DETERMINATION OF CULTIVAR-DEPENDENT VARIATION IN FOOD-FEED TRAITS IN LENTIL (*Lens culinaris*)

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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DEDICATION

I dedicate this thesis to my daughters Rahel and Selam Asemahegn who are suffering and tolerating from father's love as destitute from me throughout my study and I set aside this script to my wed beloved wife w/o Tigist Wondimu for her moral support and taking full responsibility for the family during my absence for graduate studies at Hawassa University.

STATEMENT OF THE AUTHOR

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Place: Hawassa University, Hawassa

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ACRONYMS AND ABBREVIATIONS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AOAC	Association of Official Analytical Chemists
CIMMYT	International Maize and wheat improvement Center
Co	Cobalt
CP	Crude Protein
CPY	Crude protein Yield
DOM	Digestible Organic Matter
DM	Dry Matter
EIAR	Ethiopian Institute of Agricultural Research.
FAO	Food and Agriculture Organization of the United Nations
GLM	General Linear Model
IBC	Institute of Biodiversity Conservation
ICARDA	International Center for Agricultural Research in Dry Areas
IVOMD	*In vitro* Organic Matter Digestibility
IVDMD	*In vitro* Dry Matter Digestibility
ILRI	International Livestock Research Institute
LMS	Low Moisture Stress
ME	Metabolizable Energy
m.a.s.l.	Meters above sea level
MJ	Mega Joule
MOA	Ministry of Agriculture
NDF	Neutral Detergent Fiber
N	Nitrogen
NIRS	Near Infrared Reflectance Spectroscopy
NVT	National Variety Trial
P	Phosphorus
PE	Potential Environment
PVT	Preliminary Variety Trial

OM	Organic Matter
RPD	Ratio of Performance Deviation
S	Sulfur
SEC	Standard Error of Calibration
SECV	Standard Error of Cross Validation
SEP	Standard Error of Performance
SAS	Statistical Analysis System
TLU	Tropical Livestock Unit
TIVOMD	True *In vitro* organic matter Digestibility
VFA	Volatile Fatty Acid

BIOGRAPHICAL SKETCH

The author was born to his father Kesis Mersha Habtegiorgis and his mother W/o Alemaz Demissie in November, 1970, in Arsi Zone of Oromia Region. He attended his elementary and junior school studies at Chebi Schools in Oromia Region, Arsi Zone, Tiyo district from 1976-1983. He attended his secondary education at Asella comprehensive secondary high School from 1984-1987. He, then, joined Addis Ababa University Faculty of Veterinary Medicine in 1988 and received diploma in Animal Health in July 1989.

After receiving his diploma, he was employed in the then Wollega administrative region, Gambella Region Bureau of Agriculture and Gurage Zone and served as Animal Health assistance. In 2001, he joined Hawassa University in Kiremt program and was awarded a B.SC degree in Animal production and Range land management in 2007.

Thereafter he worked as animal production and forage expert in Abeshge Woreda of Gurage Zone and Tatessa Cattle breeding and improvement Center of Southern Nation and Nationalities Peoples' Region (SNNPR) Bureau of Agriculture.

He then joined the school of graduate studies of Hawassa university again for his graduatestudies in the field of animal production in september 2013.

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Determination of Cultivar-Dependent Variation in Food-Feed Traits in Lentil (*Lens culinary*)

ABSTRACT

The study was conducted with the objectives of analyzing and evaluating of lentil varieties for haulm nutritional values, determining the relationship between fodder traits and agronomic traits, and developing Near Infrared Reflectance Spectroscopy (NIRS) equation for predicting nutritional value of lentil haulm. The samples were collected from Debre zeit, Akaki, Chefe Donsa and Minjar field experimental sites of Debre zeit Agricultural Research Center and the laboratory work was conducted at Animal Nutrition laboratory of the International Livestock Research Institute (ILRI), Addis Ababa. The study was conducted from January 2014 to April 2015. NIRS equation development was done using 633 haulm samples from preliminary and national variety trials. Only 315 samples of national variety trial were used for analysis of nutritional value on twenty seven testing and five control varieties using Random Complete Block Design (RCBD). Statistical analysis of the data was carried out using General Linear Model (GLM) procedure of Statistical Analysis System(SAS) software. The model developed by NIRS for the prediction of lentil haulm of crude protein (CP), metabolizable energy (ME), true in vitro organic matter digestibility (TIVOMD), ash and fiber fractions were accurate and successful method. In potential environment varieties (PE) haulm CP (11.53%), at Debre zeit, while crude protein yield (CPY)(0.42t/ha), ME(8.55MJ/kg DM) and TIVOMD(57.89%) at Chefe Donsa had the highest (P<0.05) values. In low moisture stress varieties (LMS) higher (P<0.05) haulm CP(9.90%) was obtained at Minjar, but higher values of CPY(0.38t/ha), ME(8.01MJ/kg DM) and TIVOMD(54.74%) were obtained from Debre zeit.In LMS Dz2012Ln0014 had the highest (P<0.05) CP (11.94%), TIVOMD (57.91%) and the lowest fiber fractions than controls, also higher in ME (8MJ/kgDM) contents than Alem Tena and local check. But, Dz2012Ln0013 had the highest(P<0.05) crude protein yield CPY). In PE Dz2012Ln0018 and Dz2012Ln0024 were the highest (P<0.05) in CP (10.05 and 10.19%), CPY (0.46 and 0.48 t/ha) and ME (8.6 and 8.58MJ/kg DM) contents than controls respectively. But, Dz2012Ln0019 had the highest (P<0.05) TIVOMD (59.45%) value. In the present study haulm yield and grain yield were positively correlated. CPY was positively correlated with all studied agronomic traits with the exceptions of grain yield and harvest index. ME and TIVOMD were positively correlated with yield and yield components. In LMS higher (P<0.05) grain yield was obtained from DZ2012Ln0004 (1.22t/ha), DZ2012Ln0001(1.07t/ha)and DZ2012Ln0005 (1.02t/ha) than controls.DZ2012Ln0005 (4.83 and 2.55t/ha), DZ2012Ln0013(4.67 and 2.46t/ha), DZ2012Ln0012 (4.43 and 2.42 t/ha) had significantly higher (P<0.05) values of haulm yield and haulm digestible dry matter yield than controls respectively. In PE Derash (2.81t/ha) had the highest (P<0.05) grain yield followed by Alemaya(2.09t/ha) andDz2012Ln0016(2.01t/ha). Significantly high (P<0.05) haulm yield and digestible dry matter yield were obtained from Dz2012Ln0017(6.52 and 3.70t/ha) and Dz2012Ln0026(5.99 and 3.36 t/ha) respectively. Varieties with high haulm nutritional value were not found to be high in their potential utility index that may be, because of their lower values of harvest index due to infestation of mild parasites and incidence of diseases.

Key words: Calibration, Validation, Lentil Haulm, Food-Feed crops, NIRS, Nutritional values.

1. INTRODUCTION

The demand for animal products in developing countries has been projected to double in the 21st century as a result of population growth, urbanization and rising income (Delgado *et al.,* 1999). To improve livestock production in such countries the availability and nutritional quality of feed resources are the major impediments. As most of the arable land is already under cultivation, increased productivity is most likely to come from improving productivity per unit area. To meet household needs under current and future scenarios the production of dual-purpose crops that provide both food (grain) for human consumption and feed (residues) for livestock feeding appears to be a more promising option (Lenne *et al.,* 2003). Thomas (2002) indicated that resource-poor farmers are adopting and improving integration of crop livestock systems as they obtain significant benefits from food–feed crops.

In the highlands of Ethiopia, crop production and livestock husbandry are commonly integrated and crop residues serve as very important feed resource during the dry season when both quantity and quality of available forages declines (Chairatanayuth, 2007; Bogale *et al*., 2008). In high agricultural potential areas of the country, where most of the grazing lands are continually put under cultivation for crop production to satisfy the food demand of the rapidly growing human population, provision of crop residues as livestock feed is becoming more practical due to shortage of alternative feed resources (Bogale*et al*., 2008). The yield and quality of crop residue varies depending on genotype, environment and management factors (Reddy *et al*., 2003). Its type and amount used in Ethiopia differs according to agro-ecological distribution and the scope of arable land availability (Tesfaye, 2010). According to study conducted by Hassen *et al*. (2010) crop residue contributes about 40.8 to 54.6% as the main feed resource in low, medium and high altitude areas of Ethiopia.

However, the fodder quality of crop residue is generally low and characterized by low voluntary intake and poor digestibility. To solve this problem more efforts have been made using various methods of physical, chemical and biological treatments (enzymatic or microbiological). However, the chemical and biological treatment may not be feasible for Ethiopian smallholder farmers because, they required technical knowledge, accessibility of financial and material inputs (Alemu and Chairatanayuth, 2007). On the other hand crop improvement program has been practiced in Ethiopia which mainly focused on grain production without due consideration of straw yield and quality as livestock feed. Rather more emphasis and focus have been given towards its mulching role for increasing soil organic matter than livestock feed. But, it is possible to develop strategies and promote crop-livestock synergies and interactions.

Therefore, studies on improvement of crop residues through collaboration of crop and livestock scientists in multidimensional crop and feed improvement initiatives are necessary. In this endeavor, International Center for Agricultural Research in Dry Areas (ICARDA) has initiated multidisciplinary research together with its Ethiopian National partners to create grain legume cultivars that better match the needs of farmers particularly in mixed crop-livestock systems that dominate many parts of Ethiopia. Among grain legumes, lentil is one of the principal crops widely grown in diverse agro-ecological zones of Ethiopia (Muehlbauer and Tullu., 1997; Schneider and Anderson, 2010). Lentil is an important part of daily diet for most of the population of the country since it is the cheapest source of protein.

Ethiopia is one of the top ten lentil producing countries in the world (Schneider and Anderson, 2010). According to CSA (2013), the national area coverage of lentil crop was 123,718 hectares. The average lentil grain yield in Ethiopia is about 0.6 ton/ha, which is below the average world yield of about 0.8 t/hectare. However, when the recommended agronomic package is applied in the highlands of Ethiopia with long favorable growing period, yields of about 4 t/ha have been obtained in experiments and more than 2 t/ha in farmers' trials. In addition to food grain, lentil haulm is valuable feed for livestock in many regions of the world. The chemical composition and nutritive values of lentil haulm like other crop residues vary depending on variety, soil, climatic conditions, sowing date, stage of harvest and storage conditions (Dutta *et al.,* 2004; Demirel *et al.,* 2012). Even though, the dry matter production of lentil is low, its husk, bran and fresh or dried leafy stems provide fodder for livestock (Bejiga, 2006). Lardy and Anderson (2009) indicated that since the crop tends to have little residue following harvest, grazing animals may be the best method of salvaging any feed. Study in Ethiopia (Fikadu *et al*., 2010) indicated that

CP, NDF, ADF, lignin contents and *in vitro* organic matter digestibility (IVOMD) of lentil haulm were within the ranges of 5.1-11.0%, 35.5-79.6%, 12.5-68.6%, 4.4-12.6%, and 39.2-70.2% respectively.

In most cases the primary producers of lentil in Ethiopia are smallholders with small, fragmented and dispersed plots of land under rain fed conditions. Productivity appears to be severely constrained by degraded soil due to high population pressure, limited or no use of fertilizers, use of unimproved cultivars with low genetic potential, use of traditional agronomic practices, prevalence of diseases and pests (Rashid *et al*., 2010). These incidences have caused a longstanding poor productivity, which ultimately resulted in food deficit, rural poverty and competition of humans and livestock for land, in the mixed crop-livestock production systems of Ethiopia.

Therefore, in order to improve overall productivity and income of the smallholder farmers, development of lentil varieties with improved grain as well as haulm yield and quality is of paramount importance. As the food-feed traits of lentil crop of the country has not been exhaustively studied, identifying genotypes that combine high haulm (fodder) yield and quality with desirable primary food traits of the crop would be a positive step towards addressing food and feed gaps in the mixed crop-livestock systems of Ethiopia.

In the analysis of fodder quality conventional laboratory methods cannot cope with the large set of sample entries from multidimensional crop improvement program(Sharma *et al*., 2010). While, in the present study Near Infrared Reflectance Spectroscopy (NIRS) was used because of much simpler, more rapid and the capability of performing several analyses simultaneously with multiple properties at one time. The goal is to derive a predictive equation using NIRS alone, bypassing the laboratory reference methods (Stuth *et al.*, 2003).

Therefore, the objectives of this study were:

- To analyze and evaluate haulm nutritional value of lentil Varieties.
- To relate fodder traits to primary food traits of lentil.
- To develop Near Infrared Reflectance Spectroscopy equations for lentil haulm based on calibration and validation models.

2. LITERATURE REVIEW

2.1. Food-Feed Crops

Food-feed crops are dual purpose crops as their pods or grain provide food for humans, whereas the haulms, straws and stovers are used for livestock feed. In dual purpose crops production no additional land and water are required for fodder production. They are important for smallholder farmers in the mixed crop-livestock systems to mitigate feed shortage and provide human with a balanced diet (Nigam and Blümmel, 2010

Grain and crop residues of various cereal and pulse crops are contributing substantial role equally to the livelihoods of smallholder farmers. Because of this, farmers' adoption to new cultivar can be influenced not only by grain yield but also by quality and quantity of crop residues as livestock feed. Therefore, it is necessary to know the factors influencing and improving grain and crop residue yield and quality synergistically (Tolera *et al.,* 1999; Blummel *et al*., 2010).

2.2. Relationship between Grain and Residues in some Crops

When sorghum crop considered there was a positive correlation among stover crude protein, *in vitro* digestibility and stover yields. However, stover crude protein content and *in vitro* digestibility were not strongly associated with grain yields (Blummel *et al*., 2010). In other studies Reddy *et al.* (2003), reported that straw digestibility has not been related to grain yield but, they suggested that, high grain yield does not always mean low in straw digestibility. According to Williams *et al.* (2004) varietal differences had influenced on grain yield and plant parts yields and leaf and stem quality, however, grain and fodder yields were positively correlated without trade-off between the two traits. In other study Tolera *et al.* (1999) also indicated that grain yield of maize was positively correlated with cob and total biomass yields but negatively correlated with CP content of the stover. It has been also confirmed that the CP content of wheat straw was negatively correlated with grain yield, straw and total biomass yield and plant height of the crop. But, the NDF content of the straw was positively correlated with straw yield, total biomass and days to maturity (Tolera *et al*., 2008). Similar result was obtained after correlation of grain yield with cob, stover, total crop residue, total biomass and harvest index of maize harvested at different stages of maturity. From the experiment harvest index was also positively correlated with grain yield but negatively correlated with cob, stover, total crop residue and total biomass (Tolera *et al.,* 1999). Like other dual purpose crops pearl millet had shown positive correlation between grain and fodder yield, the crude protein content of the leaves was also 6.8% and of the stalks 1.8% on dry weight basis (Willams *et al*., 2004).

Blummel *et al.* (2010) indicated that, the relationships between stover nitrogen contents, *in vitro* digestibility, metabolizable energy, and grain yields of pearl millet were positively correlated. The relationship between straw and seed yield has been examined with the conclusion that continued selection for a high seed yield would not adversely affected straw yield because of positive correlation between the two traits (Erskine *et al*., 1990). In faba bean harvest index had significantly higher value in high grain producing varieties, but the poor grain producing varieties had significantly lower harvest index. There were positive and significant relationships statistically found between grain number per pod and pod number per plant and between biological yield and plant height. The study also indicated that among different varieties of fab bean there were some varieties with value of high grain yield, IVOMD, straw yield and Potential utility index. This showed that the possibility of selecting varieties for straw yield and straw quality without marginalizing grain yield. Additionally the scholars indicated measurement of Potential utility of a crop is a good parameter to integrate grain yield and digestible dry matter yields from the residues (Ulukan *et al.*, 2003; Gebremeskel *et al*., 2011).Williams *et al* (2004) also concluded that systematic and concerned efforts should be made to combine yield potential for grain and fodder traits in dual-purpose crop varieties. Generally according to the previous studies it is a good opportunity to select varieties with desirable dual purpose traits and increase grain and residue yield as well as quality (Tolera *et al*., 1999; Blummel *et al*., 2010).

2.3. Crop Residues

Crop residues are the fibrous by-products of cereals, sugarcane, roots and tubers, pulses oilseeds, oil plants, vegetables and fruits plants of crops that remain after the edible portion has been harvested by human (Williams *et al*., 1997). These agricultural by-products especially, straws and stovers from cereal crops, haulms from grain legumes are important sources of roughage for livestock feed that are produced in large quantities. Reddy *et al.* (2003) suggested that the yield of crop residues varied based on genotype and environmental factors. World productivity of dry matter yield of residues as feed were maximum in sorghum (11-16.9t/ha), maize (10-16.1t/ha), and followed by oats (5.7-116 t/ha), barely (5.2-12.7 t/ha), ground nut (2.8-5.5 t/ha) and the lowest yield were obtained from pulse ranges from 0.9-4.9 t/ha.

2.3.1. Importance of crop residue as livestock feed in Ethiopia

Crop residues are pillar on the equilibrium of crop-livestock integration. They are a valuable, low-cost feed resource for animal production, and are consequently the major source of nutrients for livestock in developing countries (Delgado *et al.,* 1999). Use of crop residues as animal feed in Ethiopia has a long standing history especially cereal straws and stovers. The major crop residues used for animal feeding are leaves and stems of cereal straws and haulms of the pulses that remain after grain harvest (Tolera, 2008).Farmers do have their own traditional practices to alleviate the poor feeding value of straws. They provide their animals with residues of both cereal and legumes in mixture (Reherahie and Ledin, 2004).

The supply of crop residues is a function of the proportion of land used for cropping and the edible feed yields per unit area of land, and the straw type (Daniel, 1988). Among all crop residues, cereals account for more than 75% of the total crop residue yield in the central highlands of Ethiopia (Yoseph, 1999) and also yields 61.29% of the total feed resources in Bale highlands (Bogale *et al.,* 2008).

The importance of crop residues as livestock feed is boosting in the highlands of Ethiopia, in these areas livestock feed becomes scarce from year to year due to the conversion of grazing land into cropland. More and more of the native grasslands are cultivated to satisfy the grain needs of the rapidly increasing human population (De Leeuw, 1997). The supply of crop residues is a function of the proportion of land used for cropping and the edible feed yields per unit area of land, and the straw type (Keftassa, 1988). On average, crop residues provide generally 10 to 15% of total feed intake in the mixed crop-livestock producing areas (Mengistu, 2004).

They are used to fill feed gaps during periods of acute shortage of other feed resources and used as adjuncts to natural pastures and planted forages (Williams *et al.,* 1997). Study conducted by Bogale *et al*. (2008) indicated that crop residues are mainly used for the feeding of draught animals during the dry period especially from January to April even at the rainy season up to 81.4% of feeding trends. In other study Tesfaye *et al.* (2011) showed that the provision of crop residues as livestock feed during dry season in highlands of Ethiopia substantially increased from year to year. According to Alemu and Chairatanayuth (2007) study more than 90% of farmers had practiced on collection and storing of crop residues for livestock feed after crops harvested. However, they faced constraints of collection such as; lack of transportation, small quantity of crop residues yield, far cropping fields from homestead, use for mulching were the most important causes but it differ according to agro ecological distribution. They also indicated that annual average production of 0.67 to 1.01 ton DM per TLU crop residues can contribute at least 26 to 40% of the total annual maintenance feed requirement of ruminants. Since ruminant animals have unique capacity to utilize these by-products and can replacing roughages in rations by reducing the competition between monogastric animals and human beings on cereals (Atuhaire *et al.,* 2014). Therefore, crop residues provide fodder at low cost and they are the major feed resource available and utilized by smallholder farmers under crop- livestock mixed systems of Ethiopian highland (Alemu and Chairatanayuth, 2007).

2.3.2. Nutritive value of crop residues

In developing countries, livestock is usually fed high fibrous crop residues which characterized by increased lignification of cellulose, low fermentable energy, protein deficiencies and resulted with low digestibility impair intake, and eventually poor animal productivity and performance. Chemical composition of crop residues can give an idea of their nutritive value (FAO, 2002). Nutritive value is generally determined by feed composition, intake and utilization efficiency of digested matter (Qingxiang, 2002). Crop residues are made up of polysaccharides up to 80 percent of their dry matter (DM) because of this they are high in feed energy. However, due to lignocelluloses structure of their cell wall they are characterized by low levels of essential nutrients. Particularly, cereal stovers and straws are inherently characterized by low in crude protein (less than 60g per kg DM), metabolizable energy (less than 7.5 MJ/kg DM) essential minerals and contain high levels of structural carbohydrate (15 g DM/kg live weight/day) (FAO, 2002). Consequently, when stovers and straws are fed to ruminants, their intake, digestibility and utilization are low, resulting in low level of performance. However, leguminous crop residues are usually better and may be used as complementary forages if ample amount collected (Abubakar *et al*., 2003). Quantity and quality of residues produced by various crops vary greatly depending on crop species, agronomic practices and environmental conditions. Cereals usually give high straw yields but, have low quality. However, legumes` haulm even though, low in yield, have high nutritive quality as livestock feed (Gebrehiwot and Mohmmod, 2006).

There are various factors which may influence the feeding value of crop residues among them plant, animal and environmental factors have been the major identified. The rigid structure of plants due to lignin fraction and associated phenolic compounds are believed to be responsible for resistance of plant cells to microbial digestion in the rumen, other plant factors like, species, stage of maturity at harvest, cultivar, and proportions of leaf, sheath and stem would also influence nutritive value of crop residue (Qingxiang, 2002). The other factor that may alter the chemical composition of straw is drought, it often prematurely terminate growth resulting in less secondary cell wall formation, less translocation of nutrients to the developing grain and it also increased CP of barley straw from 37 to 74 g kg–1 DM and decreased crude fibre from 490 to 410 g kg–1 DM (McCartney *et al.*, 2006).

The productivity and quality of crop residues `are determined by the genetic makeup and by crop management factors including planting methods, irrigation, weeding, pest and disease control, post-harvest treatment, etc. However, the influences of all the other stated effects would tend to be more than the genetic effects of crop residues (Reddy *et al*., 2003). Utilization efficiency of crop residues by animal body differs according to breeds and types of animals. For instance, cattle retain fibrous feed in their rumen slightly longer than sheep and goat which has an advantage with lower quality crop residues. Straw intake and digestibility in ruminants are influenced by straw characteristics, feeding conditions, the amount offered, the frequency of feeding by animal characteristics, type, level of production and disease. Extremes of temperature and humidity and social interactions between animals may also affect intake. Apart from plant and animal factors, crop residues could be influenced by environmental factors, including location, climate, soil fertility and soil type (Qingxiang, 2002).

Straw quality improvement should be done by selection through plant breeding for increased cell wall digestibility and also by facilitating to be green for more times, thus providing fodder of better quality than varieties that become entirely yellow. Effects of management tend to interact with genetic effects on straw quality and quantity. Therefore, future research or development work by plant breeders should aim at testing of promising varieties under specific combinations of agro-climatic conditions and cultivation practices (Ceccarelli, 1993).

Straw is often a synonym for haulms, vines, husk of legume the estimated dry fodder production of pulses (grain legume straws) of world and Africa are 176.6 million and 39.93 million tons respectively (Reddy *et al*., 2003). In Ethiopia according to Beruk (2014) report 2,343,832 tons DM of pulse haulms offered as livestock feed. Many of food legume straws have a higher feeding value than cereal straws, but are much more difficult to recover. In humid climates the leaves tend to discolor or drop at or before harvest, and in dry conditions they shatter where the final drying of the crop takes place at the homestead, it is easier to recover the leaves and stems (Suttie, 2000).

Despite of their lignification, legumes straws have better nutritional quality than cereal straws, because they have higher nitrogen contents, greater voluntary intake and faster ruminal degradation. They also have higher contents of pectin’s than grasses, and these carbohydrates are important components of the intracellular spaces and degraded extensively by rumen micro-organisms (Lopez *et al*., 2005). The haulms of grain legumes are good quality roughage with a crude protein content of 5-12% (Tolera, 2008) and have high ME concentrations and lower NDF contents than cereal straws because of their greater proportion of highly digestible cell contents. Haulm from pulse crops have mean values of CP, NDF and IVDMD 7, 62.9 and63.5%, respectively. Furthermore, straw from oil crops have CP and NDF values of 5.4 and 66.4%, respectively (Yami*et al*., 1991)

However, cell wall digestibility and potential degradability as DM disappearance after 144 h of incubation *in vitro* were 15 and 7% respectively which is lower than cereal straws, may be due to their higher cell wall lignification and lower hemicelluloses content, which is the most digestible cell wall component. Their CP content varied widely from 43 to 111 g/ kg DM. Composition of the cell wall fraction represented by NDF of legume straws is higher and has a value of about 0.71 for ADF/NDF ratio and lignin/NDF is 0.15. Legume straws produced a higher proportion of acetate/propionate ratio due to some neutral detergent-soluble carbohydrates fermentation in the rumen like pectin, β-glucans and fructans. Therefore, it is possible that microbial biomass synthesis is favored when legume straws are degraded compared with cereal straws, which could be attributed to their higher CP content. The production of branched chain VFA is related to the degradation of some amino acids, and thus the higher molar proportion of iso-acids could be attributed to a higher release of rumen-degradable nitrogen when legume straws are degraded and fermented in the rumen (Broudiscou *et al.*, 2003).

2.4. Food Legume Crops

Food legumes are grain legumes or pulses, and are species of the plant family Leguminosae their seeds are consumed directly by human. They occupy an important place in global food and nutrition especially, in the dietary pattern of low-income groups of people in developing countries. They can also establish a symbiosis with nitrogen-fixing soil bacteria, turning atmospheric nitrogen into a biologically useable form (Odogola, 1994). Food legumes are grown throughout Ethiopia and account for 13 percent of cropped land that is concentrated in the Amhara and Oromia regions (Rashid *et al.,* 2010). Twelve pulse species are grown in Ethiopia of these, highland pulses faba bean (*Vicia faba)* field pea, *(Pisum sativum*), chickpea *(Cicer arietinum*), lentil (*Lens culinaris Medik*), grass pea (*Lathyrus sativus*), fenu greek (*Trigonella foenum-graecum*) and lupine (*Lupinus albus*) are grown in the cooler highlands. Conversely, haricot bean (*Phaseolus vulgaris*), soya bean (Glycine max), cowpea (*Vigna unguiculata*), pigeon pea (Cajanus cajan), and mung beans (*Vigna radiate*) are predominantly grown in the warmer and low land parts of the country (Yerga *et al.,* 2010).

Case study in Ethiopia has shown, pulses contribute to smallholder livelihoods in multiple ways in improving food security, income and they are approximately 15 percent of the average diet of the total population of the country (Rashid et al., 2010).

2.4.1.Lentil Crop

The lentil (*Lens culinaris*) is a brushy annual plant of the legume family, grown for its lens-shaped seeds. It is about 15 inches tall and the seeds grow in pods, usually with two seeds in each its stem is thin, square and generally herbaceous and weak; particularly at the early vegetative stage, but in several genotypes get stronger with advancement in age (Mulugeta, 2009). Lentil being one of the first crops to be domesticated by man and continue to be an important food source for over 8000 years through subsequent cultivation. Lentil is relatively tolerant to drought and grown throughout the world (Muehlbauer, 2011). It has been considered to be poor man's meat due to an affordable source of protein. About one third of the calories in lentil come from protein, which is the third-highest level of protein by weight of any legume. In many parts of the world lentil is the cheapest protein food and contains dietary fiber, vitamin B and minerals, iron, but lacks two essential amino acids, it is important especially for women of child-bearing age, children and vegetarians. In Ethiopia currently several local accessions of lentil varieties are under cultivation which has been identified as resistance to rust, tolerance to drought and early maturity. The crop has great significance in cereal-based cropping systems because it fixes nitrogen and the straw provides animal feed (IBC, 2007; Muehlbauer, 2011). The genotype plays an important role in realizing high productivity. Since genotype and environment interactions are significant, choice of a genotype depends on prevailing agro-climatic conditions, cropping systems, farmers' choice and local market preferences.

Lentil is classified into two groups by seed size; Chilean and Persian types the large seeded Chilean has 1000 seed weight of 50 grams or more. The small seeded Persian type has 40grms or less of an average weight per 1000 seeds. The lentil improvement program of the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with International Center for Agricultural Research in the Dry Areas (ICARDA) has released some lentil varieties, these varieties are highly resistant to the wilt root-rot complex and have yield potential of up to 2.6 tons/ha (Mulugeta, 2009).According to FAO (2009) production database, Ethiopia constitutes 2% of the world total production, and it was the first producer of lentil in Africa accounting 84% of the total regional production (96,524 tons) followed by Morocco (8.8%), Malawi(1.9%), Egypt (1.6%) and Tunisia(1.2%).Lentil is one of the major highland pulses of Ethiopia that grows in rotation with tef, wheat and barley particularly on the heavy black clay soils (vertisols). The national average productivity maintained by smallholder farmers at present is found to be between 0.4 and 0.5 tone/ha. However, improved varieties yield 1.4-5 tons/ha under research fields and 0.9-3 tons/ha and farmers' fields(Ethiopian Export Promotion Agency,2004).It is an important part of the farming system and essential to nutrition in the subsistence farming community in Ethiopia. Currently, lentil is considered as a cash crop that fetches higher price than most of the cereals and pulses (Bejiga, 2006).

Lentil research in Ethiopia was formally started in 1972 at Debre Zeit Agricultural research center, which is National Program coordinator and has released E1-142, R186, Chalew (NEL-358),Chekol (NEL-2704), Gudo (FLIP 84-78L), Adaa (FLIP 86-41L), Alemaya (FLIP 88-63L), Alem Tena and Teshale. Among these EL–142, Chekol and Alem Tena were released for the lowland dry areas. Varieties R186, Chalew, Gudo, Adaa and Alemaya were for the central, northern and south eastern highlands of Ethiopia (Bejiga and Anbessa, 1998).

2.4.1.1. Agro-ecological distribution of lentil

Lentil is relatively tolerant to drought and grown throughout the world. It is among the principal food legumes widely grown in diverse agro-ecological zones, ranging from hot sub-moist low lands to cool humid mid highlands. Lentil is widely grown in areas having an altitude range of 1,700-2,400 masl with annual rainfall ranging from 700-2,000 mm in Ethiopia (Korbu, 2009; Wang, 2012). It also well adapt to various soil types and performs best on deep, sandy loam soils with high in phosphorus and potassium content but very sensitive to water logging conditions, even slight exposure of flooded field can cause severe destruction of the crop. The different sowing dates, genotypes, cultivation years, locations, and their interactions have highly significant effects on grain yield and above ground total biomass of lentil (Wang, 2012).

2.4.1.2. Yield and some yield components in lentil

Grain yield is highly affected by climate and ecological factors, which are directly related to the performance of yield components in lentil. Yield components play important role and differ across various environments in lentil crop production. Some of the yield components are days to 50% flowering, days to 90% maturity, 100 seed weight, pods per plant, plant height, harvest index, grain yield and above ground biomass. According to Matrne and Siddique, (2009) flowering time is determines length of vegetative phases or sowing to flowering and also climatic conditions that the crop will be exposed during reproductive growth.100 seed weight is a seed test weight and very important factor for the determination of final crop yield. Plant height of lentil can range from 20 to 75cm, and harvest index is also the measure of physiological efficiency of a crop plant to convert photosynthesis into the economically important parts of the plant that is ratio of grain to above ground biomass are important indicators in seed yield (Rahman *et al*,.2013). According to study conducted by Kayan and Olgun (2012) in Ethiopia hundred seed weight and grain yield in lentil increased from 0.5-0.6gm/100 and 0.5-0.6 t/hain landraces into 4-5gm/100 and 3-3.5 t/ha improved varieties respectively through research efforts (Hassan *et al*., 2009). Correlation between yield and biological yield per plant, plant height, seed per plant harvest index and 100 seed weight were found to be positive and significant. In other study Anjam *et al*. (2005) showed that certain yield components like, plant height and pods per plant were significantly and biomass highly significantly correlated with the seed yield of lentil. As crop biomass production is determined by the biophysical environment and the genetic makeup of the crop, biomass production and translocation can govern the amount of crop residue to be produced (Tsigie *et al*., 2011). Chemical composition and yield of lentil seed had shown a significant difference among some cultivars on their crude fiber and ash contents, crude protein and water soluble protein contents (Karadavut and Genc, 2010).According to Maheri-Sis *et al* (2007) wide variation in the chemical composition of lentil cultivars was probably due to different varieties and ecological variation may also be responsible for the differences of chemical compositions.

2.4.1.3. Nutritional value of lentil haulm as ruminant feed

Crop residues from lentil are valuable livestock feed in many regions of the world in some years they have equal or greater prices that grain (Dutta *et al.*, 2004). The nutrient contents of lentil haulm depending on variety, soil, climatic, sowing time, stage of harvesting and storage condition (Demirel *et al.*, 2012). Moreover, harvesting method has also an important impact on lentil haulm quality Lopez *et al*. (2005) suggested that manual harvesting resulting in more nutritious leaf-rich haulm due to preserve of leaves whereas, machine harvesting caused stem-rich straws; study conducted by the same scholars indicated that hand-harvested lentil haulm contained 11% crude protein, 28% ADF and 8.3 MJ/kg DM ME whereas, 5 6% crude protein, 50% ADF and 6.7 MJ/kg DM ME was obtained by combine-harvested lentil crop (Lopez *et al*., 2005). Beyranvand *et al.* (2012) indicated that protein content of lentil straw significantly affected and related to planting season, their study showed during autumn highest value of about 166.213kg/ha was obtained but, according to the same study straw protein has a significantly negative correlation with seed yield, which may be due to more nitrogen concentration in seed instead of other plant parts.

Bahl (1990) suggested that digestibility variation could appear based on the proportion of plant parts; such as leaves, pods, branches and roots of the haulm. Though, lentil straw, like other legume crop residues, relatively rich in fiber, lignin and poor in protein and ether extract, it is still better feed quality than some legumes, and cereals straws. Several studies have concluded that lentil straw has a lesser NDF content, better rumen degradability, digestibility, palatable, protein, calcium and phosphorus than cereal straws (Sehu *et al*., 1998; Lopez *et al*., 2005; Lardy and Anderson, 2009; Singh *et al*., 2011). Study on plant parts of lentil by Erskine *et al.* (1990) indicated leaf 38%, branch 34%, pod 23% and root 5%, had the average dry matter digestibility values of 62, 36, 44, and 22% respectively. In addition to this percent dry matter digestibility and protein content of lentil straw differ significantly among various genotypes. Genotypic differences in DMD were consistent over the components of lentil straw. However, there was a significant interaction between genotypes and the distribution of dry weight of the components of straw showing that the genotypes varied in the relative distribution of components within the straw. Abbeddou *et* *al*.(2011) also confirmed that lentil straw contained about twice as much CP as the barley straw, which was slightly higher than 80 g/kg reported by Haddad and Husein (2001). The *in Sacco* ED of CP was high in lentil straw, though the relatively high total phenol content would indicate that part of the CP would be undegradable in the rumen (Tiemann *et al.*, 2010). This level was consistent with data from scholar (Lopez *et al*., 2005; Haddad and Husein, 2001), but different from that reported by Bruno-Soares *et al.* (2000) (>700 g NDF/kg DM).

Performance obtained by lentil straw of lamb supplemented with concentrate were found to be comparable to those obtained with alfalfa hay, and higher than those obtained with bitter vetch straw or wheat straw (Hadded and Husein, 2001). In other experiment which was conducted to determine DM *in sacco* degradability and *in vivo* DM digestibility of chickpea straw and lentil straw the latter has higher result on the two trials than the former (Dutta *et al.,* 2004). According to Hadded and Husein, (2001) study, ewes fed lentil straw gained more weight than ewes which fed on vetch and wheat straws. Its nutritive value was closer to alfalfa hay due to higher intake, digestibility and metabolizable energy.

In other study, lentil straw was rich in Ca and poorer in electrolyte content compared with barley straw, according to Abbeddou *et al.* (2011) report, almost no refusals were observed when lentil straw was included in the diet, however, the barley straw was consumed slightly less well. Which indicated that the higher ruminal degradability of the OM in lentil straw compared to barley straw as found *in sacco*. This difference was less pronounced in total tract digestibility. This leads to the assumption that the lower fiber content of lentil straw compared with barley straw, and not a better ruminal fiber degradability, resulted in a fast passage rate, which then would have increased intake capacity (Abbeddou *et al.*, 2011). In both in *vitro* and *in vivo* experimental trials the ME content tended to be higher in the lentil straw than in barley straw that is 8.3 and 6.0 MJ/kg DM respectively (Lopez *et al*., 2005).

Table 1. Nutritive value of lentil haulm

Traits	Range	Source
CP%DM	5.08-11.10	(Dutta *et al*.,2004;Lopez *et al*.,2005;Tolera,2008;Lardy *etal*.,2009;Fikadu *et al*., 2010;Abbeddu *et al*.,2011;Feedipedia,2012)
NDF%DM	35.5-79.6	(Dutta *et al*., 2004; Lopez *et al*.,2005; Tolera, 2008; Lardy *et al.,* 2009; Fikadu *et al.,* 2010;Bruno-Soaresa *et al*., 2012; Feedipedia,2012)
ADF%DM	12.5-68.60	(Dutta *et al*., 2004; Lopez *et al.,* 2005; 2008;Lardy *et al*.,2009; Fikadu *et al* .,2010; Feedipedia,2012)
ADL%DM	2.62-12.80	(Dutta *et al*., 2004; Tolera, 2008; Lardy *et al.*,2009; Fikadu *et al.*,2010 ;Feedipedia,2012)
Ash%DM	2.89-13.6	(Dutta *et al*., 2004; Fikadu *et al*.,2010;Feedipedia,2012)
MEMJ/kgDM	6.7-8.3	(Lopez *et al*.,2005)
DMD%DM	41-54.30	(Erskine *et al*., 1990;Tolera, 2008)

ADF =acid detergent fiber, CP=crude protein, DM=dry matter, ME= metabolizable energy, NDF=neutral detergent fiber,DMD = dry matter digestibility,ADL=acid detergent lignin.

2.5. Evaluation of Nutritive Value of Crop Residues

Crop residues are often referred to as lignocelluloses due to their high cellulose content which bound with a biopolymer lignin (MaheshandMohini, 2013). These structural carbohydrates are the major constraints to use the byproducts as feed resources since; they bring limited intake and digestibility and have low protein and mineral contents which cannot support adequate microbial growth (Fazaeli *et al*., 2004; Saha *et al*., 2013). However, good quality crop residues have a high nutrient potential because of their high energy, protein and mineral contents (Saha *et al*., 2013).

2.5.1. Methods available for evaluation of nutritive value of crop residues

There are mainly three types of methods for evaluation of feeding value of crop residue; these are the chemical, biological and enzymatic methods. All of them tend to simulate what is happening in the animal during the digestive process. This simulation is by definition an approach and not the real value (Reynolds, 2002).The chemical methods give information about the main chemical composition present in the feed using laboratory analyses calculated or estimated from measured feed quality attributes. Which include N or crude protein%, NDF%, ADF% ADL% digestible energy, total digestible nutrients and intake also estimated from the concentration of the various fiber components and the relationship between them, it could not give accurate information on availability of the feed to the animal systems (Saha *et al.,* 2013). Although chemical analyses give good information about the forage quality, it doesn't give sufficient information to determine the feeds true nutritive value (Cherney, 2000). As utilization of forage is largely dependent on microbial degradation within the rumen, description of forages in term of their degradation characteristics is interesting. Mathematical descriptions of GP profiles allow analysis of data and various types of models have been used to describe GP profiles. An exponential model can be used to describe kinetics of GP data, but as it assumes a constant fractional fermentation rate which is unlikely for microbial degradation, these models are not generally valid (Getachew *et al.,* 1998).

The biological methods were created to represent and simulate a part or a series of parts of the digestive tract and digestion process in animals they measure either the whole rumen digestion, or the fermentation, degradation processes or microbial synthesis individually. Among the biological methods, the digestibility with In vivo trials (In Sacco degradability and feeding trial), the In vitro two stage technique the in vitro gas production (Menke and Steingass, 1988) are widely used to evaluate nutritive value of crop residues (Devendra, 1997; Reynolds, 2002). The alternative to rumen liquor is the use of incubation of feeds with exogenous enzymes, which has the aim to mimic the digestive processes in the animal. Enzymes can break down different parts of the plant constituents, which can be divided into those that make up the structure of the plant (cell-wall constituents) and the material within the cells (cell-content constituents(Palic and Leeuw, 2009). However, the time and cost required for analysis of large number of samples were very high and unfordable when we apply these techniques. Therefore, NIRS is the modern technology that can complement the above methods (Stuth *et al.,* 2003).

2.5.2. Importance of NIRS in forage analysis

NIRS is a rapid, reliable, low-cost, nondestructive, computerized method to analyze feeds for their nutrient content. Requires no reagents, and allows for determination of multiple values. NIRS measures the reflections of near infrared light instead of chemicals to determine protein, energy, digestible organic matter (DOM) , acid detergent fiber (ADF) and neutral detergent fiber (NDF).and other variables of interest with single analytical procedure (Stuth *et al.,* 2003). It is based on the fact that each of the major chemical components of a sample has characteristic near infrared light absorption (and hence reflectance) patterns, which are used to differentiate one component from the others. Feeds can be analyzed in less than 15 minutes using NIR, compared to hours or days for wet chemical methods (Shenk and Westerhaus, 1991; Castro and Oliveira, 1996; Stuth *et al.*, 2003). The near infrared (NIR) region of the electromagnetic spectrum lies between the visible (VIS) and mid-IR regions. It is defined primarily by the signal-to-noise (S/N) response of the material used for detectors in the region**(**Barton II, 1989**)**.But, NIRS required instrumentation, depend on procedures of calibration, choice of data treatment is complex, and lack sensitivity for minor constituents. The technique also requires high-precision spectroscopic instrumentation because small changes in reflectance at specific wavelengths must be measured. The technology of the NIRS method is still in the developmental stage (Noris, 1989).

2.5.3. Determination of nutritive value of crop residues using NIRS

NIRS used to predict the chemical composition and nutritive values of crop residues substantially; it was successfully predicted NDF, ADF and ADL in cereal crop residues (Stubbs *et al*., 2009). In Ethiopia as previously studied by Fikadu *et al*. (2010b) five cereal and pulse of residues of DM, Ash, CP, NDF, ADF, lignin and *in vitro* digestibility show relatively high determination coefficient, and low standard errors of calibration (SEC) and standard errors of cross-validation (SECV) and hence, these traits could be predicted with good precision. Moreover, the predicted means for each trait were similar to the means based on conventional chemical analyses. The result indicated NIRS is a method of choice for prediction of chemical composition including *in vitro* digestibility of organic matter in the dry matter of crop residues.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Debre zeit Agricultural Research Center field experimental sites namely: Debre zeit, Akaki, Chefe Donsa and Minjar.

Table. 2. Agro-climatic characteristics of the experimental sites.

Agro-climate characteristics	Location Debre zeit	Akaki	Minjar	Chefe Dona
Altitude (masl)	1900	2200	1810	2450
Mean RF (mm)	851	1025	867	851
Max Temp (^{0} C)	28.3	26.5	29.0	26.0
Min Temp (^{0} C)	8.9	7.0	10.0	7.0
Latitude	08^{o}44′N	08^{0}53’ N	08^{0}45’N	08^0 57’ N
Longitude	38^{o}58′E	38^{0}49′E	39 ^{0}45’E	39^0 06’E
Soil type and texture	Black and Vertisols	Black and heavy clay and Eurtic Vertisols	Light	Black and heavy clay and Eurtic Vertisols

Source: (Damitew *et al*., 2012;Abera and Kebede, 2013Debre zeit Agricultural Research Center 2013/2014 cropping year)

3.2. Sample Description

Samples of 315 lentil haulms, grain yield and yield components were used for the study. The experiment was conducted on twenty seven national variety trial for potential environment (Late maturing) grain takes longer time for 50% flowering and 90% physiological maturity in this case 57 days and 109 days respectively; low moisture stress (early maturing) shorter time for 50% flowering and 90% physiological maturity of the grain 49 days and 91 days respectively.

Five controls varieties, namely: Local check Alem Tena, Alemaya, Checkol and Derash were cultivated by Ethiopian Institute of Agricultural Research (EIAR) during 2013/2014 cropping season. It was sown in the main rainy season or kiremt on thirtieth of July 2013. The local variety by farmer in the area used as local check. The management applied on the trial across each location was similar, fertilizer was not applied this is due to the ability of lentil to fix atmospheric nitrogen. After separation of grain and haulm through threshing, the sample was packed and transported within a week to the Center, therefore, it did not expose to the sun, rain and other weather conditions.

Table 3. Lists of tested lentil varieties, controls and experimental sites

Tested varieties within Trials			Controls	Experimental locations
NVT PE (n=13)				
Dz2012Ln0015	Dz2012Ln0016	Dz2012Ln0017		
Dz2012Ln0018	Dz2012Ln0019	Dz2012Ln0020		
Dz2012Ln0021	Dz2012Ln0022	Dz2012Ln0023	Alemaya	Debre zeit, Akaki
Dz2012Ln0024	Dz2012Ln0025	Dz2012Ln0026	Derash	Chefe Donsa
Dz2012Ln0027			Local check	
NVT LMS (n=14)				
Dz2012Ln0001	Dz2012Ln0002	Dz2012Ln0003		
Dz2012Ln0004	Dz2012Ln0005	Dz2012Ln0006	Alem Tena	Debre zeit
Dz2012Ln0007	Dz2012Ln0008	Dz2012Ln0009	Local check	Minjar
Dz2012Ln0010	Dz2012Ln0011	Dz2012Ln0012	Chekol	
Dz2012Ln0013	Dz2012Ln0014			

NVT PE= National Variety Trial for Potential Environment; NVT LMS= National Variety Trial for Low Moisture Stress.

3.3. Experimental Design

The experiment was conducted using RCBD design with 4 replications on NVT LMS and NVT PE trial. The size of the plot was 4m x 0.8m (4rows/plot), spacing 20cm between rows and about 2cm between plants with seed rate of 800seeds/plot (200seeds/row) Seeding rate (kg/ha) = Plant density (plants/m^2) x 100 seed weight (g) (3.17g/100) x 10 ÷ germination percentage (80%)=99kg/ha. The yield components such as days to 50% flowering, plant height (cm), above ground biomass (t/ha) and after full maturity or 90%

maturity, grain yield (t/ha), harvest index (grain yield/biomass), 100 seed weight (g/100seed), haulm yield were recorded from 2 central rows of each plot.

3.4. Sample Collection

The lentil haulm was collected from experimental sites after threshing according to the experimental design for each genotype, plot number, replication number and block using paper bag and transported to animal nutrition laboratory of ILRI, Addis Ababa. Additionally, data on the necessary agronomic and primary food traits were collected and compiled for each genotype from Debre Zeit Research Center.

3.5. Determination of Agronomic Parameters and Laboratory Analyses

The chemical composition and determination of nutritional value by NIRS were conducted at ILRI Addis Ababa and India animal nutrition Laboratories from January 2014 to April 2015 it took long duration due to delayed samples which have been sent to India for *in vitro* gas production technique. Food-feed traits of lentil were evaluated based on the yield and nutritive value of the haulm and agronomic and grain yield characteristics of the crop. The agronomic characteristics include grain yield (t/ha), harvest index (grain yield/biomass production), plant height in cm, 100 seed weight (g), day to flowering (days), day to maturity (days), biomass production (t/ha) and haulm yield (t/ha).

Grain yield (t/ha) was obtained by weighing the seeds from two central rows of each experimental plot ($1.6m^2$). Harvest index was determined as the ratio of dry seed weight to the above ground biomass yield. Plant height was measured as height in centimeters from the ground level to the tip of the plant for 5 randomly selected plants at physiological maturity. 100 Seed weight (g) was the weight of 100 seeds taken from each plot by counting 100 seeds. Biomass yield (t/ha) was recorded by weighing the total above ground biomass harvested from each experimental plot at the time of harvest we obtained the data after it has been done by researchers. Days to 50% flowering was recorded as number of days from planting to a stage where 50% of the plants in a plot produce flower. Days to 90% maturity was recorded as the number of days from planting to a stage when 90% of the plants in a plot produce matured pods (CIMMYT, 2013).

3.6. Scanning of Samples Using NIRS

NIRS machine of Foss 5000 in the 1108-2492nm spectral ranges was used to scan 633 samples of lentil haulm which contain samples from preliminary varieties (PVT PE and PVT LMS) and national varieties (NVT PE and NVT LMS). All the samples were ground in 1mm sieve size before scanning and about two spoon-full of the sample was put in paper bag and pre-dried at 60^0C overnight in an oven to standardize moisture conditions. Partially dried sample was filled into NIRS cup and scanned using NIRS machine. For the purpose of wet chemistry analysis representative samples were selected from all scanned samples using NIRS software of Win Scan version 1.5, 2000, intrasoft international, L.L.C.

3.7. Chemical Analysis Using Wet Chemistry

Representative lentil haulm samples which were selected with NIRS machine were analyzed for DM, and total ash contents by the procedures of AOAC (1990) and Nitrogen was determined by Kjeldahl method (AOAC, 1990) and CP was calculated as N x 6.25.The NDF, ADF and ADL contents were analyzed following the recommendations of Van Soest and Robertson (1985) in ILRI laboratory. The chemical composition data determined by the wet chemistry method were used for developing calibration equations and to perform regression between spectral data.

3.8. Creation of Calibration Equation and Validation

The sample population used in the calibration and validation consisted of 111 representative lentil haulm samples. Calibration was for creating a spectro-chemical prediction model, calibration equation development in this study was accomplished using NIRS spectral and referrence laboratory method which used to derive a predictive equation according to Stuth *et al*. (2003),which was done after the samples were scanned. Then NIRS equation was developed using average spectra and wet chemistry of lentil haulm by step-wise multiple linear regressions. Based on this equation, the value of CP, NDF, ADF, ADL, Ash, IVOMD and ME of all the samples was predicted. The predictive ability of the selected calibration equation or model was evaluated or assessed by NIRS validation method that was conducted using standard error of prediction (SEP) which used to judge the predictive ability of a calibration equation

3.9. *In vitro* Technique

In vitro gas production (Menke and Steingass, 1988) test was carried out at ILRI Animal Nutrition laboratory in India. ME and true *in vitro* organic matter digestibility were estimated based on gas production parameter. The estimated ME value (MJ/kg DM) was calculated using the equations of Menke and Steingass (1988) as follows:

DO =15.38 + (0.8453*GP+ (0.595*CP %)+(0.181*ash)

ME (MJ/kgDM) = 2.2+ (0.136*GP) +(0.0057*CP g/kg)

GP = ((V24-V0-GP0)*altitude correction factor *0.2)/sw*DM*0.01)

Where: GP =Blank without feed sample, but with fluid

CP = Crude protein

DO=Digestible organic matter

V24= Gas volume at 24 hours (ml/200mg)

V0=volume at 0 hour

Sw =sample weight

3.10.Dry matter yield, Digestible DM yield and Potential Utility Index

The haulm dry matter yield (t/ha) (HDMY) was calculated according to the formula developed by Tarawali *et al* (1995).

$$\text{Haulm dry matter yield (t/ha) HDMY} = \frac{\text{\%DM} \times \text{Total fresh weight of haulm(t/ha)}}{100}$$

Potential utility index integrates grain yield with digestible straw yield of the different lentil varieties and calculated, the ratio of grain yield plus digestible DM yield of lentil haulm to total above ground biomass DM yield (Fleischer et al 1989).

$$\text{Potential Utility Index} = \frac{\text{(Grain yield t/ha) + (Digestible DM yield t/ha)x100}}{\text{Total above ground plant biomass DM yield (t/ha)}}$$

3.11. Statistical Analysis

Data that was obtained from predicted values of NIRS, chemical composition and nutritive value of fodder traits correlated with primary food traits (agronomic characteristics) were analyzed using Analysis of Variance (ANOVA) by Statistical Analysis System (SAS) software version 9 and mean separation was carried out using the Duncan's New Multiple Range test. Statistical model involved the effect of variety, and location on chemical composition or nutritive value of lentil straw and agronomical traits were determined by the following model.

$Y_{ijk}= \mu+l_i+ g_j+(lg)_{ij} +b_k+e_{ijk}$

Y_{ijk}= nutritional value and agronomical characteristics of the samples

μ =overall mean

$l_{i=}$ the effect due to location (PE i=3; LMS i=2)

$g_{j\,=}$the effect due to genotypes (PEj=16; LMS j=17)

$(lg)_{ij=}$ The effect due to interaction between the i^{th} location and the j^{th} genotype

$b_{l=}$The effect of l^{th} block(l=4)

$e_{ijkl=}$ Random error associated with the observation yijkl.

4. RESULTS AND DISCUSSION

4.1. Equation Development of Lentil Haulm by NIRS

Near Infrared Reflectance Spectroscopy values for the prediction of CP, NDF, ADF, ADL, total Ash, IVOMD (on DM bases) and ME of lentil haulm samples are presented in Table 4.

The mean predicted value of crude protein (CP) of lentil haulm as indicated in Table 4 was 10.01% that was very much close to the wet chemistry result of 10%. It is within the ranges of previously reported CP value of lentil haulm determined by NIRS according to Fikadu *et al.* (2010). In addition, it had high coefficient of determination in calibration (R^2) (0.96) and lower SEC (0.60) values during calibration model, indicating that the mentioned mathematical models were closely related to the wet chemistry (Kjeldahl procedure) and values with a high degree of linearity. It had better values of SEC and R^2 than the reports of Fikadu *et al.* (2010), which were 0.99 and 0.64, respectively. The study also had low SEP (0.62) and high coefficient of determination in validation (R^2)(0.96)values of CP indicating best predictive ability of the calibration model (Table 4). The result was similar and comparable to R^2 values of 0.90 reported for other forages (Castro, 2002; Stuth *et al.*, 2003) and with the findings of Kandace and Khaleduzzaman, (2011) who reported SEC and SEP values of 0.33 and 0.37, respectively, for NIR analysis of CP value in tropical forage. Brown and Moore (1987) also reported that the standard error of calibration (SEC) ranged from 0.14 to 0.79 while those for standard error of prediction (SEP) ranged from 0.32 to 0.83 after validation in the analysis of CP of forage samples through NIRS. Then accuracy of calibration model was also evaluated by RPD value which was 5.19% and indicated an excellent prediction ability of the calibration model (Saeys *et al.* 2005).

The mean predicted values of NDF (51.54%), ADF (38.32%) and ADL (10.25%) using NIRS were very much closer to wet chemistry (laboratory) results of 51.65%, 38.32% and 10.27% respectively. Lower SEC, which ranged from 0.59 to 2.13, with higher coefficient determination in calibration (R^2) of 0.92 was observed during prediction of fiber fractions for both NDF and ADF and with r^2 values of 0.96 for ADL. As indicated in Table 4, the results obtained from the present study had lower SEC but higher R^2 values than previously reported values for lentil haulm by Fikadu *et al*. (2010) and Saeys *et al*.(2005).However, it was similar to those reported by Baloyi *et al*. (2013), and Swart *et al*. (2012). Moreover, the coefficient determination in validation (R^2) and standard error of prediction (SEP) for NDF, ADF and ADL of lentil haulm (Table 4) were similar to the above calibration results. Since $R^2$and RPD values of the three fiber component were greater than 0.90 and 3 respectively, we could observe the accuracy and excellent prediction ability of the model according to Saeys et al *et al.* (2005). The model developed for the prediction of fiber fractions appeared to be sufficiently accurate and successful method for predicting NDF, ADF and ADL values of lentil haulm.

The mean predicted value of total ash (8.93%) was almost similar to actual laboratory result (8.94%). That was within the ranges of Fikadu *et al.* (2010), performance evaluation of NIRS calibration values of 2.89 to 13.6% and laboratory results of Dutta *et al.* (2004) and Tolera (2008) reports which ranged between 6 to 11.2%. The SEC and R^2 for calibration of total ash in the haulm samples were 0.59 and 0.82, respectively. The SEP (0.60) and $R^2$0.82) values for the prediction of total ash were also similar result as calibration. The R^2 values that lie between 0.81 and 0.90 give good prediction of the model according to Saeys *et al.* (2005). The RPD value obtained in this study was between 2 and 3 (2.35%) which showed possibility of approximate quantitative predictions as Saeys *et al.* (2005) indicated.

The mean predicted values of TIVOMD and ME were 56.17% and 8.16 MJ/kg DM, respectively, using NIRS, which were similar to wet chemistry (laboratory) results of TIVOMD (56.13%) and ME (8.16MJ/kg DM). In developing calibration equation for ME and TIVOMD, the standard error of calibration (SEC) were 0.20 and 0.04 and coefficient of determination in calibration (R^2) 0.998 and 0.997 respectively. The values of SEP for

TIVOMD (0.29) and for ME (0.05) were low and coefficient of determination in validation (R^2) for TIVOMD (0.997) and for ME (0.996) high as indicated on Table 4. Furthermore, the RPD values registered in the present study were high 16.24% for TIVOMD and 14%for ME. The mean value of TIVOMD was within the range of 39.20%-70.20% reported by Fikadu *et al*. (2010) and 51.7 to 61.1 % with mean value of 56.30% reported Nigam and BlummelS (2010).

The goodness-of-fit of NIRS equation used for predicting the whole set of cultivars using calibration and validation was similar to that of Nigam and Blummel (2010) on ground nut haulm; with calibration values of IVOMD (R^2= 0.99; SEC=0.08) and ME (R^2= (0.97; SEC=0.08) and Validation IVOMD (R^2= 0.92; SEC=0.88) and ME R^2=(0.93; SEC=0.13). The high values of coefficient of correlation in calibration, coefficient of determination in validation and the low values of SEC and SEP indicated the accuracy of the technology to evaluate lentil haulm in Ethiopia.

Table 4. Results of the calibration equation and wet chemistry analysis

Chemical components	Calibration set		Validation set			Laboratory values		NIRS predicted values	
	R^2	SEC (%)	R^2v	SEP (%)	RPD (%)	Mean (%)	SD	Mean (%)	SD
Ash	0.82	0.59	0.82	0.60	1.91	8.94	1.41	8.93	1.26
CP	0.96	0.60	0.96	0.62	4.11	10. 00	3.22	10.01	3.13
NDF	0.92	2.13	0.92	2.20	3.03	51.65	7.63	51.54	7.20
ADF	0.92	1.88	0.92	1.83	3.00	38.32	6.79	38.32	6.64
ADL	0.95	0.59	0.93	0.63	3. 45	10.72	2.47	10.25	2.39
IVOMD	0.998	0.20	0.997	0.29	19.30	56.13	4.71	56.17	4.60
ME	0.997	0.04	0.996	0.05	14.58	8.16	0.70	8.16	0.68

SEC= standard error of calibration; R^2=coefficient of determination in calibration; R^2v=coefficient of determination in validation; SEP=standard error of performance; RPD= ratio of performance deviation (SD/SEP); SD= standard deviation.

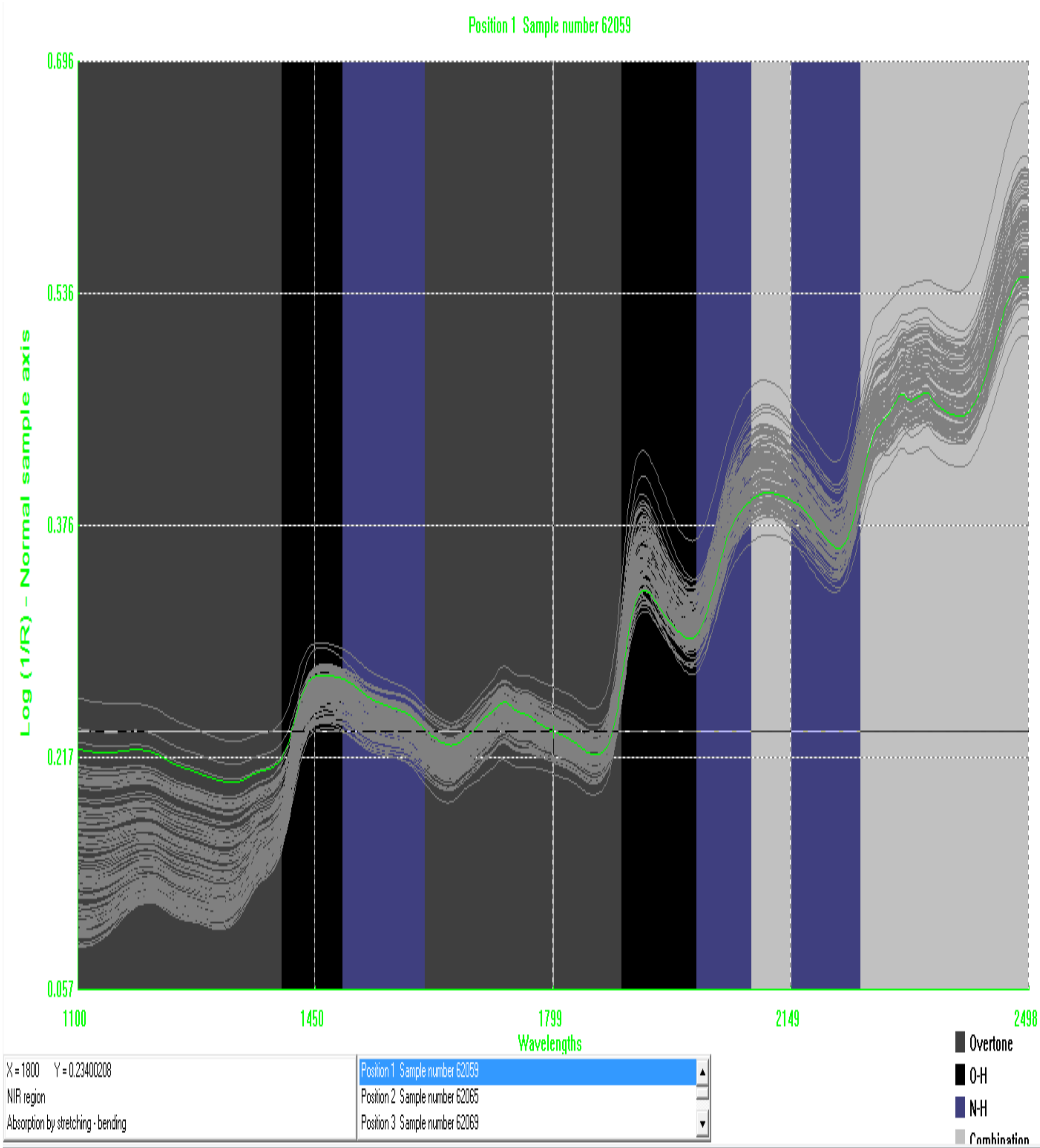

Figure 1. NIRS spectra of lentil haulm samples

X-axis electromagnetic spectrum wave length 1100nm-2500nm range

Y-axis absorbance log $_{1/R}$

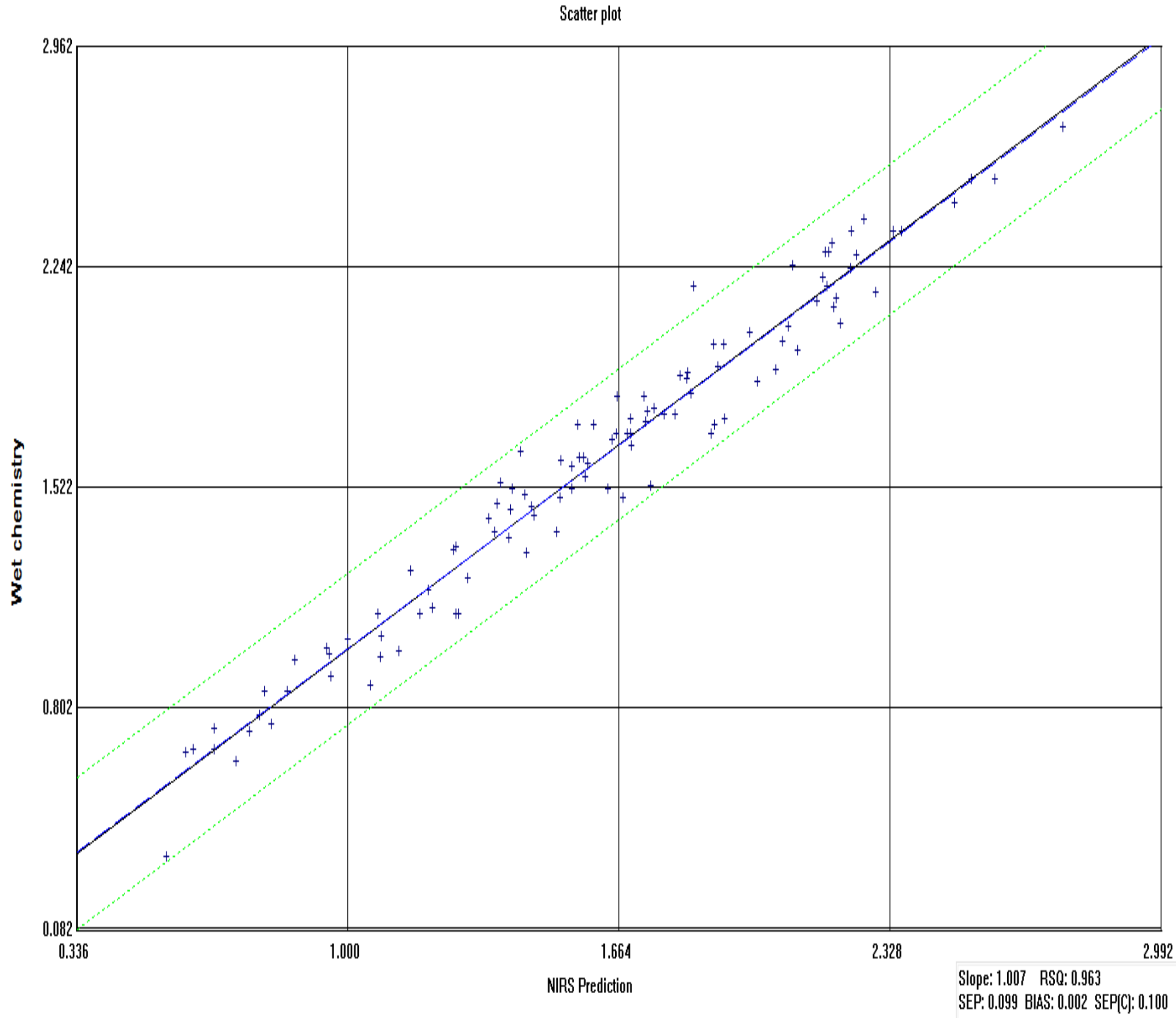

Figure 2. NIRS prediction vs wet chemistry CP (%)

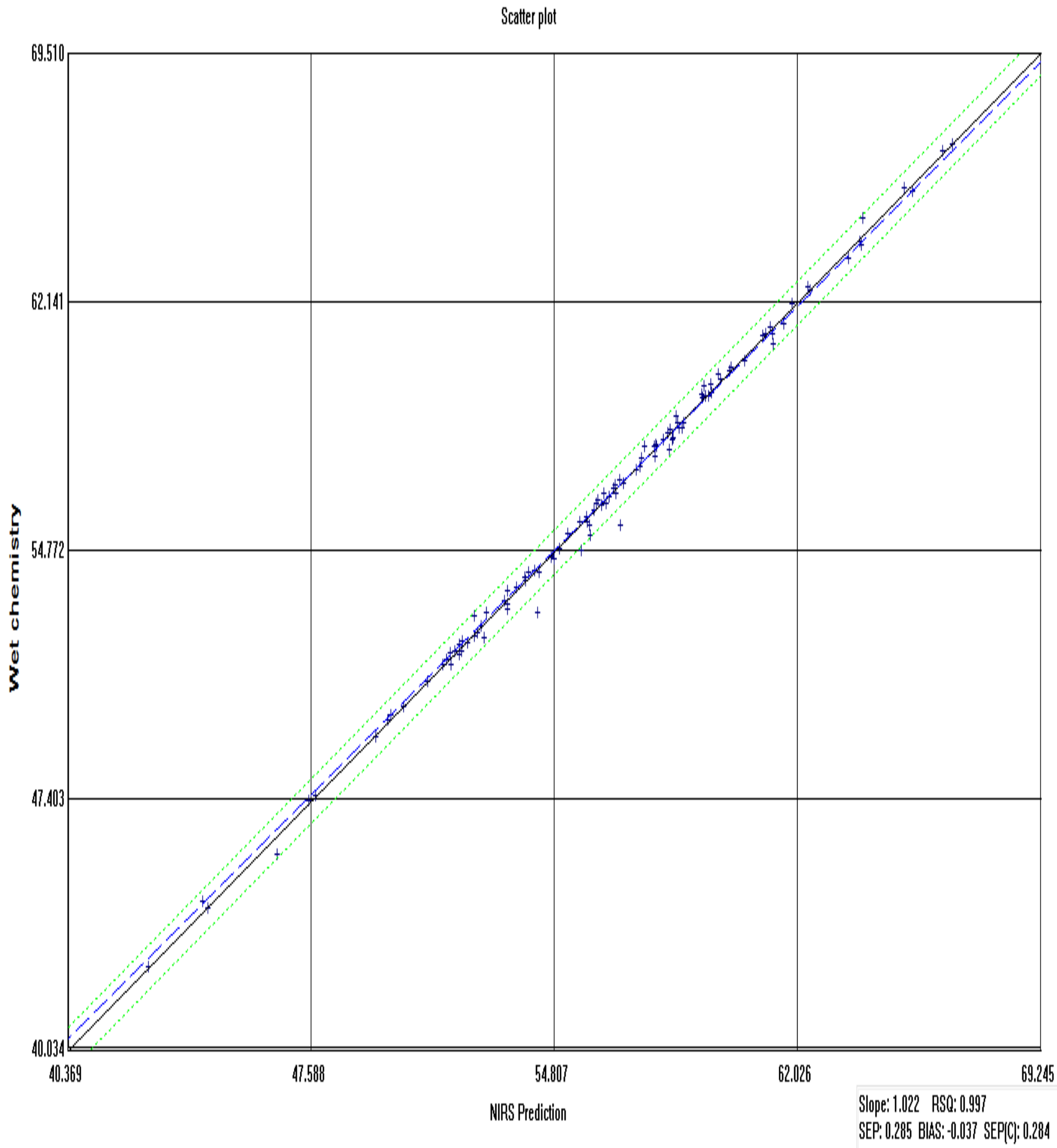

Figure 3. **NIRS prediction vs wet chemistry TIVOMD (%)**

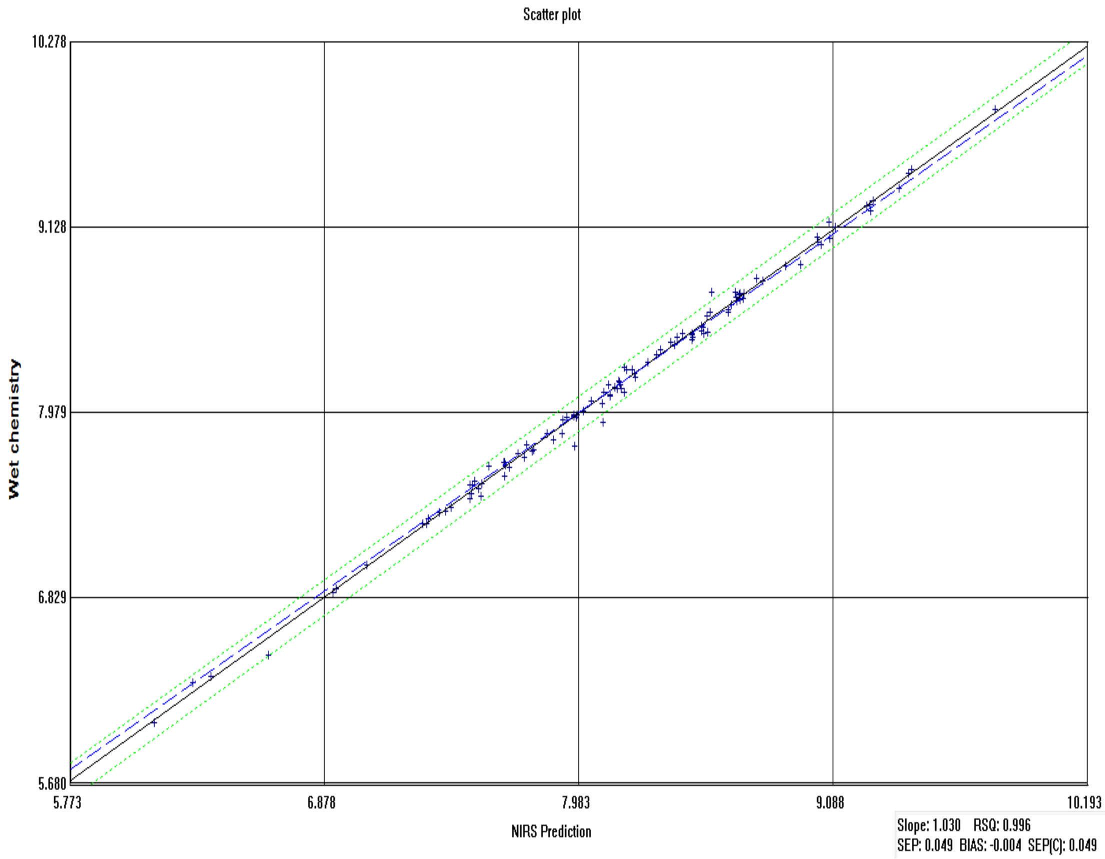

Figure 4. NIRS prediction vs wet chemistry ME (%)

4.2. Lentil Haulm Nutritional values across Locations

The analysis of variance for potential environment declared that interaction between location and variety had significant ($P<0.001$) effects on haulm NDF, ADF, ADL,CP yield, ME and ($P<0.01$) on CP and true *in vitro* organic matter digestibility. In low moisture stress, the interaction between variety and location had also significant ($P<0.001$) effect on CPY, ($P<0.01$) total ash and ($P<0.05$) on NDF, ADF and ADL. However, there was no significant ($P>0.05$) effect of the interaction between variety and location on haulm CP, ME and true in vitro organic matter digestibility in low moisture stress. That indicates the relative performance of haulm quality traits of the genotypes across locations were different. They are mostly affected by environmental factors and have no stable performance across locations (Tadesse, *et al.,* 2013).Lentil crop is sensitive to environmental effects due to different soil and climatic influences as suggested by Sharaan *et al*. (2003) and Sabaghnia *et al.* (2012).

The chemical compositions of lentil haulm at four sites in potential and low moisture stress are given in Table 5. The pooled means of CP, NDF and ADF were higher in low moisture stress variety (9.35%, 54.24% and 34.97%) than potential environment (8.56%, 49.02% and 34.67%) respectively.

However, CP yield (CPY), ME and true *in vitro* organic matter digestibility were relatively higher inpotential environment (0.36t/ha,8.29MJ/kg DM and 56.50%) than low moisture stress varieties (0.34 t/ha, 7.83MJ/kg DM and 54.12%) respectively. The result was similar to the report of Kim *et al.* (2000) as indicated late maturing varieties of oat had lower values of ADF and NDF than early maturing varieties and higher TDN and relative feed value (RFV) than early maturing varieties. Because drought-stressed plants were lower in moisture content and have been known to accumulate nitrate. Nitrate concentration is positively related to protein content of the plant, since, protein is made up of nitrogen. Furthermore, they indicated that there are small positive relationships among ADF, NDF and nitrate (Mahmood *et al.,* 2010). On the other hand, the mean CP yield obtained from the results were higher at potential environment might be due to higher dry matter yield in the plant tissue because of prolonged growing period of the varieties (Sasithon *et al.,*2001).

Abayomi, (2008) also indicated late maturing soybean varieties had shown significantly higher dry matter yield than early maturing.

In the present study the chemical composition of lentil haulm was compared across locations(Table 5). In potential environments the CP, NDF, ADF, ADL contents of the lentil haulm at Debre Zeit were higher (P<0.05) than the contents of these constituents at the other two experimental locations (Akaki and Chefe Donsa). On the other hand, the ash and ME contents were lower (P<0.05) than the haulm harvested from Akaki and Chefe Donsa. The CPY value was highest at Chefe Donsa followed by Debre zeit and the lowest at Akaki, true *in vitro* organic matter digestibility was also higher (P<0.05) for Chefe Donsa than for Akaki and Debre zeit. In low moisture stress varieties higher (P<0.05) haulm CP, NDF, ADF, ADL were obtained from Minjar than Debre zeit, but higher values CPY, ME and true *in vitro* organic matter digestibility were obtained from Dere zeit. Generally, from all four locations higher haulm quality traits expressed by relatively higher cumulative CPY, ME and true in *vitro* organic matter digestibility lower fiber fractions were obtained at Chefe Donsa followed by Debre zeit and Akaki sites.

The lentil haulm harvested from Minjar showed the lowest nutritional value with the exception of CP and CPY. The difference in the nutritive values may due to environmental factors and soil fertility since the experimental sites were to some extent varying in their agro-ecological conditions (Demirel *et al.*, 2012). Moreover, Buxton (1995) and Erskine *et al.* (1990) suggested that environment has high influence on forage quality by altering leaf to stem ratios as well causing other morphological modifications and changes in chemical composition of plant parts including cell walls. The low crude protein content is often considered the most limiting factor in the utilization of crop residues for livestock feeding. It is more pronounced in cereal than in leguminous crop residues (Van Soest, 1994). The overall mean of haulm crude protein value in each location was relatively higher than the rumen microbial requirement for fermentation and effective degradation that is 1 to 1.2% nitrogen equivalents to 6.25-7.5% crude protein according to Van Soest (1994). And also relatively higher than previously reported results (Dutta *et al*, 2004; Tolera, 2008; Nigam and Blummel, 2010; Feedipedia, 2013), which could be due to differences in environmental and management conditions among the different studies.

However, the CP content of the current study was within the ranges of values reported by Fikadu *etal.* (2010) for NIRS predicted CP content of lentil straw in Ethiopia.The mean values of NDF and ADF contents in the study trial were within the medium range of forage quality (45-65% and 31-45%, respectively) as indicated by Ball *et al.* (2007).

In low moisture stress varieties, relatively higher CP and fiber contents were associated with lower CPY, ME and true *in vitro* organic matter digestibility. In potential environments, we observed lower CP and fiber fractions with higher CPY, ME and *in vitro* organic matter digestibility. These indicate negative relationship between ME and organic matter digestibility with fiber contents, however positive relationship between CPY with ME and TIVOMD in most of the cases. Prolonged harvesting days resulted in an increase in total dry matter yield in late maturing varieties might be due to the additional tillers developed which brought an increase in total herbage and leaf formation, leaf elongation and stem development. The present study indicated that the CPY was lowest at early maturing 8 (moisture stress) varieties due to lower DM concentration, which contributed to the lower CPY. However, as plants aged, the DM content was higher, resulting in an increased dry matter yield this in turn increased CPY of late maturing variety(Knettle *et al.*, 1991).

According to Evitayani *et al.* (2004) digestibility of legumes depends on chemical composition particularly, fiber, lignin and silica contents, forage species, stage of maturity, leafiness, and soil fertility and other environmental factors. Forage with higher lignin content could have lower digestibility than lower lignin containing varieties (Gebremeskel *et al.*, 2011). Similarly, Abreu and Bruno-Soares (1998) indicated that the greater range of digestibility in forage may be due to the level and composition of their cell walls. Buxton (1995) suggested that moisture stress has inconsistent effects on total forage CP concentration occurred because CP concentration in stems increased up to 10%, whereas that in leaves decreased by up to 14%. In addition, the Akaki site has relatively higher rainfall and lower temperature than Debra zeit according to Gerba *et al.* (2013), the protein content of wheat crop in Akaki was lower than Debre zeit because the area has relatively higher rainfall that might cause nitrogen loss through gaseous denitrification, leaching, and lower temperature of the area. Even though, Debre zeit had lower biomass production than

Akaki, its crude protein yield was significantly higher than Akaki due to higher dry matter yield, since it yielded relatively very low grain eventually resulted in higher haulm yield because of biotic factors mild parasites and diseases according to the data obtained from the field book of the Research Center.

It indicated that focusing merely on crude protein content is not enough for conclusive evaluation of nutritional value of a feed. It is also a false perception that protein content is always the most limiting nutrient in the animal’s diet and CP is the ultimate measure of a forage quality, but CP yield of forage also taken into consideration. In fact, the energy value of forages is often the most limiting attribute for meeting an animal’s requirements in most forage-based feeding, furthermore, since the values of ADF and ADL were low we could predict the energy value of the haulm would be high(Saha *et al*., 2010).

Table.5. Mean comparison of nutritional values in experimental location

Location and Variety	CP %DM	CPY (t/ha)	NDF %DM	ADF %DM	ADL %DM	Ash %DM	ME MJ/kg DM	TIVOMD (%)
Potential Environment								
Debre zeit	11.53[a]	0.38[b]	51.45[a]	38.93[a]	10.55[a]	8.46[a]	8.02[c]	55.42[b]
Akaki	6.76[b]	0.21[c]	46.75[b]	33.63[b]	7.70[b]	10.27[a]	8.30[a]	56.33[b]
Chefe Donsa	7.60[b]	0.42[a]	47.94[b]	32.46[b]	7.71[b]	10.23[a]	8.55[a]	57.89[a]
Mean	8.56	0.36	49.02	34.97	8.80	9.56	8.29	56.50
SE(±)	0.25	0.01	0.50	0.45	0.17	0.11	0.04	0.27
Low Moisture Stress								
Debre zeit	8.86[b]	0.38[a]	52.53[b]	39.19[b]	9.97[b]	8.51[a]	8.01[a]	54.74[a]
Minjar	9.90[a]	0.30[b]	56.17[a]	42.34[a]	11.64[a]	8.43[a]	7.71[b]	53.41[b]
Mean	9.35	0.34	54.24	40.67	10.75	8.47	7.87	54.12
SE(±)	0.16	0.01	0.49	0.49	0.17	0.01	0.02	0.27

Means within columns followed by the same letter (s) are not significantly different at P <0.05 level %DM= percent dry matter; CP= crude protein;CPY= crude protein yield; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin, ME= metabolizable Energy, TIVOMD= True *In vitro* organic matter digestibility (gm/kgDM). PE= Potential Environment; LMS= Low Moisture Stress.

4.3. Comparison of Haulm Nutritional values of Lentil Varieties

Tables from 6-9 present comparisons of the mean values of CP, CPY, NDF, ADF, ADL, Ash, ME and true *in vitro* organic matter digestibility (TIVOMD) of lentil haulm samples across genotypes and genotypes across location. Varieties with superior value than local checks and standards in CP, CPY, Ash, ME, IVOMD contents and lower values in NDF, ADF and ADL contents were compared within maturity and location categories.

Table 6 shows means comparison of genotypes for haulm nutritional values in low moisture stress at Debre Zeit and Minjar experimental sites. Varieties Dz-2012-Ln-0014 (11.94%) and Dz-2012-Ln-0013 (11.47%) showed significantly higher (P<0.05) CP contents than Alem Tena (8.82%), Chekol (9.86%) and Local check (10.12%). In addition, Dz-2012-Ln-0012 with CP value of 10.58% was higher (P<0.05) than Alem Tena. The value of CPY was higher (P<0.05) inDz-2012-Ln-0013 (0.54t/ha)and Dz-2012-Ln-0012 (0.47t/ha) than Alem Tena (0.25t/ha), Chekol (0.34t/ha) and Local check (0.28t/ha).Dz-2012-Ln-0014,Dz-2012-Ln-0013,Dz-2012-Ln-0012,Dz-2012-Ln-0001,Dz-2012-Ln-0011andDz-2012-Ln-0004 had lower (P<0.05) NDF contents than Alem Tena, Chekol and local check.

Similarly the ADF content was lower (P<0.05) in Dz-2012-Ln-0014, Dz-2012-Ln-0012, Dz-2012-Ln-0001, Dz-2012-Ln-0005, Dz-2012-Ln-0014 and Dz-2012-Ln-0012 than Alem Tena and Chekol varieties (Table 6). The lowest ADL (8.67%) was recorded from Dz-2012-Ln-0001. The lowest CP content (7.65%) was obtained from Dz-2012-Ln-0001 and the highest NDF (59.11%) and ADF (44.70%) content were obtained from Dz-2012-Ln-0006. In addition, higher (P<0.05) ME was obtained in Dz-2012-Ln-0014 than Alem Tena and Local check, it had also high (P<0.05) TIVOMD value than all three control varieties. The lowest (P<0.05) ME content (7.56MJ/kg DM) and true *in vitro* organic matter digestibility (56.91%) were observed in Dz-2012-Ln-0007.

Table.7.Shows mean comparison of lentil varieties for haulm CP, CPY, ME and true *in vitro* organic matter digestibility cultivated at Debre zeit and Minjar in low moisture stress. At Debre zeit, the CP content was significantly (P<0.05) higher in Dz-2012-Ln-0014

(11.44%) and Dz-2012-Ln-0013 (11.34%) than Alem Tena (8.29%), Checkol (9.98%) and Local check (9.87%), but higher (P<0.05) CPY was obtained from Dz-2012-Ln-0013(0.54 t/ha) than Alem Tena and Local check. At Minjar as well the CP content of Dz-2012-Ln-0014 (12.70%) was higher (P<0.05) than Alem Tena (9.54%), Checkol (9.70%) and Local check (10.37%). In addition, the CP content of Dz-2012-Ln-0013 (11.66%) and Dz-2012-Ln-0002 (11.71%) were also significantly (P<0.05) higher than Alem Tena and Local check at Minjar. Higher CPY was obtained by Dz-2012-Ln-0005 (0.52 t/ha) at Mijar, moreover, varieties like; Dz-2012-Ln-00012,Dz-2012-Ln-0013, Dz-2012-Ln-0014,Dz-2012-Ln-0008 and Dz-2012-Ln-0003had significantly (P<0.05) higher values of CPY than controls. The ME and true *in vitro* organic matter digestibility values at Debre zeit were significantly (P<0.05) higher in Dz-2012-Ln-0014 and Dz-2012-Ln-0013 than Alem Tena. At Minjar there was no significant (P>0.05) difference among varieties in ME and TIVOMD, but the values were relatively higher in Dz-2012-Ln-0014.Generally, in this group Dz-2012-Ln-0014 had the highest haulm nutritional values and showed stable performance across experimental locations than the other tested varieties on CP and other values, however if we consider CPY better value and stable performance was obtained by Dz-2012-Ln-0013.

Table 6. Mean comparison of nutritional values of lentil haulm of low moisture stress variety cultivated from Debre Zeit and Minjar.

List of Variety	CP %DM	CPY (t/ha)	NDF %DM	ADF %DM	ADL %DM	Ash % DM	ME MJ/kgDM	TIVOMD (%)
Dz2012Ln0001	7.65^{g}	0.33^{def}	50.84^{cd}	37.72^{ef}	8.67^{h}	8.79^{a-d}	7.84^{bc}	53.67^{bcd}
Dz2012Ln0002	10.05^{cde}	0.27^{def}	56.65^{ab}	41.52^{a-d}	10.62^{c-g}	8.48^{bcd}	7.77^{bc}	53.41^{bcd}
Dz2012Ln0003	8.63^{fg}	0.37^{b-e}	$57..62^{a}$	42.31^{abc}	10.51^{c-g}	7.90^{de}	7.56^{c}	52.49^{d}
Dz2012Ln0004	8.83^{efg}	0.35^{c-f}	51.75^{dc}	38.53^{abc}	10.54^{c-g}	9.02^{abc}	7.89^{bc}	54.54^{bcd}
Dz2012Ln0005	9.30^{def}	0.45^{abc}	52.50^{bc}	37.78^{ef}	9.63^{fgh}	9.14^{ab}	8.03^{abc}	55.11^{a-d}
Dz2012Ln0006	8.63^{fg}	0.23^{f}	59.11^{a}	44.70^{a}	12.70^{a}	7.35^{e}	7.71^{c}	52.95^{d}
Dz2012Ln0007	8.42^{fg}	0.28^{def}	58.23^{a}	44.34^{ab}	12.56^{a}	8.18^{cd}	7.56^{c}	51.99^{d}
Dz2012Ln0008	8.86^{ef}	0.35^{c-f}	55.70^{ab}	42.03^{abc}	10.93^{cde}	8.52^{bcd}	7.68^{c}	52.91^{d}
Dz2012Ln0009	9.59^{c-f}	0.26^{def}	58.42^{a}	43.71^{ab}	11.50^{bc}	8.17^{cd}	7.71^{c}	53.18^{cd}
Dz2012Ln0010	10.04^{cde}	0.33^{def}	55.80^{ab}	41.92^{a-d}	11.22^{cd}	7.91^{de}	7.95^{bc}	54.76^{bcd}
Dz2012Ln0011	8.97^{def}	0.29^{def}	51.63^{cd}	39.99^{c-f}	11.51^{bc}	8.54^{a-d}	7.98^{abc}	54.79^{bcd}
Dz2012Ln0012	10.58^{bc}	0.47^{ab}	50.55^{cd}	37.30^{f}	9.57^{gh}	8.72^{a-d}	8.20^{ab}	56.22^{abc}
Dz2012Ln0013	11.47^{ab}	0.54^{a}	49.80^{cd}	37.55^{def}	10.03^{dfg}	9.10^{ab}	8.22^{ab}	56.36^{ab}
Dz2012Ln0014	11.94^{a}	0.38^{bcd}	48.39^{d}	36.77^{f}	9.80^{efg}	9.40^{a}	8.40^{a}	57.91^{a}
Alem Tena	8.82^{efg}	0.25^{ef}	55.45^{ab}	41.54^{a-d}	10.10^{c-g}	8.45^{bcd}	7.92^{bc}	54.45^{bcd}
Chekol	9.86^{cde}	0.34^{c-f}	55.99^{ab}	41.76^{a-d}	10.79^{c-f}	8.60^{a-d}	7.97^{abc}	54.71^{bcd}
Local Check	10.12^{cd}	0.28^{def}	53.48^{ab}	36.97^{b-e}	10.56^{c-g}	8.63^{a-d}	7.90^{bc}	54.31^{bcd}
Mean	9.39	0.33	54.50	40.81	10.73	8.49	7.88	54.22
SE(±)	0.13	0.01	0.45	0.38	0.16	0.08	0.04	0.25

Means within columns followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple tests.CP; crude protein, DM; Dry matter, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; metabolizable energy, MJ; mega joule, kg; kilo gram, ME; metabolizable , TIVOMD; true in vitro organic matter digestibility, SE; standard error.

Table7. Mean comparison of CP, CPY, ME true in vitro organic matter digestibility at Debre zeit and Minjar in low moisture stressvariety.

List of Variety	CP (%)		CPY(t/ha)		ME (MJ/kg DM)		TIVOMD (%)	
	Debre zeit	Minjar	Debre zeit	Minjar	Debre zeit	Minjar	Debre zeit	Minjar
Dz-2012-Ln-0001	7.23^{e}	8.07^{g}	0.31^{c}	0.29^{cde}	8.40^{b-e}	7.63^{a}	54.43^{bcd}	51.90^{a}
Dz-2012-Ln-0002	8.94^{bcd}	11.71^{ab}	0.34^{c}	0.18^{def}	8.02^{bc}	7.40^{a}	53.88^{e}	51.64^{a}
Dz-2012-Ln-0003	8.23^{de}	9.03^{fg}	0.40^{bc}	0.34^{bcd}	7.83^{de}	7.34^{a}	53.38^{cd}	53.72^{a}
Dz-2012-Ln-0004	8.32^{cde}	9.34^{efg}	0.39^{bc}	0.31^{b-e}	7.91^{cde}	7.96^{a}	54.13^{bcd}	54.95^{a}
Dz-2012-Ln-0005	8.57^{b-e}	10.28^{b-f}	0.40^{bc}	0.52^{a}	8.17^{a-d}	7.75^{a}	55.92^{abc}	54.05^{a}
Dz-2012-Ln-0006	8.73^{b-e}	8.49^{fg}	0.30^{c}	0.15^{ef}	7.67^{e}	7.54^{a}	52.48^{d}	53.38^{a}
Dz-2012-Ln-0007	8.41^{b-e}	8.44^{fg}	0.39^{bc}	0.17^{def}	7.65^{e}	7.48^{a}	52.22^{d}	51.76^{a}
Dz-2012-Ln-0008	8.05^{de}	9.66^{c-g}	0.34^{c}	0.37^{abc}	7.93^{cde}	7.44^{a}	54.24^{bcd}	51.58^{a}
Dz-2012-Ln-0009	9.30^{bcd}	9.88^{b-g}	0.35^{c}	0.17^{def}	7.86^{de}	7.57^{a}	53.94^{bcd}	52.43^{a}
Dz-2012-Ln-0010	8.93^{bcd}	11.14^{a-d}	0.39^{bc}	0.27^{cde}	8.01^{b-e}	7.80^{a}	54.74^{bcd}	54.77^{a}
Dz-2012-Ln-0011	7.90^{de}	10.04^{b-g}	0.31^{c}	0.28^{cde}	7.91^{cde}	8.05^{a}	55.89^{b-e}	55.69^{a}
Dz-2012-Ln-0012	9.91^{b}	11.48^{a-d}	0.47^{abc}	0.47^{ab}	8.36^{abc}	8.00^{a}	57.04^{ab}	55.12^{a}
Dz-2012-Ln-0013	11.34^{a}	11.66^{abc}	0.58^{a}	0.47^{ab}	8.46^{ab}	7.85^{a}	58.12^{a}	53.72^{a}
Dz-2012-Ln-0014	11.44^{a}	12.70^{a}	0.40^{bc}	0.35^{abc}	8.57^{a}	8.15^{a}	58.88^{a}	56.46^{a}
Chekol(std)	9.98^{b}	9.70^{c-g}	0.54^{ab}	0.09^{f}	8.30^{a}	7.56^{a}	56.73^{abc}	52.15^{a}
Alem Tena (std)	8.29^{cde}	9.54^{d-g}	0.32^{c}	0.15^{ef}	7.98^{cde}	7.84^{a}	54.89^{bcd}	54.26^{a}
Local check	9.87^{bc}	10.37^{b-f}	0.41^{bc}	0.14^{ef}	8.28^{a-d}	7.53^{a}	56.48^{abc}	52.15^{a}
Mean	8.96	9.89	0.39	0.27	8.04	7.71	54.96	53.36
SE(±)	0.16	0.19	0.01	0.01	0.04	0.06	0.29	0.39

Means within columns followed by the same letter (s) are not significantly different at $P < 0.05$ level of Duncan multiple tests. CP; crude protein, CPY; crude protein yield, ME; metabolizable energy, MJ; mega joule, kg; kilo gram, ME metabolizable , TIVOMD; true in vitro organic matter digestibility, SE; standard error.

Table 8 shows comparison of nutritional values of haulm in potential environment. Lentil varieties Dz-2012-Ln-0027, Dz-2012-Ln-0024, Dz-2012-Ln-0018, Dz-2012-Ln-0021,Dz-2012-Ln-0017 and Dz-2012-Ln-0026 had significantly higher (P<0.05) CP and crude protein yield values than Derash, Alemaya and Local check. Lower (P<0.05) NDF and ADF contents were obtained in Dz-2012-Ln-0024 and Dz-2012-Ln-0026 than Local check, Alemaya and Derash. The values of ADL and total ash contents were not significantly (P>0.05) different between tested and control varieties. Dz-2012-Ln-0018 and Dz-2012-Ln-0024 had higher (P<0.05) ME than Alemaya, Derash and Local check. In addition, Dz-2012-Ln-0026 and Dz-2012-Ln-0020 had shown significantly (P<0.05) higher ME values than Derash and Local check. True *in vitro* organic matter digestibility was significantly higher (P<0.05) in Dz-2012-Ln-0019 (59.45%) than Alemaya (56.50%), Derash (55.65%) and Local check (54.21%).The lowest CP (6.51%), and ME (7.89MJ/kg DM) the highest NDF (56.30%) and ADF (39.79%) contents were obtained from Dz2012Ln0016. But, the lowest true *in vitro* organic matter digestibility was obtained in Local check (54.21%).

Table 9 shows mean comparison of lentil varieties based on their haulm CP, CPY, ME and true *in vitro* organic matter digestibility cultivated at Debre zeit, Akaki and Chefe Donsa in potential environment. The CP content varies according to location overall mean was highest at Debrezeit (11.20%), while at Akaki and Chefe Donsa it was within the range or on the threshold of rumen microbial requirement (6.25-7.5%) of crude protein according to Van Soest (1994). Moreover, CP content of genotypes differ significantly (P<0.05) among each other at the three locations. At Akaki the CP content in Dz-2012-Ln-0018(9.34%) and Dz-2012-Ln-0024 (9.37%) were significantly (P<0.05) higher than Alemaya (6.78%), Derash (6.29%) and local check (7.66%). Furthermore, the CP content of Dz-2012-Ln-0021 (8.37%) was higher (P<0.05) than the two standard controls (Alemaya and Derash). At Chefe Donsa Dz-2012-Ln-0026, Dz-2012-Ln-0020, Dz-2012-Ln-0019,Dz-2012-Ln-0027, Dz-2012-Ln-0024,Dz-2012-Ln-0018 and Dz-2012-Ln-0017 were superior (P<0.05) in their CP contents than Alemaya, Derash and Local check. When we consider crude protein yield at Akaki and Debre zeit no significant (P>0.05) different were obtained between controls and most of the tested varieties, however at Chefe Donsa most of the varieties had higher (P<0.05) values than the controls, high CPY value was obtained by Dz-2012-Ln-0020 (0.60 t/ha) followed by Dz-2012-Ln-0017 (0.59 t/ ha) andDz-2012-Ln-

0026 (0.57 t/ha). At Debre zeit the highest (P<0.05) crude protein contents were obtained in Dz-2012-Ln-0018 (13.28%), Dz-2012-Ln-0021 (13.56%) and Dz-2012-Ln-0024 (13.16%) than Alemaya (7.93%), Derash (9.91%) and Local check (10.55). At Chefe Donsa the values of ME and true *in vitro* organic matter digestibility showed significantly (P<0.05) higher in Dz-2012-Ln-0017, Dz-2012-Ln-0018, Dz-2012-Ln-0019, Dz-2012-Ln-0020, Dz-2012-Ln-0022, Dz-2012-Ln-0024 and 2012-Ln-0027 than Alemaya, Derash and Local check. However, at Akaki and Debre zeit their values showed no difference (P>0.05) from control varieties. Therefore, according to the above results the varieties which had relatively consistent performance across the locations on their haulm nutritional values were Dz-2012-Ln-0018 and Dz-2012-Ln-0024 and they have considered to better quality varieties.

Even though, much less information has been published on lentil straw we could observe from the results that the mean ranges of tested haulm nutritional values were within the ranges of previously reported values by other authors (Tolera,2008; Lardy and Andrson, 2009; Feedipedia, 2013) which had values and ranges of CP (5.08-11.00%), NDF (35.50-79.60%), ADF (12.5-68.60%), ADL (5.9-13.30%), and Ash (6.0-11.2%) and also similar result with urea treated wheat and lentil straws. However, the results showed higher values than most of legume straws studied by Abreu and Bruno-Soares (1998), Bruno-Soares *et al.* (2000), Lopez *et al*. (2005) and Fikadu *et al.* (2010) and organic matter digestibility (47.22%) reported by Dutt *et al*. (2004) on lentil straw. The CP contents of roughage feeds classified as high (9.92-15%), medium (6.61-9.91% and low (3-6.5%) according to Nsahlai *et al* (1996). In the present study the quality of varieties in their haulm CP contents vary according to maturity and location, in potential environment all the varieties cultivated at Debre zeit were classified as high quality in their CP content except Dz-2012-Ln-00019 (9.72%) while, at Akaki and Chefe Donsa most of the varieties were classified as medium quality forage. Likewise, in low moisture stress at Debre zeit all the varieties were within the ranges of medium with the exceptionsDz-2012-Ln-0013 andDz-2012-Ln-0014. But, at Minjar and Chefe Donsa most of the varieties had medium quality.

In the present study the values of crude protein content and crude protein yield were not coincide across the experimental locations that might be due to difference in their above ground biomass and grain yield, for instance, CP was the lowest at Chefe Donsa, but CP yield became the highest because of high biomass yield and proportional value of grain to haulm ratio. On the other hand, Akaki was the second in CP value, but its CP yield had lower value than Debre zeit, because grain yield at Debre zeit showed disproportional ratio to haulm yield (0.87 to 3.42) respectively owing to mild infestation of parasites and incidence of disease according to the field document. Therefore, when we deducted grain yield from biomass the value of haulm yield became high at Debre zeit than Akaki.

The values of ME in the present study in each genotype were within the range of tropical forage legumes 6.50MJ/kg DM to 8.30MJ/kg DM (Evitayani *et al.*, 2004) also similar to Lopez *et al.* (2005) report of leaf-rich straw sample of lentil (8.30MJ/ kg DM). While, higher than Abreu and Bruno-Soares (1998), values of stem-rich lentil haulm metabolizable energy (6.20MJ/kg DM) and OMD (46.60%) findings. The minimum ME (7.51MJ/kg DM) and true *in vitro* organic matter digestibility (51.27%) of the genotypes were from low moisture stress varieties.

Table 8. Mean comparison of nutritional value of lentil haulm from potential environment variety cultivated from Debre Zeit, Akaki and Chefe Donsa.

List of Variety	CP %DM	CPY (t/ha)	NDF %DM	ADF %DM	ADL %DM	Ash % DM	ME MJ/kgDM	TIVOMD (%)
Dz-2012-Ln-0015	7.61^{cde}	0.28^{fg}	49.59^{cde}	33.98^{cde}	8.06^{cde}	10.17^{a}	8.12^{def}	55.84^{b-e}
Dz-2012-Ln-0016	6.51^{f}	0.18^{gh}	56.30^{a}	39.79^{a}	9.75^{a}	9.05^{e}	7.89^{f}	55.24^{cde}
Dz-2012-Ln-0017	9.11^{b}	0.48^{ab}	44.24^{e-h}	32.20^{cde}	8.86^{a-d}	9.85^{a-d}	8.29^{a-e}	55.54^{abc}
Dz-2012-Ln-0018	10.05^{a}	0.46^{abc}	46.24^{fgh}	33.49^{de}	8.55^{b-e}	9.36^{b-e}	8.60^{a}	57.71^{ab}
Dz-2012-Ln-0019	8.05^{cd}	0.28^{fg}	50.88^{cd}	36.28^{bc}	9.33^{ab}	8.35^{f}	8.42^{a-d}	59.45^{a}
Dz-2012-Ln-0020	10.16^{a}	0.38^{cde}	48.89^{def}	35.90^{bcd}	9.72^{a}	9.27^{de}	8.50^{abc}	57.05^{bcd}
Dz-2012-Ln-0021	9.14^{b}	0.42^{bcd}	45.71^{gh}	33.40^{de}	8.78^{b-e}	10.03^{ab}	8.20^{c-f}	55.67^{b-e}
Dz-2012-Ln-0022	8.22^{bc}	0.35^{def}	46.87^{e-h}	33.21^{de}	8.16^{cde}	9.71^{a-e}	8.46^{a-d}	57.59^{abc}
Dz-2012-Ln-0023	6.88^{ef}	0.19^{gh}	54.50^{ab}	38.76^{a}	9.24^{ab}	9.33^{c-e}	8.03^{ef}	55.19^{cde}
Dz-2012-Ln-0024	10.19^{a}	0.48^{ab}	45.36^{h}	33.24^{e}	8.01^{de}	9.76^{a-d}	8.58^{a}	56.47^{b-e}
Dz-2012-Ln-0025	8.28^{bc}	0.39^{cde}	48.45^{d-h}	34.37^{cde}	8.51^{b-e}	9.81^{a-d}	8.2^{c-f}	55.00^{de}
Dz-2012-Ln-0026	9.10^{b}	0.53^{a}	45.53^{h}	32.19^{e}	8.28^{cde}	10.13^{a}	8.51^{abc}	56.70^{bcd}
Dz-2012-Ln-0027	10.24^{a}	0.45^{abc}	46.17^{fgh}	33.53^{de}	8.88^{a-d}	9.99^{abc}	8.38^{a-d}	57.71^{ab}
Alemaya	6.84^{ef}	0.26^{g}	48.73^{d-g}	35.54^{bcd}	7.87^{e}	9.68^{a-e}	8.25^{b-e}	56.50^{b-e}
Derash	7.15^{def}	0.32^{efg}	49.47^{cde}	35.42^{bcd}	7.88^{e}	9.86^{a-d}	8.15^{def}	55.65^{b-e}
Local check	7.66^{cde}	0.27^{fg}	53.32^{bc}	38.05^{ab}	8.96^{abc}	10.06^{ab}	7.99^{ef}	54.21^{e}
Mean	8.28	0.34	49.24	35.24	8.68	9.62	8.26	56.37
SE**(±)**	0.22	0.008	0.42	0.38	0.14	0.09	0.04	0.23

Means within column followed by the same letter (s) are not significantly different at P <0.05 significant level of Duncan multiple tests CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, SE; standard error, ME; metaboizable energy (MJ/kg DM), TIVOMD; true *in vitro* organic matter digestibility (gm/kg DM).

Table 9.Means comparison of haulm CP, ME and true *in vitro* organic matter digestibility in potential environment varieties cultivated at Akaki, Chefe Donsa and Debre Zeit.

List of Variety	CP			CPY			ME			TIVOMD		
	Akaki	Chefe Donsa	Debre zeit	Akaki	Chefe Donsa	Debre zeit	Akaki	Chefe Donsa	Debre zeit	Akaki	Chefe Donsa	Debre zeit
Dz-2012-Ln-0015	5.97^{de}	4.94^{f}	11.25^{a-d}	0.15^{bcd}	0.25^{ef}	0.45^{ab}	8.36^{a}	8.26^{fgh}	7.78^{bcd}	56.78^{a}	55.86^{fg}	54.88^{ab}
Dz-2012-Ln-0016	4.83f	5.50^{ef}	9.92^{cde}	0.11^{d}	0.19^{ef}	0.24^{d}	8.07^{a}	8.01^{hi}	7.59^{cd}	54.71^{a}	54.28^{gh}	56.76^{ab}
Dz-2012-Ln-0017	-	7.16^{abc}	11.72^{a-d}	-	0.59^{ab}	0.34^{bcd}	-	8.90^{abc}	7.48^{d}	-	60.03^{abc}	54.22^{ab}
Dz-2012-Ln-0018	9.34^{a}	7.17^{abc}	13.28^{a}	0.32^{a}	0.51^{abc}	0.48^{ab}	8.45^{a}	8.82^{abc}	8.46^{ab}	57.01^{a}	59.41^{bcd}	56.37^{ab}
Dz-2012-Ln-0019	6.40^{d}	7.61^{abc}	9.72^{de}	0.14^{bcd}	0.19^{e}	0.38^{a-d}	8.50^{a}	9.11^{a}	7.66^{cd}	57.69^{a}	61.43^{a}	58.78^{a}
Dz-2012-Ln-0020	-	7.63^{ab}	12.06^{a-d}	-	0.60^{a}	0.22^{d}	-	8.92^{ab}	8.18^{a-d}	-	60.26^{ab}	54.63^{ab}
Dz-2012-Ln-0021	8.37^{b}	6.60^{bcd}	13.56^{a}	0.31^{a}	0.50^{bc}	0.48^{ab}	8.29^{a}	8.24^{fgh}	8.02^{a-d}	56.17^{a}	55.87^{fg}	59.28^{abc}
Dz-2012-Ln-0022	7.51^{bc}	6.65^{bcd}	10.78^{bc}	0.26^{ab}	0.39^{d}	0.35^{a-d}	8.09^{a}	8.73^{bcd}	8.34^{abc}	55.07^{a}	59.04^{b-e}	54.74^{ab}
Dz-2012-Ln-0023	5.33^{ef}	5.31^{ef}	10.01^{cde}	0.13^{cd}	0.16^{f}	0.27^{cd}	8.52^{a}	7.90^{i}	7.68^{cd}	57.64^{a}	53.83^{h}	54.10^{ab}
Dz-2012-Ln-0024	9.37a	7.42^{abc}	13.16^{ab}	0.29^{a}	0.52^{abc}	0.49^{ab}	8.48^{a}	8.60^{cde}	8.57^{a}	57.42^{a}	58.11^{cde}	54.59^{ab}
Dz-2012-Ln-0025	7.42^{bc}	6.54^{cd}	11.46^{a-d}	0.29^{a}	0.45cd	0.40^{abc}	8.09^{a}	8.42^{efg}	8.00^{a-d}	55.02^{a}	57.14^{ef}	52.12^{b}
Dz-2012-Ln-0026	-	7.83^{a}	10.79^{bcd}	-	0.57^{ab}	0.49^{ab}	-	8.94^{ab}	8.49^{ab}	-	57.93^{de}	55.06^{ab}
Dz-2012-Ln-0027	-	7.38^{abc}	12.39^{abc}	-	0.54^{abc}	0.36^{a-d}	-	8.52^{def}	7.99^{a-d}	-	59.97^{abc}	55.02^{ab}
Alemaya	6.78^{cd}	6.08^{de}	7.93^{e}	0.26^{ab}	0.26^{ef}	0.28^{cd}	8.49^{a}	8.20^{ghi}	8.01^{a-d}	57.53^{a}	55.34^{fgh}	56.68^{ab}
Derash	6.29^{de}	5.95^{de}	9.91^{cde}	0.21^{a-d}	0.28^{e}	0.52^{a}	8.34^{a}	8.04^{hi}	8.05^{a-d}	56.44^{a}	54.61^{gh}	55.98^{ab}
Local check	7.66^{bc}	5.50^{ef}	10.55^{cd}	0.24^{abc}	0.19^{ef}	0.41^{abc}	8.61^{a}	7.62^{j}	7.97^{a-d}	58.88^{a}	52^{i}	54.47^{ab}
Mean	6.78	6.52	11.20	0.21	0.39	0.38	8.34	8.44	8.01	56.59	57.12	55.42
SE(±)	0.22	0.14	0.25	0.01	0.02	0.01	0.01	0.06	0.42	0.32	0.37	0.42

Means within columns followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple tests. CP; crude protein, ME; Metabolizable Energy (MJ/kg DM), TIVOMD; true *in vitro* organic matter digestibility.SE; standard error.

The true *in vitro* organic matter digestibility of all the genotypes were higher than 50% indicating that the high potential to supply metabolizable energy, as suggested by Abdulrazak *et al.* (2001). The chemical composition and nutritive values differ according to maturity and genotypes, relatively higher mean CP, fiber fractions and lower ME and true *in vitro* organic matter digestibility were obtained from low moisture stress varieties. While lower CP and fiber fractions but, higher ME and true *in vitro* organic matter digestibility were obtained from highland varieties or from potential environment varieties. The lower value of ADF in this study could be indicative of its better digestibility than other straws. On the other hand, those genotypes with higher lignin content could have low digestibility than the lower lignin containing varieties (Gebremeskel *et al.,* 2011).

The results may indicated similar reasons as previously put by Susmel *et al.* (1994) high temperature increases protein and cell wall (NDF) ADF, ADL contents and low ME and true *in vitro* organic matter digestibility. Generally, the results of this study showed that nutritive value of lentil haulm studied appeared to be relatively high as ruminant feed. It was suggested that differences in nutrient digestibility may be related to differences in chemical composition of the forages particularly in fiber, lignin and silica contents, forage species, soil fertility and other environmental factors (Evitayani *et al.,* 2004).

4.4. Relationship among Parameters

Table.10. shows Pearson correlation coefficients of lentil haulm nutritional values; crude protein yield (CPY) (t/ha), NDF, ADF, ADL ash, ME, true *in vitro* organic matter digestibility (TIVOMD), and agronomic traits; days to 50% flowering (DF), day to 90% maturity (DTM), plant height (PLH), hundred seed weight (HSW), above ground biomass (BM) grain yield (GYD), harvest index (HI), haulm yield (HLY) of the trial given.

In the present study crude protein yield was positively correlated with all studied agronomic traits with the exceptions of grain yield and harvest index, however, its association was not significant (p>0.05) with days to 90% maturity, hundred seed weight and grain yield. NDF and ADF had significant (P<0.001) negative correlations with all yield and yield components with the exceptions of plant height and harvest index. We could also observe that ADL had significant (P<0.001) negative correlation with all yield and yield components. On the other hand, the correlation between total ash and agronomic traits were positive and significant (P<0.001), but it was loosely associated (r=0.16; P<0.05) with plant height. ME and TIVOMD showed positive and significant (P<0.001) correlations with days to 50% flowering, days to 90% maturity, hundred seed weight, grain yield and haulm yield, however, their associations with plant height, biomass and harvest index were not significant (P>0.05). The association between grain yield and haulm yield showed significantly positive (r=0.16; P<0.001) correlation. Furthermore, grain yield and haulm yield had positive correlations with all studied agronomic traits, except haulm yield with harvest index that showed significant negative correlation (Table 10).

According to the present study the trend of correlations showed that increased or prolonged length of flowering days, high in plant height, high biomass and high haulm yield associated with increased haulm crude protein yield because these yield components directly related to haulm yield. On the other hand, there was inversely association of crude protein yield with grain yield and harvest index as indicated on the table that is may be due to significant negative correlation of haulm yield with harvest index, because of low harvest index value in the most of the varieties.

In the present study days to 90% maturity and grain yield were significantly and positively associated similarly as Abayomi (2008) study, moreover Thomson *et al*. (1997) indicated that longer days to maturity may increase grain yield in lentil,(Erskine *et al*., 1990; Latif *et al*., 2010; Pania *et al.,* 2011)also found that seed yield were associated with extended period of vegetation growth and days to 90% maturity has indirect effect on grain yield.

The significant positive correlation of grain yield with haulm yield was consistence with Blummel *et al*. (2010) report that good opportunities on farm productivity for both traits. Moreover, the correlation between days to 90% maturity and haulm yield was positive that is contrary to Fleischer *et al*. (1987) report that indicated crop residue yield significantly decreased with increasing growth period. Seed yield is the result of many characters some of these characters are highly associated among themselves (Dugassa *et al*., 2014). Therefore, Hassan-AW *et al*. (2009) reported that change in grain yield directly related with any variation in yield components in lentil because, it is a combined effects of individual yield components which are substantially influenced by environmental factors.

Generally, in most of the cases the present study indicated that the associations among certain yield components and yield such as, above ground biomass, harvest index, grain yield and haulm yield are in agreement with the reports which found by Erskine *et al.(* 2000),Kayan, (2008) Tuba and Sakar; (2008),Shrestha *et al.(*2009), Aghili*et al.(* 2012) and Mondal*et al*., (2013).

Nori *et al.* (2008) reported that grain yield was positively correlated to CP content contrary to the present result of crude protein yield with grain yield association.It is may be due to negative correlation of harvest index with haulm yield, because of lower value of harvest index. On the other hand, may due to translocation or mobilization of more soluble nutrients like nitrogen from the vegetative parts to the seed during grain filling and made plant parts lower in Nitrogen content in the expense of seed as the demand is high (Tolera *et al.*, 2007). Furthermore, McDonald *et al.* (2002) and Bilal *et al.* (2007) indicated as length of days to 90% maturity increased the composition of CP content in the forage will be declined. Thomson *et al.* (1997) study showed that an indeterminate growth habit or post-flowering growth of lentil crop increasing the number of high order branches such as secondary and tertiary branches when longer days to maturity the nutrient might be used up by newly increased or emerged branch of plant parts; because of this, ultimately the nitrogen content of the straw will be decreased. The result was in similar manner to previously studied(Tolera *et al*., 2007; Blummel *et al.*, 2010; Tadesse *et al.*, 2013) on maize stover and Pearl millet stover.

Table 10. Simple correlation between agronomic traits, haulm yield and haulm qualitytraits in potential and low moisture stress varieties.

Traits	CPY	NDF	ADF	ADL	ash	ME	TIVOMD	GYLD	HLMY
DF	0.16^{**}	-0.60^{***}	-0.60^{***}	-0.45^{***}	0.56^{***}	0.51^{***}	0.38^{***}	0.20^{***}	0.23^{***}
DTM	0.02^{ns}	-0.54^{***}	-0.64^{***}	-0.55^{***}	0.63^{***}	0.50^{***}	0.37^{***}	0.16^{**}	0.08^{ns}
PLH	0.22^{**}	-0.08^{ns}	-0.11^{ns}	-0.12^{*}	0.16^{*}	0.07^{ns}	0.04^{ns}	0.23^{***}	0.31^{***}
HSW	0.07^{ns}	-0.19^{***}	-0.26^{***}	-0.19^{**}	0.21^{***}	0.44^{***}	0.38^{***}	0.10^{ns}	0.14^{*}
BM	0.64^{***}	-0.45^{***}	-0.54^{***}	-0.60^{***}	0.50^{***}	0.21^{ns}	0.16^{ns}	0.67^{***}	0.93^{***}
GYLD	-0.04^{ns}	-0.28^{***}	-0.44^{***}	-0.56^{***}	0.57^{***}	0.25^{***}	0.24^{***}	….	0.36^{***}
HI	-0.54^{***}	0.02^{ns}	-0.11^{ns}	-0.25^{***}	0.26^{***}	-0.02^{ns}	0.003^{ns}	0.26^{***}	-0.44^{***}
HLMY	0.83^{***}	-0.42^{***}	-0.45^{***}	-0.45^{**}	0.33^{***}	0.40^{***}	0.36^{***}	0.36^{***}	…..

P<0.05,** P<0.01,*** P<0.001 levels of probability; CPY; crude protein yield (t/ha), NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; metabolizable energy (ME/kg DM), TIVOMD; true *in vitro* organic matter digestibility (%DM),DF; days to 50% flowering, DTM; days to 90% maturity(days); PLH, plant height; HSW, hundred seed weight; BM, biomass; GYLD; grain yield(t/ha); HI, harvest index; HLY, haulm yield(t/ha).

The positive significant correlation of hundred seed weight, grain yield and haulm yield with ME and TIVOMD indicated that the possibility of increasing these traits simultaneously. In addition, absence of significant correlation between plant height, biomass and harvest index with ME TIVOMD also presents a good opportunity for increasing these traits simultaneously without tradeoff effect (Tolera *et al.,* 2007; Tadesse *et al.*, 2013).

4.5. Grain yield Haulm quality and quantity Traits and Potential Utility Index

In table 11 significantly (P<0.05) high grain yield was obtained by DZ-2012-Ln-0004, DZ-2012-Ln-0001 and DZ-2012-Ln-0005 than checks Alem Tena, Local check and Checkol. The lowest grain yield was obtained from DZ-2012-Ln-0014 (0.21t/ha) it had also low harvest index value as indicated from the data obtained from EIAR, which was due to mild Ascochyt and wilt infection according to researcher sfield book report. In haulm yield and haulm digestible dry matter yield DZ-2012-Ln-0005, DZ-2012-Ln-0013 and DZ-2012-Ln-0012 had significantly (P<0.05) higher values than Alem Tena and Local check. The lowest values of haulm yield (2.55t/ha) and digestible dry matter yield (1.12t/ha) were obtained from genotype DZ-2012-Ln-0006. The Potential Utility Index values were not significantly (P>0.05) different from control varieties, however, relatively higher values were obtained in DZ-2012-Ln-0006, followed by Local check, DZ-2012-Ln-0004 and DZ-2012-Ln-0002.

Table 11. Grain, Haulm and digestible DM yield (t/ha) and potential utility index of 17 varieties in low moisture stress variety.

Variety	Grain yield(t/ha)	Haulm yield (t/ha)	Digestible DM yield of haulm (t/ha)	Potential Utility (%)
Dz-2012-Ln-0001	1.07^{ab}	3.97^{a-d}	2.10^{a-d}	69.48^{a-e}
Dz-2012-Ln-0002	0.84^{bc}	2.85^{de}	1.69^{b-e}	71.09^{a-d}
Dz-2012-Ln-0003	0.86^{bc}	4.26^{abc}	2.13^{a-d}	65.27^{b-e}
Dz-2012-Ln-0004	1.22^{a}	4.06^{a-d}	2.24^{abc}	71.27^{abc}
Dz-2012-Ln-0005	1.02^{ab}	4.83^{a}	2.55^{a}	68.79^{a-e}
Dz-2012-Ln-0006	0.84^{bc}	2.55^{e}	1.32^{e}	72.13^{a}
Dz-2012-Ln-0007	0.65^{cde}	3.30^{b-e}	1.70^{b-e}	65.73^{a-e}
Dz-2012-Ln-0008	0.65^{cde}	4.06^{a-d}	2.10^{a-d}	64.57^{de}
Dz-2012-Ln-0009	0.62^{cde}	2.74^{de}	1.38^{de}	67.16^{a-e}
Dz-2012-Ln-0010	0.51^{de}	3.36^{b-e}	1.79^{a-e}	66.92^{a-e}
Dz-2012-Ln-0011	0.51^{de}	3.02^{cde}	1.62^{cde}	69.28^{a-e}
Dz-2012-Ln-0012	0.74^{cd}	4.43^{ab}	2.42^{ab}	67.27^{a-e}
Dz-2012-Ln-0013	0.39^{ef}	4.67^{ab}	2.46^{ab}	63.82^{e}
Dz-2012-Ln-0014	0.21^{f}	3.33^{b-e}	1.86^{a-e}	64.87^{cde}
Alem Tena	0.69^{cd}	2.88^{cde}	1.62^{cd}	69.86^{a-e}
Chekol	0.53^{de}	3.81^{abc}	2.24^{abc}	69.99^{a-e}
Local Check	0.62^{cde}	2.77^{de}	1.63^{cde}	71.77^{ab}
Mean	0.72	3.59	1.91	68.19
SE**(±)**	0.03	0.01	0.08	0.54

Means within column followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple tests.

Table 12 in potential environment Derash (2.81t/ha) had significantly (P<0.05) the highest grain yield followed by Alemaya (2.09t/ha), from all tested genotypes Dz-2012-Ln-0016(2.01t/ha) had better yield than the rest. Grain yield was significantly lower (p < 0.05) in Dz-2012-Ln-0024 than most of the varieties. Significantly higher (P<0.05) haulm yield and haulm digestible dry matter yield were obtained from Dz-2012-Ln-0017 andDz-2012-Ln-0026 and Dz-2012-Ln-0027. The values of potential utility index were highest by Derash (79.85%) followed by Dz-2012-Ln-0023, Alemaya and Dz-2012-Ln-0016. However, the lowest value was obtained from varieties Dz-2012-Ln-0017(68.08%).

Table 12. Grain, Haulm and digestible DM yield (t/ha) and potential of 16 varieties in potential environment.

Variety	Grain yield t/ha	Haulm yield t/ha	Digestible DM yield of haulm t/ha	Potential Utility
Dz-2012-Ln-0015	1.69^{b-f}	3.68^{fgh}	1.98^{ef}	75.17^{cd}
Dz-2012-Ln-0016	2.01^{bc}	2.86^{ij}	1.51^{gh}	78.58^{ab}
Dz-2012-Ln-0017	1.19^{gh}	6.52^{a}	3.70^{a}	68.08^{g}
Dz-2012-Ln-0018	1.36^{e-h}	4.96^{bcd}	2.82^{bc}	71.32^{ef}
Dz-2012-Ln-0019	1.55^{c-f}	3.37^{hij}	1.87^{fg}	76.85^{bc}
Dz-2012-Ln-0020	1.41^{e-h}	4.17^{efg}	2.39^{d}	78.04^{ab}
Dz-2012-Ln-0021	1.83^{b-e}	5.23^{b}	2.87^{bc}	72.98^{de}
Dz-2012-Ln-0022	1.55^{c-h}	4.46^{cde}	2.50^{cd}	73.09^{de}
Dz-2012-Ln-0023	1.77^{b-f}	2.74^{j}	1.46^{h}	78.58^{ab}
Dz-2012-Ln-0024	1.08^{h}	5.06^{bc}	2.85^{bc}	69.88^{fg}
Dz-2012-Ln-0025	1.65^{b-g}	4.95^{bcd}	2.70^{bcd}	72.20^{ef}
Dz-2012-Ln-0026	1.33^{fgh}	5.99^{a}	3.36^{a}	69.57^{fg}
Dz-2012-Ln-0027	1.47^{d-h}	5.17^{bc}	2.94^{b}	70.33^{efg}
Alemaya	2.09^{b}	3.63^{fgh}	1.98^{ef}	78.60^{ab}
Derash	2.81^{a}	4.32^{def}	2.33^{de}	79.85^{a}
Local Check	1.91^{bcd}	3.64^{ghi}	1.84^{fgh}	76.95^{bc}
Mean	1.71	4.25	2.34	74.84
SE(±)	0.07	0.15	0.08	0.53

Means within column followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple tests.

Grain is the primary trait that is targeted in all crop improvement programs in Ethiopia (Tadesse *et al.*, 2013).Variability existed among lentil varieties under tested locations for grain yield, haulm quality and quantity traits. The overall mean of grain yield, haulm yield, digestible dry matter yield and potential utility index of the haulm were relatively higher in late maturing varieties, because grain yield and biomass production had a wide variation in lentil from cultivar to cultivar among locations. Furthermore, lentil plants have an indeterminate growth habit which continues to flower and sprout new branches which is most predominant in late maturity varieties that may increase biomass, yield and haulm digestibility (Thomson *et al.*, 1997). The values of potential utility index in the present study were relatively similar within the range of Gebremeskel *et al*. (2011); but, higher than Tolera *et al*. (2007) and Geleti *et al.* (2011).

Even though, potential utility index is a good parameter in measuring food-feed crop by integrating grain yield with residues yield and digestible dry matter yields (Fleischer *et al*., 1989)**.** In the present study it was not coincide with fodder quality traits because most of the varieties had lower values of harvest index. Hassan-AW *et al* (2009) suggested thatlow crop harvest index is the major cause of less crop yield. That may be due to the mild incidence of parasites and diseases (Ascochyt, wilt and Rust) as observed from the combined field book report of the Research Center. Therefore, the tested varieties which showed the highest values in haulm nutritional value in the present study were not found to be high in their potential utility index, rather they performed low grain yield. However, there were some varieties which combined or compromised moderately high grain and haulm yield better haulm quality traits and ultimately medium potential utility index among the tested varieties.

Lentil variety with better values in low moisture stresswasDZ-2012-Ln-0005 with CP (9.30%), CPY (0.45 t/ha), ME (8.03MJ/kg DM), TIVOMD (55.11%), grain yield (1.02t/ha), haulm yield (4.83t/ha), digestible dry matter yield of (2.55t/ha) and potential utility index (68.79%). In potential environment combined values in grain yield, haulm quality and quantity traits were obtained from Dz-2012-Ln-0021 with CP (9.14%), CPY (0.42 t/ha), ME(8.20MJ/kg DM), TIVOMD(55.67%), grain yield (1.83t/ha),haulm yield (5.23t/ha), digestible dry matter yield(2.87t/ha) potential utility index (73.09%).

5. CONCLUSION AND RECOMMENDATIONS

The study showed that the mean predicted values of CP, NDF, ADF and ADL, total Ash, ME and TIVOMD of lentil haulm samples by NIRS were very close to those determined by the wet chemistry analysis. Therefore, it could efficiently be used to predict the nutritional quality of lentil haulm. The effects of location and variety on chemical composition of the lentil haulm were significantly high in the trial. The study also showed the presence of considerable cultivar differences in chemical composition of lentil haulm.

The overall means of CP, NDF and ADF were higher in low moisture stress variety than potential environment. However, CP yield, ME and true *in vitro* organic matter digestibility were relatively higher in potential environment than low moisture stress varieties.

In potential environment varieties the CP, NDF, ADF, ADL contents of the lentil haulm at Debre Zeit were higher than Akaki and Chefe Donsa. On the other hand, CP yield, ME and TIVOMD values were the highest at Chefe Donsa.

In low moisture stress varieties higher haulm CP, NDF, ADF, ADL were obtained from Minjar than Debre zeit, but higher values CPY, ME and true *in vitro* organic matter digestibility were obtained from Debre zeit. Generally, from all four locations higher haulm quality traits expressed by relatively higher cumulative CPY, ME and true in *vitro* organic matter digestibility lower fiber fractions were obtained at Chefe Donsa followed by Debre zeit and Akaki sites.

Relatively consistent performance across the locations on their haulm nutritional values were Dz-2012-Ln-0018 and Dz-2012-Ln-0024 and they have considered to be better quality varieties in potential environment variety. While in low moisture stress Dz-2012-Ln-0014 had the highest haulm nutritional values and showed stable performance across experimental locations than the other tested varieties on CP and other values, however if we consider CPY better value and stable performance was obtained by Dz-2012-Ln-0013.

Grain yield and haulm yields had shown significant and positive associations with ME and TIVOMD in the present study. So, there is a possibility of selecting varieties of lentil that combine high grain and straw yield with desirable straw quality. Thus plant breeders can select varieties that will give higher grain and haulm yield and better quality straw in a range of environments.

Even though, lentil varieties with superior nutritional values were not found to be higher in grain yield and potential utility index, there are varieties which have optimum values that compromise relatively high haulm CP, CPY, ME, TIVOMD, grain yield, haulm yield, and digestible dry matter yield of the haulm and potential utility index. Therefore, in low moisture stress varieties Dz2012Ln0005 and from potential environmentDz2012Ln0021.

There exists appreciable variability in nutritional attributes of fodders from lentil crops grown for food. Appling this variability to maximize the fodder quantity and quality traits obviously requires that the crop and livestock scientists work in tandem. Comprehensive research programs targeting assessment of variability in nutritional quantity and quality among existing cultivars and new breeding lines would certainly help in the most economical use of haulm for ruminant feeding. However, the best way forward would be a mandatory approach for large scale assessment of variability in feed quality traits among upcoming cultivars, and subsequently going for the one with the best of both. Further the fodder quality traits should also be considered by the plant breeders as a criterion for releasing new cultivars. Based on the above findings the following recommendations are forwarded:

The experiment should be conducted over two years, since it is difficult to conclude on all vital results within one year study due to unpredictable weather condition that may cause over and under performance.

Superior genotypes need to be studied in terms of animal performance. Agronomic practice has to be given more emphasis during study and improvement of food-feed traits in crops in the future research program.

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7. APPENDICES

7.1.Appendix. I.Analysis of Variance Tables

APPENDEX Table 1.Analysis of variance for PE. The GLM Procedures considering Crude Protein (CP)

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	859.2552452	23.2231147	23.05	<.0001
Error	85	85.6366914	1.0074905		
Corrected Total	122	944.8919366			

R-Square	Coeff Var	Root MSE	CP Mean
0.909369	11.72792	1.003738	8.558537

CP

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	139.3812688	11.6151057	11.53	<.0001
Location	2	597.2760401	298.6380201	296.42	<.0001
Block	3	3.1624586	1.0541529	1.05	0.3764
Treatment*location	20	44.7976724	2.2398836	2.22	0.0060

APPENDEX Table 2.Analysis of variance for NVT PE. The GLM Procedures considering Crude Protein Yield(CPY)

Dependent Variable: CPY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	2.54087492	0.06867230	10.63	<.0001
Error	84	0.54273246	0.00646110		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Corrected Total	121	3.08360738			

R-Square	Coeff Var	Root MSE	CPY Mean
0.823994	22.49708	0.080381	0.357295

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatment	12	1.03399492	0.08616624	13.34	<.0001
location	2	0.46290469	0.23145235	35.82	<.0001
Block	3	0.00065921	0.00021974	0.03	0.9915
treatment*location	20	0.53335987	0.02666799	4.13	<.0001

APPENDEX Table 3.The GLM Procedures considering NDF

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	2916.393395	78.821443	8.07	<.0001
Error	85	829.811602	9.762489		
Corrected Total	122	3746.204997			

R-Square	Coeff Var	Root MSE	NDF Mean
0.778493	6.373904	3.124498	49.02016

NDF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	1724.614799	143.717900	14.72	<.0001
Location	2	650.672552	325.336276	33.33	<.0001
Block	3	35.063498	11.687833	1.20	0.3158
Treatment*location	20	606.910087	30.345504	3.11	0.0001

APPENDEXTable 4.The GLM Procedures considering ADF

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	2530.698190	68.397248	10.21	<.0001
Error	85	569.439244	6.699285		
Corrected Total	122	3100.137434			

R-Square	Coeff Var	Root MSE	ADF Mean
0.816318	7.401635	2.588298	34.96927

ADF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	772.736373	64.394698	9.61	<.0001
Location	2	1232.905057	616.452529	92.02	<.0001
Block	3	21.226823	7.075608	1.06	0.3722
Treatment*location	20	486.551731	24.327587	3.63	<.0001

APPENDEX Table 5.The GLM Procedures considering ADL

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	345.4281725	9.3358966	10.53	<.0001
Error	85	75.3627755	0.8866209		
Corrected Total	122	420.7909480			

R-Square	Coeff Var	Root MSE	ADL Mean
0.820902	10.70491	0.941605	8.796016

ADL

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	40.4392975	3.3699415	3.80	0.0001
Location	2	229.2511592	114.6255796	129.28	<.0001
Block	3	2.1383495	0.7127832	0.80	0.4951
Treatment*location	20	62.8827897	3.1441395	3.55	<.0001

APPENDEX Table 6.The GLM Procedures considering Ash

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	150.6443528	4.0714690	8.64	<.0001
Error	85	40.0773886	0.4714987		
Corrected Total	122	190.7217415			

R-Square	Coeff Var	Root MSE	Ash Mean
0.789865	7.181329	0.686658	9.561707

Ash

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	35.23756421	2.93646368	6.23	<.0001
Location	2	88.14457484	44.07228742	93.47	<.0001
Block	3	0.77340303	0.25780101	0.55	0.6517
Treatment*location	20	21.01449111	1.05072456	62.23	0.0059

APPENDEX Table7.**The GLM Procedures considering Metabolizable Energy (ME**

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	20.41002580	0.55162232	5.61	<.0001
Error	85	8.36427339	0.09840322		
Corrected Total	122	28.77429919			

R-Square	Coeff Var	Root MSE	ME Mean
0.709314	3.782507	0.313693	8.293252

ME

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	5.63224852	0.46935404	4.77	<.0001
Location	2	7.08373569	3.54186785	35.99	<.0001
Block	3	0.11417661	0.03805887	0.39	0.7628
Treatment*location	20	6.76685739	0.33834287	3.44	<.0001

APPENDEXTable 8.The GLM Procedures considering True *In Vitro* Organic Matter Digestibility (TIVOMD)

Dependent Variable:TIVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	586.808222	15.859682	3.07	<.0001
Error	85	438.580544	5.159771		
Corrected Total	122	1025.388766			

R-Square	Coeff Var	Root MSE	TIVOMD Mean
0.572279	4.013032	2.271513	56.60341

TIVOMD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	12	201.9728170	16.8310681	3.26	0.0007
Location	2	164.3577970	82.1788985	15.93	<.0001
Block	3	22.1892477	7.3964159	1.43	0.2387
Treatment*location	20	205.2538131	10.2626907	1.99	0.0158

APPENDEXTable 9.Analysisof variance for LMS.The GLM Procedures considering Crude Protein (CP)

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	167.9323933	5.5977464	5.19	<.0001
Error	69	74.3506507	1.0775457		
Corrected Total	99	242.2830440			

R-Square	Coeff Var	Root MSE	CP Mean
0.693125	11.10617	1.038049	9.346600

CP

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	118.3073581	9.1005660	8.45	<.0001

Location	1	32.8671146	32.8671146	30.50	<.0001
Block	3	1.2953493	0.4317831	0.40	0.7529
Treatment*location	13	16.0735957	1.2364304	1.15	0.3366

APPENDEXTable 10.Analysisof variance for LMS.The GLM procedures considering Crude Protein Yield(CPY)

Dependent Variable: CPY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	0.96257043	0.03208568	3.16	<.0001
Error	68	0.69103765	0.01016232		
Corrected Total	98	1.65360808			

R-Square	Coeff Var	Root MSE	CPY Mean
0.582103	29.50051	0.100808	0.341717

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatment	13	0.62252794	0.04788676	4.71	<.0001
location	1	0.12702994	0.12702994	12.50	0.0007
Block	3	0.02357901	0.00785967	0.77	0.5129
treatment*location	13	0.19859028	0.01527618	1.50	0.1390

APPENDEX Table 11. **The GLM Procedures considering NDF**

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	1751.463778	58.382126	6.88	<.0001
Error	69	585.214753	8.481373		
Corrected Total	99	2336.678531			

R-Square	Coeff Var	Root MSE	NDF Mean
0.749553	5.369119	2.912280	54.24130

NDF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	1066.752839	82.057911	9.68	<.0001
Location	1	308.814912	308.814912	36.41	<.0001
Block	3	69.906814	23.302271	2.75	0.0494
Treatment*location	13	242.084734	18.621903	2.20	0.0186

APPENDEXTable 12.The GLM Procedures considering ADF

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	1155.116468	38.503882	5.40	<.0001
Error	69	491.711916	7.126260		
Corrected Total	99	1646.828384			

R-Square	Coeff Var	Root MSE	ADF Mean
0.701419	6.563755	2.669506	40.67040

ADF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	664.9475727	51.1498133	7.18	<.0001
Location	1	227.7352032	227.7352032	31.96	<.0001
Block	3	49.5282258	16.5094086	2.32	0.0832
Treatment*location	13	195.9305953	15.0715843	2.11	0.0238

APPENDEXTable 13. The GLM Procedures considering ADL
Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	221.9389762	7.3979659	8.02	<.0001
Error	69	63.6469148	0.9224191		
Corrected Total	99	285.5858910			

R-Square	Coeff Var	Root MSE	ADL Mean
0.777136	8.930296	0.960426	10.75470

ADL

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	122.6042786	9.4310984	10.22	<.0001
Location	1	66.3035510	66.3035510	71.88	<.0001
Block	3	7.8948936	2.6316312	2.85	0.0435
Treatment*location	13	24.4121026	1.8778540	2.04	0.0301

APPENDEXTable 14.The GLM Procedures considering Ash

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	40.74914499	1.35830483	2.84	0.0002
Error	69	33.00227401	0.47829383		
Corrected Total	99	73.75141900			

R-Square	Coeff Var	Root MSE	Ash Mean
0.552520	8.161196	0.691588	8.474100

Ash

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	28.38345241	2.18334249	4.56	<.0001
Location	1	0.58194047	0.58194047	1.22	0.2738
Block	3	1.49175099	0.49725033	1.04	0.3806
Treatment*location	13	10.48503767	0.80654136	1.69	0.0836
Error	69	33.00227401	0.48		
Corrected total	99	73.75141900			

APPENDEXTable 15. The GLM Procedures considering ME

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	8.83261765	0.29442059	2.33	0.0020
Error	69	8.71193835	0.12625998		
Corrected Total	99	17.54455600			

R-Square	Coeff Var	Root MSE	ME Mean
0.503439	4.512825	0.355331	7.873800

ME

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	4.40174416	0.33859570	2.68	0.0042
Location	1	2.06740603	2.06740603	16.37	0.0001
Block	3	0.40815332	0.13605111	1.08	0.3644
Treatment*location	13	1.42062460	0.10927882	0.87	0.5916
Error	69	8.71193835	0.13		
Corrected total	99	73.75141900			

APPENDEXTable 16. The GLM Procedures considering TIVOMD
Dependent Variable: TIVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	348.4956597	11.6165220	2.03	0.0082
Error	69	395.5861243	5.7331322		
Corrected Total	99	744.0817840			

R-Square	Coeff Var	Root MSE	Invitro Mean
0.468357	4.421817	2.394396	54.14960

TIVOMD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	13	192.8603873	14.8354144	2.59	0.0056
Location	1	43.1445409	43.1445409	7.53	0.0077
Block	3	19.3354507	6.4451502	1.12	0.3454
Treatment*location	13	66.9607330	5.1508256	0.90	0.5586
Error	69	395.5861243	5.33		
Corrected total	99	744,081784			

7.2. AppendixTable II mean square tables

Appendix Table 1 mean square table for haulm chemical composition

		Mean squares						
S.O.V	DF	CP	NDF	ADF	ADL	Ash	ME	IVO
NVT PE								
Genotype	12	11.62***	143.72***	64.39***	3.36***	2.94***	0.47***	16.83**
Location	2	299***	325.34***	616***	115***	44***	3.54***	82.18**
Block	3	1.05ns	11.69ns	7.08ns	0.71ns	0.26ns	0.04ns	7.40ns
G * L	20	2.24**	30.35***	24.33***	3.14**	1.05**	0.34***	10.26*
Error	85	1.01	9.76	6.70	0.89	0.47	0.10	5.33
NVT LMS								
Genotype	13	9.10***	82.06***	51.15***	9.43**	2.18***	0.34**	14.84**
Location	1	32.87***	309***	228***	66.3***	0.58ns	2.07***	43.14**
Block	3	0.43ns	23.30*	16.51ns	2.63*	0.50ns	0.14ns	6.41ns
G * L	13	1.24ns	18.62*	15.07*	1.88*	0.81**	0.11ns	5.15ns
Error	69	1.08	8.48	7.13	0.92	0.48	0.13	5.33

Appendix Table 2.mean square table for haulm yield and grain yield of lentil.

Source of variations	DF	Means squares GYD	HLY
NVT PE			
Genotype	12	27.33***	6.62***
Location	2	0.36ns	115***
Block	3	0.51**	0.29ns
G*L interaction	20	0.20	3.90***
Error	83	0.45***	0.52
NVT LMS			
Genotype	13	0.12ns	1.15***
Location	1	0.07ns	9.73***
Block	3	0.09*	0.22ns
G*L interaction	13	0.04	0.32ns
Error	67		1.22

7.3.Appendix III Working Document

Lentil National Variety Trial for Potential Environment 2013/2014

A. Layout and Randomization

R-IV

64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49
9	8	4	14	10	5	16	3	12	1	2	11	13	15	6	7

R-III

33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
8	2	9	16	1	15	12	4	10	11	6	13	7	14	3	5

R-II

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
3	16	6	11	10	13	15	2	14	9	7	4	12	8	1	5

R-I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	16	2	1	7	11	1	12	15	8	9	14	10	5	3	13

15.60M

N.B 1. Number from 1-64 are plot numbers (the upper)
Number from 1-16 are treatment codes (the lower)

A. Variety

1. Dz-2012-Ln-0015
2. Dz-2012-Ln-0016
3. Dz-2012-Ln-0017
4. Dz-2012-Ln-0018
5. Dz-2012-Ln-0019
6. Dz-2012-Ln-0020
7. Dz-2012-Ln-0021
8. Dz-2012-Ln-0022
9. Dz-2012-Ln-0023
10. Dz-2012-Ln-0024
11. Dz-2012-Ln-0025
12. Dz-2012-Ln-0026
13. Dz-2012-Ln-0027
14. Alemaya (Std)
15. Derash (Std)
16. Local check

Lentil National Variety Trial for Low Moisture Stress 2013/2014

A. Layout and Randomization

R-IV

68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52
15	9	2	16	14	11	10	5	8	7	3	12	4	6	17	1	13

R-III

35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
8	16	1	2	11	17	1	9	15	12	10	13	3	14	4	5	6

R.II

34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18
17	5	11	10	13	16	1	15	8	6	4	9	3	12	7	2	14

R-I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
7	16	17	6	1	11	4	13	2	12	15	14	5	8	3	9	10

16.60m → ←

N.B. Numbers from 1-68 are plot numbers (the upper)
Numbers from 1-17 are treatment codes (the lower)

B. Variety

1. Dz-2012-Ln-0001
2. Dz-2012-Ln-0002
3. Dz-2012-Ln-0003
4. Dz-2012-Ln-0004
5. Dz-2012-Ln-0005
6. Dz-2012-Ln-0006
7. Dz-2012-Ln-0007
8. Dz-2012-Ln-0008
9. Dz-2012-Ln-0009
10. Dz-2012-Ln-0010
11. Dz-2012-Ln-0011
12. Dz-2012-Ln-0012
13. Dz-2012-Ln-0013
14. Dz-2012-Ln-0014
15. Alem tena (Std)
16. Chekol(Std)
17. Local check