# IMPROVING THE QUANTITY AND QUALITY OF FORAGES PRODUCED FROM INTERCOPPING OF FABA BEAN *(Vicia faba L.)* WITH FORAGE OATS IN LEMO DISTRICT, HADIYA ZONE, ETHIOPIA

**MSc THESIS**

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**HARAMAYA UNIVERSITY, HARAMAYA**

# Improving the Quantity and Quality of Forages Produced from Intercropping of Faba Bean *(Vicia faba L.)* with Forage Oats in Lemo District, Hadiya Zone, Ethiopia

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I hereby certify that I have read evaluate their Thesis entitled Improving the quality and Quantity of Forages produced from intercropping of Faba Bean with Forage Oats in Lemo Worada, Hadiya Zone Ethiopia prepared under my guidance by Tesfaye Abiso. I recommended thet it be submitted as fulfilling the thesis requirement

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As a number for the Board of Examiners of the MSc Thesis Open Defense Examination, I certify that I have read evaluated the Thesis prepared by Tesfaye Abiso and examined the candidate. I recommend that the thesis be accepted as fulfilling the Thesis requirement for the degree of Masters of Science in Animal Production.

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## DEDICATION

I dedicate this thesis manuscript to my wife Zeritu Zemedikun, my son Mintesnot Tesfaye (Baby), my father Abiso Jatana and my mather Bizunesh Buche for their endless love and moral support during the study at Haramaya University and during Field work at Lemo.

## STATEMENT OF THE AUTHOR

By my signature below, I declared and affirm the thesis is my own work. I have following all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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# BIOGRAPHICAL SKETCH

Tesfaye Abiso was born in 1982 in Boloso Sore woreda of Wolayta Zone, Southern Nations Nationalities and Peoples Region. He started his education in Dubo St. Marry elementary and junior schools, and completed his senior secondary education at Areka Comprehensive High School.

Upon completion of his high school studies, he joined Alage ATVET College in October, 2002 and graduated with a Diploma in Animal Science in August, 2004 and Work as Development agents at Wolayta zone Humbo Woreda. After five years experience he changed his work place to Areka Agricultural Research Center as Technical assistance of the research. Also he joined Wolayta Soddo University in September, 2008 and graduated with a BSc. degree in Animal and Range Sciences in July, 2011. Then, he changed his work position to Senior Animal and Forage Multiplication Expert and the technology multiplication work process coordinator in Areka Agricultural Research center and has been working there till and he joins the graduate studies in Animal production to Haramaya University in 2014, as summer program.

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# ACRONYMS AND ABBRIVATIONS

| | |
|---|---|
| ADF | Acid Detergent Fiber |
| ADL | Acid Detergent Lignin |
| ANOVA | Analysis of Variance |
| AOAC | Association of Official Analytical Chemists |
| CSA | Central Statistical Agency |
| CP | Crude Protein |
| RCBD | Randomized Completely Block Design |
| DM | Dry Matter |
| ETB | Ethiopian Birr |
| GJ | Giga Jules |
| IVTOMD | In vitro True Organic Matter Digestibility |
| ME | Metabolisable Energy |
| MJ | Mega Jules |
| M.a.s.l | Meters above sea level |
| MSE | Mean Square Error |
| NDF | Neutral Detergent Fiber |
| NIRS | Near Infrared Reflectance Spectroscopy |
| SDMY | Straw Dry Matter Yield |
| SAS | Statistical Analysis System |
| SPSS | Statistical Package for Social Science |
| PPl | Pods per Plant |
| SPd | Seeds per Pod |
| SE | Standard Error |

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## Abstract

*Faba bean (Vicia faba* L.*), also called broad bean or horse bean is an annual crop, which mainly grows in the highlands of Ethiopia for human consumption. The objective of this study was to* improve the quantity and quality of forages produced from intercropping of faba bean *(Vicia faba L.)* with forage oats *(Avena sativa L.) on forage biomass, straw, grain yields, and straw quality. Farmers have an experience of not weeding faba bean plots to get more weed biomass. The field trial involved each farmer has 2(10×30) $m^2$ large plots and each plot divided in to (3*10) $m^2$ for two faba bean varieties and three treatment practices The land was selected carefully for uniformity of slope and fertility. Soil was prepared carefully before sowing. Samples were taken from each treatment plots beginning before soil samples from the upper 15 cm to lower 30cm, the final after harvest soil sample from each treatment plot. The highest ($P<0.01$) tiller count, number of pods per plant (PPP), seeds per pod (SPP) and grain yield was under improved management, whereas the lowest ($P<0.01$) was obtained from intercropping management practice. The total feed dry matter (DM), crude protein (CP) and metabolizable energy yields were greater ($P<0.05$) under intercropping than the remaining management practices. Gebelcho under intercropping had the highest CP content (9.53%) and the lowest CP contents were observed for Dosha under traditional management (6.84%). The mean CP content was highest ($P<0.05$) under intercropping and lowest ($P<0.05$) in traditional management practice. The NDF content was lower under intercropping than the remaining management practices. In vitro true organic matter digestibility value (%) ranged from 55.9 (Gebelcho) traditional to 65.9 (Dosha) intercropping management practice. In vitro true dry matter digestibility (IVTDMD) value was higher ($P<0.05$) under intercropping than other management practices. Generally intercropping management gave higher net benefit and particularly intercropping the variety Dossha (41869ETB $ha^{-1}$) gave highest net benefit as compared to the remaining variety and management practices. It can be concluded that intercropping faba bean with oats could be feasible to provide reasonable nutritive value of forages without or less affecting the faba bean grain yield in the crop-livestock production systems of Ethiopia.*



*Key words: biomass, chemical composition, digestibility, faba bean, management practice,*

*Variety, yield*

# 1. INTRODUCTION

In many developing countries, livestock play an important role in the livelihoods of most small-scale farmers, as sources of food in the form of meat and milk, services (transport and draught power), cash income, manure (for soil fertility management and fuel) and serve as store of wealth and hedge against inflation (Sere *et al*., 2008). The livestock population of Ethiopia is currently estimated to be about 55.3 million cattle, 27.35 million sheep, 28.16 million goats, 1.96 million horses, 6.95 million donkeys, 0.36 million mules, 1.1 million camels, 51.35 million poultry (CSA, 2015). Livestock production is an integral part of the subsistence crop-livestock mixed farming system of Ethiopian highlands (Amede *et al*., 2006). The highlands of Ethiopia are inhabited by high human and livestock populations. About 88% of the human, 75% of the cattle, 75% of the sheep and 34% of the goat population in Ethiopia are found in the highlands. High density of human and livestock population in the Ethiopian high lands is one of the major reasons for severe degradation of the natural resource base resulting in poor animal nutrition (CSA, 2008).

Even though, there is enormous contribution of livestock to the livelihood of farmers, the poor quality feed resources remains to be the major bottleneck to livestock production in the highlands of Ethiopia (Ahimed *et al*., 2010). Traditional livestock production system mainly depends upon poor pasturelands and crop residues which are usually insufficient to maintain reasonable livestock production (Assefa, 2005), and are high in fiber, with low digestibility and low levels of nitrogen. Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Bogale, 2008a). Legumes have lower contents of structural fiber, higher protein contents and greater digestibility (Diriba *et al*., 2013) resulting in higher nutrient intake rates and animal production when they are used as fodder (Frame *et al*., 1998).

Feed shortage problems in crop-livestock production system could be alleviated by integration of improved forage crops into the farming system. This is highly important and appropriate in areas where land scarcity is a problem and the agricultural production system is subsistence (Getnet *et al*., 2003). The inclusion of grain legumes like faba bean in forage intercrops can provide a more sustainable source of N to cropping systems through biological N fixation (Crews and Peoples, 2004). This is partly recognized due to the fact that legumes are capable of fixing atmospheric nitrogen through a symbiotic association with soil bacteria called rhizobium (Jensen *et al*., 2010). Faba bean is considered as a cash crop. It grows well on well-structured loam or clay soils for best production. It has been grown successfully in areas of soil pH 6.5-9.0 (Jensen, 2010). This crop is widely grown in southern Ethiopia and due to feed shortage that farmers experience during the cropping season, they traditionally use the weed that grows with the faba bean crop as an important feed resource. Building on the existing experience of growing voluntary forages or weeds on faba bean plots to improve the feed resource base appears to be an alternative option. Lemo is one of the Woredas in Hadiya zone of southern Ethiopia, where there is high population pressure and grazing lands are limited.

In order to alleviate the feed shortage in Lemo district, establishment of forage crops and legumes is feasible due to the area receiving bimodal rainfall distribution. Hence, cultivation of faba bean/oat mixtures has the potential to provide high quantity and quality fodder production, soil erosion prevention, and soil fertility restoration (Zewdu, 2004). Cultivation of faba bean and oat in mixture is more suitable for feed production than the cultivation of these species separately (Micek, 2012). However, there is shortage of information in the scientific literature concerning the importance of faba bean intercropping with oats and on the nutritive value of straws of faba bean varieties especially in southern Ethiopia.

Owing to very few hectares of arable lands per household in the study area, expansion of cultivated land and land for forage production, which is one way of improving food and feed resources, is becoming almost impossible since maximum expansion has been attained earlier by ever increasing population. Thus, increasing productivity must go to another dimension and focuses on intensively utilizing the available land in both time and space essential way to address food and feed problem in the study area.

Soil fertility in general and nitrogen in particular has been depleted in most cereal growing smallholder farms because of continuous cropping without adequate replenishment of the nutrients taken up by crop and thus intern limits feed resources. Intercropping legume crops with fodder species appears to be feasible option to address both food and feed production issues in the mixed farming systems of Ethiopian highlands. Therefore, the objectives of the MSc thesis research was to improve the quantity and quality of qorages produced from intercropping of faba bean *(Vicia faba L.)* with forage oats *(Avena sativa L.),* where the specific objective of the study were:-

- To estimate the amount of forage biomass, faba bean straw and grain yield produced under traditional and improved management practices of faba bean cultivation
- To determine the quality of forage and faba bean straw produced under different management practices
- To compare the performance of faba bean varieties for intercropping with improved forage oats; and
- To analyze the trade-offs of intercropping faba bean with improved forages in the total farm productivity

# 2. REVIEW OF LITERATURE

## 2.1. Description of Faba Bean and Oat

### 2.1.1. Faba bean (*Vicia faba L.*)

Faba bean also known as broad bean or horse bean or plate bean (*Vicia faba L.*) which family of (Fabaceae), has erect stems, large leaflets, large pods, and large flattened seeds (Martin *et al*., 2006). It is the world's seventh most important grain legume (Rees *et al*., 2000). Faba bean grain is an important grain legume for human diets and animal feed for the reason that it is a major source of protein, starch, cellulose and minerals from its mature seed. Faba bean grain is used widely as an animal feed in Europe (Turpin *et al.,* 2003). Its seeds contain 27 to 34% protein with high lysine content and are free from tannins (Duc, 1997). A straw of faba bean is rich in protein, calcium and magnesium than cereal straws, and if properly harvested, it is useful roughage feeds for ruminant animals (Kossila, 1984). Generally, pulse straws contain 10-15% crude protein (CP) in DM and their energy content is higher compared to the respective cereals by-products and sugar cane, with satisfactory palatability (Kossila 1984). Another major feature of the faba bean is its symbiotic nitrogen (N) fixing capability, enabling it to produce substantial yields without the addition of N fertilizer, thus making it an attractive break-crop in an arable rotation (Schwenke *et al*., 1998).

Faba beans grow in climates ranging from temperate to semi-arid, using different cultivars and crop management practices. They are generally sown in the spring in northern latitudes, in the winter in warm-temperate and subtropical areas with specific cultivars for each region (Duc, 1997). They are grown predominately in areas with more than 400 mm average annual rainfall but in drier regions, they are commonly irrigated (Agung and McDonald, 1998). They are sensitive to water stress, and irrigation is needed to improve yield and yield stability (Husain *et al*., 1988). Where water is not limiting, temperature has a major effect on germination and initial growth of faba bean. As a legume, faba bean straw has a higher feed quality than grasses and is preferred by livestock (Charlton and Stewart, 2006). Faba bean is categorized as an annual cool season legume that could fit into a double cropping system (Vilamanya, 1987).

### 2.1.2 Oats *(Avena sativa L.)*

Oat is an annual cereal grain crop belonging to the family *Gramineae* (Langer and Hill, 1982). It grows well in cool, moist conditions. It is frost tolerant in the seedling and tiller stages (White *et al*., 1999). Oats complete their life cycle from sowing/germination to harvest/maturity in 6 to 11 months. Its grain is used for both animal and human consumption. It can also be used to overcome seasonal feed shortages and is convenient in crop rotations (Forsberg and Reeves, 1995). Greater plant height in oats crops increases the susceptibility to lodging and has contributed to severe yield losses (Brouwer and Flood, 1995).

Ground or chopped oats are fed to breeding or young dairy cattle and ground oats are fed to poultry. Oats were much more favored by the growers compared with other small grains, as a forage crop, because of its finer stem and higher palatability (Miller, 1984). Oats have a high crude fiber content compared with barley and wheat but a lower protein content of 11 to 14% (Church and Richard, 2002).

## 2.2. Nutritive Value of Faba Bean

Evaluation of nutritive value of forage crops is an important aspect of crop selection, especially the determination of metabolisable energy and crude protein content as indicators of pasture quality (Mohammad, 2012). The nutritional value of faba bean grain is high, and in some areas is considered to be higher to peas or other grain legumes (Crepon *et al*., 2010). Faba bean is a significant source of protein rich food in developing countries and is used both as a human food and a feed for pigs, horses, poultry and pigeons in industrialized countries (Duke, 1981). The intercropping of legumes like faba bean with cereal crop has the potential for improving forage yield and quality. Improvement of protein content has been recognized as of the benefits of intercropping cereals and legumes in forage production. The protein content in the faba bean was higher than that of oat, therefore, the addition of faba bean as legume could improve the quality of oat forage, because oat contains lower crude protein concentration, and faba bean as whole crop has been shown to produce high crude protein. Similarly, a CP of 10% in an oat mono-crop was lower than in faba bean -oats intercrops (15% CP) (Mohammad, 2012). In organic farming systems, cultivation of faba bean and naked oat in mixtures is more suitable for feed production than the cultivation of these species separately (Micek, 2012).

The local faba bean straw has the same crude protein (12.78%) with wheat bran (13.13%) (Negash *et al*., 2015) and has lower NDF (592 g/kg DM) content than wheat stubble (786 g/kg DM) (Solomon *et al*., 2008a). Hemicellulose content of faba bean straw (124 g/kg DM) is lower than that of wheat straw (310 g/kg DM) (Solomon *et al*., 2008a). Moreover, faba bean seed is outstandingly rich in potassium (1.73%), poor in calcium (0.07%) and sulphur (0.04%) content (Hosain and Mortuza, 2006). However, faba bean straw is rich in calcium (1.5 g/kg DM) and poor in phosphorus (0.8 g/kg DM) content (Wondatir *et al*., 2011). Inter-cropping of faba bean with oat significantly increased the crude protein content in oat grain, but had little effect on the chemical composition of faba bean seeds (Miceka, 2012).

Table 1. Nutrient composition of faba bean straw (DM %)

| Nutrients (%) | (Abreu and Bruno-Soares, 1998). | (Bogale *et al*., 2008a). | (Wondatir *et al*., 2011). |
|---|---|---|---|
| DM | - | 94.4 | 92.6 |
| Ash | 7.6 | 10.3 | 6.6 |
| CP | 6.6 | 8.8 | 6.1 |
| NDF | 72.3 | 59.2 | 73.4 |
| ADF | 55.4 | 46.8 | 51.0 |
| ADL | 11.6 | 13.2 | 9.9 |
| ME(MJ/kg DM) | 6.2 | - | 7.1 |

%= percent; DM=dry matter, OM=organic matter, CP= crude protein, NDF= neutral detergent fiber; ADF = acid detergent fiber; ADL= acid detergent lignin, ME (MJ/kg DM) = metabolizable energy

In Ethiopia, there are a number of faba bean and oat cultivars being cultivated on research station and by farmers and this can give a potential opportunity for use in livestock feed but information on chemical composition, digestibility and nutritive value of faba bean straw and oat mixtures is generally scarce.

## 2.3. The Role of Faba Bean as Livestock Feed

Faba beans are palatable, digestible and nontoxic when incorporated into rations for livestock and poultry. Protein from legumes is a good complement to cereals; hence mixtures containing lupine, faba bean have a high biological value (Księżak, 2007). Its seeds can be successfully used as a compound of high-protein concentrates for adult animals. Concentrate mixtures with a 10% or 25% share of ground faba beans are also good feeds for calves and permit maintaining satisfactory body weight gain (Bidwell-Porębska and Piotrowski, 1991). Nevertheless, the presence of anti-nutritional compounds in faba bean seeds, mostly tannins and glycosides, limits their usefulness in rations, especially for growing animals (Baranowski, 2005).

Straws consist of the stems and leaves of plants after the removal of the ripe seeds by threshing, and are produced from most cereal crops and from some legumes. All the straws are extremely fibrous, most have a high content of lignin, and all are of low nutritive value. Their high fiber content restricts their use to that as food for ruminants (McDonald *et al*., 2010).
In Ethiopia, during wet seasons, livestock depend on grazing (more than 80% of the ration) with small supplements of legume straws. In dry seasons, they depend totally on legume and cereal straws for stall feeding 70% of the farmers feed legume straws regardless of the production purpose. Straws of legume crops have generally better nutritive value, forage quality and thus are nutritionally superior to cereal straws (Walli, 2004). A straw of faba bean is rich in protein, calcium and magnesium than cereal straws, and if properly harvested, it is useful roughage feeds for ruminant animals (McDonald *et al*., 2010). Generally, pulse straws contain 10 -15% crude protein (CP) in DM and their energy content is higher compared to the respective cereals by - products and sugar cane, with satisfactory palatability (Yetimwork *et al*., 2011).

## 2.4. The Role of Faba Bean Intercropping in Improving Feed Resources

The incorporation of legumes in forage mixtures with grasses or cereals is an important and well-established practice in some regions. Furthermore, oat, barley, wheat and triticale are added to provide a climbing frame for the legumes and to increase the bulk of feed produced. In forage-animal production system, legumes are preferred owing to several advantages over monocultures (Haynes, 1980). The grain cereal-legume intercropping has the potential to provide higher grain yield (Haymes and Lee, 1999), and more nutritionally balanced forage (Anil *et al*., 1998). In general, legumes are rich in protein while grasses/cereals are rich in carbohydrates. Cereals constitute forages relatively low in protein (Robinson, 1969), and animals usually require some form of relatively costly protein concentrate supplementation (Anil *et al*., 1998).

Choice of cereal species affects the performance of intercrops grown for forage (Jedel and Helm, 1993). The choice of a legume species and compatible plant densities are very important for high forage yields and quality in intercrops with cereals (Altinok *et al*., 1997). Intercropping oat with pulse crops produced, greater DM yield than intercropping barley with pulse crops (Ross *et al*., 2004). Yields are generally higher in the mixtures because of more efficient light utilization (Brougham, 1958), transfer of symbiotically fixed nitrogen (Ledgard, 1991).

## 2.5. Digestibility of Faba Bean

The *in vitro* true digestibility of faba bean seeds depend more on its share in mixtures than observed for oat grain. The presence of anti-nutritional factors, mainly tannins, could also have a significant impact on the *in vitro* digestibility of faba bean by forming insoluble complexes with protein, thus inhibiting its digestion and, consequently, reducing its digestibility (Crépon *et al*., 2010). The *in vitro* true digestibility of oat grain and faba bean seeds did not depend on mixture composition. Most cereal straws have lower nutritive value than the haulm from grain legumes. The grain legume like faba bean contains good quality roughage with a crude protein content of 5-12% (Adugna, 2008). Dry matter intake and digestibility of dry matter, organic matter and energy of faba bean crop straw were greater than wheat straw, but were similar with medium quality alfalfa-brome hay (Thorlacius *et al*., 1979). Thus, the nutritive value of faba bean crop residue was greater than that of wheat straw. The *in vitro* dry matter digestibility of faba bean straw was higher than maize Stover (Solomon *et al*., 2008a).

## 2.6. Competition Indices

Legumes, like faba bean can provide N to the non-legume directly through mycorrizal links, root exudates, or decay of roots and nodules; or indirectly when the legume fixes atmospheric nitrogen ($N_2$), and thereby reducing competition for soil $NO_3$ with the non-legume (Anil *et.al*., 1998). Oat is more competitive than faba bean varieties mainly in the faba bean-oat intercrops (Dhima *et al*., 2013). Similarly, it is a greater competitor than faba beans during the shortage of rainfall (Klimek-Kopyra *et al*., 2015).

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The study was carried out in Lemo Woreda, Southern Ethiopia. Its capital city is Hossana, located at about 230 kilometers away to the south of Addis on the road running from Addis to Wolaitta Soddo through Butajira is found at the Southern tip of the Woreda and, 208 kilometers away from Hawassa, the capital city of Southern Nations, Nationalities and Peoples Regional State. The Woreda lies between $7^0$.22” to $7^0$ .45' 00" Latitude and $37^0$.40” to $38^0$.00’ Longitude with an altitude range of 1501 – 2500 m.a.s.l. The mean annual rain fall varies between 1001 mm to 1200 mm, and the mean annual temperature varies between 15 $^oC$ and 20 $^oC$. It is bordered by Silte Zone in the North, Kembata Tembaro Zone in the South, Gombora Woreda of Hadiya Zone in the North West, Ana Lemo Woreda of Hadiya Zone in the North East and Shashogo Woreda of Hadiya Zone in the East. It has an estimated number of 118,578 human populations and land area 8,928.9 square care meter (Census, 2008). The Woreda is classified in to two climatic zones: Dega or the highland (9%), Weina Dega or midland (91%).The soil type of the area was loam soil. Type of crops grown in the area was wheat, faba bean, ‘Enset’ oat, coffee, pea. According to the Woreda council annual report (2014), the Woreda has a total of 33 rural and 2 (two) urban kebele.

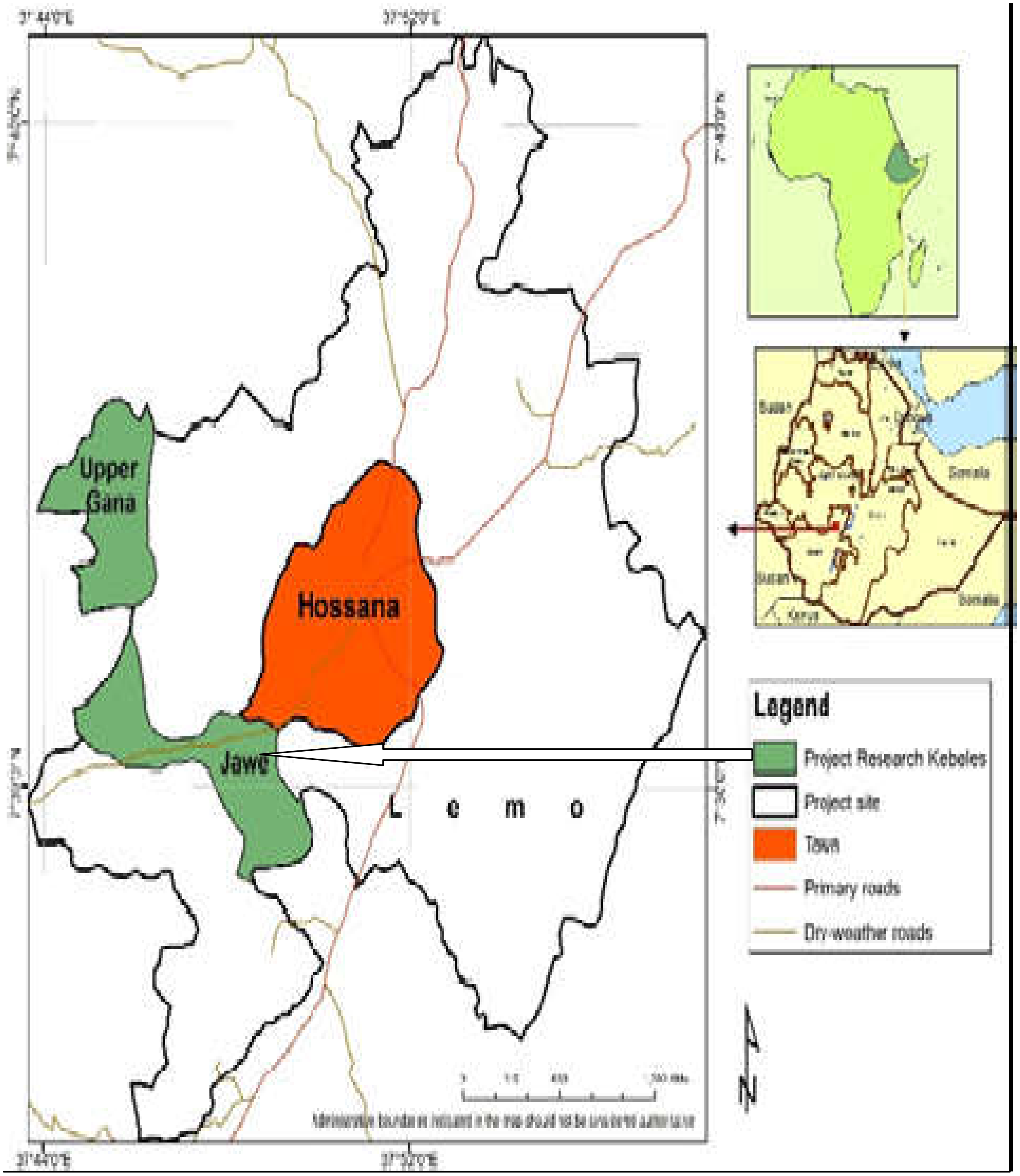


Figure 1: Map of the study area

## 3.2. Sampling Methods

Prior to the start of the actual field experiment kebele was selected purposely. This kebele's was project action sites for the ILRI led project working on sustainable intensification of the mixed farming system in the highlands. Within the kebele consultation meeting was held with the communities and farmers who showed interest to allocate land and participate in the trials were selected. Participant Farmers were oriented about the land area, land preparation, management practices and sowing date for Faba bean and Forage intercropping trials.

## 3.3. Experimental Design and Treatments

### 3.3.1. Land preparation, planting and management

The field experiment was carried out during the 2015 short rainy cropping season (July, August, September and October). The farmers who participated in the field trial were selected based on availability of land to carry out the field experiment and training was given concerning the objectives of the project activities, preparation of the plot, management of experimental crops, sampling methods, and data collection before the start of the experiment. Ploughing was done during the short rainy season in early February using oxen and was made before ploughing to loosen the soil. The land, after ploughing, was then classified considering uniformity, fertility and level into plots as per the design of the experiment.

The experiment involved two faba bean varieties (Gebelcho and Dosha) and three management practices. Traditional management where faba bean plots were not weeded but the weeds were harvested as fodder, improved management where faba bean plots were regularly weeded, and improved forage faba bean intercropping where the faba bean plots were intercropped with improved oat fodder. The treatments were assigned to individual plots using Randomized Completely Block Design (RCBD). Farmers were used as replications. Each farmer had two main plots for the two faba bean verities. Each main plot was 10 meters wide and 32 meters long and it was divided in to three plots, each measuring 10 meters long and 10 meters wide. The three plots were then randomly assigned to one of the three management practices of faba bean growing: traditional, improved and intercropping with oat forage.

The seeding rates as varieties released recommends 200 kg/ha for faba bean and 65 kg/ha for oats, while seeding rates for the intercrops was proportional to the pure stand seeding rates. The distance between faba bean rows was 40 cm while the distance between plants was 10 cm. Twenty five rows of faba bean was made per plot and placed in from both sides of the 20 cm length. Thus the net size of a plot was 10 meters long and 9.6 meters wide. Two seeds were drilled in each space (one was thinned out after verification of germination and establishment). Oat seed rate per plot was sixty five grams. Twenty four rows per plot were placed between the two adjacent faba bean rows. Thus, the distance between faba bean rows and oat rows was 20 cm. One kilogram of di-ammonium phosphate (DAP) was applied for each plot at the time of planting.

For the improved management practice, plots were weeded three times by hand. At first weeding, the faba bean crops, under the traditional, improved and intercropping management, were thinned.

### 3.3.2. Treatments

Field trial was arranged in Randomized Completely Block Design (RCBD) as shown in the Table 2 below. The field trial was involved (30 x 10) $m^2$ and divided in to three (10 x 10) $m^2$ for each management practice and experiment with twenty four replications, whereby three faba bean growing management practices were tested with two faba bean varieties.

Table 2. Description of treatment

| Treatments | Management practices | Faba Bean Variety | Number of farmers/ replication |
|---|---|---|---|
| $T_1$ | Traditional | Dosha | 24 |
| $T_2$ | Traditional | Gebelcho | 24 |
| $T_3$ | Improved | Dosha | 24 |
| $T_4$ | Improved | Gebelcho | 24 |
| $T_5$ | Intercropping | Dosha | 24 |
| $T_6$ | Intercropping | Gebelcho | 24 |
| | | | |

## 3.4. Measurements and Observations

### 3.4.1. Harvesting and sampling

Samples were taken from each treatment plots beginning before soil samples from the upper 15 cm to lower 30cm, to the final after harvest soil sample from each treatment plot by the same manner. The oat forage in the intercropped plots and weed in the traditional plots were harvested so that the height of the oat and weed did not exceed that of the faba bean. Cuttings were done two times for oats forage and weed at forty five days of sowing and counting from the first cut, after fifteen days then second cut were done by 5-7 centimeters above the ground from a net plot size (9.6 m x 10 m area). Fresh biomass was mixed and weighed right after each round harvest and samples were taken for dry matter determination. For determination of biomass yield, all the faba bean plots were harvested at maturity stage. Weight of the total fresh biomass yield was recorded from each plot in the field and then separated into oats fodder, faba bean grain, faba bean straw and weeds to calculate proportions of each component. For all value determination each sample type, the amount taken was one kilogram. Samples were then taken and oven dried for 48 hours at a temperature of 65 $^{o}$C for laboratory analysis. The oven dried samples were weighed to determine the total dry matter yield.

### 3.4.2. Data collection

Close observation was made after planting to evaluate the rate of germination and early establishment performance of the faba bean varieties. In order to support the visual assessment of the establishment performance, seedling counts were made on the whole plot on the 23$^{rd}$ day of planting. Flowering date and maturity date of faba bean were recorded for each plot. Number of tillers of faba bean was taken at the panicle stage. Tiller count of randomly selected five faba bean plants from each plot was recorded and the mean was calculated. The plant height (cm), for both oats and faba bean, was measured from the ground to apex by averaging the natural standing height of five randomly selected plants per plot. Pods of five faba bean plants from each plot were counted and the number of pods per plant was computed on the average basis. Number of seeds per pod was determined by counting number of seeds in pod and the average seed per pod was recorded.

All plots of faba bean were harvested at maturity on average of three months to asses straw DM yield. The straw dry matter yield (SDMY) was calculated according to the formula developed by (Tarawali *et al*., 1995).

$$\mathrm{SDMY(t/ha)} = \frac{\mathrm{DM\% \times TFW\ (t/ha)}}{100}$$ Where:

TFW = Total fresh weight, DM% = Dry matter percentage of the straws.

### 3.4.3. Chemical analysis

The samples were dried in the forced air drying oven at 65 °C for 48 hours and then ground to pass a 1 mm screen. The ground samples were oven dried at 105 $^{0}$C over night for determination of dry matter (DM). The nitrogen (N) content was determined by Kjeldahl method, and Crude protein concentration (CP) was calculated by multiplying N concentration by 6.25 (AOAC, 1995). Ash was determined by igniting the samples for 5-6 hours at 550 $^{o}$C in a muffle furnace (AOAC, 1995).

The chemical composition and IVTOMD contents were determined using the Near Infrared Reflectance Spectroscopy (NIRS) facilities available at International Livestock Research Institute (ILRI). The metabolizable energy (ME) content was estimated from IVTOMD value using the equation: ME (MJ/kg DM) =0.15*IVOMD (g/kg) (Beever and Mould, 2000).

The *in-vitro* true digestibility of faba bean straw was estimated using a Daisy $^{II}$ Incubator based on the modified two stages *in vitro* (Tilley and Terry procedure, 1963) as modified Van Soest and Robertson (1985). The dried and ground (1 mm) sample of faba bean straw was placed in filter bags (F57) made from polyester/ polyethylene extruded filaments (50 x 55 mm exterior size). The rumen fluid was taken before the morning feed (before feeding the diet supplement). Not more than 15 minutes before the trial starts, one liter rumen fluid was collected by using a rumen cannula in equal proportions from two donor sheep under the same feeding regime (at ILRI, baled natural pasture grass hay from Sululta given ad libitumand a total of 2.4 kg faba bean straw given per day as supplement). The sample was filtered through two layers of cheese cloth into a warm flask (kept in a bucket of water at 38 °C) and flushed with carbon dioxide ($CO_2$) (Osuji *et al*., 1993).

According to Ankom's recommendations, 0.50 g of sample per bag was weighed. The bags (2 jars x 2 replications) were then incubated in an incubation jar in buffered ruminal fluid for 48 h. After incubation, the jars were drained and the bags rinsed thoroughly with cold tap water. The bags with residues were boiled for 75 min in neutral detergent solution (in an Ankom$^{200/220}$ apparatus). After the solution was removed, 2 liters of hot (90 °C-100 °C) $H_2O$ and 4.0 ml of α-amylase were used in the first and second rinses of bags. The bags were then oven dried and weighed immediately after the samples were allowed to cool to room temperature.

## 3.5. Statistical Analysis

Data on agronomic parameters, faba bean straw dry matter yield, chemical composition, IVTOMD, IVTDMD and ME of faba bean straw were analyzed using the General Linear Model (GLM) procedure of the statistical analysis system (SAS, 2002). Tukey's Student Range Test was used to determine the statistical significances between treatment means at 5% level of significance. The model for determining data for the trial was:

$Y_{ijk} = \mu + A_i+B_j + (A_iB_j) + E_{ijk}$

Where: $Y_{ijk}$ = the measured response

$\mu$ = overall mean

$A_i$ = variety effect

$B_j$ = management effect

$(A_iB_j)$ = interaction effect of $j^{th}$ management and $i^{th}$ variety

$E_{ijk}$ = the error term associated with each $Y_{ijk}$

The model for oat and weed DM yield was:

$Y_{ijk} =\mu+ D_i+F_j+ (D_iF_j)+ E_{ijk}$

Where: $Y_{ijk}$ = the measured response, $F_j$ = effect of $j^{th}$ cutting round

$\mu$ = the overall me, $D_i$ = effect of $i^{th}$ faba bean variety

$(D_iF_j)$ = interaction of $j^{th}$ cutting round and $i^{th}$ faba bean variety,

$E_{ijk}$ = the error term

# 4. RESULTS

## 4.1. Agronomic Characteristics

The agronomic practices measure taken by each faba bean variety under different management practices to vigor, flowering; plant height and days to flower are shown in Table 3.

There was a significant difference observed in vigor among management practices and faba bean varieties grown under the three management practices. Plant vigor was the highest in Gebelcho and lowest in Dosha, ranging between from (3.63) in (Dosha) to 4.28 (Gwbelcho).the vigor bases on management and faba bean verity which improved management and the verity gebelcho, in this management no cooption.

Substantial differences were found between faba been varieties in height under different management practices. (Dosha) under improved management had constantly lowest heights (71.5cm) up until flowering stage as compared to the remaining faba bean variety under the three management practices. The height rates with plant growth to food competition. In the case of improved management no comption for food and it is a normal growth. (Table 3).

The interaction effect of faba bean variety and management practice had also significant effect on vigor. These was significant interaction effect between faba bean variety "Dosha" (3.63) grown under traditional to "Gebelcho" (4.28) under improved management practices.

Table 3: The vigor, height at flowering and days to flower for the two faba bean varieties at different management practices

| Management practice | Faba bean variety | Vigor (1-5 scale)* | Height (cm) | Days to flowering |
|---|---|---|---|---|
| | | Mean ± SE | Mean ± SE | Mean ± SE |
| Improved | Dosha | $3.69 \pm 0.08^{b}$ | $71.5 \pm 0.33^{b}$ | $60.8 \pm 0.31$ |
| | Gebelcho | $4.28 \pm 0.08^{a}$ | $72.1 \pm 0.33^{b}$ | $60.9 \pm 0.31$ |
| Traditional | Dosha | $3.63 \pm 0.08^{b}$ | $75.4 \pm 0.33^{a}$ | $61.0 \pm 0.31$ |
| | Gebelcho | $3.77 \pm 0.08^{b}$ | $75.6 \pm 0.33^{a}$ | $60.6 \pm 0.31$ |
| Intercropped | Dosha | $3.74 \pm 0.08^{b}$ | $76.1 \pm 0.33^{a}$ | $61.3 \pm 0.31$ |
| | Gebelcho | $3.81 \pm 0.08^{b}$ | $76.2 \pm 0.33^{a}$ | $61.3 \pm 0.31$ |
| Level of significance | | | | |
| MP | | 0.0167 | <0.0001 | 0.1786 |
| Variety | | <0.0001 | 0.2643 | 0.7424 |
| Varity*MP | | 0.0003 | 0.8007 | 0.7036 |

SE-= standard error, cm=centimeter, MP=management practice, *=vigor scale, (1=the lower and 5=the highest), $^{ab\cdots}$Means with different letters with a column is significant at $p \leq 0.05$.

## 4.2. Yield and Yield Components

Plant tiller, numbers of pods per plant, number of seeds per pod and grain yield for different faba bean varieties are presented in Table 4.

Significant variations were observed in plant tillers number (P< 0.001) among management practices. In the Improve management, the number of tillers varied from 0.46 (Gebelcho) to 0.44 (Dosha). Plant tillers ranged from 0.40 (Gebelcho) to 0.28 (Dosha) under traditional management practice and from 0.72 (Gebelcho) to 0.47 (Dosha) under intercropping.

Number of pods per plant varied between management practices. Dosha had the highest (12.5) number of pods per plant in the improved management practice, while, the least number of pods per plant was observed for Gebelcho (9.69) under traditional management practices. At the improved management Dosha variety was significantly differ ($p<0.0001$) than Gebelcho under improved management practices. The mean number of pods was less ($P<0.01$) in Gebelcho traditional than intercropping and improved management practices.

The mean number of seeds per pod (SPd) varied between faba bean varieties and management practices. The lowest ($P<0.05$) number of seeds per pod was for Dosha traditional and intercropped (2.72) and the highest ($P<0.05$) was for Gebelcho improved (2.96). The SPd count varied from 2.92 (Dosha) to 2.96 (Gebelcho) in improved management, 2.72 (Dosha) to 2.76 (Gebelgho) in traditional management and, 2.72 (Dosha) to 2.76 (Gebelcho) under intercropping management. Among the three management practices, the lowest ($P<0.001$) SPd was observed under traditional and intercropping Dosha Varity than in the other management practices.

Considerable differences were also observed among varieties in grain yield (t $ha^{-1}$) under different management practices. The mean grain yield of different faba bean varieties in the same management practice was not different but it was varied significantly from one management practice to another management practice. Dosha varied from 3.62 t $ha^{-1}$, 3.27 t $ha^{-1}$ and 3.38 t $ha^{-1}$ in improved, traditional, and intercropped respectively. The highest ($P<0.01$) grain yield was for Dosha (3.62 t $ha^{-1}$) in improved management practice and the lowest ($P<0.01$) was for Gebelcho (3.19 t $ha^{-1}$) under intercropped management practice. The reason for yield increment for improved management was because of management practices such as improved regular weeding and the others decrement was a competition for nutrients and air and lakes long day for growth.

Table 4: Growth and yield attributes of two faba bean varieties grown under the three different management practices at maturity stage.

| Management practice | Faba bean variety | Tiller (n) | Height (cm) | PPl (n) | SPd (n) | SPl (n) | FB grain yield (t/ha) |
|---|---|---|---|---|---|---|---|
| | | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| Improved | Dosha | $0.44 \pm 0.10^{ab}$ | $124 \pm 2.97^{ab}$ | $12.5 \pm 0.52^{a}$ | $2.92 \pm 0.05^{a}$ | $32.2 \pm 1.52^{a}$ | $3.62 \pm 0.07^{a}$ |
| | Gebelcho | $0.46 \pm 0.10^{ab}$ | $122 \pm 2.97^{ab}$ | $11.5 \pm 0.52^{ab}$ | $2.96 \pm 0.05^{a}$ | $27.9 \pm 1.52^{b}$ | $3.58 \pm 0.07^{a}$ |
| Traditional | Dosha | $0.28 \pm 0.10^{b}$ | $123 \pm 2.97^{ab}$ | $9.97 \pm 0.52^{c}$ | $2.72 \pm 0.05^{b}$ | $25.0 \pm 1.52^{bc}$ | $3.27 \pm 0.07^{b}$ |
| | Gebelcho | $0.40 \pm 0.10^{b}$ | $129 \pm 2.97^{a}$ | $9.69 \pm 0.52^{c}$ | $2.76 \pm 0.05^{b}$ | $23.5 \pm 1.52^{c}$ | $3.28 \pm 0.07^{b}$ |
| Intercropped | Dosha | $0.47 \pm 0.10^{ab}$ | $123 \pm 2.97^{ab}$ | $10.2 \pm 0.52^{bc}$ | $2.72 \pm 0.05^{b}$ | $25.0 \pm 1.52^{bc}$ | $3.38 \pm 0.07^{b}$ |
| | Gebelcho | $0.72 \pm 0.10^{a}$ | $117 \pm 2.97^{b}$ | $9.74 \pm 0.52^{c}$ | $2.76 \pm 0.05^{b}$ | $23.5 \pm 1.52^{c}$ | $3.19 \pm 0.07^{b}$ |
| Level of significance | | | | | | | |
| *MP | | 0.0492 | 0.1375 | <0.0001 | <0.0001 | 0.0001 | <0.0001 |
| *Variety | | 0.1211 | 0.7496 | 0.1746 | 0.3081 | 0.0493 | 0.2140 |
| *Varity*MP | | 0.5535 | 0.0918 | 0.7541 | 0.9968 | 0.5640 | 0.3270 |

[ab…]Means with different superscript letters under the same column are significantly ($P<0.05$) different; PPl=pods per plant; SPd= seeds per pod; SPl= seed per plant; cm = centimeter; n= number; t/ha = tone per hectare; SE= standard error; MP= management practice.

## 4.3. Dry Matter Yield

The straw DM yield (t $ha^{-1}$) of faba bean varieties under different management practices was shown Table 5. The mean straw DM yield varied between faba bean varieties and among management practices. The highest (2.60 t $ha^{-1}$) and lowest (2.47 t $ha^{-1-}$) straw DM yield for Dosha under improved management practices, whereas Gebelcho (1.34 t $ha^{-1}$) produced the lowest straw DM yield under intercropping management practices. For Straw DM yield, improved management was greater than that of traditional and intercropped management practices for all faba bean varieties because the improved management has favorable conditions in the case of regular weeding.

Table:5. The mean straw dry matter yield of two different faba bean varieties under different management practices

| Management practice | Faba bean variety | FBSDMY (t/ha) |
|---|---|---|
| | | Mean ± SE |
| Improved | Dosha | $2.59 \pm 0.14^{a}$ |
| | Gebelcho | $2.47 \pm 0.14^{a}$ |
| Traditional | Dosha | $1.81 \pm 0.14^{b}$ |
| | Gebelcho | $1.35 \pm 0.14^{c}$ |
| Intercropped | Dosha | $1.76 \pm 0.14^{b}$ |
| | Gebelcho | $1.34 \pm 0.14^{c}$ |
| Level of significance | | |
| *MP | | <0.0001 |
| *Variety | | 0.0048 |
| *MP*Variety | | 0.4341 |

SE= standard error; FBSDMY = Faba beab straw dry matter yield; t $ha^{-1}$ = tone per hectare; $^{ab\ldots}$Means with different superscript letters under the same column are significantly (P<0.05); MP = management practice.

Dry matter yields harvested from oats intercropped and weed traditional management practices with faba bean varieties at different cutting rounds is presented in Table 6. There was significant variation was observed in DMY between cutting rounds of oats. The highest (P<0.001) DM yields of oats were observed at second cutting and the lowest (P<0.001) DM yields were at the first cutting stage. The highest DM yield of the first cut was because of the highest tiller number. Also the DM yield (t $ha^{-1}$) of weed fodder harvested from traditionally managed plots of two different faba bean varieties was significantly (P<0.01) affected by cutting stages. The DM yield of weeds varied from 2.85 (Dosha) to 3.18 (Gebelcho) at first cut and from 0.85 (Gebelcho) to 0.90 (Dosha) at second cut. The DM yield of weeds grown under two faba bean varieties was higher at the first cut than to the second cut; because of weeds have less till rising character. .

Table 6: Tiller count (n), height (cm) at different cutting and DM yield (t/ha) of oat (ODM) and weed (WDM) harvested from different faba bean plots at the two cutting stages.

| Cutting | Faba bean variety | Tiller (n) | Height (cm) | ODM yield (t/ha) | WDM yield (t/ha) |
|---|---|---|---|---|---|
| | | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| First cutting | Dosha | 3.08 ± 0.26 | 79.2 ± 2.23$^{a}$ | 1.16 ± 2.36$^{b}$ | 2.85 ± 0.15$^{a}$ |
| | Gebelcho | 3.04 ± 0.26 | 79.4 ± 2.23$^{a}$ | 1.16 ± 2.36$^{b}$ | 3.18 ± 0.15$^{a}$ |
| Second cutting | Dosha | 3.33 ± 0.26 | 37.5 ± 2.23$^{b}$ | 4.48 ± 2.36$^{a}$ | 0.90 ± 0.15$^{b}$ |
| | Gebelcho | 3.42 ± 0.26 | 35.2 ± 2.23$^{b}$ | 4.90 ± 2.36$^{a}$ | 0.85 ± 0.15$^{b}$ |
| Level of significance | | | | | |
| *Cutting | | 0.2241 | <0.0001 | <0.0001 | <0.0001 |
| *Variety | | 0.9351 | 0.6421 | 0.3756 | 0.3538 |
| *Varity*Cutting | | 0.8072 | 0.5645 | 0.3943 | 0.2030 |

[ab…]Means with different superscript letters under the same column are significantly (P<0.05); SE= standard error; ODM= oat dry matter; WDM=weed dry matter ; n= number; cm= centimeter; kg = kilogram.

Figures 1 show the summary of total feed dry matter yields under the three management practices. The highest (P<0.001) total dry matter yield was under intercropping (7.43 t $ha^{-1}$), whereas the lowest was under the improved management practice (2.53 t $ha^{-1}$) practice. Also, under intercropping, the total protein and metabolizable energy yields were greater than under traditional and improved management practices.

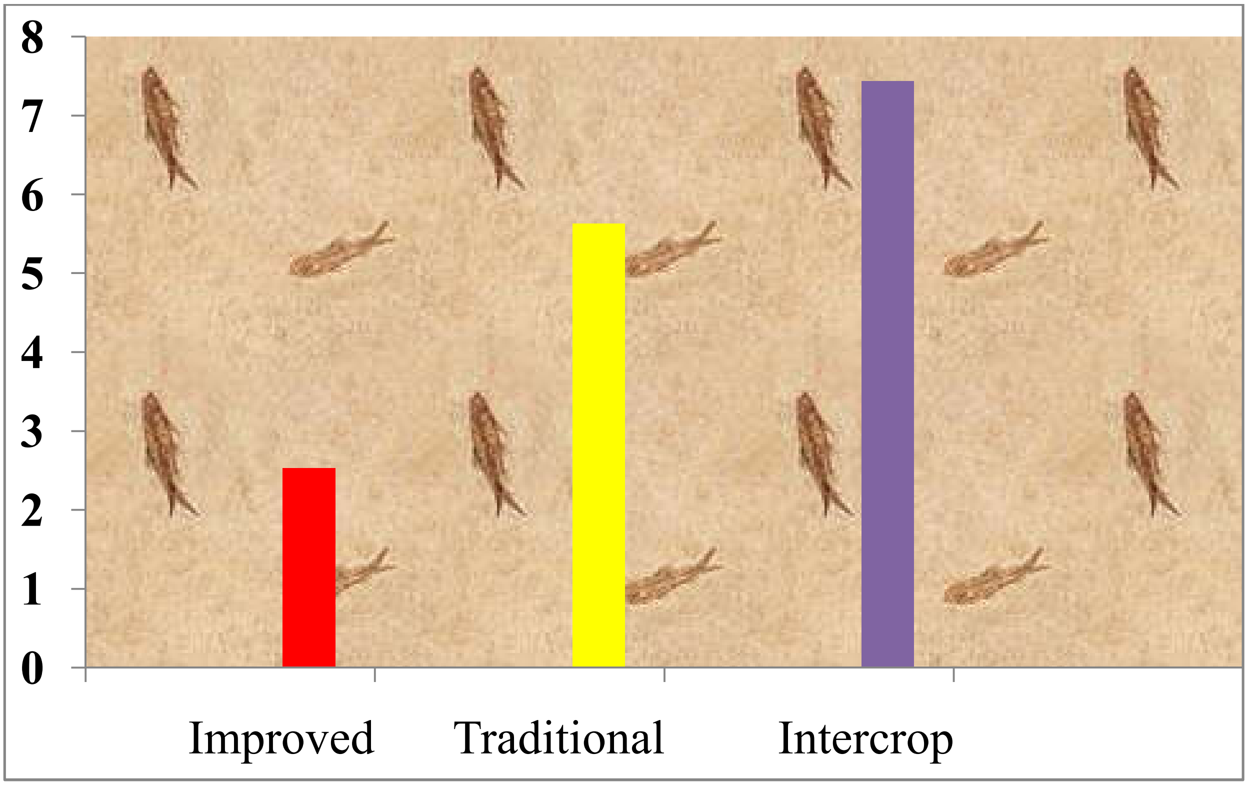


Figure 2: The total feed dry-matter yield (t $ha^{-1}$) harvested from (faba bean improved, faba bean and weed traditional and faba bean and oat intercropped) management practices

In the figure intercropping had high feed biomass yield because of high tiller number of forage oats and cutting replication, in the case of improved the straw was only faba bean residues.

### 4.4. Chemical Composition and Digestibility of Straws of Faba Bean Varieties

Nutrient contents of straws of two different faba bean varieties are presented in Table 7. There were significant in variety and management interactions practice across all chemical compositions of the faba bean straw. Also the management practices across all chemical compositions of the faba bean straw were significant, except dry matter %. The significant had been seen in Ash and CP (%) content among faba bean varieties. Gebelcho (9.53) under intercropping has the highest crude protein content, followed by Dosha (9.48) under the same management practice. However, the lowest CP contents were observed for Dosha (6.84) grown under traditional management practice. In general, the mean CP content was highest under intercropping and lowest in traditional management practice.

The NDF content (%) of (Dosha) 72.3 and (Gebelcho) 70.7 in improved management, (Dosha) 72.4 and (Gebelcho) 76.0 under traditional management and (Dosha) 60.3 and (Gebelcho) 58.5 under intercropping management practice. Generally, the NDF content was lower under intercropping than the remaining management practices.

Differences were observed in ADF content among faba bean varieties and management practices. The ADF content (%) for (Dosha) improved was 69.4 and (Gebelcho) improved was 67.6. Under traditional management, the ADF content of the two varieties was 69.4 for (Dosha) and 73 for (Gebelcho). The ADF content under intercropping management were 57.5 for Dosha and 55.9 for Gebelcho. The mean ADF content was lower in intercropping compared with improved and traditional management practices.

The mean ADL content % for the faba bean varieties ranged from 9.93 (Gebelcho) intercropped to 14.3 (Gebelcho) in traditional. The average mean ADL content %of both management and variety were 12.6. The mean ADL content ranked in the following order: improved > traditional > intercropping management practice.

The cellulose content (%) was highly significant at management practice observed for Gebelcho (46) under intercropping management practice. Generally mean cellulose content of faba bean varieties grown under intercropping was relatively lower than the remaining management practices.

The hemicellulose content (%) highly significant at management practice observed for Gebelcho (2.6) under intercropping management practice. In general, the hemicellulose content was lowest under intercropping and highest in improved management practice.

Table 7: Chemical composition of straw of faba bean varieties grown under the three management practices.

| Management practice | Faba bean variety | Chemical composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DM | Ash | CP | NDF | ADF | ADL | CELL | H.CEL. |
| | | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE |
| Improved | Dosha | $90.4 \pm 0.13^{a}$ | $8.09 \pm 0.16^{a}$ | $7.67 \pm 0.17^{b}$ | $72.3 \pm 0.72^{b}$ | $69.4 \pm 0.71^{b}$ | $14.2 \pm 0.21^{a}$ | $55.2 \pm 0.69^{b}$ | $2.84 \pm 0.07^{bc}$ |
| | Gebelcho | $90.2 \pm 0.13^{ab}$ | $8.19 \pm 0.16^{a}$ | $7.86 \pm 0.17^{b}$ | $70.7 \pm 0.72^{b}$ | $67.6 \pm 0.71^{b}$ | $13.3 \pm 0.21^{b}$ | $54.3 \pm 0.69^{b}$ | $3.07 \pm 0.07^{a}$ |
| Traditional | Dosha | $90.3 \pm 0.13^{ab}$ | $6.11 \pm 0.16^{c}$ | $6.84 \pm 0.17^{c}$ | $72.4 \pm 0.72^{b}$ | $69.4 \pm 0.71^{b}$ | $13.8 \pm 0.21^{ab}$ | $55.6 \pm 0.69^{b}$ | $3.02 \pm 0.07^{ab}$ |
| | Gebelcho | $89.8 \pm 0.13^{c}$ | $7.43 \pm 0.16^{b}$ | $7.82 \pm 0.17^{b}$ | $76 \pm 0.72^{a}$ | $73.0 \pm 0.71^{a}$ | $14.3 \pm 0.21^{a}$ | $58.7 \pm 0.69^{a}$ | $3.00 \pm 0.07^{ab}$ |
| Intercropped | Dosha | $90.0 \pm 0.13^{bc}$ | $5.98 \pm 0.16^{c}$ | $9.48 \pm 0.17^{a}$ | $60.3 \pm 0.72^{c}$ | $57.5 \pm 0.71^{c}$ | $10.3 \pm 0.21^{c}$ | $47.2 \pm 0.69^{c}$ | $2.80 \pm 0.07^{c}$ |
| | Gebelcho | $90.5 \pm 0.13^{a}$ | $6.36 \pm 0.16^{c}$ | $9.53 \pm 0.17^{a}$ | $58.5 \pm 0.72^{c}$ | $55.9 \pm 0.71^{c}$ | $9.93 \pm 0.21^{c}$ | $45.9 \pm 0.69^{c}$ | $2.59 \pm 0.07^{d}$ |
| Level of significance | | | | | | | | | |
| *Management practice | | 0.1882 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| *Variety | | 0.4051 | <0.0001 | 0.0033 | 0.9461 | 0.9390 | 0.1432 | 0.5993 | 0.9489 |
| *Varity*MP | | 0.0009 | 0.0004 | 0.0131 | 0.0002 | 0.0002 | 0.0037 | 0.0026 | 0.0059 |

[ab…]Means with different superscript letters under the same column are significantly (P<0.05) different; DM= dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF = acid detergent fiber; %= percent; SE= standard error; MP= management practice; CELL= cellulose & H.CEL= hemicellulose.

Differences were found in digestibility (OM and DM) and ME (MJ/kg DM) values between faba bean varieties and among management practices (Table 8). The IVTDMD values (%) varied between 61% for improved (Gebelcho) to (Dosha) 60% for Traditional (Dosha) 57% to (Gebelcho) 56% and 57% for Intercropped (Gebelcho) to 66% Doshe. Generally, IVTDMD value was higher under intercropping for which variety compared with traditional and improved management practices.

The mean IVTOMD value (%) for Dosha and Gebelcho under improved management practices were 50.4 and 51.1, under traditional management practice the varieties, Dosha and Gebelcho had IVTOMD values 47% and 465, respectively and 56% and 55% in the intercropped management practices respectively. The highest IVTOMD value (%) was found for Dosha (56%) in the intercropping management, whereas the lowest value was obtained for Gebelcho (46%) in the traditional management practice. Generally, IVTOMD and IVTDMD were significant under intercropping management practice.

ME value (MJ/kg DM) was the highest for Dosha (7.86) under intercropping and lowest for Gebalcho (6.31) under traditional management practice. The mean ME value was the highest under intercropping and the lowest in the traditional management practice.

Table 8. Least square means for *in vitro* true OM digestibility (IVTOMD), DM digestibility (IVTDMD) and metabolizable (ME) of straws of different faba bean varieties grown under different management practices.

| Management practice | Faba bean variety | IVTDMD (%) | IVTOMD (%) | ME (MJ/kg DM) |
|---|---|---|---|---|
| | | Mean ± SE | Mean ± SE | Mean ± SE |
| Improved | Dosha | 60.4 ± 0.65$^{b}$ | 50.4 ± 0.65$^{b}$ | 6.90 ± 0.95$^{b}$ |
| | Gebelcho | 61.1 ± 0.65$^{b}$ | 51.1 ± 0.65$^{b}$ | 7.05 ± 0.95$^{b}$ |
| Traditional | Dosha | 56.9 ± 0.65$^{c}$ | 46.9 ± 0.65$^{c}$ | 6.51 ± 0.95$^{c}$ |
| | Gebelcho | 55.6 ± 0.65$^{c}$ | 45.6 ± 0.65$^{c}$ | 6.31 ± 0.95$^{c}$ |
| Intercropped | Dosha | 65.9 ± 0.65$^{a}$ | 55.9 ± 0.65$^{a}$ | 7.86 ± 0.95$^{a}$ |
| | Gebelcho | 65.5 ± 0.65$^{a}$ | 55.5 ± 0.65$^{a}$ | 7.84 ± 0.95$^{a}$ |
| Level of significance | | | | |
| *MP | | <0.0001 | <0.0001 | <0.0001 |
| *Variety | | 0.5164 | 0.5164 | 0.7345 |
| *MP*Variety | | 0.2704 | 0.2704 | 0.1882 |

$^{ab\ldots}$Means with different superscript letters under the same column are significantly ($P<0.05$) different; DM= dry matter; IVTDM= *in vitro* true dry matter digestibility; IVOMD = *in vitro* organic matter digestibility; ME= metabolizable energy; MJ/kg = mega jule per kilogram; %= percent; SE= standard error; MP= management practice.

## 4.5. Economic Analysis

In order to evaluate the economic benefits of the different management practices, partial budget analysis was conducted. Two years average market grain price of faba bean (ETB10 $kg^{-1}$), oat forage seed (ETB 25 $kg^{-1}$), farm gate price of faba bean straw (ETB 145 $q^{-1}$), and oat forage (DM) (ETB 265 $q^{-1}$). In addition based on the current market price, labor value at ETB 50 per person per day was used. Faba bean weeding was done for eight days per hectare and four persons per day were participated in two times weeding practices. Therefore, the average extra labor cost for weeding in the improved management was Birr 3200 $ha^{-1,}$ and for weed and forage oat two times harvesting four persons per four days for each cutting 50 Birr and a total of Birr 1600 , but other management costs were assumed to be the same for all practices. The forage seed cost under intercropping management practice was 1625 ETB $ha^{-1}$.

The result of partial budget analysis showed that the highest net return return (ETB 41869 $ha^{-1}$) was obtained in the Dosha intercropping management practice, while the lowest (ETB 35032.5 $ha^{-1}$) was for Dosha in the traditional management practice (Table 9).

Table 9: Partial budget analysis of the different varieties under different management practices

| Management practices | FB variety | Feed DM yield (t ha$^{-1}$) | | | | Grain yield (t ha$^{-1}$) | Returns (ETB ha$^{-1}$) | | | | | Extra costs (ETB ha$^{-1}$) | | | Net return (ETB ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Straw | Weed | Oat | Total feed | | Straw | Weed | oat | Grain | Total rerun | Labor | Forage seed | Total cost | |
| Improved | Dosha | 2.59 | - | - | 2.59 | 3.62 | 3755.5 | - | - | 36200 | 39955.5 | 3200 | - | 3200 | 36755.5 |
| | Gebelcho | 2.47 | - | - | 2.47 | 3.58 | 3581.5 | - | - | 35800 | 39381.5 | 3200 | - | 3200 | 36181.5 |
| Traditional | Dosha | 1.81 | 3.75 | - | 5.56 | 3.27 | 2624.5 | 1875 | - | 32700 | 37199.5 | 1600 | - | 1600 | 35032.5 |
| | Gebelcho | 1.35 | 4.03 | - | 5.38 | 3.28 | 1957.5 | 2015 | - | 32800 | 36772.5 | 1600 | - | 1600 | 35172.5 |
| Intercropping | Dosha | 1.76 | - | 5.64 | 7.4 | 3.38 | 2552 | - | 8742 | 33800 | 46969 | 1600 | 1625 | 3225 | 41869 |
| | Gebelcho | 1.34 | - | 6.06 | 7.4 | 3.19 | 1943 | - | 9393 | 31900 | 45251 | 1600 | 1625 | 3225 | 40011 |

ETB ha$^{-1}$= Ethiopian Birr per hectare; na = not available; the variable costs and income were calculated based on the existing farm-gate prices of grains, straw, weed and oat forage; FB= faba bean; DM = dry matter.

# 5. DISCUSSION

## 5.1. Agronomic Characteristics

The faba bean varieties under all management practices took fewer number of days to flowering as compared to the mean (63) days to flower for different faba bean varieties (Negash *et al*., 2015). This is advantageous because early maturing varieties such as Gebelcho have advantage over the late maturing ones in environments where rain begins late and ends early (Negash *et al*., 2015). Late maturity of some of the varieties could be associated with a decrease in digestibility (Xing, 1995). In the current study; 'Dosha' under all management practices took less number of days to maturity than previous report of days to maturity for the same variety (Negash *et al*., 2015). The height at maturity for Gebelcho (117cm) under intercropped management was in nearer to that reported (Negash *et al*., 2015) for the same variety (112 cm) Johnston *et al*. (1998) reported that as maturity advanced; forage yield increased, but CP content reduced by about 40 to 50%; ADF and NDF levels increased by 15 to 25%.

## 5.2. Yield and Yield Components of Faba Bean

The high number of tillers for faba bean varieties managed as intercropping compared to the traditional and improved management practices might be due to regular cutting of oat cultivars. (Dhima *et al*., 2013), noted that oat was a greater competitor during the shortage of rainfall, but faba bean was a more competitor in heavy rainfall conditions. Similarly, oat is more competitive than faba bean varieties mainly in the faba bean-oat intercrops (Dhima *et al*., 2013) may be due to its tillering capacity.

In the current study, irrespective of management practices, the number of pod per plant for faba bean varieties grown under all management practices was similar to the value reported by (Karadavut *et al*., 2010; Seif *et al*., 2015; Negash *et al*., 2015) but higher from those obtained in other faba bean varieties by (Bakry *et al*., 2011). Under all management practices, the number of seed per pod was higher as compared to the result obtained for faba bean varieties reported by (Karadavut *et al*., 2010; Seif *et al*., 2015) but similar to that of (Negash *et al*., 2015). According to the current study, the number of seeds per pod for faba bean varieties under intercropping management was greater than the value obtained by faba bean variety-oat mixture reported by

(Micek, 2012). Gebelcho under improved management had higher grain yield which is in agreement with other reports (Yetimwork *et al*., 2011).

The great differences in grain yield observed among varieties and management practices could help farmers to identify potential faba bean varieties under different management practices.

## 5.3. Dry Matter Yield

In the three management practices the faba bean varieties, the straw yield was lower to the reports of (Yetimwork *et al*., 2011). Likewise the straw yield obtained from faba bean varieties was lower than that of oat variety (Fekede, 2004). However, the faba bean varieties grown in the traditionally managed trial in the current study had lower straw ,likewise the oat value was lower similar to reports for the oat varieties  (Fekede, 2004) and for the  faba bean and field pea varieties (Yetimwork *et al*., 2011). In the current study, straw yield of Dosha under improved management was higher than yields of faba bean straw under the remaining managements and varieties. Difference in morphological composition of straw could be due to inherited genetic characteristics of the varieties (Capper, 1988).

In the current study, relatively lower DM yield of oat at first cut in all intercropped faba bean plots might be due to lower DM accumulation per plant and high contents of water in the plant tissues at early stages of physiological development, whereas for the latter cuts, the DM yield increased with increased plant growth and increased plant population. The findings is in agreement with (Mariotti *et al*., 2006) who reported increased dry matter concentration of forage from the first to the second harvest, owing to the progress of cereal biological cycle. In indicated in the current study, the weed DM yield at the second cut was less than the first cut. This indicates that weed infestation was low and the faba bean varieties were not suffered from weed competition, due to their rapid growth and soil cover.

The greater DM production of intercropping management in the current study agrees with report of (Dordas and Lithourgidis, 2011) who found that faba bean-cereals intercropping produced higher DM yield than faba bean sole crop.

Similar to the current result, (Sheri *et al*., 2008) reported the highest protein yields with intercropping of faba bean-barley and pea-barley. In my study, the higher protein yield under intercropping management practice could be due to its higher forage yield.

In general, the production of greater forage per hectare is very important for producers. However, production of forages with high nutritive value is also important for livestock producers. As a result, legume-cereal forage intercropping is a viable option for farmers in the mixed crop-livestock systems of Ethiopia.

## 5.4. Chemical Composition and Digestibility of Straws of Faba Bean Varieties

The ash content of faba bean straw in the current study was higher at improved management at Gebelcho and lower at Dosha and Gebelcho traditional and intercropped management than the reported value of 7.60% for faba bean straw (Abreu and Bruno-Soares, 1998), faba bean and field pea straws (Wondatir *et al*., 2011), field pea straws (Solomon *et al*., 2008a).However, the ash value in the current study was lower than the value of faba bean straw reported by (Solomon *et al*., 2008; Asar *et al*., 2010) and oats varieties (Fekede, 2004).

In my study, the CP value for the varieties grown as intercropping was less than the value of faba bean straw reported (Yetimwork *et al*.,2011), However, CP content in the current study is comparatively similar to the value reported (Kossila, 1984), which ranged between 10-15% for the intercropped faba bean varieties. The mean CP content of the faba bean straws in the current study, except for traditionally managed Dosha faba bean variety, were higher than the critical value of 7 % required for normal rumen microbial function and feed intake (Van Soest, 1982). Pasture and other roughage feeds are classified as high, medium and low quality according to their CP contents. Accordingly, roughage feeds with CP content of 9.92 to 15.2%, 6.6 to 9.1% and 3 to 6.5% were classified as high, medium and low quality roughage feeds, respectively (Nsahlai *et al*., 1996). The faba bean varieties evaluated in this study could thus be classified as high quality feed for those grown as intercrop and medium quality for those grown in traditional and improved managements based on their CP contents. In addition, (Adugna and Said, 1994) indicated proper utilization of the DM of feeds when CP content is higher than the critical value of 7%.

In the present study, the NDF content of the two faba bean varieties, grown under intercropping management, was lower than the value reported for faba bean and field pea straws (Abreu and Bruno-Soares, 1998; Wondatir *et al*., 2011) and field pea (Solomon *et al*., 2008a). According to (Buxton, 1996), intake potential of feeds is negatively related with NDF contents. The NDF content of some of the varieties grown as intercropping were similar to the critical level of 55-60%, which was reported to decrease voluntary feed intake and feed conversion efficiency due to longer rumination time (Shirley, 1986). (Buxton,1996) reported the extreme cell wall concentration (NDF) of diets that will not hinder intake and animal production can be as high as 70 to 75% NDF for mature beef cows, and as low as 15 to 20% NDF for finishing ruminants. Similarly, (Adugna and Said, 1994) reported that total cell wall concentration (NDF) exceeding 60% was reported to be associated with lower voluntary feed intake, longer rumination period and decreased efficiency of conversion of ME to net energy. According to (Singh and Oosting, 1992), roughage diets are categorized into average quality feed, if NDF content is between 45%-65%, and feed, which had below 45% NDF contents were generally classified as high quality roughage feed. In the current study, the NDF contents (58.46 to 60.28%) of faba bean varieties under intercropping were considered average quality feed, while the values of Gebelcho and Dosha (under traditional and improved management) were higher than critical range and considered low quality feed. The relatively lower NDF content of the faba bean varieties suggest better voluntary intake than most of the cereal straws and maize stover, which are available to smallholder farmers.

The ADF values of intercropping managements in this study was higher than the values of faba bean and field pea straw reported (Yetimwork *et al.,* 2011; Solomon *et al*., 2008a), barley and wheat straw (Teklay, 2008; Abadi *et al*., 2015; Abreu and Bruno-Soares, 1998; Wondatir *et al*., 2011; Luelseged and Jemal, 1989) and oats straw (Fekede, 2004), which could be attributed to differences in crop management, variety, soil fertility and climate. Kellems and Church (1998) characterized roughages with less than 40% ADF as high quality and above 40% as low quality. Likewise, legumes with ADF contents less than 31% are considered as high quality, although those with values greater than 55% are rated as poor quality (Mihai *et al*., 2012). Hence, for the variety Gebelcho grown under intercropping management, the comparatively lower value of ADF in this study could be indicative of its better digestibility than the remaining varieties and management practice.

According to the current study, the lignin contents of faba bean varieties 'Gebelcho' grown under intercropping management was lower to faba bean, purple vetch and lentil straws (Aberu and Bruno-Soares *et al*., 1998), wheat, barley, oats and field pea straws (Solomon *et al*., 2008a; Wondatir *et al*., 2011), whereas the values were comparatively similar to faba bean hull reported by (Abadi *et al*. 2015; Wondatir *et al*., 2011). Faba bean varieties grown under improved and traditional managements had higher lignin contents as compared to the values reported for faba bean hull (Abadi *et al*., 2015), faba bean and field pea straw (Wondatir *et al*., 2011), maize Stover (Tolera *et al*., 1999) and oats straw (Fekede, 2004). Lignin is a component, which attributes strength and resistance to plant tissue, thereby limiting the ability of the rumen microorganisms to digest the cell wall polysaccharides, cellulose and hemicellulose, resists microbial enzyme attack and hence reduces digestibility (Reed *et al*., 1988). The polysaccharides of the cell wall become more digestible once the lignin has been removed (Jones and Wilson, 1987). Therefore, the variety Dosha and Gebelcho grown under intercropping management practices consistently have lower lignin content than the critical level of 10% which was indicated to limit DM intake (Reed et al., 1986). The ADL fraction forms complexes with cellulose and hemicellulose fractions through physical encrustation (Kellems and Church, 1998). This limits digestion of the cellulose and hemicellulose fractions to microbial enzymes (McDonald *et al*., 1995).

The current study shows that the cellulose content for the faba bean varieties grown under intercropping management was comparatively similar to the values reported for faba bean hull (Abadi *et al*., 2015), field pea straw (Solomon *et al*., 2008a) and higher than the value reported for herbaceous and browse legumes (Diriba *et al*., 2013). Thus, the lower cellulose content of straws of faba bean varieties grown under intercropping managements obtained in this study suggests the better nutritive value. According to (Qingxian, 1996), hemicellulose concentration in legumes is much lower, generally between 8-15%. The hemicellulose content in the present study was below this range.

The IVTOMD values (45.8 % to 55.9 %) in the current study were similar with the values (43.5% to 55.3%) in legume straws reported by (Abreu and Bruno-Soares, 1998) and faba bean straw by (Thorlaciusi *et al*., 1979). In the intercropping management, the IVTOMD values were higher than the value reported by (Kafilzadeh *et al*., 2012) for straws of different oat cultivars.

However, all the faba bean varieties under three management practices had revealed lower IVTOMD than the values for herbaceous and browse legumes (Diriba, 2013). As might be expected, the ME value of faba bean straws parallels IVTOMD value (Abreu and Bruno-Soares, 1998).

The *in vitro* digestibility values greater than 65% indicate good nutritive value, and values below this level result in reduced intake due to lowered digestibility (Meissner *et al*., 2000). Hence, in the present study, the IVTDMD values of faba bean varieties in the intercropping were higher than this critical level, whereas the IVTDMD values for Gebelcho and Dosha in both traditional and improved managements were lower than the critical value. The IVTDMD value of all the faba bean varieties, under intercropping management, studied in the current study was higher than the values for field pea and faba bean straws reported by (Solomon *et al*., 2008; Gashaw, 1992). In the intercropping management, the IVTDMD values (65.5% to 65.9%) were similar with the values (65% to 73.8%) in straws of different faba bean varieties reported by (Yetimwork *et al*., 2011). The current values were higher under all management practices compared with the value of straws of different oat cultivars reported by (Kafilzadeh *et al*., 2012).

(Xing, 1995) reported that as plants mature, nutrient digestibility generally declines, due to decrease in the digestibility of cell wall components. The same author reported a variation in chemical composition and digestibility of crop residues among cultivars. With advancing age the digestibility of the leaf decreases slowly and that of the stem falls rapidly (Minson, 1990). Hence, the lower IVTDMD and IVTOMD values of 'Gebelcho and Dosha' under traditional and improved management practices could be associated with late maturity. According to (Minson, 1990), cell wall digestion depends on the degree of lignifications. In the current study, also those varieties, which had high content of lignin, had lower value of IVTOMD and IVTDMD than those varieties with lower lignin content. Generally, differences in the digestibility of straws may be due, among other factors, to variety (Dias-da-Silva and Guedes, 1990; Micek *et al*., 2012), level of weeds (Sundstod, 1988); the level and composition of their cell walls (Abreu and Bruno-Soares, 1998).

This implies the varietal and management practices differences in chemical composition, digestibility and energy values need to be considered in promoting faba bean-oat intercropping under smallholder farmers' condition in Ethiopia.

## 5.5. Economic Analysis

In this study, the economic return was higher under intercropping management than the other management practices. In line with this result, (Sheri *et al*., 2008) reported that intercropping of pea and barley gave high economic return than that grown separately. The higher economic return under intercropping management in the current work could be attributed to higher oat forage DM yield and lower forage seed cost (Woldesembet *et al*., 2014).

The cost analysis did not include costs related to faba bean seed and harvesting which were assumed similar across the management practices. However it appears that the increased forage yield and nutritive value of faba bean- oat intercropping may be economically beneficial. In addition to the economic benefit, faba bean-forage intercropping plays vital roles in weed control, soil fertility, soil conservation and efficient use of land and labor resources.

# 6. SUMMARY, CONCLUSION AND RECOMMENDATION

The results of the current study indicate that the variety Gebelcho took more number of days to mature under traditional management and consistently lower under intercropping management practice. The faba bean variety 'Dosha' was at the same maturity stage in all management practices but had higher grain and straw dry matter yield under improved management practice. This shows the possibility of selecting 'Dosha' for high grain and straw dry matter yield under improved management practices. Under intercropping management practice, lower straw DM yield was recorded for the variety 'Gebelcho' as compared to the remaining management practices.

The varieties as intercropping had lower fiber contents, higher CP contents and *in vitro* digestibility values than other varieties and managements. Although, faba bean intercropping with oats produced lower grain yield than other practices, it provided significantly higher feed dry matter, CP, *in vitro* digestible organic matter, ME and lower fiber contents than those of traditional and improved management practices. The estimated values of returns in terms of grain yield and feed biomass indicated that intercropping appears to be economically feasible to provide both grain for the household and feed for their livestock.

Generally, intercropping of faba bean varieties such as Dosha followed by Gebelcho with oats could be used as alternatives to traditional and improved management practices in order to provide reasonable straw yield and nutritive value of forages in the mixed crop-livestock production systems of my study area.

However, further studies are required to evaluate variations in intake and animal performances and the level of inclusion of straws of different faba bean varieties under various management practices to develop faba bean straw based diets for ruminants in mixed crop-livestock systems of Ethiopian highlands.

# 7. REFERENCES

Abadi Nigus, Mehammed Yousuf and Getachew Animut. 2015. Determination of Digestibility of Faba Bean *(Vicia Faba L.)* Hull and Wheat Bran in Afar Sheep. *Journal of Biology, Agriculture and Healthcare,* 5 (1):73-74.

Abreu, J.M.F., Bruno-Soares, A.M. 1998. Characterization and utilization of rice, legume and rape straws.In: Antongiovanni M. (eds.). Exploitation of Mediterranean roughage and by products.Zaragoza:Ciheam, p. 39-51 (Options Méditerranéennes: Série B. Etudes et Recherches; pp.17.

Adugna Tolera and Said, A.N. 1994. Assessment of feed resources in Wolayta Sodo: Quantity estimation and laboratory evaluation. *Ethiopian Journal of Agricultural Science,* 14: 69-87.

Adugna Tolera, Berg, T. and Sundstøl, F.. 1999. The effect of variety on maize grain and crop residue yield and nutritive value of the Stover. *Animal Feed Science and Technology,* 79: 165- 177.

Adugna Tolera. 2008. Feed resources and feeding management: A manual for feedlot operators and development workers. Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM) Texas Agricultural Experiment Station (Taes)/Texas A and M University, Addis Ababa. pp 36.

Adugna Tolera, Alemu Yami and Dawit Alemu. 2012. Livestock feed resources in Ethiopia: Challenges, Opportunities and the need for transformation. Ethiopia Animal Feed Industry Association, Addis Ababa, Ethiopia.

Agung, S. and McDonald, G. K. 1998. Effect of seed size and maturity on the growth and yield of faba bean (*Vicia faba*). *Australian Journal of Agricultural Research*, 49:79- 88.

Ahmed Hassen, Abule Ebro, Mohammed Kurtu and Treydte, AC. 2010. Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. *Livestock Resource Rural Development,* 2(12):125-132. http://www.lrrd.org/lrrd22/12/cont2212.html.

Altinok, S., Sampson, H., Martin, R. C. 1997. The morphology and yield of Barley and Forage Legumes in Intercrops.

Amede Tilahun, Solomon Melaku and Ralph, R. 2006. Intensification of Livestock Feed Production in Ethiopian Highlands: Potential and Experiences of the African Highlands Initiative.

Anil L, Park, J., Phipps, R. H., Miller F. A. 1998. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass and Forage Science*, 53:301–317.

AOAC (Association of Official Analytical Chemists). 1995. Animal Feed: Sample preparation (950.02). Official methods of analysis, 16$^{th}$ edition.

Asar, M. A., Mona, O., Yakout, H. M. and Safoat, A. 2010. Utilization of Corn-Cob Meal And Faba Bean Straw In Growing Rabbits Diets And Their Effects On Performance, Digestibility And Economical Efficiency: *Egypt Poultry Science*, 30:415-442.

Assefa Abegaz. 2005. Farm management in mixed crop livestock systems in the Northern Highlands of Ethiopia. *Ph.D. Thesis*, Wageningen Agricultural University, Wageningen, The Nether lands.

Bakry, B.A., Elewa, T.A., El. Karamany, M.F., Zeidan, M.S. and Tawfik, M.M. 2011. Effect of Row Spacing on Yield and its Components of Some Faba Bean Varieties under Newly Reclaimed Sandy Soil Condition: *World Journal of Agricultural Sciences,* 7(1): 68-72.

Baranowski, A. 2005. Faba bean seeds in feeding of fattening bulls (in Polish). Prz. hod. 72(8):11-12.

Beever, D.E. and Mould, F.L. 2000. Forage evaluation for efficient ruminant livestock production. In: Givens D.I., Owen E., Axford R.F.E. and Omed H.M. (eds.). Forage Evaluation in Ruminant Nutrition. CAB International, Wallingford, UK. pp. 15-43.

Bidwell-Porębska, K. and Piotrowski, J. 1991. Faba bean and lupine seeds in concentrate mixtures for young calves (in Polish), 59 (2): 16-18.

Brougham, R. W. 1958. Interception of light by the foliage of pure and mixed stands of pasture plants*. Australian Journal of Agricultural Research*, 9: 39-52

Brouwer, J. and Flood, R. G. 1995. Aspects of oats physiology.In: R. W. Welch, (ed). The Oat Crop: Production and Utilization. London: Chapman and Hall, 177-222.

Buxton, D.R. 1996. Quality-related characteristics of forage as influenced by plant environment and agronomic factors. *Animal Feed Science and Technol*ogy, 59: 37-49.

Capper, B.S. 1988.Genetic variation in the feeding value of cereal straw. *Animal Feed Science Technology*, 21:127-140.

CSA (Central statistical Agency). 2008. Ethiopian Statistical Abstract, Central Statistical. Authority, Addis Ababa, Ethiopia.

CSA (Central statistical Agency). 2015. Ethiopian Statistical Abstract, Central Statistical Authority: Statistical bulletin 578. Addis Ababa, Ethiopia.

CSA (Central statistical Agency). 2008. Summary and Statistical Report of 2007 Population and Housing Census: population size by age and sex, FDROE, Addis Ababa, Ethiopia

Charlton, D. and Stewart, A. 2006.Pasture and Forage Plants for New Zealand. Palmerston North: New Zealand Grassland Association. pp.74 .

Church, D. C. and Richard, O. K. 2002. Livestock Feeds and Feeding (5th Ed). New Jersey: Pearson, Education, Inc. 654 pp.CSA (Central Statistical Agency). 2012. Agricultural Sample Survey Report on Land Utilization. Statistical Bulletin 532, Addis Ababa, Ethiopia.

Crepon, K., Marget, P., Peyronet, C., Carrouee, B., Arese, P. and Duc, G. 2010. Nutritional value of faba bean (Vicia faba L.) seeds for feed and food. *Field Crop Research*, 115 :329-339.

Crews, T.E. and Peoples, M.B. 2004. Legume versus fertilizer sources of nitrogen: Ecological trade-offs and human needs. *Agricultural Ecosystem*, 102:279–297.

Diriba Geleta, Mekonnen Habtegiorgis, Ashenafi Mekonin and Adugna Tolera. 2013. Nutritive Value of Selected Browse and Herbaceous Forage Legumes Adapted to Medium Altitude Subhumid Areas of Western Oromia, Ethiopia. *Global Veterinarian*, 11(6): 809-816

Dias-da-Silva, A.A. and Guedes, C.V.M. 1990.Variability in the nutritive value of straw cultivars of wheat, rye and triticale and response to area treatment. *Animal Feed Science Technology,* 28: 79-89.

Dhima, K. V., Vasilakoglou, I. B., Keco, R. Xh., Dima, A. K., Paschalidis, K. A. and Gatsis, T. D. 2013. Forage yield and competition indices of faba bean intercropped with oat. Grass and Forage Science. *The Journal of the British Grassland Society; Official Journal of the European Grassland Federation.*

Dordas, C.A. and Lithourgidis, A.S. 2011. Growth, yield and nitrogen performance of faba bean intercrops with oat and triticale at varying seeding ratios. *Grass and Forage Science*, 66:569–577

Duc, G. 1997. Field bean (*Vicia faba* L.). *Field Crops Research*, 53:99-109.

Duke, J.A. 1981. Handbook of Legumes of World Economic Importance, Plenum Press, New York, USA, 199-265

Fekede Feyissa. 2004. Evaluation of potential forage production qualities of selected oats *(Avena sativa L.)* genotypes. MSc Thesis Presented to the School of Graduate Studies of Alemaya University. pp. 190.

Fekede Feyissa, Adugna Tolera and Solomon Melaku. 2008. Proportions of morphological fractions of oats (*Avena sativa L*.) as affected by variety and growth stage. *Livestock Research for Rural Development*, 20 (6) 2008

Forsberg, R. A. and Reeves, D. L. 1995. Agronomy of oats. *In:* W. W. Robert, (Ed). The Oat Crop: Production and Utilization. London: Chapman and Hall, 223-251.

Frame, J., Charlton, JFL. and Laidlaw, AS. 1998. Temperate forage legumes. CAB International. Wallingford, pp. 327.

Gashaw Gade. 1992. Assessment of Feed Resource Base and Performance of Crossbred Dairy Cows Distributed to Smallholder in the Selale Dairy Development Project Area. M. Sc. Thesis. Alemaya University of Agriculture, Alemaya, pp. 171.

Getnet Assefa, Tekleyohanes Brhanu, Lemma Gizachew, Mesfin Dejene and Diriba Geleta. 2003. Major herbaceous forage legumes: Some achievements in species and varietal evaluation in Ethiopia. *In* Kemal A, Seid A, Surendra B, Gemechu K, Rajendra M and Khaled M. (eds.). Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of the work shop on food and forage legumes 22- 26 September 2003. Addis Ababa, Ethiopia.

Haymes, A. R. and Lee, E H.C. 1999. Competition between autumn and spring planted grain intercrops of wheat (*Triticumaestivum*) and field bean (*Vicia faba*). *Field Crops Research,* 62: 167-176.

Haynes, R.J. 1980. Competitive aspects of the grass-legume association. *Advanced Agronomy*, 33: 227-261.

Hosain, M.S. and Mortuza, M.G. 2006. Chemical composition of *Kalimatar*, a locally grown strai of faba bean (*vicia* faba L.). Bangladesh Agricultural University, Mymensingh-2202, Bangladish. *Pakistan Journal Biological Science*, 9(9): 1817-1822.

Jedel, P.E. and Helm, J.H. 1993. Forage potential of pulse-cereal mixtures in central Alberta. *Canada Journal of Plant Science*, 73: 437-444.

Jensen, E.S., Peoples, M.B. and Hauggaard-Nielsen, H. 2010. Faba bean in cropping systems. *Field crops research*, 115:203-216.

Johnston, J., Wheeler, B. and Mckinlay, J. 1998. Forage production from spring cereals and cereal-pea mixture. Ministry of Agriculture and food, Ontario, Canada.

Jones, D.I. and A.D. Wilson. 1987. Nutritive quality of forage. pp. 65-89. In: J.B. Hacker and I.H. Ternouth (eds.). The Nutritive of Herbivores.Academic Press, Australia.

Kafilzadeh, F., Heidary, N. and Bahraminejad, S. 2012.Variety effect on composition, kinetics of fermentation and *in vitro* digestibility of oat (*Avena sativa* L.) straw and its neutral detergent fibre. South. *African Journal of Animal Science*, 42 (4):206.

Karadavut, U., Patla, C., Kavurmaci, Z. and Bölek, Y. 2010. Some grain yield parameters of multi- environmental trials in faba bean ( *Vicia faba* L.) genotypes. *International Journal of Agricultural Biology,* 12: 217 – 220.

Kellems, R.O. and Church, D.C. 1998. Livestock Feeds and Feeding (4th edition.). Prentice-Hall, Inc. New Jersey, USA, Pp. 573.

Klimek-Kopyra Agnieszka, Bogdan. K., Andrzej, O. and Tadeusz, Z. 2015. Agronomic performance of naked oat (*Avenanuda*L.) and faba bean intercropping. Agriculture University in Krakow, Institute of Plant Production, AlejaMickiewicza. 21:31-120.

Kossila, V. 1984. Location and potential feed use.P. 9. In: Sundstøl F, Owen E (Ed). Straw and other fibrous by-products as feed. Developments in animal and veterinary sciences, 14.Elsevier Science Publishers B.V. Amsterdam.

Księżak, J. 2007. The development of pea and spring barley plants in the mixtures on various soil types (in Polish). *Zesz problem Post Naukrol*, 51(6):93-90.

Langer, R. H. M. and Hill, G. D. 1982. Agricultural Plants. Cambridge, U.K: Cambridge University Press. Pp. 344.

Ledgard, S.F. 1991. Transfers of fixed nitrogen from white clover to associated grasses in swards grazed by dairy cows estimated using 15 methods. *Plant and soil science*, 131: 215-223.

Lulseged, G. and Jamal, M. 1989. The potential of crop residues, particularly wheat straw, as livestock feed in Ethiopia. p.144. In: A.N, Said, B.H. Dzowela (eds.). Overcoming constraints to the efficient utilization of agricultural by-products as animal feed. ILCA (International Livestock Center for Africa), Addis Ababa, Ethiopia.

Martin, J. H., Waldren, R. P. and Stamp, D. L. 2006. Principles of Field Crop Production.

Mariotti, M., Masoni A., Ercoli, L. and Arduini, I. 2006. Forage Potential of Winter Cereal/Legume Intercrops in Organic Farming: *Italian Journal of Agronomy*, 3:403-412

Meissner, H.H., P.J.K. Zacharias and P.J. Reagain. 2000. Forage quality (Feed value). pp. 66-88. In: Tainton, N.M. (eds.). Pasture Management in South Africa. University of Natal press, Pietermaritzburg.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. and Morgan, C.A. 1995. Animal Nutrition. (Fifth Edition). Longman Group, Harlow, United Kingdom, pp: 607.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., Morgan, C. A., Sinclair, L. A., Wilkinson, R. G. 2010. Animal Nutrition, seventh edition.

Micek, P., Woznica, P., Kulig, B. and Sajdak, A. 2012.The nutritive value for ruminants of faba bean (Vicia faba) seeds and naked oat *(Avenanuda)* grain cultivated in an organic farming system. University of Agriculture in Krakow, Department of Animal Nutrition and Feed Management, Department of Crop Production. Mickiewicza Al. 21:31-120.

Miller, D. A. 1984. Forage Crops. New York: McGraw-Hill, Inc. pp. 530.

Minson, D.J. 1990. Forage in ruminant nutrition. Academic Press, London.

Mohammad Martini Yousof. 2012. Physiological and environmental constraints to winter forage crops production.Lincoln University Digital Thesis, Canterbury, New Zealand 2012.

Negash Tesfaye Tewodros, Azanaw Asfaw, Getachew Tilahun, Kibersew Mulat and Samuel Sahile Woldemariam. 2015. Evaluation of Faba bean (*Vicia faba* L.) varieties against chocolate spot (*Botrytis fabae)* in North Gondar, Ethiopia: *African Journal of Agricultural Research.*

Nsahali, I.V. and N.N. Ummuna. 1996. Sesbania and lablab supplementation of oat hay basal diet fed to sheep with or without maize grain. *Animal Feed Science Technology*, 61: 275-289.

Osuji, P.O., Nsahlai, I.V. and Khalili, H. 1993.*Feed evaluation*. ILCA Manual 5. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 40 pp. ISBN 92–9053–278 5.

Qingxian, M. 1996. Composition, nutritive value and upgrading of crop residues.China Agricultural University.

Pariyar, D. 2002. Fodder Oats in Nepal. Pasture and Fodder Research Division. National Agricultural Research Centre (NARC). Kathmandu, Nepal.

Reed, J.D., Kebede Yilma, Fussell, L.K. 1988. Factors affecting the nutritive value of sorghum and millet crop residues. pp. 233-251. In: L.D. Reed, B.S. Capper and P.J.H. Neate (eds.). Plant breeding and the nutritive value of crop residues. Proc. Workshop held at ILCA, Addis Ababa, Ethiopia, 7-10 December 1987, ILCA, Addis Ababa.

Rees, R.O., Richards, R. and Faris, F. 2000. World and regional trade : Quantity versus quality. *In:* R. Knight, (ed). Linking Research and Marketing Opportunities for Pulses in the 21st century. The Netherlands: Kluwer Academic Publishers, 143-153.New Jersey: Pearson rentice Hall. Pp. 954.

Robinson, R.C. 1969. Annual legume: cereal mixtures for forage and seed. *Agronomy Journal*, 61: 759-761.

Ross, S.M., King, J.R., O'donovan, J.T. and SpaneR, D. 2004. Forage potential of inter-cropping berseem clover with barley, oat, or triticale. *Agronomy Journal* ,96: 1013-1020.

SAS (Statistical Analysis System software ). 2002. Statistical Analysis System software, Version 9.0, SAS Institute, Inc.Cary,NC,USA.

Schwenke, G. D., Peoples M. B., Turner G. L., and Herridge, D. F. 1998. Does nitrogen fixation of commercial, dry land chickpea and faba bean crops in north-west New South Wales maintain or enhance soil nitrogen. *Australian Journal of Experimental Agriculture*, 38: 61-70.

Seif, G., Solafa, A., Hamad, A., Awadalla, A. and Mohamed Ahmed Isam, A. 2015.Yield and quality attributes of faba bean inbre lines grown under marginal environmental conditions of Sudan. Food Science and Nutrition, doi: 10.1002/fsn3.245

Sere, C., Ayantunde, A., Duncan, A., Freeman, A., Herrero, M., Tarawali, S. and Wright, I. 2008. Livestock production and poverty alleviation-challenges and opportunities in arid and semi- arid tropical rangeland based systems. In: the proceedings of multi-functional grasslands in a changing world. XXI International Grassland Congress and VII International Rangeland Congress, China. Pp. 19-29.

Singh, G.P. and Oosting, S.J. 1992.A model for describing the energy value of straws. Indian Dairyman XLIV: 322-327.

SheriStrydhorst, M., KingJane, R., LopetinskyKen, J. and Neil HarkerK. 2008. Forage Potential of Intercropping Barley with Faba Bean, Lupin, or Field Pea. *Agronomy Journal*, 100:182–190.

Shirley, R.Z. 1986. Nitrogen and energy nutrition of ruminants. Academic Press.Inc, Orlando, Florida, USA..

Solomon Bogale. 2004. Assessment of Livestock Production Systems and Feed Resource Base in SinanaDinsho District of Bale Highlands, Southeast Oromia. MSc. Thesis. Alemaya University of Agriculture, Alemaya. Pp.141.

Solomon Bogale, Melaku Solomon and Yami Alemu. 2008a. Potential use of crop residues as livestock feed resources under conditions of smallholder farmers in Bale highlands of Ethiopia. *Tropical and Sub-tropical Agro-ecosystems, 8: 107–114*

Sundstod. 1988. Straw and other fibrous by-products. *Livestock Production Science*, 19: 137-158.

Tarawali, S.A., Tarawali, G., Larbi, A. and Hanson, J. 1995. Methods for the evaluation of legumes, grasses and fodder trees for use as livestock feed.ILRI manual.ILRI (International Livestock Research Institute), Nairobi, Kenya, p.51.

Teklay Asgedom. 2008. Assessment of the feeding systems and feed resources of dairy cattle in Lemu BilbiloWereda dairy products-processing cooperatives, Arsi Zone of Oromia Regional State, Ethiopia, unpublished MSc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, P. 77.

Tessema Zewudu. 2004. "Grain and straw yield of barley as influenced by under sowing time of annual forage legumes and fertilization." *Tropical Science,* 44: 85-88.

Tilly, J.M. and Terry, R.A.1963. A two stage technique for the *in vitro* digestion of forage crops. *Journal of British grassland Society*, 18:104-111.

Thorlacius, S. O., Coxworth, E. and Thompson, D. 1979. Intake and Digestibility of Faba bean Crop Residue by Sheep. *Canadian Journal of Animal Science*, 59(2):459-462.

Turpin, J. E., Robertson, M. J., Haire C., Bellotti, W. D., Moore, A. D. and Rose, I. 2003. Simulating faba bean development, growth and yield in Australia. *Australian Journal of Agricultural Research,* 54: 39-52.

Van Soest, P.J. 1982. Nutritional Ecology of the Ruminant. O and B books, Corvallis, Oregon, USA. Pp. 373.

Van Soest, P.J. and Robertson, J.B. 1985.Analysis of forages and fibrous foods. AS 613 Manual, Department of Animal Science, Cornell University, Ithaca, NY.

Vilamanya, L. J. 1987. Traditional cropping systems in northwestern Spain. (Galicia). *Agri-cultural System*, 23:259-275.

Walli, T.K. 2004. Straws as important feed resource under sustainable crop-dairy production system. *Indian Dairyman*, 56: 35-43.

White, J. G. H., Millner, J. and Moot, D. J. 1999.Cereals.*In:* J. White and J. Hodgson, (eds). New Zealand Pasture and Crop Science. Victoria. Oxford University Press, 223-224.

Woldesembet Mitiku, Tamado Tana, Singh, TN. and Teferi Mekonnen. 2014. Effect of Integrated Nutrient Management on Yield and Yield Components of Food Barley (*Hordeumvulgare*L.) in Kaffa Zone, Southwestern Ethiopian Science. *Technology Arts Resource Journal,* 3(2):34-42.

Wondatir Zewdu. 2010. Livestock production system in relation to feed availability in the highlands and central rift valley of Ethiopia. M.Sc. Thesis. Haramaya Uninversity.Dire Dewa, Ethiopia. P. 31.

Wondatir Zewdu, Mekasha Yosef and Bram, W. 2011. Assessment of productive performance of dairy cattle nexus with feed availability in selected peri-urban areas of Ethiopia. PP.313.

Xing, T. 1995. Nutritional value and utilization of crop residues. Channgsha, China: Human Science and Technology. P.58.

Yetimwork Gebremeskel, Awet Estifanos and Solomon Melaku. 2011.Effect of Selected Faba Bean (*Vicia faba* L.*)*Varietal Difference on Straw DM Yield, Chemical Composition and Nutritional Quality. *Journal of the Dry lands*, 4(2): 333-340.

# 8. APPENDEXCES

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Appendix Table 1. Analysis of variance for vigor, days to flower and d maturity

| Source | DF | Sum Square | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Days to flowering | | | | | |
| MP* | 2 | 8.04166667 | 4.02083333 | 1.74 | 0.1785 |
| Variety | 1 | 0.25000000 | 0.25000000 | 0.11 | 0.7424 |
| MP*variety | 2 | 1.6250000 | 0.81250000 | 0.35 | 0.7036 |
| Height at flowering | | | | | |
| MP* | 2 | 521.1376389 | 260.5688194 | 97.41 | <.0001 |
| Variety | 1 | 3.3611111 | 3.3611111 | 1.26 | 0.2643 |
| MP*variety | 2 | 1.1909722 | 0.5954861 | 0.22 | 0.8007 |
| Vigor | | | | | |
| MP* | 2 | 1.40930556 | 0.70465278 | 4.22 | 0.0167 |
| Variety | 1 | 3.30027778 | 3.30027778 | 19.76 | <.0001 |
| MP*variety | 2 | 2.81847222 | 1.40923611 | 8.44 | 0.0003 |
| Height at maturity | | | | | |
| MP* | 2 | 851.557172 | 425.778586 | 2.01 | 0.1375 |
| Variety | 1 | 21.638003 | 21.638003 | 0.10 | 0.7495 |
| MP*variety | 2 | 1028.171506 | 514.085753 | 0.28 | 0.0918 |

MP*= management practice, DF= degree of freedom; ANOVA= analysis of variance.

Appendix Table 2. Analysis of variance for tiller, pods per plant, seeds per pod, seed plant & grain yield.

| Source | DF | Sum Square | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Tiller** | | | | | |
| MP* | 2 | 1.58597222 | 0.79298611 | 3.08 | 0.0492 |
| Variety | 1 | 0.62673611 | 0.62673611 | 2.43 | 0.1211 |
| MP*variety | 2 | 0.330597222 | 0.15298611 | 0.59 | 0.5535 |
| **Pods per plant** | | | | | |
| MP* | 2 | 139.3426389 | 69.6713194 | 10.54 | <.0001 |
| Variety | 1 | 12.3084028 | 12.3084028 | 1.86 | 0.1746 |
| MP*variety | 2 | 3.7393056 | 1.8696528 | 0.28 | 0.7541 |
| **Seeds per pod** | | | | | |
| MP* | 2 | 1.26465000 | 0.63232500 | 10.73 | <.0001 |
| Variety | 1 | 0.06166944 | 0.06166944 | 1.05 | 0.3081 |
| MP*variety | 2 | 0.00037222 | 0.00018611 | 0.00 | 0.9968 |
| **Seed per plant** | | | | | |
| MP* | 2 | 1058.001667 | 529.000833 | 9.59 | <.0001 |
| Variety | 1 | 217.071111 | 217.071111 | 3.93 | 0.0493 |
| MP*variety | 2 | 63.470556 | 31.735278 | 0.58 | 0.5640 |
| **Grain yield** | | | | | |
| MP* | 2 | 29.58970972 | 14.79485486 | 29.91 | <.0001 |
| Variety | 1 | 4.06694444 | 4.06694444 | 8.22 | 0.0048 |
| MP*variety | 2 | 0.83050972 | 0.41525486 | 0.84 | 0.4341 |

MP*= management practice, DF=degrees of freedom

Appendix Table 3. Analysis of variance for chemical composition of two faba bean varieties under three different management practices

| Source | DF | Sum Square | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Ash** | | | | | |
| MP* | 2 | 97.40930556 | 48.70465278 | 80.90 | <.0001 |
| Variety | 1 | 13.00804444 | 13.00804444 | 21.61 | <.0001 |
| MP*variety | 2 | 9.95957222 | 4.97978611 | 8.27 | 0.0004 |
| **CP** | | | | | |
| MP* | 2 | 126.7427556 | 63.3713778 | 94.76 | <.0001 |
| Variety | 1 | 5.9698776 | 5.9698778 | 8.93 | 0.0033 |
| MP*variety | 2 | 5.9803722 | 2.9901861 | 4.47 | 0.0131 |
| **NDF** | | | | | |
| MP* | 2 | 5973.538443 | 2986.769222 | 239.39 | <.0001 |
| Variety | 1 | 0.057201 | 0.057201 | 0.00 | 0.9461 |
| MP*variety | 2 | 224.920543 | 112.460272 | 9.01 | 0.0002 |
| **ADF** | | | | | |
| MP* | 2 | 5725.338022 | 2862.669011 | 233.33 | <.0001 |
| Variety | 1 | 0.072003 | 0.072003 | 0.02 | 0.9390 |
| MP*variety | 2 | 227.617272 | 113.808636 | 9.28 | 0.0002 |
| **ADL** | | | | | |
| MP* | 2 | 461.4636347 | 230.7318174 | 216.01 | <.0001 |
| Variety | 1 | 2.3154694 | 2.3154694 | 2.17 | 0.1432 |
| MP*variety | 2 | 12.4797764 | 6.2398882 | 5.84 | 0.0037 |
| **Cellulose** | | | | | |
| MP* | 2 | 2952.946168 | 1476.473084 | 129.62 | <.0001 |
| Variety | 1 | 3.159506 | 3.159506 | 0.28 | 0.5993 |
| MP*variety | 2 | 141.915904 | 70.957852 | 6.23 | 0.0026 |
| **Hemi-cellulose** | | | | | |
| MP* | 2 | 2.69001806 | 1.34500903 | 12.77 | <.0001 |
| Variety | 1 | 0.00043403 | 0.000043403 | 0.00 | 0.9489 |
| MP*variety | 2 | 1.12425139 | 0.56212569 | 5.34 | 0.0059 |

MP*= Management Practice, CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; DF= degree of freedom.

Appendix Table 4. Analysis of variance (ANOVA) for digestibility and metabolizable energy value of two faba bean varieties under three different management practices

| Source | DF | Sum Square | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| IVTOMD | | | | | |
| MP* | 2 | 2145.165010 | 1072.582505 | 106.39 | <.0001 |
| Variety | 1 | 4.267667 | 4.267667 | 0.42 | 0.5164 |
| MP*variety | 2 | 26.624026 | 13.312013 | 1.32 | 0.2704 |
| IVTDMD | | | | | |
| MP* | 2 | 2145.165010 | 1072.582505 | 106.39 | <.0001 |
| Variety | 1 | 4.267667 | 4.267667 | 0.42 | 0.5164 |
| MP*variety | 2 | 26.624026 | 13.312013 | 1.32 | 0.2704 |
| ME | | | | | |
| MP* | 2 | 50.38717639 | 25.19358819 | 117.30 | <.0001 |
| Variety | 1 | 0.02480625 | 0.02480625 | 0.12 | 0.7345 |
| MP* variety | 2 | 0.72627917 | 0.36313950 | 1.69 | 0.1882 |

MP*= Management practice, IVTOMD= *in vitro* true organic matter digestibility; IVTDMD= *in vitro* true dry matter digestibility; ME= metabolizable energy

Appendix Table 5. Analysis of variance (ANOVA) for (faba bean straw, oat and weed) DM yield

| Source | DF | Sum Square | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Straw DM yield | | | | | |
| MP* | 1 | 3817.625000 | 1908.812500 | 1.12 | 0.3277 |
| Variety | 1 | 802.777778 | 802.777778 | 0.47 | 0.4927 |
| MP*variety | 1 | 2034.180556 | 1017.090278 | 0.60 | 0.5506 |
| Oat DM yield | | | | | |
| Cutting | 1 | 29.905158547 | 29.905158547 | 223.92 | <0.0001 |
| Variety | 1 | 10.5878118 | 10.5878118 | 0.79 | 0.3756 |
| Cutting*variety | 1 | 9.7825658 | 9.7825658 | 0.73 | 0.3943 |
| Weed DM yield | | | | | |
| Cutting | 1 | 1.7061149022 | 1.7061149022 | 1.69 | 0.1968 |
| Variety | 1 | 9.3052072548 | 9.3052072548 | 0.92 | 0.3394 |
| Cutting*variety | 1 | 9.6855731590 | 9.6855731590 | 0.96 | 0.3298 |

MP*= management practice, DM= dry matter; DF=degree of freedom; ANOVA= analysis of variance.