanden) besloeg kan geconcludeerd worden dat supplementatie met *Sesbania sesban* op een niveau van 30% van het rantsoen (0,98 % van het lichaamsgewicht) de voeropname, de vertering, de groei en de reproductieve prestatie van de schapen verbeterde. De anti-nutritionele factoren in *Sesbania sesban* lieten geen zichtbare negatieve effecten zien.

We concluderen dat de waarden van exotische multifunctionele voederbomen passen bij de bedrijfssystemen. De aard van de belemmeringen voor adoptie zoals boeren deze ervaren suggereert dat het voor introductieprogramma's van deze bomen belangrijk is om de meervoudige doelstellingen van boeren, lokale voederbomen, lokale kennis en de diversiteit van bedrijfssystemen in ogenschouw te nemen. Multifunctionele voederbomen zouden niet als boom alleen geïntroduceerd moeten worden, maar in combinatie met training van boeren en voorlichters op het gebied van de voederpraktijk. De verbetering van de prestatie van schapen als gevolg van de *Sesbania sesban*-supplementatie laat zien dat het een mogelijk eiwitsupplement kan zijn dat gebruikt kan worden om commercieel krachtvoer te vervangen voor kleine boeren in de Ethiopische hooglanden.

Curriculum vitae

Abebe Mekoya Kassa was born on November 07, 1961 in Debre Markos, Ethiopia. He started his university education in Alemaya University of Agriculture, in Ethiopia where he obtained his BSc degree in Animal Sciences in July 1986. He was employed in the Ministry of Agriculture and served at various positions as a development worker and coordinator in livestock and fisheries development department. After 10 years of services, he joined Alemaya University for his MSc study. He obtained an MSc degree in Animal Production in March, 2000. After his MSc, he joined Sheno Agricultural Research Center under the Amhara Region Agricultural Research Institute (ARARI) as an associate researcher in Animal Production Research Division, and worked on various on-farm and on-station animal experiments. Since 2001, he was also the coordinator of the National Small Ruminant Research Program until he was admitted to Wageningen University as a PhD student. In November 2003, he was awarded a PhD fellowship from the project "SIDA-Amhara Region Rural Development Program" financed by the Swedish government. His PhD study entitled ***"Multipurpose fodder trees in Ethiopia; Farmers' perception, constraints to adoption and effects of long-term supplementation on sheep performance''*** was undertaken under the supervision of the Animal Production Systems and Animal Nutrition Groups of Wageningen University, and the International Livestock Research Institute, Ethiopia.

He is married and a father of three sons.

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Mekoya, A, Oosting, S.J., Fernandez-Rivera, S., Tamminga, S., Tegegne, A. and Van der Zijpp, A.J., 2007. Effect of supplementation of *Sesbania sesban* on post-weaning growth performance and sexual development of Menz sheep (Ethiopia). Submitted to Livestock Science.

Mekoya, A, Oosting, S.J., Fernandez-Rivera, S., Tamminga, S., Tegegne, A. and Van der Zijpp, A.J., 2007. Effect of supplementation of *Sesbania sesban* on reproductive performance of sheep. Submitted to Livestock Science.

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Training and Supervision Plan		Graduate School WIAS
PhD student	**Abebe Mekoya Kassa**	
Project title	**Multipurpose fodder trees in Ethiopia:** Farmers' perception, constraints to adoption and effects of long-term supplementation on sheep performance	
Groups	Animal Production Systems and Animal Nutrition	

EDUCATION AND TRAINING	Year	ECTS
The Basic Package		
WIAS Introduction Course	2004	1.50
Course on philosophy of science and/or ethics	2004	1.50
Subtotal Basic Package		**3.00**
Scientific Exposure (conferences, seminars and presentations)		
International conferences		
Ethiopian Society of Animal production conference, Addis Ababa, Ethiopia	2005	0.90
EAAP (European Association for Anima Production) conference, Antalya, Turkey	2006	1.20
Innovation Africa Symposium conference, Kampala, Uganda	2006	1.20
EAAP (European Association for Anima Production) conference, Dublin, Ireland	2007	1.20
Seminars and workshops		
Food-feed crop production in mixed livestock systems in the tropics, ILRI, Ethiopia	2005	0.15
Indigenous knowledge and innovations, ILRI, Ethiopia	2005	0.15
WIAS Science day-March 2004, 2007, Wageningen	2004, 07	0.60
Governance for food quality in tropical food chains, Wageningen	2006	0.30
Dynamics of knowledge transfer in agriculture, Wageningen	2006	0.15
Livestock's long shadow: livestock revolution and the global environment, Wageningen	2007	0.30
Presentations		
Oral: Fodder trees utilization and constraints to adoption in the Ethiopian highlands, EAAP, Antalya, Turkey	2006	0.50
Oral: Fodder trees development and constraints to adoption in the Ethiopian highlands, ILRI, Ethiopia	2004	0.50
Poster: Fodder trees development and farmers' innovative ideas to balance multiple household objectives in the Ethiopian highlands, IAS, Kampala, Uganda	2006	0.50
Oral: Farmers' knowledge and perception of multipurpose fodder trees in the Ethiopian highlands, WIAS Science day, Wageningen	2007	0.50
Oral: Farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators, Dublin, Ireland	2007	0.50
Subtotal International Exposure		**8.65**
In-Depth Studies		
Advanced statistics for the life sciences	2007	1.50
Advanced statistical courses, ILRI, Ethiopia (three courses, each one week)	2005	4.50
Future Livestock systems	2004	4.00
Subtotal In-Depth Studies		**10.00**
Professional Skills Support Courses		
WIAS Course Techniques for Scientific Writing	2006	1.20
Use of laboratory animals	2007	3.00
Time planning and project management	2004	1.20
End note course	2003	0.30
Subtotal Professional Skills Support Courses		**5.70**
Research Skills Training		
Preparing own PhD research proposal	2004	6.00
Subtotal Research Skills Training		**6.00**
Education and Training Total (minimum 30 ECTS)		**33.35**

One ECTS credit points represents a study load of 28 hours

Colophon

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Cover design by Fokje Steenstra and Abebe Mekoya. The pictures on the cover were taken by Abebe Mekoya in Lay-Armachuhuo, Debay-Tilatgen and Sidama Districts of Amhara and Southern Nations, Nationalities and Peoples Region in Ethiopia. The largest cover design represents the landscape in the Ethiopian Highlands. At the back of the cover, the small picture at the top shows farmers in discussion with enumerators during the survey study. The middle small picture is a plantation of exotic and local multipurpose fodder trees in the backyard of a farmer, and the bottom one represents a typical grazing system in the Ethiopian highlands with sheep grazing in a communal grazing land

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