VARIABILITY IN FOOD-FEED TRAITS IN CHICKPEA (*Cicer arietinum*) VARIETIES

MSc THESIS

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VARIABILITY IN FOOD-FEED TRAITS IN CHICKPEA (*Cicer arietinum*) VARIETIES

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As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by Tena Alemu.

Entitled: Variability in Food-Feed Traits in Chickpea (*Cicer arietinum*) Varieties and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Animal and Range Sciences (Specialization: Animal Production).

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I hereby certify that I have read this thesis prepared under my direction and recommend that it accepted as fulfilling the thesis requirement.

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DEDICATION

I dedicate this thesis manuscript to my mother DINKINESH MAMO, my brother ZENEBE ALEMU, and my wife GENET SHILEGA for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my genuine work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillments of the requirement for MSc degree at Hawassa University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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ABBREVIATIONS

AAFC	Agriculture and Agri-Food Canada
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CP	Crude Protein
CR	Crop Residue
CSA	Central Statistical Authority
CV	Coefficient of Variation
DDMHYLD	Digestible Dry Matter Haulm Yield
DOM	Digestible Organic Matter
DM	Dry Matter
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
GLM	General Linear Model
GE	Gross Energy
GYLD	Grain Yield
HYLD	Haulm Yield
IBC	Institute of Biodiversity Conservation
ICARDA	International Center for Agricultural Research in Dry areas
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFFRI	International Food Policy Research Institute
IGAD	Inter-Governmental Authority on Development
IVDMD	In vitro Dry Matter Digestibility
IVOMD	In vitro Organic Matter Digestibility
ILRI	International Livestock Research Institute
KLMS	Kabuli for Low Moisture Stress
KPE	Kabuli for Potential Environment
Mg	Magnesium
ME	Metabolisable Energy
MJ	Mega Joule
Mn	Manganese
MOA	Ministry of Agriculture
MT	Metric Tone
N	Nitrogen
NDF	Neutral Detergent Fiber

NFE	Nitrogen Free Extracts
NIRS	Near Infrared Reflectance Spectroscopy
OM	Organic Matter
P	Phosphorus
PLS	Partial List Square
PUI	Potential Utility Index
RCBD	Randomized Complete Block Design
RDA	Recommended Dietary Allowance
RPD	Ratio Performance Deviation
SAS	Statistical Analysis System
SEC	Standard Errors of Calibration
SECV	Standard Errors of Cross-Validation
SEP	Standard Error of Prediction
USA	United States of America
Zn	Zinc

BIOGRAPHICAL SKETCH

The authoress, **Tena Alemu Yindo**, was born in Southern Nation, Nationalities and Peoples' Regional States (SNNPRS), Guragae zone, Cheha woreda, Emdiber town, Anzanzbat kebele in 1984 G.C. and attended his elementary school in Dibreatye (grade 1^{st}-6^{th}) from 1990-1996 G.C. and grade 7^{th}-8^{th} from 1997-1998 G.C. in Emdibir elementary school, and secondary school education (grade 9^{th}-12^{th}) from 1999-2002 G.C. in Emdibir Secondary School. After completion of his high school education, he joined the then Haromaya University in 2003 and graduated with Bachelor of Science degree in Animal Production and Health in 2006.

Soon after graduation, the author was employed by Ministry of Agriculture in Southern Nation, Nationalities and Peoples Regional States (SNNPRS), Gurage zone, Cheha Woreda and assigned as an Animal & Animal Productions and Marketing study expert. Later, he was worked in the different levels of position up to now. In October 2013 academic year, the author joined the School of Graduate Studies of the then Hawassa University to pursue MSc studies in Animal and Range Sciences with specialization Animal Production. I was done MSC thesis on Variability in Food-Feed Traits in Chickpea Varieties.

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LIST OF TABLES

LIST OF FIGURES

Variability in Food-Feed Traits in Chickpea (*Cicer arietinum*) Varieties

ABSTRACT

The study was conducted with the objectives of analyzing and developing Near Infrared Reflectance Spectroscopy (NIRS) equation for predicting nutritional value and mineral constituents of chickpea haulm, and to determine the relationship between fodder quality and agronomic traits of chickpea. The samples were collected from Akaki, Alem Tena, Chefe Donsa, Debre-zeit 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. A total of 105 tested and 8 control genotypes with 1348 samples of chickpea haulms from preliminary and national variety trials were used for NIRS prediction. Calibration models were developed between chemical and NIRS spectral data. Randomized Complete Block Design with 4 replications was used in the experiment. The plot size was 4m x 1.2m (4rows/plot), 30cm between rows and about 10cm between plants spacing was used. All management activities were done. *Statistical analysis of the data was carried out using the General Linear Model (GLM) procedure of SAS (Statistical Analysis System) used for analyzing the data with samples of 597 chickpea haulms from national variety trials. The model developed by NIRS for the prediction of chickpea haulm Crude Protein (CP), ME (Metabolizable Energy), TIVOMD(True In Vitro Organic Matter Digestibility) values and fiber fractions were accurate and successful method. The coefficients of determination for Calibration (r^2c), validation (r^2v) and Ratio Performance Deviation (RPD) of chemical constituents were within the range of 0.97-0.99, 0.96-0.99 and 3.61-26, respectively. The r^2c, r^2v and RPD for minerals were between the range of 0.71-0.99, 0.68-0.92 and 1.58-3.55, respectively. Higher CP value was recorded in kabuli and desi type chickpea at Debre zeit, Alem Tena and Minjar locations. Dz2012ck0084 and dz2012ck0018 had higher ($P<0.05$) CP, ME, TIVOMD and lower in fiber fractions for moisture stress area. On the other hand, dz2012ck0036 had higher grain yield. The CP content of the haulm was significantly ($p<0.001$) higher and negatively correlated with days to 90% maturity (DTM), grain yield (GYLD), biomass (BM) and haulm yield (HYLD). Moreover, the ME and TIVOMD were negatively correlated to all agronomic traits, except hundred seed weight (HSW). The highest correlation coefficient with strong associations ($p<0.001$) were observed for BM with HYLD ($r=0.90$), BM with GYLD ($r=0.82$), GYLD with HYLD ($r= 0.51$) and DTF with DTM ($r= 0.63$). Grain yield was positively and significant ($p<0.001$) correlated with DTM and BM and also significantly ($p<0.001$) and negatively correlated with HSW. Genotypes which combined moderately high grain and haulm yield, better haulm quality traits and ultimately medium potential utility index were Dz2012ck000024, Ejere, Chefe and Dz2012ck0017 from kabuli for moisture stress area, Dz2012ck0007, Dz2012ck0001, Dz2012ck0012, Arerti and Dz2012ck0004 from kabuli for potential environment, Dz2012ck0036, Dz2012ck0031 and Dz2012ck0029 and Natoli from desi type chickpea. Generally, the present showed the possibility for simultaneous improvement of high grain and haulm yield with desirable haulm quality traits to address the high demand existing for dual purpose food-feed traits of chickpea genotypes in mixed-livestock system of Ethiopia.*

Keywords: Calibration equations, chemical composition, chickpea haulms, genotypes, mineral, multi-location, NIRS, nutritional quality.

1. INTRODUCTION

Ethiopia is an agrarian country endowed with diverse agro-ecological zones suitable for production of diverse crop and livestock species (Tolera *et al*., 2012; Solomon *et al*., 2010 and IBC, 2012). The country has the largest livestock population in Africa. The livestock sector significantly contributes to the national economy of the country, and still promising to rally round the economic development of the country (CSA, 2013; Solomon *et al*., 2003; Tilahun and Schmidt, 2012). The sector plays vital roles in generating income to farmers, creating job opportunities, ensuring food security, providing services, contributing to asset, social, cultural and environmental values, and sustain livelihoods. It also contributes 15% of export earnings and 30% of agricultural employment (Behnke, 2010). The livestock currently support and sustain livelihoods for 80% of all rural population (Metaferia *et al*., 2011). The contribution of the livestock to the overall agricultural Gross Domestic Product (GDP) in Ethiopia is 47% (IGAD, 2010).

Regardless of the large livestock population, existing favourable environmental conditions and significant importance of livestock in the country, the productivity and economic contribution of the sector is much below the potential (Tolera, 2008). This is associated with a number of inter-related factors such as inadequate feed and nutrition, in adequate veterinary services, widespread diseases, poor health and breeding practices, inefficiency of livestock development services with respect to credit, extension, marketing, and infrastructure (Benin *et al*., 2003; Jabbar *et al*., 2007; Negassa *et al*., 2011; Solomon *et al.*, 2003; Yirga and Hassen, 2000). Tolera *et al*. (2012) further showed that shortage of feed in terms of quantity and quality is the main technical constraint hindering the full exploitation of the potential of the livestock resources of the country. The rising feed cost is also an important factor threatening productivity of the livestock sector in Ethiopia (Beyene, 2009; FAO, 2010; Gebremedhin *et al*., 2009, Hussein *et al*., 2008). Moreover, the poor feed quality and its inadequate supply is leading to poor nutrition, which is manifested in slow growth rate, poor production and reproduction performance, and increased susceptibility to diseases (Tolera and Sundstøl, 2000; Bediye *et al*., 2007). As described by Lenne *et al*., (2003), to fulfill needs of home now and in the future depends the production of dual-purpose crops that supply both food (grain) for human consumption and feed (residues) for feeding livestock seems to be a more plausible choice.

In mixed crop-livestock systems, livestock feed supply is mainly dependent on natural pastures, crop residues, aftermath grazing and other agricultural by-products. These feed resources could not fulfill the nutritional requirement of animals particularly in the dry season. According to CSA (2011), Ethiopian grasslands account for over 30% of the land cover and constitute to 66% of feed resources for livestock. However, the contribution of natural pastures to livestock feed is decreasing from time to time as most of the available land is cultivated for crop production due to increasing population pressure. The quantity and quality of the available forage is low during the dry season. On the other hand, Cereal straws and grain legume haulms are becoming important sources of roughage feeds during the dry season (Tolera, *et al*., 2012; Bogale *et al*., 2008; Alemu and Chairatanayuth, 2007). Based on the CSA (2014/2015) data, Ethiopia pulses crops covered 12.41% (1.56 million hectares) of the grain crop area and 9.88% (about 2.67 million tons) of the grain production was drawn from the same crops. Chickpea was planted to 1.91% (about 0.239 million hectares) of the grain crop area and the production obtained from this was 1.70% (0.458 million tons) of the grain production. As cited by Tolera (2007), the conversion factors used for estimation of the amount of crop residues or fibrous by-products produced from pulse crops stover is 1.2 (Kossila, 1984 and FAO, 1987). Therefore, the total amount of crop residues obtained at harvesting from pulse crops are 3.2 million tones and from this chickpea contributes about 0.55 million tones of residues (CSA, 2014/2015). The straws of cereals and pulses are the main crop residues used for animal feeding. However, the actual quantities of crop residues available for livestock feeding is reduced by the cost of collection, transport, storage and processing, seasonal availability, other alternative uses and wastage (Tolera *et al*., 2012). Crop residue contributes about 40.8 to 54.6% as the main feed resource in low, medium and high altitude of Ethiopia (Hassen *et al*., 2010).

The fodder quality of crop residues is generally low and characterized by low voluntary intake and poor digestibility. Efforts made to upgrade their feeding value through physical, chemical, and biological treatments of straw have seen little adoption by Ethiopian smallholder farmers, which could be due to limitations in skill, cost, labour and material input requirements (Alemu and Chairatanayuth, 2007; Blummel *et al*., 2010).

Although crop residues make a substantial contribution as sources of livestock feed in mixed crop-livestock production systems of Ethiopia, the different crop improvement programs like fertilizer applications, variety selection, etc. were focused on grain production only with no consideration of the yield and nutritive value of the crop residues. Therefore, assessments on improvement of crop residues through collaboration of crop and livestock scientists in multidimensional crop and feed improvement initiatives are necessary. In this attempt, International Center for Agricultural Research in Dry Areas (ICARDA) has initiated multidisciplinary research together with its Ethiopian National partners to produce grain legume cultivars that better cope with the interest of farmers particularly in mixed crop-livestock systems that prevail in many parts of Ethiopia. With the increasing in crop coverage and production with increasing crop residues production such studies to maximize crop residues utilization is very essential. Therefore, this topic is very important. The main problems to initiate this study were the quality of crop residue is low and they need to analyze quality in relation to variety differences to maximize food-feed crop, variability of cultivars in terms of yield and quality is not well known in Ethiopia, variation in yield and quality affected by agronomic practice like soil type, location and related practices.

Chickpea is a cool season food legume and grown as a winter crop in the tropics and as a summer or spring crop in the temperate environments, adapted to deep black soils in the cool semi-arid areas of the tropics, sub-tropics as well as the temperate areas. Chickpea is the 4th largest grain-legume crop in the world, with a total production of 11.6 million tons from an area of 12.3 million ha and productivity of 0.94 tons per ha (FAO STAT, 2012). During 2006-09, the global chickpea production area was about 11.3 million ha, with production of 9.6 million metric tons (MT) and average yield of 849 kg per ha (FAOSTAT, 2011).

Chickpea straw has been reported to have higher nutritive value than cereal straws (Lopez *et al*., 2004; Lopez *et al*., 2005; Bampidis *et al*., 2011) but lower than that of other legume straws (Bruno-Soares *et al*., 2000; Lopez *et al*., 2005). Even though different scholars studied the nutritive value of chickpea straw/haulms; there is no detailed information on the straw/haulms quality of different chickpea varieties in Ethiopia. This study was thus attempt to bridge the gap. As the food-feed traits of chickpea crop of the country has not been exhaustively studied and based on high quality and yield of fodder for livestock and primary food traits, identifying existing genotypes which have these dual purpose traits would be a positive steps towards addressing food and feed gaps in the mixed crop-livestock systems to improve overall productivity and income of Ethiopian smallholder farmers.

Techniques of feed evaluation has been modified and refined since the mid 1980s when Weende method was proposed. Since then various chemical, biological and physical methods have been proposed and applied for feed resource characterization. Near infrared spectroscopy (NIRS) is one of the recent techniques being applied for the nutritional characteristics of animal feeds. The NIRS region is the wavelength range between 12000-4000 cm-1 in the electromagnetic spectrum. When a sample is analyzed, the radiant energy is absorbed selectively according to the specific vibration of the molecules presents, which produces an overtone in the spectrum (Conzen, 2006). The technique is, thus far, noted to be one of the robust applications to estimate chemical entity and parameters like *in-vitro* organic matter digestibility and metabolizable energy. Unlike most conventional analytical methods, NIRS technique is rapid, low-cost, and nondestructive to the crop sample. NIRS requires very little sample preparation and no chemicals, is reliable and accurate (Foss, 2008), allows a larger range of samples to be tested, and can be used to analyze multiple properties at one time (Stuth *et. al*., 2003; Eldin, 2011).

NIRS uses the near-infrared absorbance of a sample to measure organic functional groups and quantitatively predict a particular factor. The predictive accuracy of NIRS in general relies heavily upon obtaining a calibration set which represents the variation in the main population, accurate laboratory analyses and the application of the best mathematical procedures (Park *et al*., 1998). Although the reliability of NIRS has been investigated well for temperate feeds little work has been done for tropical feeds. Moreover, the variation in ecological set up, the biological diversity in feed resources in the country requires quite robust and cost effective method for characterization. This research result meant to fill these gaps with objectives:

- To study the diversity of the varieties in terms of grain, biomass and quality and identify the most appropriate variety for food-feed.
- To study the nutritive value and mineral composition of chickpea haulms of different varieties collected from five locations
- To develop and validate prediction equation for determining the nutritional value of chickpea haulms using Near Infrared Reflectance Spectroscopy (NIRS).
- To determine the relationship between haulm quality traits with primary food traits of chickpea.

2. LITERATURE REVIEW

2.1. Introduction

Food-feed crops are multi-purpose crops their pods (grain) provide food for humans, whereas the haulms, straws and stovers are used for livestock feed. They are used for smallholder farmers in the mixed crop-livestock systems to extenuate feed shortage and providing a balanced diet for human beings (Nigam and Blümmel, 2010). Adoption of new cultivars by smallholder farmers can be affected both grain yield and the quality and quantity of crop residues as livestock feed, since grain and crop residues of various cereal and pulse crops are contributing to the livelihoods of farmers. So, it is better to understand the factors which are affecting as well as bettering grain and crop residue yield and quality synergistically (Tolera *et al*., 1999: Blummel *et al*., 2010).

According to Blummel *et al.* (2010) indicated in his results, there was a positive correlation among stover crude protein, *in vitro* digestibility and stover yields in sorghum crop. But, stover crude protein content and in vitro digestibility were not strongly associated with grain yields. On the other hand, Tolera *et al*. (1999) showed 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. However, there was a positive correlation between the NDF content of the straw, 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. Tolera *et al.* (1999) in his experiments showed that, there was a positive correlation between harvest indexes, grain yield but negatively correlated with cob, stover, total crop residue and total biomass.

2.2. Crop Residues

Crop residues (CRs) are the fibrous remnants or by-products produced after crop harvest or primary processing which result from the cultivation of cereals (e.g. tef, wheat, barley, maize, sorghum etc.), pulses or grain legume haulms (e.g. haricot beans, field peas, chickpeas, lentils, groundnut etc.)., oil plants, roots and tubers and they are widely used in animal feeding resource next to grazing (CSA, 2003). Crop residues are fibrous and high in lignin content, which limit the feeding value (McDonald *et al.*, 2002; Tolera, 2009). The crude protein content is insufficient to fulfil even the maintenance requirement of animals (Van Soest, 1994; Rehrahe and Ledin 2004). Ruminant animals have the ability to utilize crop residues and can substitute roughages in rations by reducing the competition between monogastric animals and human beings on cereals (Atuhaire *et al*., 2014). Thus, 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). Tolera *et al*. (2012) reported that crop residues contribute to about 50% the total feed supply in Ethiopia. Crop residues are becoming increasingly important as sources of roughage in feedlots. However, the principal crop residues used for animal feeding are the straws of cereals and pulses. The most important components of the crop residues are the leaves and stems that remain after the grain is harvested (Tolera, 2008).

Crop residues are the most important available feed resources that are used by smallholder farmers in Ethiopia during feed scarcity (Mengistu A., 2006; Solomon *et al*., 2008; Tesfaye and Chairatanayuth, 2007). They may be left in the field as grazing for livestock and / or as mulch, or transported to the homestead for stall feeding. Both the quantity and quality of crop residues used in Ethiopia varies according to agro-ecological distribution, the crop species, extent of processing and post harvesting or processing treatment, and the scope of arable land availability. The yield and quality of crop residues are significant as criteria for farmers' evaluation of varieties. In Ethiopia, the annual production of crop residues has increased from year to year due to the expansion of cultivated land and increased crop productivity (CSA, 2008). As reported by Alemu and Chairatanayuth (2007), more than 90% of farmers had the pattern of collection and storage 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.

2.2.1. Chemical composition and feeding value of crop residues

The significance of crop residues on livestock production has got critical economic, social and environmental benefits by saving grain feeding for animals and encourages the return of the residues to farmland as manure rather than direct application. It also spares chemical fertilizers and decrease costs of grain production (Alemu, 2006). Unfortunately, a much lower level of utilization is possible because of problems of collection, transportation, storage and processing, alternative uses, seasonal availability, and perhaps most importantly, an apparently poor nutritional value. So, most crop residues are deficient in protein, essential minerals like sodium, phosphorus and calcium, and are rather fibrous (40-45% crude fiber). Due to this problem, it leads to low feed intake, poor digestibility, and a low level of performance. Crop residues 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). Low intakes and poor digestibility result specifically from high cell wall lignin content, and the chemical bonding between this fraction and potentially nutritious cell wall constituents such as cellulose and hemicelluloses. According to Reddy et al., (2003), the yields and quality of crop residue varies depending on genotype, environment and management factors and also both the quality and quantity of crop residues used in Ethiopia differs according to agro-ecological distribution and the range of arable land availability (Tesfaye, 2010).

Crop residues are potentially rich sources of energy because about 80% of their DM consists of polysaccharide which usually underutilized especially cereal straws and stovers due to lignocelluloses structure of their cell wall which is low in digestible energy of less than 7.0MJ/kg DM and low crude protein(less than 60 g/kg DM), high lignin and have deficiency in essential nutrients for growth of rumen microorganisms for maintenance, optimum growth, and production of livestock (FAO, 2002). Therefore, feeding of stovers and straws to ruminants, their intake, digestibility and utilization are low, leading to low level of performance. Nevertheless, leguminous crop residues are usually better and may be used as complementary forages if copious amount collected (Abubakar *et al*., 2003).

The nutritive value of crop residues is variable greatly depending on the crop species and variety of the crops, time of harvest, handling and storage conditions and other factors. According to Qingxiang (2002), nutritive value is generally determined by feed composition, intake and utilization efficiency of digested dry matter. The haulms of pulse crops represent medium quality roughage with a CP 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. DM digestibility and rumen degradability of the legume straws were on average 10 and 42% respectively and higher than the cereal straws (Haddad *et al*., 2001).

Legume straws also have higher contents of pectins than grasses, and these carbohydrates are important components of the intracellular spaces and degraded extensively by rumen micro-organisms. Cereals usually give high straw yields but are of inferior quality that is characterized by relatively low nutrient content, high fiber content, low digestibility and low voluntary intake (limited consumption) by animals but, legume residues have better nutritive quality but low yield that is used as livestock feed. Legume straws contain less fiber, high digestible protein than cereal straws (Tesfaye, 1999; Solomon, 2004 and Tolera, 2007).

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2.2.2. Factors which limit feeding value of crop residues

There are different factors which may influence the feeding value of crop residues among them plant; animal factors, biological factors and environmental factors. Plant factors like, species, stage of maturity at harvest, cultivar, and proportions of leaf, sheath and stem would influence nutritive value of crop residue (Agbagla *et al*., 2001; Qingxiang, 2002) and also factors known to affect the composition and digestibility of straw are variety and cultivar (Mould *et al.*, 2001; Kafilzadeh & Maleki, 2011). Animal factors include species/genotype, live weight, age, body condition, type and level of production and disease. Biological factors (genetic makeup of the crop) also influence on yield and quality of crop residues. Besides this, growing and harvesting condition, and threshing and storage methods also their limitations. The efficiency of utilization of crop residues with animal body is different among various breeds and types of animals. Crop residues could be influenced by environmental factors, including location, climate, soil fertility and soil type (Qingxiang, 2002) and seasonal effects (Mathison *et al*., 1999).

The nutritive value of residues from a given variety varies widely due to differences in growing conditions (season, elevation or latitude). High humidity and rain during and after grain harvest reduce nutritive value. Loss of leaves through wind or trampling of crop residues left in the field also causes deterioration (Tolera, 2007). In general, quantity and quality of the crop, varietal and environmental effects are the most important factors for the feeding values of crop residues.

2.3. Utilization of Food Legumes as Feed

Food legumes are grain legumes or pulses, and are species of the plant family Leguminosae also called Fabacae that are consumed directly by human. They are mainly grown for their edible seeds, and thus are also named grain legumes. Food legumes are a valuable source of feed for livestock. The whole seed of most legumes is a rich source of energy and amino acids. For the oilseed legumes, peanuts and soybeans, the meal are a by-product of oil extraction and are used as a protein concentrate. There is also considerable potential to use the residues left after harvesting the seeds as sources of fodder for livestock. Food legumes cover about 10% of the area under crop production in Ethiopia and contribute to nearly 13% of total annual crops production (CSA, 2004). Chickpea is widely cultivated, particularly in the central and northern parts of the country. Rashid *et al*., (2010) showed that around 13 percent of cropped land of Ethiopia is grown food legumes which are concentrated in the Amhara and Oromiya regions.

In Ethiopia pulse crop species are grown in both cooler and warmer environments. Those grown in cooler environments of the country are faba bean; field pea, chickpea, lentil, grass pea; fenugreek and lupine are categorized as highland pulses and grown in the cooler highlands. Besides this, other pulse crops grown in warmer environments are haricot bean, soya bean, cowpea, pigeon pea, and mung beans. These are predominantly grown in the warmer and low land parts of the country and account for the resting 32 percent (Yirga *et al*., 2010). 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, 2.3 million tons pulse haulms provided as livestock feed (Biruk, 2014). According to Lopez *et al*. (2005), legumes straws have better nutritional quality than cereal straws but they are more lignified due to higher nitrogen contents, greater voluntary intake and faster ruminal degradation. For ruminants, legumes appear to have an advantage relative to cereals in that they cause little disruption to the micro-flora of the rumen when introduced in high quantities. The crude protein content of food legumes straws is higher than cereal straws but less than that of hays, feed grains and many by-products. The phosphorus content, in common with cereal straws and hays, is low and would not meet animal requirements if provided as the sole feed. Food legumes contain relatively low levels of starch and high levels of fibre compared to cereals.

2.3.1. Chickpea Crop and its Importance

Chickpea is a less labor-intensive crop and its production demands low external inputs compared to cereals. Chickpea is an important crop in mixed crop-livestock systems in Ethiopia. It is cultivated as a food-feed crop, where the pods provide food for humans and the fodder for the livestock. In these mixed crop-livestock systems, fodder shortage is commonly a serious constraint to get higher benefit from livestock (Rangnekar, 2006).

In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop (Shiferaw *et al*., 2007a). First, it fixes atmospheric nitrogen in soils and thus improves soil fertility and saves fertilizer costs in subsequent crops. Second, it improves more intensive and productive use of land, particularly in areas where land is scarce and the crop can be grown as a second crop using residual moisture. Third, it reduces malnutrition and improves human health especially for the poor who cannot afford livestock products. Fourth, the growing demand in both the domestic and export markets provides a source of cash for smallholder producers. Fifth, it increases livestock productivity as the residue is rich in digestible crude protein content compared to cereals. Chickpea is cholesterol free and a good source of high quality protein, carbohydrates, together constituting about 80% of the total dry seed mass (Chibbar *et al*., 2010). In comparison to other pulses and it is a good source of protein, vitamins (thiamine and niacin), and minerals such as calcium, phosphorous, iron, magnesium, and potassium (AAFC, 2006; Güler *et al*., 2001; Pekşen & Artık, 2005; Wood *et al*., 2007 and Muhammad, 2007).

According to Dadi *et al*. (2005), chickpea (*Cicer arietinum*) is one of the most important food legumes in Ethiopia contributing to about 17% of the countries' total pulse production. Ethiopia is the largest chickpea growing country in Africa, with a contribution of about 37% in area and 48% in production (FAO STAT, 2008) and also more than 1 million rural Ethiopian households cultivate chickpea. Chickpea, locally known as "shimbra", is one of the major pulse crops (including faba bean, field pea, haricot bean, lentil and grass pea) in Ethiopia and in terms of production it is the second most important legume crop after faba beans. Although chickpea is widely grown in Ethiopia, the major producing areas are concentrated in the two regional states - Amhara and Oromia. These two regions cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production (IFPRI, 2010).

Chickpea is a multipurpose cool-season grain legume that may withstand hot temperatures during fruiting and ripening (Ecoport, 2013) and notably as a source of protein (Bejiga *et al*., 2006). Chickpea provides a high quality and cheapest sources of protein, mainly, to the people in developing countries and it can be eaten raw, roasted or boiled. It can also be processed into flour or dehulled grain (dal) and also play a key role to alleviate protein-energy malnutrition (Manjunatha, 2007). Even though chickpea is produced worldwide particularly India, Australia, Pakistan, Turkey, Myanmar, Ethiopia, Iran, USA and Canada are the main producers (FAO, 2013; ICRISAT, 2013), but the international trade of chickpea is relatively limited that is only 10% of total production (FAO, 2013).

The demand for chickpea has increased over the last few years, due to its notable nutritional value (Jukanti *et al*, 2012). Additional health benefits include low allergenic properties and high *s* protein digestibility (Shad *et al*., 2009). Several by-products of chickpea cultivation and processing are used for animal feeding, including low-grade and culled chickpea grains, bran, straw (Taylor *et al*., 2007; Bejiga *et al*., 2006). Chickpea is a N-fixing legume (up to 100 kg N/ha) often used to restore soil fertility before cereal or oilseed crops. It is used as disease cycle breaker and helps to reduce pesticides and herbicides (Ecoport, 2013). The straw and dried roots of chickpea are used as fuel for cooking. Chickpeas are low in fat and most of this is polyunsaturated and also contain a variety of secondary compounds that can impair nutrient absorption from the gastrointestinal tract (Bampidis *et al*., 2011). FAO data (2007) revealed that chickpea is the fourth largest foreign currency earning crop of Ethiopia with a total revenue of USD 25,177 thousand following coffee, sesame and haricot bean.

There are two main types of chickpea (kabuli and desi types), distinguished by seed size, shape, color and there are about 20 different chickpea varieties released in Ethiopia; at the federal agricultural research centers (16 varieties) and at regional agricultural research centers (4 varieties). The one produces relatively small seeds with an angular shape, the common seed colors include various shades and combinations of brown, yellow, green and black called desi, the other produces large, rounded, and characterized by white, cream color seeds or beige-colored seed with ram's head shape, thin seed coat, smooth seed surface, white flowers, and is called kabuli. Kabuli chickpea seeds are grown in temperate regions, whereas the desi type is grown in the semi-arid tropics (Naghavi and Jahansouz, 2005; Iqbal *et al*., 2006a). Several new Desi and Kabuli type chickpea varieties have been developed through collaborative research programs involving ICRISAT and ICARDA (Shiferaw *et al*., 2007b). Seed size is an important trait for trade and component of yield and adaptation in chickpea (Upadhyaya *et al*., 2006).

2.3.2. Agro-ecological distribution of chickpea crop and its production in Ethiopia

Chickpea is the third most important crop in volume of production after faba bean and haricot bean, in Ethiopia (CSA, 2010). Chickpea is mostly consumed as a seed food in several different forms and consumed in roasted, boiled, salted and fermented forms. The diverse biophysical and agro-climatic conditions in Ethiopia make it very suitable for growing a number of pulses and legume crops. Chickpea is one of the most important pulses grown widely across the highlands and semi-arid regions of the country (Dadi *et al*., 2005).

Ethiopia has suitable agro-climatic conditions for production of both desi and kabuli type chickpeas. The crop is highly integrated into the farming system and ecologically friendly for growing in many areas that suffer from soil nutrient depletion. Chickpea can be grown as sole crop or in rotation with flax, sorghum, tef (*Eragrostis tef*); pearl millet (*Pennisetum glaucum*), wheat or other crops (Bejiga *et al*., 2006). The crop is widely grown in different volumes across the country. National average yield of chickpea in Ethiopia is 1.33 tones ha-1 (CSA, 2010), which is far below the potential yield of 4.5 tones ha-1. Chickpea productivity usually average 400-600 kg/ha, but can surpass 2,000 kg/ha, and in experiments have attained 5,200 kg/ha and yields from irrigated crops are 20-28% higher than yields from rain fed crops.

Chickpea grows from sea level to up to 2500 m in areas where temperatures ranges from 15°C to 29°. The plant is well adapted to tropical climates with moderate temperatures and is successfully cultivated under irrigation in the cool season of many tropical countries, i.e., it can grow in places where annual rainfall ranges from 500-1800 mm (Bejiga *et al*., 2006). It can benefit from spring rains provided that the soil is well drained. Well-aerated sandy to sandy loam soils and black cotton soils with pH ranging from 5-7 or even higher are suitable but salinity and sodicity should be avoided (Ecoport, 2013). It is tolerant of drought but does not stand humid and hot lowland tropics. It likes cool, dry and bright weather. Temperature, day length and availability of moisture are the three major abiotic factors affecting flowering. In general, flowering is delayed under low temperatures and also under short-days. Chickpea is sensitive to high (maximum daily temperature >35°C) as well as low (mean of maximum and minimum daily temperatures <15°C) temperatures at the reproductive stage. Both extremes of temperatures lead to flower drop and reduced pod set.

2.3.3. Yield and yield components in chickpea

According to Tsigie *et al*. (2011), there is a possibility to estimate the amount of crop residue to be produced based on the production of crops because; crop residue yield is a function of biomass production and translocation. Crop biomass production can be calculated by the biophysical environment and the genetic makeup of the crop. Yield components like days to 50% flowering, days to 90% maturity, grain yield, biomass, haulm yield, 100 grain weight, pods per plant, plant height, and harvest index are very important and they are different across various environments. According to Matrne and Siddique, (2009) flowering time determines length of vegetative phases or sowing to flowering and also climatic conditions that the crop will be exposed during reproductive growth. Hundred grain weights, pods per plant, plant height, and harvest index are important indicators in seed yield. Mostly, grain yield in pulse influence by number of pods and number of seed in pod.

Ndakidemi and Dakora (2007) reported a reduction in cowpea number of pods per plant under intercropping, compared to sole cropping. Because of positive correlated yield with number of pods, it seems that decreasing of number of pods causes yield reduction; due to enhancing inter-specific competitive between crops for utilization of available resource in intercropping. Arshad *et al.* (2004) reported that seed yield per plant was positive and significantly correlated with plant height, pods per plant, 100 seed weight and biological yield.

Kayan and Sait Adak, (2012) concluded that plant height, biological yield per plant and pods per plant are the most important yield variables to be considered in chickpea. Thus, high yield of chickpea plants can possibly be obtained by selecting breeding materials with high plant height, biological yield per plant and pods per plant. Lesoing and Francis (1999) also reported a direct relationship between 100-grain weight and number of pods with yield. The grain yield per plant exhibited a significant positive correlation with grain yield and the number of pods. Yield and its components are multigenic traits, which are strongly influenced by the environment and other factors both known and yet to be identified (Yücel *et al*., 2006).

Rahimi Azar *et al*. (2013) indicated in his results of the simple correlation between grain yield and yield components of chickpea is showed that the grain yield exhibited a significant positive correlation with the number of pods. Seed size did not affect yield components, but differences among varieties for only plant height, first pod height and 100 seed weight were significant. For chickpea, effect of seed size on yield and 100 seed weight was significant; large seeded chickpea produced more seed yield and larger seed (Tuba Biçer, 2009).

2.3.4. Chickpea haulm as livestock feed

Chickpea straw is the main by-product produced after chickpea grain threshing which is usually equal to or more than the seed yield. Significant difference was observed in the yield of straw [from 1041 to 1174 kg dry matter /ha] from different varieties; the proportion of seed/straw from different varieties varied from 0.61 to 0.93(Kafilzadeh and Maleki, 2011). Chickpea haulm can be used as a ruminant feed (Bampidis *et al*., 2011) and it contains higher nutritive value than cereal straws (44-46% TDN and 4.5-6.5% CP) and more palatability than wheat straw, but it is suggested that animals should be allowed to acclimate to the taste before offering large quantities (Lardy and Anderson, 2009; Ei bordeny *et al*., 2010 and Kafilzadeh and Maleki, 2011).

Chickpea haulm contains slightly more protein than a cereal straw (about 5% DM) and also more metabolizable energy concentrations but remains fibrous forage (30-40% DM of crude fiber). Pod husks have a similar composition, perhaps more fibrous. Dry matter digestibility and rumen degradability of chickpea straw were about 10 to 42% higher than those of the cereal straws, respectively (Kafilzadeh and Maleki, 2011). Bampidis and Christodoulou (2011) reviewed that digestible energy and metabolizable energy content of chickpea straw were 8.3 and 7.7 MJ/Kg DM, respectively. Besides this, chickpea pod husks contain a large ruminally degradable DM fraction, above 94% (Ngwe *et al*., 2012). In 6-8 month old lambs and wethers, chickpea pod husks included at 10 to 20% of the diet (DM basis) replacing deoiled rice bran or supplemented rice straw increased the digestibilities of DM, OM, NDF and ADF digestibility (Ngwe *et al*., 2012; Sreerangaraju *et al*., 2000). Decreased digestibility of crude protein with inclusion of 10% (DM basis) of chickpea pod husks was reported (Ngwe *et al*., 2012).

Although most chickpeas are produced for human consumption, they provide the livestock industry with an alternative protein and energy feedstuff (Christodoulou, 2005). According to Bampidis and Christodoulou (2011) indicated that chickpeas can be used as a high energy and protein feed in animal diets to support milk, meat and/or egg production. Moreover, chickpea straw can be used as alternative forage in ruminant diets. In sheep, reported DM, OM, crude protein and energy digestibility of chickpea straw were 49%, 60%, 51%, 62%, 60% and 59% respectively (Bampidis *et al*., 2011). In rams, potential DM and NDF in-sacco degradability were 45% and 39% respectively (Bruno-Soares *et al*., 2000).

Abdel-Magid *et al*. (2008) showed that, OM, CP, CF and NFE digestibility of the diet containing chickpea straw were lower than those of diets containing pea straw or berseem hay which showed similar values; Body weights at the end of the trial were similar for groups fed on the control or pea straw diets, being higher than those of the group fed on chickpea straw diets; Daily dry matter intake was the highest with pea straw diets followed by the control and being the lowest with chickpea straw diets. Fed in the Total mixed ration (TMR) of 10-month old camel calves (BW 187–240 kg) with chaffed dry groundnut forage and concentrate (700:150:150 g/kg of the TMR), chickpea straw supported a body weight(BW) gain of 0.38–0.42 kg/day (Bampidis *et al*., 2011).

2.3.5. Nutritional value of chickpea haulm

Chemical composition and nutritive value of chickpea straw varies according to many factors; among this variety, cultivar, environmental and seasonal effects, and proportion of different morphological fractions of straws, sowing date, stage of harvest and storage conditions.

(Kafilzadeh and Maleki, 2011); but generally chickpea straw contains slightly more protein than a cereal but remains a fibrous forage; Pod husks have a similar composition, perhaps more fibrous (Bampidis *et al*., 2011). Naser, *et al*., (2011) showed in his results chickpea straw has a DM, CP, EE, Ash, NDF, ADF are 92.18%, 6.05%, 5.5%, 8%, 57.8%, 37.4%, respectively. Fikadu et al. (2010a) also showed chickpea straw has a chemical composition of DM (91.5-92), Ash (8.67-9), CP (6.19-6.36), NDF (55.1-57.5), ADF (40.5-41.4) and ADL (8.04-8.52).

Compared to other straws, chickpea straw has a relatively high nutritive value (Lopez et al., 2004; Lopez *et al*., 2005; Bampidis *et al*., 2011) but lower than that of other legume straws (Bruno-Soares *et al*., 2000; Lopez *et al*., 2005). CP, NDF, ADL and ME ranged were (2.8-8.8; 46-78; 8.5-15.8; 6.5-7.5) respectively. The Gross Energy (GE) and Metabolisable Energy (ME) contents of chickpea straw are 18.4 MJ/kg DM and 7.7 MJ/kg DM (Lopez *et. al*., 2005), respectively.

2.3.6. Mineral composition of chickpea haulm

Minerals are essential inorganic compounds, very important in animal production for growth, maintenance, reproduction and lactation. Macro minerals are required in large amounts while micro minerals required in small amounts. Trace mineral are used as structural, physiological, catalytic and regulatory functions. Chickpeas are a good source of minerals, such as Ca, P, Mg, Fe and K (Carla *et al*., 2013). A single 100 g serving of cooked chickpeas can provide 24%, 43% and 39% of the recommended dietary allowance (RDA) for the macronutrient P and for the micronutrients Mn and Cu, respectively (Costa *et al*., 2006). Therefore, chickpea has become an important source of vitamins and minerals to the cereal-based daily diet of millions of people in under-developed countries (Jukanti, *et al*., 2012). Chickpea contained good amounts of calcium, zinc and copper which is better than lentil, cow pea and green pea and also higher potassium and sodium content than lentil (Iqbal *et al*., 2006b). There were no significant differences between the kabuli and desi genotypes except for calcium, with desi types having a higher content than kabuli types (Wang *et al*., 2004 and Ibáñez *et al*., 1998). A review by Bampidis *et al*., (2011) indicated that, chickpea straw contains calcium 1.69g/kg dry matter, phosphorus 3.42g/kg dry matter, magnesium 1.78g/kg dry matter, potassium 11.13g/kg dry matter, sodium 0.77g/kg dry matter, copper 10.65 mg/kg DM, Iron 90 mg/kg DM, manganese 22.43 mg/kg DM, zinc 42.2 mg/kg DM.

2.4. Determination of Fodder Quality

Fodder quality can be determined by estimation of nitrogen content; in vitro digestibility and in vitro metabolisable energy using a combination of conventional chemical and in vitro laboratory analysis and Near Infrared Reflectance Spectroscopy (NIRS) as described by Bidinger and Blümmel, (2007) and Blümmel *et al*. (2007). Low nitrogen (N) content is often considered to be one of the most limiting factors in the utilization of cereal crop residues as livestock fodder, as N contents below 1.0–1.2% in fodder dry matter is thought to depress voluntary feed intake because of lack of N for rumen microbes (Van Soest, 1994). In vitro digestibility gives an estimate about the proportion of the fodder availability in the animal while metabolisable energy determination enable reliable estimations of the fodders potential to support maintenance requirement and milk and meat production (McDonald *et al*., 1988).

Low nitrogen content is widely considered the most limiting factor in utilization of crop residues for livestock feeding. This constraint is more pronounced in cereal than in leguminous crop residues. Rumen microbes require a minimum of 1 to 1.2% (equivalent to 6.25-7.5% crude protein) in the fodder to effectively degrade it (Van Soest, 1994). Nitrogen contents below this threshold result in low voluntary feed intakes and consequently in low livestock productivity (Van Soest, 1994). Good-quality crop residues have a high nutrient potential because of their high energy, protein and mineral contents (Saha *et al*., 2013).

2.5. Purpose of NIRS in Forage Analysis

The near infrared reflectance spectroscopy (NIRS) method of analysis is an instrumental based method for rapidly, and reproducibly measuring the chemical composition of samples with minimal sample preparation (Norris, 1989). NIRS is a rapid; reliable; low-cost; non-destructive; does not usually require labor-intensive sample processing; allows for the determination of multiple values in a single analytical procedure; computerized method to analyze feeds for their nutrient content (Williams, 2001). Feeds can be analyzed rapidly(less than 15 minutes) using NIR, compared to hours or days for wet chemical methods (Castro *et al*,. 1996, Shenk and

Westerhaus, 1991 and Stuth *et al*., 2003). In addition to this, the method requires no reagents hence nonpolluting, and characterizes the entire sample of interest rather than specific component of interest (Deaville and Flynn, 2000). 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).

2.6. Prediction of Nutritive Value of Crop Residues using NIRS

NIRS used to predict the chemical composition and nutritive values of crop residues considerably; it was successfully predicted NDF, ADF and ADL in cereal crop residues (Stubbs *et al*., 2009). Fikadu *et al*. (2010a) studied different crop residues of cereals and pulse in Ethiopia. The calibration equations for DM, Ash, CP, NDF, ADF, Lignin and in vitro digestibility indicate comparatively high coefficient of determination, and low standard errors of calibration (SEC) and standard errors of cross-validation (SECV) and thus, these traits could be predicted with good precision. In addition, the predicted means for each trait were similar to the means based on conventional chemical analysis. Higher SEC value was recorded for the feed types of each class may be due to the broader range of variation for the trait (Fikadu *et al*., 2010a). 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.

2.7. Prediction of Mineral composition of Crop Residues using NIRS

Analysis of mineral concentration with NIRS has produced mixed results since minerals do not absorb in the near infrared region and they are low in concentration in the tissue. However, their detection by NIR can be possible due to complexes formed with organic compounds, many of which vary among species (Clark *et al*., 1987). Low levels and narrow ranges in forage plants also hamper the estimation of minerals by NIR. Because of this narrow range, some authors argue that mineral equations should be evaluated by coefficient of variation (CV) rather than R^2, as the narrow range in concentration could render R^2 values misleading (Roberts *et al*., 2003; Stuth *et al*, 2003).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The study was conducted at Debre zeit Agricultural Research Center at five field experimental sites: Akaki, Alem Tena, Chefe donsa and Debre zeit locations. They are located in East Shewa zone of Oromia Regional State in Central Ethiopia, while Minjar is located in North Shewa zone of Amhara Regional State. Debre-zeit is located at 47km away from the capital Addis Ababa to the East at an altitude of 1900m above sea level. The site is characterized by tepid to cool sub-moist agro-ecology, with dominant soil types consisting of light Alfisols/Mollisols and heavy black soil (Vertisols) (EIAR, http://www.eiar.gov.et). Akaki lie at a distance of 30km southeast of Addis Ababa. Alem Tena is the administrative center of Bora woreda. General features of the five sites are shown in Table 1.

Table 1. Description of the Experimental sites.

Characteristics	Locations				
	Akaki	Alem Tena	Chefe Donsa	Debre-zeit	Minjar
Altitude	2200masl	1575masl	2450masl	1900masl	1810masl
Latitude	08^{0}53’ N	8° 18'N	08^{0} 57’ N	08^{0}44’N	08^{0}55’N
Longitude	38^{0}49′ E	38° 57'E	39^{0} 06’E	38^{0}58'E	39 ^{0}45’E
Annual max. Tem.	26.5^{0}c	29.8^{0}c	26^{0}c	28.3^{0}C	28^{0}C
Annual min. Tem.	7^{0}c	12.9^{0}c	7^{0}c	8.9^{0}C	10^{0}C
Mean annual RF	1025mm	728mm	843mm	851mm	867mm
RF distribution	Bimodal, less erratic	erratic rainfall	Bimodal, less erratic	Bimodal	bimodal/uni-modal
Soil type	Vertisols	Light	Vertisols	Vertisols	Light

Sources: Befakadu (2008); Damitew *et al*. (2012); Abera and Kebede (2013); Kebede and Taddesse (2011); and Debre zeit agricultural research center 2013/2014 cropping year.

3.2. Sample Description

A total of 1348 samples of chickpea haulms from preliminary and national variety trials for potential environments (Late maturing varieties) and moisture stress (early maturing varieties) which has not been released were used in the experiment for NIRS analysis. However, total samples of 597 chickpea haulms and 48 genotypes of the crop from National variety trial were used for statistical analysis, because these varieties are already tested preliminarily on fields in terms of agronomic traits, diseases resistance, etc. by the breeders. Among these, eight existing varieties (Local check/variety used by farmers in the area, Arerti, Ejere, Habru, Chefe, Minjar, Natoli and DZ-10-4) were used as control.

Table 2. Lists of chickpea genotypes studied under the experiment for haulm and grain traits

Tested genotypes within Trials	Controls	Locations
National Variety Trial kabuli for potential environment (n=13) Dz2012CK0001 Dz2012CK0006 Dz2012CK0010 Dz2012CK0002 Dz2012CK0007 Dz2012CK0011 Dz2012CK0003 Dz2012CK0008 Dz2012CK0012 Dz2012CK0004 Dz2012CK0009 Dz2012CK0013 Dz2012CK0005	Arerti Ejere Habru Dz-10-4	Akaki Chefe Donsa Debre zeit
National Variety Trial kabuli for low moisture stress (n=13) Dz2012CK0014 Dz2012CK0019 Dz2012CK0024 Dz2012CK0015 Dz2012CK0020 Dz2012CK0025 Dz2012CK0016 Dz2012CK0021 Dz2012CK0026 Dz2012CK0017 Dz2012CK0022 Dz2012CK0018 Dz2012CK0023	Chefe Dz-10-4 Ejere Habru	Alem Tena Debre zeit Minjar
National Variety Trial for Desi (n=14) Dz2012CK0027 Dz2012CK0032 Dz2012CK0037 Dz2012CK0028 Dz2012CK0033 Dz2012CK0038 Dz2012CK0029 Dz2012CK0034 Dz2012CK0039 Dz2012CK0030 Dz2012CK0035 Dz2012CK0040 Dz2012CK0031 Dz2012CK0036	Local check Minjar Natoli	Akaki Chefe Donsa Debre zeit

National variety trial in Kabuli type chickpea for potential environment (n=13), National variety trial in Kabuli type chickpea for moisture stress (n=13) and National variety trial in Desi type chickpea (n=14).

Kabuli chickpea types of both potential and moisture stress areas varieties and also desi type chickpea varieties are all tested in Debre zeit locations. Since, Debre zeit location was not totally highland or lowlands. The varieties listed in potential environment (highland varieties) were not found in moisture stress area, i.e. kabuli types of potential varieties are different from moisture stress and desi type varieties.

3.3. Experimental Design

Randomized Complete Block Design (RCBD) with 4 replications was used in the experiment. The plot size was 4m x 1.2m (4rows/plot), 30 cm between rows and about 10cm between plants spacing was used, and the seed rate was 0.097 kg/plot and maintain number of plants to 40 after germination by thinning the extra 10 plants form each rows. Local check variety was used as control by farmers in the area according to the recommended seeding rate mentioned. Season of cropping for kabuli chickpea for national variety trial at Debre zeit, Akaki and Chefe Donsa was August 19, 2013 and while for desi type chickpea, the sowing date was August 21/06/2013, i.e. using residual moisture, the soil type is black clay. In case of Minjar and Alem Tena site, season of cropping was August 1/08/ 2013 and the previous crop planted in the area for all locations was wheat, there is no application of fertilizer before or after planting. The test genotypes consisted of both Desi and Kabuli chickpea types. All the agronomic practice of crop management were done from sowing the land to harvesting and after full maturity (90% maturity) the harvesting had been conducted from 2 central rows of each plot ($2.4m^2$) to calculate the yield in each location.

3.4. Sample Collection and Analysis

The haulm samples were collected after harvest from chickpea experimental sites (Akaki, Alem Tena, Chefe Donsa, Debre zeit and Minjar) and threshing the samples were carried out at the end of October, 2013 in each location and after threshing the samples, the seed and the residue was separated and the residue for this was collected and put in paper bag and labeled it and after this, the residue was transported to animal nutrition laboratory of ILRI campus, Addis Ababa for analysis. Additionally, the necessary agronomic and primary food traits data such as days to 50% flowering and days to maturity, plant height (cm), 100 seed weight (g), biomass yield (tone/ha) and grain yield (tone/ha) and harvest index (grain yield/bio mass yield) were collected and compiled for each genotype from Debre zeit Agricultural Research Center. The collected chickpea haulm samples were analyzed for chemical composition and mineral contents using NIRS at ILRI's Animal Nutrition laboratory, Addis Ababa and *in-vitro* gas production was done at ILRI Animal nutrition laboratory, India.

3.4.1. Analysis of Nutritive Value using NIRS and Conventional Methods

Chickpea haulm samples were analyzed for chemical composition, mineral analysis and nutritional value using Near Infrared Reflectance Spectroscopy and wet chemistry.

3.4.1.1. Scanning of chickpea haulm samples using NIRS

NIRS was performed on ground samples (1mm sieve size) using Foss NIRS 5000 with software package WinISI II in the 1108-2492nm spectra ranges to scan chickpea haulm samples and the spectra of each sample was taken by scanning (Win Scan version 1.5, 2000, intrasoft international, L.L.C). Before scanning about two-spoonful of the samples was put in paper bag and pre-dried at 60^{o}C overnight in an oven to standardize moisture conditions. Partially dried chickpea sample was filled into NIRS cup and scanned.

3.4.1.2. Chemical analysis using conventional methods

A total of 130 representative chickpea haulm samples were selected using the software based on NIRS spectra data for laboratory analysis. The samples were analyzed for DM and total ash contents by the procedures of AOAC (1990). Nitrogen was determined by Kjeldahl method (AOAC, 1990) and CP content was calculated as N x 6.25. Van Soest and Robertson (1985) procedure was used to determine Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL). These all chemically determined data were used for calibration equations to perform regression with NIRS spectral data. I was involved, for all the laboratory works like NIRS, wet chemistry and mineral analysis but the *in-vitro* technique was done at ILRI Animal Nutrition Laboratory in India.

3.4.1.3. Mineral analysis

Phosphorous (P) content was determined by spectrophotometer methods (Khalil & Manan, 1990) whereas calcium (Ca), magnesium (Mg), managanese (Mn), iron (Fe), and zinc (Zn) contents were determined by atomic absorption spectrophotometer (A. Analyst 300, Perkin Elmer, Shelton, USA) (AOAC, 1990). A mineral standard was run in each analysis to ensure the accuracy of estimation.

3.4.1.4. *In vitro*- technique

In-vitro gas production (Menke and Steingass, 1988) test was carried out at ILRI Animal Nutrition Laboratory in India on 130 representative samples, which were used in the wet chemistry study, to estimate digestibility and metabolizable energy contents. The digestible organic matter and metabolizable energy were calculated using the equations as follows:

DOM= 15.38+ (0.483*GP) + (0.595*CP %) + (0.181*ASH %)

ME= 2.2 + (0.136*GP) + (0.0057*CP g/Kg)

GP= ((V_{24}-V_0-GP_0)*altitude correction factor*0.2/SW*DM*0.01)

Where: V_O= Blank

GP_O= Gas Produced without sample, i.e. gas produced for rumen fluid itself

GP = is 24 h net gas production (ml/200 mg),

CP = Crude protein, V= Volume and ME= metabolizable energy (MJ/Kg DM)

SW= Sample Weight

3.4.1.5. DM Yield, Digestible DM yield and Potential Utility Index

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

Haulm dry matter yield (t/ha) HDMY = %DM × Total fresh yield of haulm/ha*100

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

$$\text{Potential Utility Index} = \frac{(\text{Grain yield t/ha}) + (\text{Digestible DM yield t/ha})}{\text{Total above ground plant biomass DM yield (t/ha)}} \times 100$$

3.5. NIRS Equation Development

3.5.1. Calibration

Calibration is the process of creating a spectro-chemical prediction model (Shenk and Westerhaus, 1996). In essence, the process relates chemical information contained in the spectral properties of a substance to chemical (or physical) information showed by reference laboratory methods (Lobos *et al*., 2013). The goal is to create a predictive equation by passing the laboratory reference method (Stuth *et al*., 2003). Partial least squares (PLS) regression was used to develop the calibration models. The sample population used in the calibration consisted of 130 chickpea haulm whereas 60 samples were used for validation. After the samples were scanned with NIRS and laboratory reference data were acquired and matched; and mathematical and statistical procedures were performed. Calibration equations were developed using average spectral and wet chemistry data by stepwise multiple linear regressions based on this equation. Values for DM, CP, NDF, ADF, ADL, ash contents and IVOMD, OMD, ME of all the samples were predicted or calculated based on the developed prediction models. The best models obtained were selected for each constituent based on the highest calibration coefficients (r^2c), and the smallest standard error of calibration (SEC) (Conzen, 2006).

3.5.2. Validation

Equation validation was conducted to assess the predictive ability of the selected calibration equation. Validation means prediction of either an independent set of samples, i.e. from a different population than the calibration set, with known reference values, or removing a certain number of samples from the calibration set, and not using them in the calibration process. The standard error of prediction (SEP) is used to judge the predictive ability of a calibration equation.

This method was described as the single best estimate of the predictive capability of NIRS equation (Shenk and Westerhaus, 1996). The lowest standard error of prediction (SEP) assess the overall error between modeled and reference values (Conzen, 2006). The coefficient of determination in prediction (r^2p) and the ratio performance deviation (RPD) were also used as additional techniques to evaluate the predictive ability of the models. The RPD is a qualitative measure for the assessment of the validation results.

3.6. Statistical Analysis

Data obtained from predicted value of NIRS, chemical compositions regression results, mineral constituents and *in vitro* gas production of fodder traits were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) and also correlated with primary food traits (agronomic characteristics) using statistical analysis system (SAS, 2002) software version 9.1.3. The statistical significance of the differences between means was tested using the Duncan's multiple range tests. A statistical model involved the effect of genotype, location and the interaction between location and genotype for chemical composition, mineral contents and agronomic traits of chickpea haulms. A statistical model used was:-

Randomized Complete Block Design (RCBD)

Model: $Y_{ijkl} = \mu + L_i + G_j + LG_{ij} + B_k + E_{ijk}$,

Where: Y_{ij}= the response variable

μ= Over all mean

L_i= effect of i^{th} location (i=5)

G_j= effect of j^{th} genotype (j=48)

LG_{ij}= interaction effect of i^{th} location and j^{th} genotype

B_k= effect of l^{th} block effect (l=4)

E_{ijk}= random error

4. RESULTS AND DISCUSSION

4.1. Nutritional Value of Chickpea Haulms and NIRS Analysis

The calibration and equation statistics for chemical constituents, ME content, TIVOMD and mineral composition of chickpea haulms are given in Table 3.

Table 3. Equation statistics of the calibration and Validation

Traits	Calibration set (n=130)		Validation set(n=60)			Laboratory Values		NIRS Predicted Values		
	r^2_c	SEC (%)	r^2_v	SEP (%)	RPD (%)	Mean (%)	SD	Mean (%)	SD	CV (%)
DM (%)	0.84	0.19	0.78	0.24	1.96	90.40	0.47	90.41	0.39	0.27
Ash (%)	0.97	0.35	0.96	0.56	3.61	9.01	2.02	9.01	1.93	6.22
CP (%)	0.99	0.21	0.99	0.425	8.09	6.04	3.44	6.01	3.39	7.04
NDF (%)	0.99	0.85	0.99	1.3	6.65	53.75	8.64	53.79	8.6	2.42
ADF (%)	0.99	0.64	0.99	1.09	6.45	39.66	7.03	39.6	6.97	2.75
ADL (%)	0.99	0.22	0.98	0.36	5.06	9.13	1.82	9.13	1.77	3.94
ME (MJ/ Kg DM)	0.99	0.06	0.99	0.036	24.4	7.86	0.88	7.88	0.87	0.46
IVOMD (%)	0.99	0.45	0.99	0.218	26	53.79	5.69	53.85	5.67	0.40
Zn(mg/kg)	0.93	1.89	0.91	2.272	3.26	12.87	7.41	12.98	6.95	17.6
Mn(mg/kg)	0.89	14.23	0.89	14.65	3.03	70.54	44.4	70.11	42.1	20.8
Ca(g/kg)	0.91	1.07	0.89	1.66	2.24	13.52	3.72	13.47	3.29	12.3
Mg(g/kg)	0.88	0.15	0.84	0.16	2.69	2.01	0.43	2.02	0.39	7.9
Fe(mg/kg)	0.92	192	0.92	208	3.56	685	741	675	691	30
P(g/kg)	0.71	0.33	0.68	0.45	1.58	0.89	0.71	0.82	0.54	50

DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF =Acid detergent fiber; ME=Metabolizable energy; TIVOMD= True in-vitro organic matter digestibility; Zn= Zinc; Mn=Manganese; Ca=Calcium; Mg=Magnesium; Fe=Iron; P= Phosphorous, n=number of samples, SEC= Standard Error of Calibration; r^2c= R-Square (coefficient of correlation in calibration); r^2v= coefficient of determination in validation; SEP=Standard error of prediction; RDP= Ratio of Performance to Deviation(RPD=SD/SEP); SD=Standard Deviation; CV=Coefficient of Variation (CV=SEP/mean*100).

The results show high correlation coefficient in calibration and validation, low standard errors of calibration (SEC), low standard errors of predictions (SEP) and high ratio of prediction deviation (RPD), which indicate that these traits could be predicted with good precision. That means the composition predicted by NIRS corresponded closely with that of chemical analysis for the variables studied.

4.2. NIRS Calibration and Validation

Haulms of chickpea samples which were scanned varied in their chemical composition (DM, total Ash, CP, NDF, ADF, lignin, ME contents and TIVOMD (Table 3). There were significant differences among the samples for all entities which suggest the presence of sufficient variation among the samples to develop Nears Infrared Reflectance Spectroscopy (NIRS) equation.

4.2.1. Prediction of crude protein (CP)

Crude protein was the parameter with the best prediction results. The error of calibration obtained in this work for CP was lower than the values obtained by Lobos *et al*. (2013), Decruyenaere *et al*. (2009) and Fikadu *et al*. (2010b) who obtained RMSEC values of 0.46, 8.6 and 0.92, respectively. Also, NIRS calibration for CP showed a RPD of 8.09, better than that of Alomar et al. (2009), with a value of 3.7 (Table 3). Stuth *et al*. (2003) declared that good prediction accuracy is usually obtained when measuring protein content in feeds and forages (with R^2 of 0.95 or higher), which is related to strong (-N-H-) absorptions in the NIR region. Thus, in the present study, r^2 value for protein content in chickpea haulm was 0.99 (see Table 3).

The correlation coefficients in calibration (r^2c= 0.99) and validation (r^2c= 0.99) of CP content of chickpea haulm in this study were higher than previously observed values by Fikadu *et al*. (2010a) who found 0.90 and 0.86 respectively. The model had low standard error of calibration (SEC=0.21), low standard error of prediction (SEP=0.425) and higher values of ratio prediction deviation (RPD=8.09), which indicates best predictive ability of the calibration model (Table 3). The NIRS predicted CP content of the haulm was 6.01, which was lower than the value reported by Fikadu *et al*. (2010a). The r^2 (0.99) and low SEC (0.21) values found in this study were higher than the values reported by Fikadu *et al*. (2010b) who reported R^2 and SEC values of 0.83 and 0.92, respectively while determining chemical entities of natural pasture from Ethiopia using

NIRS. This shows that the calibration model in the current study were closely related to the wet chemistry (Kjeldahl method) values with a high degree of linearity. The coefficient of determination (r^2) used in this study was higher whereas SEC and SEP values lower than the respective values obtained in previous (Castro, 2002; Khandaker and Khaleduzzaman, 2011, Baloyi *et al*., 2013; Lobos *et al*., 2013).

The standard error of calibration (SEC) and standard error of prediction (SEP) in this study was within the range of Brown and Moore (1987) who noticed that the SEC and SEP 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 and then, the accuracy of calibration model also considerably evaluated by ratio prediction deviation (RPD) value which was 8.09 and indicated an excellent prediction ability of the calibration model as reported by Saeys *et al*. (2005).

4.2.2. Prediction of fiber fractions (NDF, ADF and ADL)

In the present study, the mean values of NDF (53.79%), ADF (39.6%) and ADL (9.13%) predicted by NIRS were comparable to the wet chemistry values as shown in Table 3. Higher values of correlation coefficient for calibration (r^2c=0.99) and validation (r^2v >0.98), low SEC (0.22 - 0.85%) and SEP (0.36 -1.3%) and high RPD values (5.06% - 6.65%) were observed. The r^2c, SEC and RPD values found in this work (Table 3) were better than or comparable to the values reported by Stubbs et al. (2009) for NDF (SEC=0.82, r^2= 0.94, RPD= 3.79); ADF (SEC= 0.74, r^2= 0.94, RPD= 3.56) and ADL (SEC= 0.43, r^2= 0.72, RPD= 1.72). Since the r^2 and RPD values of the three fiber component were greater than 0.98 and 5, respectively, the accuracy and prediction ability of the model can be considered excellent according to Saeys *et al*. (2005).

4.2.3. Prediction of ME and TIVOMD

The mean values predicted by NIRS for ME (7.88 MJ/kg DM) and TIVOMD (53.85%) were comparable to the wet chemistry values (Table 3). High values of coefficient of determination for calibration (r^2c=0.99 and 0.99) and validation (r^2v =0.97 and 0.97), low SEC (0.06 and 0.45), low SEP (0.036 and 0.218) and high RPD values (24.4 and 26) were observed for both ME and TIVOMD, respectively. The r^2c and r^2v values for TIVOMD shown in the present study were higher than the r^2c and r^2v of 0.92 and 0.80, respectively, for TIVOMD in chickpea straw previously reported by Fikadu *et al*. (2010a). Even though, different scholars said that estimation of IVOMD or ME was difficult because of the variation with rumen fluid, etc. but in my study the estimation for both IVOMD and ME was higher; this may be due to low standard error of calibration and prediction and this indicated that the higher value of ratio performance deviation.

To summarize, the value of coefficient of determination was greater than 0.92 (Corson *et al*., 1999), which shows the homogeneity of the samples collected. The r^2c value was below 0.80 and less accurate in the case of DM. It is generally accepted that models with an r^2 values of 0.66 to 0.81 can only be used for screening and possibly some other approximate applications (quantitative predictions), models with r^2 value between 0.83 to 0.90, can be used for many applications, while models with values of 0.92-0.96 are suitable for most applications including quality assurance and a value of more than 0.98 is usable in any application (Lebot *et al*., 2009; Williams, 2001). Therefore, in the present study, the result of r^2 for chemical constituents (CP, NDF, ADF and ADL) as well as ME and TIVOMD were greater than 0.98.

Generally, the r^2c and RPD (SD/SEP) and standard errors of prediction corrected for bias (SEP) are considered for evaluating the accuracy of NIRS prediction (Williams, 2001; 2007 and Nie *et al*., 2009a). High r^2 and RPD and low SEP indicate good NIRS performance; a prediction with an r^2 >0.90 and RPD >3.0 is usually classified as successful. RPD values below 1.5 are considered unusable, those between 1.5 and 2.0 can be used for rough predictions, those between 2.0 and 2.5 allow approximate quantitative predictions, while values above 2.5 and 3.0 are considered good and excellent predictive models, respectively (Ceballo *et al*., 2006 and Deaville *et al*., 2009). In the present study, the values of r^2 and RPD for all other chemical constituents except for DM as well as for ME and were greater than 0.90 and 3.0 respectively. Thus, NIRS prediction for chemical constituents, ME and TIVOMD of chickpea haulms was successful.

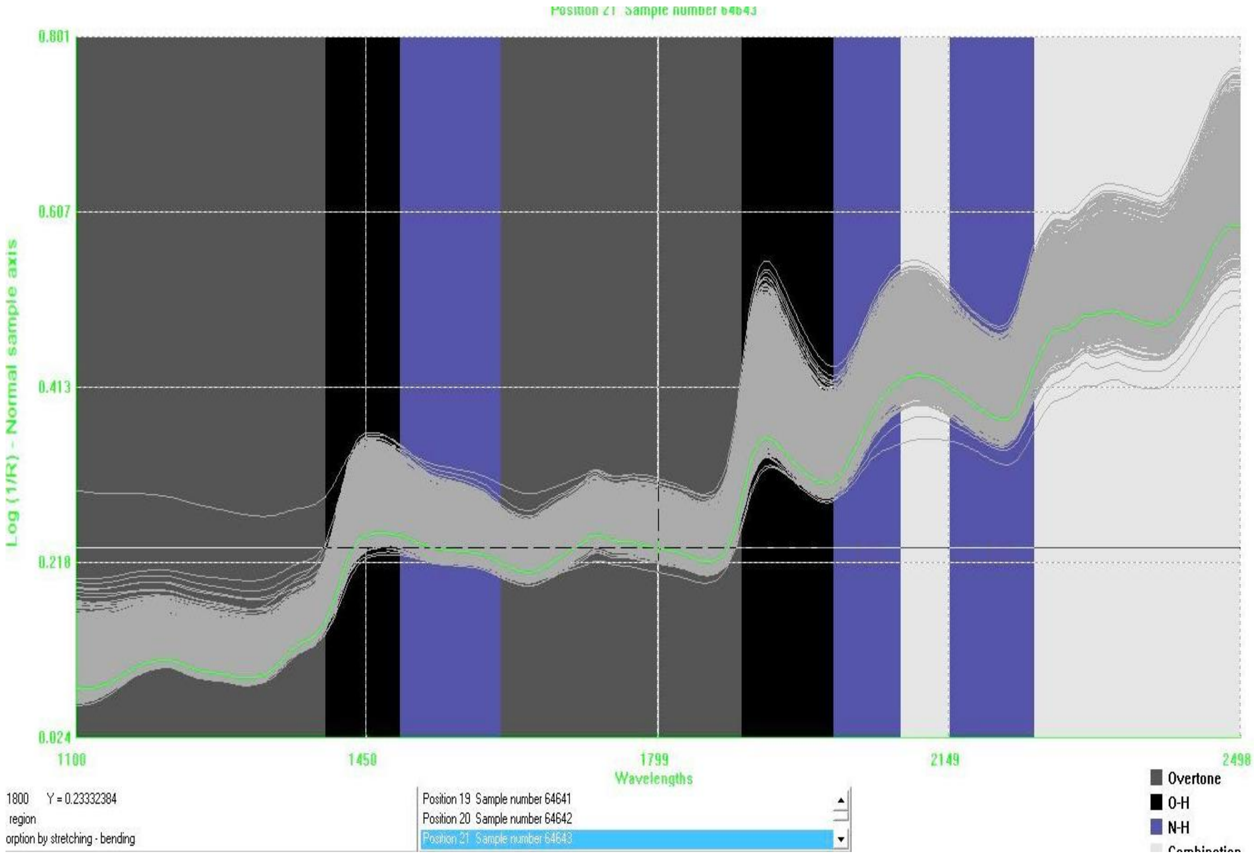
4.2.4. Prediction of minerals using NIRS

The calibration and equation statistics for mineral compositions of chickpea haulm samples for the minerals Zn, Ca, Mn, Mg, Fe and P are given in Table 3. Zinc, Ca and Mg show high coefficient of determination low standard errors of calibration (SEC) and standard errors of prediction (SEP). The prediction of minerals by NIRS found in this study was better than previously studied work on alfalfa by Brogna *et al*. (2009) who reported Ca (r^2c=0.91, r^2v= 0.89), Mg (r^2c=0.81, r^2v=0.76), Fe (r^2c=0.90, r^2v=0.87, SEC= 196) and P (r^2c=0.70, r^2v=0.55). However; the calibrations for P were poor because absorbance of minerals does not occur in the near infrared region. This is consistent with the findings of de Boever *et al.* (1995) for compound feeds for cattle. Accordingly, except for Mn and Fe, the calibration error should be comparable to the sampling error and this value is similar to standard error of performance (SEP). Iron and Mn had high standard error of calibration, which could be explained by the fact that an error that may occur in the reference method may increase the uncertainty and the errors in the calibration model. The SEC, SEP and r^2 values indicate how well the equations will perform within the same population (Cozzolino & Moron, 2004). However, with minerals, the SEC and especially r^2 are not good indicators of calibration performance because of the NIRS not directly measuring the element (Stuth *et al*., 2003; Cozolino & Moron, 2004).

According to Williams (2001) and Ceballo *et al*. (2006), the prediction of Ca, Mg and Zn are successful when r^2 values of 0.88, CV of <20% and RPD of 2.5. Because low concentrations and a narrow range are generally observed for mineral concentrations, which could render r^2 values misleading (Murray and Cowe, 2004; Nie *et al*., 2009b) and some authors suggest evaluating the NIRS prediction of minerals by using the coefficient of variation rather than r^2. As proposed by Clark *et al*. (1989), the coefficient of variation of prediction {CVP = [SEP/mean] × 100} between chemically analyzed and NIRS-predicted values is considered a useful tool in evaluating NIRS performance across minerals. Clark *et al*. (1987, 1989) described useful NIRS mineral equations with coefficients of variation ranging from 11 to 28% across 3 forage data sets, and Halgerson *et al*. (2004) accurately predicted several minerals by NIRS in alfalfa with coefficients of variation ≤20% and 1-VR ≥0.60. Based on the criteria of CVP <20% and r2 >0.60 (Clark *et al.*, 1987, 1989; Halgerson *et al*., 2004), the NIRS predictions for Zn, Ca and Mg concentrations were successful, with CV for prediction of 17.6%, 12.3%, 7.9% and r^2 values of 0.93, 0.91 and 0.88, respectively, whereas P were unsuccessful with a much higher CV for prediction of 50% and RPD values of 1.58 (Table 3).

Mineral concentration relies on their association with organic and hydrated inorganic molecules. Ca and Mg were found to be predictable by spectral peaks of their corresponding organic acid salts (Clark *et al.,* 1989). Other factors that influence the accuracy of NIRS equations are the average concentration and the range for each constituent (Murray and Cowe, 2004; Nie *et al.*, 2008). The successful predictions of Zn, Ca and Mg in the present study were mainly explained by their higher concentrations and ranges. Prediction of Ca and Mg in our study was better than the value reported by Tremblay *et al.* (2009) in timothy (*Phleum pratense L*.) mineral concentrations of 1108 samples (Ca; r^2=0.90, CV= 10.9 and Mg; SEP=0.17, r^2=0.89 and CV=11). P in plants exist in multiple valences and in different organic forms, such as phytate, phospholipids, and nucleic acids, and the proportion of total P in different forms varies seasonally or among species and genera. This attribute may lead to unstable NIRS calibrations and inconsistent prediction results. In our study, the prediction performance of P was restricted by its low concentrations and range of values.

Therefore, the result of chemical constituents, ME content, TIVOMD and mineral compositions (Zn, Ca and Mg) showed that NIRS was useful to estimate the chemical composition and nutritional quality of chickpea haulms, and has a great potential to be used as a rapid decision tool for the studied analysis. However; application for NIRS for the calibrations for P was poor because low concentration and minerals do not absorb in the near infrared region.



NIR spectra are plots of reciprocal $\log_{10}$ reflectance (log 1/R) versus the wavelength

Figure 1. NIRS spectra data for chickpea haulms.

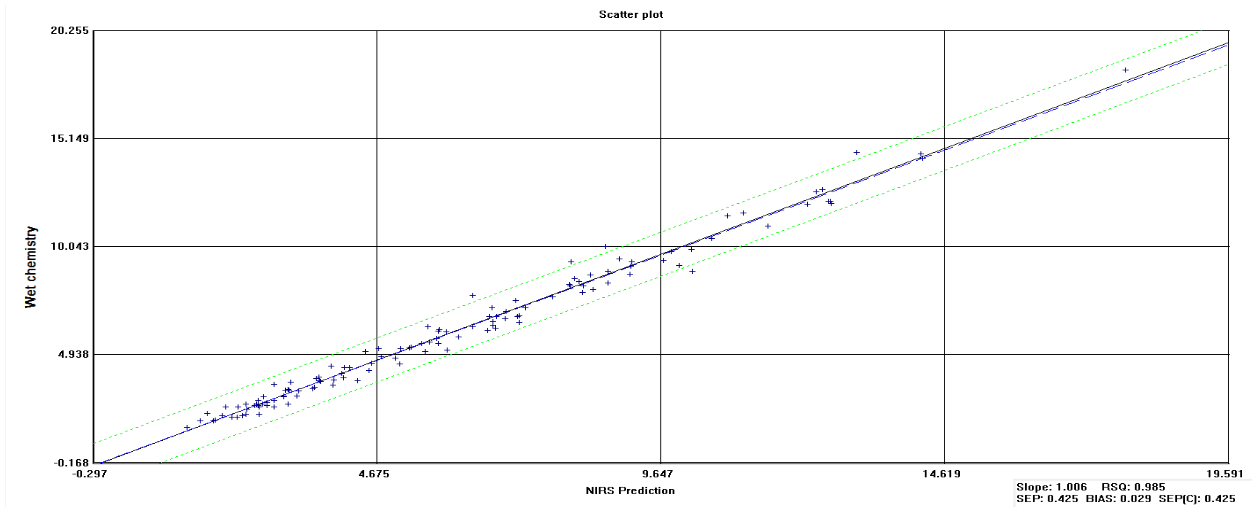


Figure 2. NIRS Prediction VS wet chemistry values of CP (%).

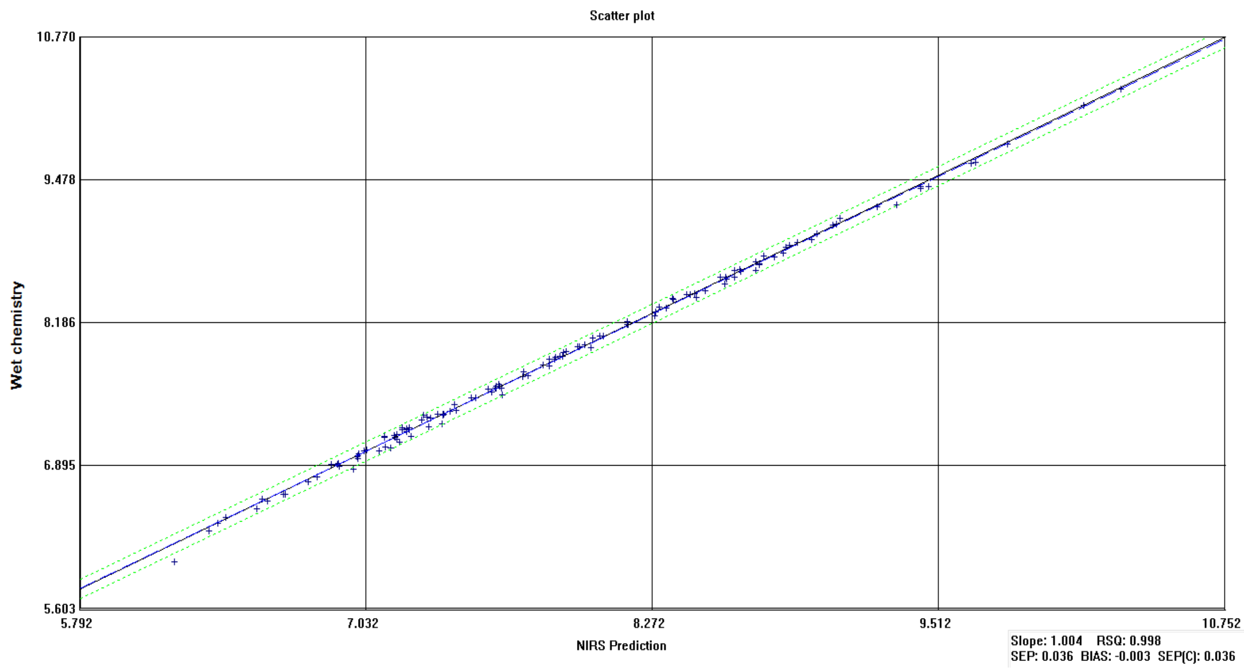


Figure 3) Wet chemistry vs NIRS prediction Validation graphs of ME(%)

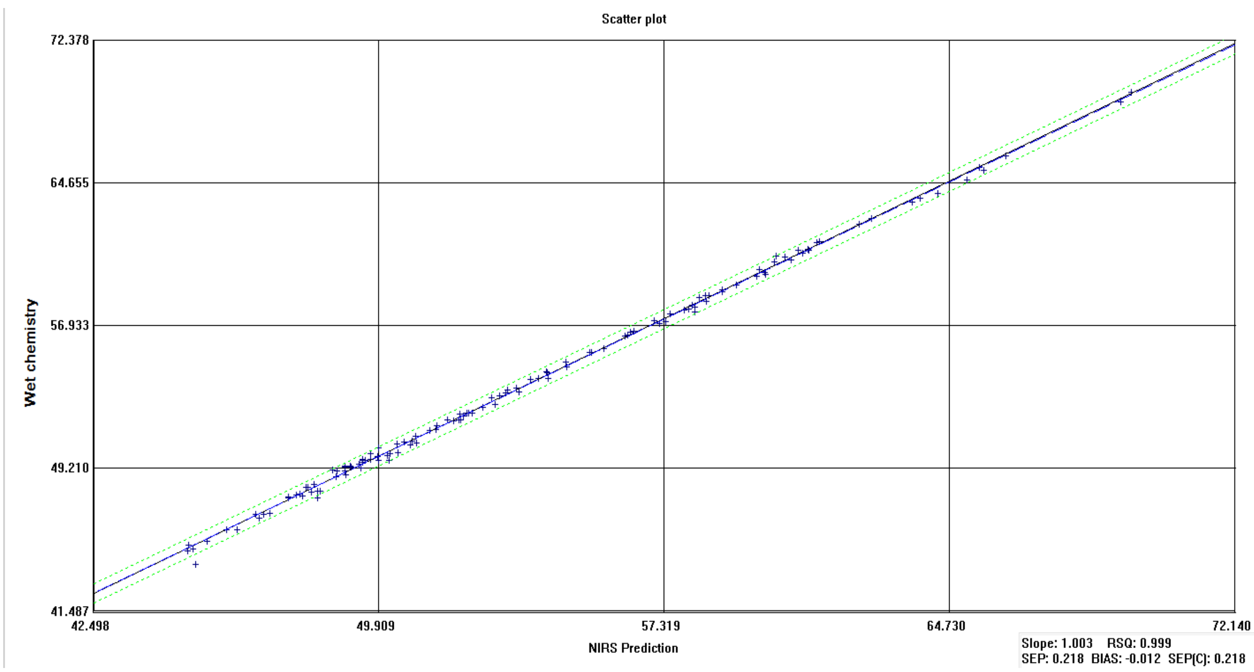


Figure 4) Wet chemistry vs NIRS prediction Validation graphs of IVOMD(%)

4.3. Nutritional Value of Chickpea Haulms across Locations

4.3.1. Effect of location on haulm nutritional value

The chemical compositions of chickpea haulms of kabuli and desi type across the experimental locations were presented in (Table 4). The overall mean of %CP were showed within the range of 4.05- 6.41. Though the average is within this, the range or variation is very big (2.6-8%), this indicated that the effect of location was higher than genotype effect and also location Akaki and Chefe Donsa was relatively highlands compared to Debre zeit location. Kabuli chickpea in low moisture stress (LMS), the mean value of %CP (6.41%) found in this research was better than previously reported results by other researchers (Naser, *et al.*, 2011; Fikadu *et al.*, 2010a and Tolera, 2007).

Table 4. Mean comparison of nutritional values of kabuli chickpea for potential environment and low moisture stress area on experimental locations.

Locations	DM (%)	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	ME(MJ/ kg DM)	TIVOMD (%)
Potential Environment								
Akaki(n=68)	90.14	7.08[b]	2.64[b]	61.46[a]	43.96[b]	10.64[b]	7.31[b]	49.41[b]
Chefe Donsa(n=67)	90.13	6.32[c]	2.89[b]	62.42[a]	45.52[a]	11.17[a]	7.07[c]	48.46[c]
Debre Zeit(n=68)	90.12	9.93[a]	7.98[a]	47.98[b]	33.05[c]	7.68[c]	8.7[a]	58.97[a]
Overall mean	90.13	7.78	4.51	57.26	40.82	9.82	7.69	52.29
SE(±)	0.01	0.12	0.19	0.52	0.43	0.12	0.05	0.36
Low moisture stress								
Alem Tena(n=66)	90.52	10.84[a]	6.36[b]	46.87[c]	34.99[c]	7.77[c]	8.28[b]	56.96[b]
Debre zeit(n=68)	90.32	9.76[b]	7.01[a]	50.39[b]	35.79[b]	8.17[b]	8.53[a]	57.85[a]
Minjar(n=57)	90.62	7.58[c]	5.77[c]	60.22[a]	47.25[a]	10.78[a]	6.83[c]	47.74[c]
Overall mean	90.47	9.48	6.41	52.11	38.93	8.81	7.94	54.53
SE(±)	0.01	0.12	0.16	0.54	0.47	0.11	0.06	0.38

[a, b, c, d] Means within columns followed by the same letter (s) are not significantly different at $P < 0.05$; Sig. is significant. DM, dry matter; CP, crude protein; NDF, neutral detergent fiber;

ADF, acid detergent fiber; ADL, acid detergent lignin; True in-vitro Organic Matter Digestibility(TIVOMD); Metabolisable Energy(ME).

The CP content of kabuli chickpea was significantly higher ($p<0.05$) in the Alem Tena and Debre zeit than in the other locations in both trials while the reverse was true for NDF, ADF and ADL content in Akaki, Chefe Donsa and Minjar. However, the CP content of desi type chickpea was significantly ($p<0.05$) higher in Minjar and Debre zeit locations than Akaki and Chefe Donsa sites. The CP content of haulms of kabuli chickpea for potential environment and low moisture stress area at Debre zeit locations (%CP=7.98% and %CP= 7.01%), respectively, was significantly ($p<0.05$) higher than Alem Tena (%CP=6.36%) followed by Minjar (5.77%), Chefe Donsa (2.89%) and Akaki (2.64%). The CP content was significantly higher ($p<0.05$) in potential environments than low moisture area as indicated in Table 4. Moreover; Debre zeit location had significantly ($p<0.05$) higher %CP content (7.98%) in potential environment for kabuli chickpea.

The % CP content of kabuli chickpea both in potential environment (%CP=7.98%) and low moisture stress area (%CP=7.01%), Debre zeit had significantly ($p<0.05$) higher than the other locations and also Alem Tena location was showed %CP of 6.36% for low moisture stress area. In this study, the overall mean value of %CP content was significantly ($p<0.05$) higher in low moisture stress area than potential environments for kabuli chickpea. One of the most important factors for plant production and geographical distribution is water availability (Bartles and Villabo, 2002). A decline in biomass, number of tillers and spikes, and a decrease in grain weight were observed with increasing water stress levels. With increasing water stress, decreased leaf “greenness” and increased protein content (Gous *et al*., 2013).

The difference in CP content across locations may due to differ in cultivar, agro-ecology and soil fertility. Debre zeit, Alem Tena and Minjar are relatively water stressed areas compared to Chefe Donsa and Akaki. Reddy *et al*. (2003) indicated that water stressed/shortage plants were similar to have higher nitrogen content and digestibility because the plant matures early in low moisture stress. The CP% content in Akaki and Chefe Donsa are low and these locations are relatively highlands compared to the other experimental locations, this may be related to the longer period of time required for physiological maturity of the crop that induces dilution of CP (low %CP) and enhances lignifications (McDonald *et al*., 1995). Despite this, crop residues are harvested at grain maturity. According to Akin *et al*. (1994) water-stressed sorghum plants had higher a proportion of leaves and a lower proportion of stems, were more digestible and had lower percentage of lignin. Moreover, crude protein content decline considerably (P<0.01) with increasing growth period which directly related to the concept of early and late maturing variety genotypes (Fleischer *et al*., 1989).

The %CP content of chickpea haulms at Alem Tena for moisture stress area and Debre zeit location for potential environment and moisture stress area was better than the result reported by Fikadu *et al.* (2010a) who studied, characterizing and prediction of different crop residues using NIRS in Ethiopia. Susmel *et al*., (1994) showed that high temperature increases protein and cell wall (NDF, ADF and ADL) contents. Debre zeit, Alem Tena and Minjar are relatively hotter than Akaki and Chefe Donsa sites. Moreover, Wahid *et al*. (2007) studies on heat tolerance in plants, indicated that stress devolve both qualitative and quantitative attributes of plant since the plant metabolic pathways are entertained to invest more energy for stress tolerance and also Mahmood *et al*. (2010) proposed that plants capable of having high stress tolerance ability also tend to show better nutritional quality.

Table 5. Mean comparison of nutritional values of desi type chickpea collected from three experimental locations.

Locations	DM (%)	Ash (% DM)	CP (% DM)	NDF (% DM)	ADF (% DM)	ADL (% DM)	ME(MJ/ Kg DM)	TIVOMD (%)
Akaki	90.26	8.53[b]	2.69[c]	61.15[a]	43.95[b]	10.44[b]	7.3[b]	49.9[b]
Chefe Donsa	90.31	7.16[c]	2.86[b]	61.55[a]	46.28[a]	10.84[a]	7.08[c]	48.5[c]
Debre Zeit	90.49	10.26[a]	7.01[a]	52.32[b]	37.79[c]	8.41[c]	8.25[a]	55.92[a]
Overall mean	90.35	8.65	4.19	58.32	42.67	9.89	7.54	51.45
SE(±)	0.01	0.07	0.14	0.19	0.13	0.05	0.04	0.27
Sig. level	*	***	***	***	***	***	***	***

[a, b, c, d] Means within columns followed by the same letter (s) are not significantly different at P <0.05; Sig. is significant; ***, significant at p<0.001. DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; True in-vitro Organic Matter Digestibility (TIVOMD); Metabolisable Energy (ME).

The mean comparison of nutritional value of desi type chickpea haulm indicates in Table 5. The Ash content was significantly higher ($p<0.05$) at Debre zeit than the other location. Haulms of desi type chickpea were significantly ($p<0.05$) higher in %CP content of 7.33% in Minjar and 7.01% in Debre zeit sites, respectively. Debre zeit location had %CP content of 7.01% followed by Chefe Donsa (2.86%) and Akaki (2.69%) locations.

Ruminants need a minimum of 6.25% CP for lactation and growth and 7.5 % for rumen function (Van Soest, 1994). The %CP value of haulms of kabuli chickpea at Debre zeit location and for haulms of desi type chickpea at Minjar and Debre zeit locations, respectively were sufficient to satisfy the rumen microbial function and effective degradation of fodder (1 to 1.2% N) (equivalent to 6.25-7.5% crude protein) according to Van Soest (1994).

According to Kebede *et al*. (2014), the main important points to find out effective forage quality was the amount of total neutral detergent fiber (NDF) which implies voluntary intake of the forage. In addition to this, acid detergent fiber was very useful for determining the feed quality by predicting digestibility which is highly indigestible and slowly digestible material in a feed. The NDF, ADF and ADL content of Akaki and Chefe Donsa locations were significantly ($p<0.05$) higher than Minjar and Debre zeit.

When compared to the haulms of kabuli and desi type chickpea, the %CP content of kabuli chickpea at Debre zeit location was better in %CP content than the desi type chickpea for all the other locations. Besides this, Debre zeit site was significantly ($p<0.05$) higher in CP than the other locations for both kabuli and desi type chickpea. The %CP values vary across locations; this might be linked to differences in variety, plant part or season (Savodogo *et al*., 2000; Rivas-Vega *et al*., 2006; Ravhuhali *et al*., 2010; Anele *et al*., 2011a and 2011b). The NDF and ADL content of kabuli chickpea in low moisture stress area was better in fiber fractions than desi type chickpea. Roughage feeds with NDF content of less than 45% are categorized as high quality, 45 to 65% as medium quality and those with more than 65% as low quality roughages (Singh and Oosting, 1992). In the present studies, the mean values of NDF% of kabuli and desi type chickpea were between the ranges of 45-65%, thus; it was categorized as medium quality roughages.

According to Kazemi *et al*. (2012), legumes with ADF values less than 31% are rated as having superior quality whereas those with values greater than 55% are considered inferior. Kellems and Church *et al*. (1998) also indicated that roughages with less than 40% ADF are categorized as high quality and those with greater than 40% as poor quality. The difference in NDF and ADF contents across locations could be attributed to differences in climate and soil fertility. In this study, the lignin content was high for chickpea haulm as compared to the maximum level of 7%, which limits DM intake. Lignin is completely indigestible and forms lignin-cellulose/hemicelluloses complexes (Kellems and Church, 1998) due to physical encrustation of the plant fiber and reduces its availability to microbial enzymes (McDonald *et al*., 1995). The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated (Ensminger *et al*., 1990). Cell-wall content is negatively correlated with intake. High cell-wall content increases rumination time and is associated with decreased efficiency of conversion of metabolisable energy to net energy. The ability of the rumen microorganisms to digest cell-wall polysaccharides is limited by the presence of phenolic and other aromatic compounds (Hartley, 1981).

4.3.2. Effect of locations on ME and TIVOMD of chickpea haulms

The overall mean value of Metabolizable Energy and True *in vitro* organic matter digestibility for kabuli chickpea for low moisture stress area was significantly higher than the potential environment. This may be due to variety differences between them. Kabuli chickpea for moisture stress area was significantly($P<0.05$) higher in ME(7.94MJ/kg DM) and TIVOMD(54.53%) than the potential environment(PE) which had a values of ME(7.69MJ/kg DM) and TIVOMD(52.29%), respectively. Debre zeit location for potential and moisture stress area was significantly ($P<0.05$) higher in ME and TIVOMD than the other locations.

The mean value of ME and TIVOMD for desi type chickpea was 7.54MJ/kg DM and 51.45%, respectively. Debre zeit location was significantly ($P<0.05$) higher in ME and TIVOMD contents than the other locations. When compared to kabuli and desi type chickpea, the mean value of ME and TIVOMD of kabuli chickpea was significantly ($p<0.05$) higher than desi type. The mean *in vitro* digestible organic matter in the dry matter (IVDOMD) for crop residues was 46.6%, which is lower than the minimum level of 50% required for quality roughages (Mosi and Butterworth, 1985; Seyoum and Fekede, 2008). In this study, the mean value of ME for the chickpea accessions was better than the critical threshold of 7.5 MJ/Kg DM. Differences in ME might be due to differences in environment, soil fertility and/or crop variety used (McDowell, 1988).

4.3.3. Effect of locations on mineral composition of chickpea haulms

Table 6 presents comparison of mean values of mineral compositions of kabuli and desi type chickpea haulms. Magnesium (2.09g/kg) content of kabuli and desi type chickpea was significantly ($p<0.05$) higher at Debre zeit locations. A significant difference between the mineral compositions of haulms of kabuli and desi type chickpea were observed across locations. Kabuli chickpea at Alem Tena location was significantly ($p<0.05$) higher in Zn (17.24mg/kg), Mn (110.86 mg/kg) and Fe (490.5mg/kg) content than Minjar, Akaki, Chefe Donsa and Debre zeit. Calcium (15.27g/kg) content at Akaki location for kabuli chickpea was significantly higher than the other locations but the lowest Zn and P contents. Debre-zeit location was better in Mg (2.26g/kg) content than the other experimental sites while Chefe Donsa was lower in Mg content.

The haulms of kabuli chickpea for potential environment were higher in Ca (14.57g/kg) content than low moisture area across experimental locations. However, kabuli chickpea in low moisture stress area was significantly ($p<0.05$) higher in terms of Zn (13.61mg/kg), Mn (73.51mg/kg), Mg (2.11g/kg), Fe (410.14mg/kg) and P (0.98g/kg) than the potential environment across locations. The value of Mn (51.54mg/kg), Fe (349.77mg/kg) at Chefe Donsa location was significantly ($p<0.05$) higher than the other locations and also Akaki was low in Zn and P contents.

Table 6. Comparison of mean values of mineral compositions of chickpea haulms on the experimental locations

Factors	Zn(mg/kg)	Mn(mg/kg)	Ca(g/kg)	Mg(g/kg)	Fe(mg/kg)	P(g/kg)
Kabuli chickpea						
Location						
Akaki	6.74[d]	46.5[c]	15.27[a]	1.83[d]	373.43[c]	0.14[c]
Alem Tena	17.24[a]	110.86[a]	12.37[c]	2.09[b]	490.5[a]	0.99[a]
Chefe Donsa	7.57[d]	44.3[c]	14.13[b]	1.56[e]	358.95[c]	0.20[b]
Debre zeit	13.67[b]	43.39[c]	14.26[b]	2.26[a]	309.85[d]	0.97[a]
Minjar	10.30[c]	62.69[c]	11.57[d]	1.98[c]	414.78[b]	1.01[a]
Potential environment	9.61[b]	43.76[b]	14.57[a]	1.89[b]	341.19[b]	0.48[b]
Low moisture	13.61[a]	73.51[a]	12.78[b]	2.11[a]	410.14[a]	0.98[a]
Desi chickpea						
Akaki	6.3[c]	49.08[a]	15.36[a]	1.77[b]	288.82[b]	0.34[b]
Chefe Donsa	7.73[b]	51.54[a]	14.47[b]	1.61[c]	349.77[a]	0.39[b]
Debre zeit	9.59[a]	33.54[b]	15.58[a]	2.46[a]	262.23[c]	1.15[a]
Sig. level						
Location	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

[a, b, c, d] Mean values with similar letters in a column within each category are not significantly different ($p > 0.05$); Sig. is significant; ***, significant at $p<0.001$. Zn, zinc; Mn, manganese; Ca, calcium; Mg, magnesium; Fe, iron; P, phosphorous; potential environment; low moisture stress; kg, kilo gram; g, gram; mg, milligram.

Mineral concentrations in plants generally reflect the adequacy with which the soil can supply absorbable minerals to the roots. However, plants react to inadequate supplies of available minerals in the soil by limiting their growth, reducing the concentration of the deficient elements in their tissues or, more commonly, by reducing growth and concentration simultaneously(Suttle, 2010). The extent to which a particular response occurs varies with different minerals and different plant species or varieties and with the soil and climatic conditions. Nevertheless, the primary reason for mineral deficiencies in grazing animals, such as those of phosphorus, sodium, cobalt, selenium and zinc, is that the soils are inherently low in plant-available minerals (Alloway, 2004).

Large differences can exist between the mineral needs of plants and those of the animals dependent on those plants. Concentrations of manganese in plants decrease markedly as soil pH increases. Leguminous species are generally much richer in macro-elements than grasses growing in comparable conditions, whether temperate or tropical (Suttle, 2010). Minson (1990) reported mean calcium concentrations of 14.2 and 10.1 g kg^{-1} DM in temperate and tropical legumes, respectively, against 3.7 and 3.8 g kg^{-1} DM in the corresponding grasses. Many tropical legumes are exceedingly low in sodium, with half containing less than 4 g kg^{-1} DM (Minson, 1990).

Plants mature partly in response to internal factors inherent in their genetic makeup and partly in response to external factors, either natural (e.g. season, climate) or manmade (e.g. provision of irrigation, shelter), and there are associated changes in mineral composition. Phosphorus concentrations of crop and forage plants decline markedly with advancing maturity, although the decline is less in legumes than in grasses (Coates *et al*., 1990; Suttle, 2010).

The NRC recommended mineral requirement of Ca (%), P (%), Mg (%), K(%) in the dry matter for lactating large dairy cows for higher production are 0.77, 0.48, 0.25 and 1 while for lactating smaller cows for lower production the value are 0.43, 0.28, 0.20 and 0.90 respectively. However, the maximum tolerable Ca (%), P (%), Mg (%), K(%), Fe (ppm), Mn (ppm) and Zn (ppm) in the dry matter for lactating dairy cows are 2, 1, 0.50 , 3, 1000, 1000 and 500, respectively (NRC, 1989).

4.4. Effect of Genotype on Haulm Nutritional values

Table 7 indicates that there was no significant ($p<0.05$) difference in %CP, ME (MJ/kg DM) and TIVOMD(%) contents of the genotypes in kabuli chickpea for potential environment. The maximum and minimum mean values of %CP were recorded in dz104 (5.12%) and dz2012ck0005 (3.83%). Furthermore, the control varieties (dz104, ejere, arerti and habru) were recorded with % CP values of 5.12%, 4.82%, 4.67% and 4.26%, respectively. The genotype dz2012ck0005 contained higher %NDF (59.31%) and %ADF (42.53%) while genotype dz2012ck0006, dz2012ck0002 contained the lowest %NDF (55.65%, 55.37%) and %ADF (40.14%, 39.50%), respectively.

Table 7. Nutritional values of Kabuli chickpea for potential environment in three experimental sites (Akaki, Chefe Donsa and Debre zeit).

Genotype	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	ME(MJ/ Kg DM)	TIVOMD (%)
dz104	8.29[a]	5.12	56.16[ab]	40.36[ab]	9.36[c]	7.91	53.63
dz2012ck0010	7.64[bc]	5.04	56.73[ab]	40.82[ab]	9.82[a-c]	7.71	52.29
dz2012ck0002	8.06[ab]	4.85	55.37[b]	39.50b[b]	9.49[bc]	7.78	52.85
Ejere	7.72[a-c]	4.82	57.05[ab]	41.37[ab]	9.97[ab]	7.64	52.07
dz2012ck0004	7.96[a-c]	4.77	56.89[ab]	40.57[ab]	9.67[a-c]	7.68	52.39
Arerti	7.75[a-c]	4.67	57.35[ab]	40.89[ab]	9.94[ab]	7.70	52.35
dz2012ck0011	7.73[a-c]	4.63	57.64[ab]	41.09[ab]	9.93[ab]	7.66	52.05
dz2012ck0006	7.89[a-c]	4.5	55.65[ab]	40.14[ab]	9.79[a-c]	7.77	52.69
dz2012ck0001	7.92[a-c]	4.57	57.28[ab]	40.81[ab]	9.81[a-c]	7.68	52.17
dz2012ck0003	7.69[a-c]	4.56	57.56[ab]	40.90[ab]	9.91[ab]	7.65	52.09
dz2012ck0007	7.7[a-c]	4.56	56.76[ab]	40.19[ab]	9.67[a-c]	7.77	52.76
dz2012ck0012	7.91[a-c]	4.42	56.95[ab]	40.69[ab]	9.85[a-c]	7.63	51.91
dz2012ck0013	7.59[bc]	4.31	57.47[ab]	40.72[ab]	9.86[a-c]	7.68	52.11
Habru	8.07[ab]	4.26	57.61[ab]	41.08[ab]	9.84[a-c]	7.68	52.15
dz2012ck0008	7.6[c]	4.23	57.95[ab]	41.08[ab]	9.81[a-c]	7.72	52.44
dz2012ck0009	7.44[c]	4.20	58.58[a]	41.24[ab]	10.04[ab]	7.71	52.21
dz2012ck0005	7.39[c]	3.83	59.31[a]	42.53[a]	10.17[a]	7.50	50.99
Overall mean	7.78	4.53	57.26	40.82	9.82	7.69	52.29
SE(±)	0.12	0.19	0.52	0.43	0.12	0.05	0.36

[a, b, c] Means with in column followed by different letter (s) are significantly different at $P < 0.05$ level of Duncan multiple range tests. CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; Metabolizable energy, TIVOMD; True *in vitro* organic matter digestibility, SE; standard error.

Table 8 shows that most of the tested genotypes other than control varieties except dz104 were significantly ($p<0.05$) higher in %CP contents and can fulfill the minimum requirements of rumen bacteria function. Dz2012ck0018 had significantly ($p<0.05$) higher %CP (8.36%), ME

(8.57MJ/kg DM) and TIVOMD (58.71%) contents than the other tested and control varieties. The mean %CP, ME (MJ/kg DM) and TIVOMD (%) values of the control varieties dz104 (7.78%; 8.74 MJ/kg DM and 54.14%), ejere (4.79%, 7.68 MJ/kg DM and 52.11%), habru (4.69%, 7.68 MJ/kg DM and52.78%) and chefe (4.65%, 7.59 MJ/kg DM and 52.19%) respectively. This showed that kabuli chickpea for low moisture stress, the control varieties but not dz104, were significantly ($p<0.05$) lower than the other tested genotypes in %CP values listed in table 8.

Table 8. Nutritional values of kabuli chickpea for low moisture stress on three experimental sites (Alem Tena, Minjar and Debre-zeit).

Genotype	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	ME(MJ/ kg DM)	TIVOMD (%)
dz2012ck0018	10.28^{ab}	8.36^{a}	45.28^{g}	33.70^{i}	7.50^{h}	8.57^{a}	58.71^{a}
dz104	9.47^{c-f}	7.78^{ab}	52.29^{c-e}	39.76^{a-e}	8.74^{d-f}	7.84^{e-g}	54.14^{d-g}
dz2012ck0015	9.06^{d-g}	7.76^{ab}	50.18^{ef}	38.47^{d-f}	8.76^{d-f}	7.96^{c-e}	54.96^{b-e}
dz2012ck0019	8.54^{gh}	7.41^{bc}	52.63^{b-e}	40.34^{a-d}	9.33^{a-c}	7.69^{e-g}	53.22^{e-h}
dz2012ck0022	8.79^{f-h}	7.32^{bc}	53.19^{a-e}	38.99^{c-f}	8.71^{d-f}	8.14^{b-d}	55.77^{b-d}
dz2012ck0016	9.44^{c-f}	7.26^{b-d}	50.50^{d-f}	37.09^{fh}	8.46^{fg}	8.14^{b-d}	55.78^{b-d}
dz2012ck0021	9.05^{d-g}	7.09^{b-d}	51.66^{c-e}	37.93^{e-g}	8.54^{e-g}	8.29^{b}	56.70^{b}
dz2012ck0020	8.89^{e-h}	6.99^{cd}	52.12^{c-e}	39.14^{c-f}	8.94^{b-f}	7.88^{ef}	54.31^{c-g}
dz2012ck0017	8.95^{e-h}	6.48^{cd}	53.66^{a-d}	40.75^{a-c}	9.27^{a-d}	7.74^{e-g}	53.32^{e-h}
dz2012ck0014	10.81^{a}	6.33^{cd}	48.56^{f}	36.24^{gh}	8.07^{g}	8.21^{bc}	56.14^{b-c}
dz2012ck0026	10.52^{a}	6.29^{cd}	47.66^{fg}	35.42^{hi}	8.17^{g}	8.17^{b-d}	55.89^{b-d}
dz2012ck0023	8.34^{h}	6.24^{cd}	55.65^{ab}	41.79^{a}	9.53^{a}	7.68^{fg}	52.84^{f-h}
dz2012ck0025	9.69^{bd}	6.07^{ed}	53.43^{a-d}	39.57^{b-e}	8.81^{c-f}	7.93^{d-f}	54.43^{c-f}
dz2012ck0024	9.82^{bc}	5.11^{ef}	53.17^{a-e}	39.39^{b-e}	9.05^{a-e}	7.86^{e-g}	53.83^{e-h}
Ejere	9.49^{c-f}	4.79^{f}	56.22^{a}	41.82^{a}	9.45^{ab}	7.66^{fg}	52.51^{gh}
Habru	9.86^{bc}	4.69^{g}	54.37^{a-c}	40.33^{a-d}	9.13^{a-d}	7.68^{fg}	52.78^{f-h}
Chefe	9.56^{c-e}	4.65^{f}	55.85^{a}	41.47^{ab}	9.39^{ab}	7.59^{g}	52.19^{h}
Overall mean	9.48	6.45	52.11	38.93	8.81	7.94	54.53
SE(±)	0.12	0.16	0.54	0.47	0.11	0.06	0.38

$^{a, b, c, d, e, f, g, h}$ Means with in column followed by the same letter (s) are not significantly different at $P < 0.05$ level of Duncan multiple range tests. CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; Metabolizable energy, TIVOMD; True in vitro organic matter digestibility, SE; standard error.

Genotypes, dz2012ck0018, dz2012ck0021, dz2012ck0014 and dz2012ck0026 were significantly ($P<0.05$) higher in ME and TIVOMD than the other tested and control varieties. The mean values of %NDF, %ADF and %ADL for checks (ejere, chefe and habru) and dz2012ck0023 were significantly ($p<0.05$) higher than the other tested varieties. The lowest value of %NDF, %ADF and %ADL was recorded in dz2012ck0018 (45.28%, 33.70% and 7.5%). The mean value of %Ash recorded in this trial was 10.81% for dz2012ck0014, 10.52% for dz2012ck0026 and 10.28% for dz2012ck0018. From the control varieties, habru had higher in %Ash (9.86%) content, followed by Chefe (9.56%), Ejere (9.49%) and dz104 (9.47%).

Therefore, kabuli chickpea for low moisture stress, most of the tested genotypes were fulfilled the minimum requirements of rumen bacterial function and dz104 variety was significantly ($p<0.05$) higher in %CP than the other control and tested genotypes other than dz2012ck0018. The tested genotypes dz2012ck0018 significantly($p<0.05$) higher, since it had higher in %CP, ME(MJ/kg DM), TIVOMD(%) and low values of %NDF, %ADF and %ADL compared to the other varieties.

Table 9 shows that genotypes of dz2012ck0037, dz2012ck0035 and dz2012ck0027 had contained higher %CP of 5.21%, 4.75%, and 4.55% respectively; than the other tested genotypes and checks and also the genotype dz2012ck0034 was the lowest value of %CP (3.31%) from the listed genotypes. The control varieties (Natoli, Minjar and Local check) were %CP 4.55%, 4.4% and 3.4%, respectively. The maximum values of %NDF, %ADF and %ADL were recorded in dz2012ck0034 (60.33%, 44.69% and 10.35%) and the minimum values were indicated for the genotype dz2012ck0037 (56.38%, 41.12% and 9.44%), respectively. The %NDF, %ADF and %ADL values of checks (control varieties) contained 59.75%, 43.75% and 9.86% for Local check; 58.18%, 42.92% and 9.78% for Minjar and 57.87%, 41.64% and 9.84% for Natoli, respectively as shown in Table 9.

Table 9. Nutritional value of Desi type chickpea on three experimental sites (Akaki, Chefe donsa and Debre zeit).

Genotype	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	ME(MJ/Kg DM)	TIVOMD (%)
dz2012ck0037	8.71^{b-e}	5.21^{a}	56.38^{d}	41.12^{d}	9.44^{c}	7.78^{a}	53.07^{a}

dz2012ck0035	8.86^{a-c}	4.75^{ab}	56.92^{cd}	41.85^{b-d}	9.72^{bc}	7.64^{a-c}	52.14^{ab}
dz2012ck0027	8.95^{ab}	4.55^{a-c}	57.32^{b-d}	41.43^{cd}	9.72^{bc}	7.66^{a-c}	52.28^{ab}
Natoli	8.79^{a-d}	4.55^{a-c}	57.87^{a-d}	41.64^{b-d}	9.84^{a-c}	7.65^{a-c}	52.15^{ab}
Minjar	8.51^{b-g}	4.40^{a-c}	58.18^{a-d}	42.94^{a-d}	9.78^{bc}	7.56^{a-c}	51.61^{ab}
dz2012ck0039	8.69^{b-f}	4.31^{a-c}	58.46^{a-d}	42.83^{a-d}	9.83^{a-c}	7.53^{a-d}	51.42^{a-c}
dz2012ck0032	9.19^{a}	4.27^{a-c}	58.64^{a-d}	43.64^{ab}	9.99^{ab}	7.39^{cd}	50.51^{bc}
dz2012ck0033	8.31^{e-g}	4.27^{a-c}	57.23^{b-d}	41.65^{b-d}	9.86^{a-c}	7.63^{a-c}	52.02^{ab}
dz2012ck0030	8.15^{g}	4.19^{a-c}	58.36^{a-d}	42.11^{b-d}	9.97^{ab}	7.69^{ab}	52.41^{ab}
dz2012ck0038	8.85^{a-c}	4.16^{a-c}	59.02^{a-d}	43.36^{a-c}	9.97^{ab}	7.42^{b-d}	50.79^{bc}
dz2012ck0028	8.41^{c-g}	3.96^{bc}	59.16^{a-c}	43.21^{a-d}	9.92^{a-c}	7.49^{b-d}	51.07^{bc}
dz2012ck0040	8.59^{b-g}	3.93^{bc}	58.65^{a-d}	42.93^{a-d}	10.07^{ab}	7.51^{a-d}	51.20^{a-c}
dz2012ck0036	9.23^{a}	3.82^{bc}	57.62^{b-d}	42.32^{b-d}	9.80^{bc}	7.53^{a-d}	51.35^{a-c}
dz2012ck0029	8.51^{b-g}	3.74^{bc}	58.64^{a-d}	42.49^{b-d}	10.08^{ab}	7.51^{a-d}	51.14^{a-c}
dz2012ck0031	8.70^{b-e}	3.73^{bc}	59.01^{a-d}	43.45^{a-c}	9.99^{ab}	7.42^{b-d}	50.69^{bc}
Local check	8.37^{d-g}	3.40^{c}	59.75^{ab}	43.75^{ab}	9.86^{a-c}	7.55^{a-c}	51.25^{a-c}
dz2012ck0034	8.23^{fg}	3.31^{c}	60.33^{a}	44.69^{a}	10.35^{a}	7.27^{d}	49.51^{c}
Overall mean	8.65	4.15	58.32	42.67	9.89	7.54	51.45
SE(±)	0.09	0.17	0.37	0.31	0.09	0.04	0.27

[a, b, c ,d, e, f, g] Means with in column followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple range tests. CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; Metabolizable energy, TIVOMD; True in vitro organic matter digestibility, SE; standard error.

The value of ME and TIVOMD of the genotypes dz2012ck0037 (7.78MJ/kg DM, 53.07%); dz2012ck0030 (7.69MJ/kg DM, 52.41%), dz2012ck0027 (7.66MJ/kg DM, 52.28%) and also control varieties; Local check (7.55MJ/kg DM, 51.25%); Minjar (7.56MJ/kg DM, 51.61%) and Natoli (7.65MJ/kg DM, 52.28%). The lowest value of ME and TIVOMD were recorded in dz2012ck0034 (7.27MJ/kg DM and 49.51%). Therefore, in this trial dz2012ck0037 was the best variety to be selected when compared to the other varieties and checks in terms of %CP, ME(MJ/kg DM) and TIVOMD(%) and low values of %NDF, %ADF and %ADL. In the present study, the values of ME in each genotype for both kabuli and desi type chickpea were within the range of tropical forage legumes 6.50MJ/kg DM to 8.30MJ/kg DM (Evitayani *et al.*, 2004). The true *in vitro* organic matter digestibility of all the genotypes in both chickpea types, except dz2012ck0034; were higher than 50% indicating the high potential to supply metabolizable energy. The nutritional values differ according to genotypes, relatively higher mean CP, ME and true *in vitro* organic matter digestibility and lower fiber fractions were obtained from low moisture stress varieties. While lower CP, ME and true *in vitro* organic matter digestibility but high fiber fractions were obtained from highland varieties or from potential environment varieties.

4.5. Relationship among parameters

4.5.1. Correlation between Agronomic traits and Haulm Nutritional Value

The correlation between agronomic characteristics (days to 50% flowering (DTF), days to 90% maturity (DTM), plant height (PLHT), hundred seed weight (HSW), above ground biomass (BM), grain yield (GYLD), harvest index (HI), haulm yield (HYLD) and haulm nutritional value (DM, Ash, NDF, ADF, ADL ,CP, HYLD, ME and TIVOMD) of chickpea crop was indicated in Table 10.

Table 10. Correlation coefficients of nutritional values of haulm with grain yield and agronomic characteristics of chickpea crop,

Agronomical traits	Ash (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	CP (%DM)	HYLD (t/ha)	ME(MJ/ kg DM)	TIVOMD (%)
DTF	-0.45***	0.34***	0.25***	0.36***	-0.37***	0.47***	-0.26***	-0.29***
DTM	-0.73***	0.61***	0.57***	0.67***	-0.57***	0.47***	-0.58***	-0.59***
HSW	-0.08ns	-0.01ns	0.01ns	0.05ns	-0.07ns	0.02ns	-0.04ns	-0.02ns
PLHT	-0.35***	0.23***	0.28***	0.29***	-0.05ns	0.36***	-0.3***	-0.28***
BM	-0.35***	0.41***	0.37***	0.38***	-0.42***	0.91***	-0.33***	-0.36***
GYLD	-0.23***	0.42***	0.35***	0.35***	-0.48***	0.52***	-0.32***	-0.36***
HI	0.06ns	0.2***	0.12*	0.11*	-0.25***	0.33***	-0.11*	-0.15**
HYLD	-0.36***	0.32***	0.29***	0.32***	-0.30***		-0.27***	-0.28***
ME	0.77***	-0.86***	-0.91***	- 0.92***	0.71***	0.27***		
TIVOMD	0.78***	-0.88***	-0.92***	-0.93***	0.75***	0.28***	0.99***	

ns, non-significant* P<0.05,** P<0.01,*** P<0.001 levels of probability; DM, dry matter; Ash, CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; acid detergent lignin, ME; Metabolizable energy, TIVOMD; True in vitro organic matter digestibility; DTF= days to 50% flowering; DTM= days to 90% maturity; PLHT= plant height (cm); HSW, hundred seed weight(gm); BM, above ground biomass(t/ha); GYLD; grain yield(t/ha); HI, harvest index; HYLD, haulm yield (t/ha).

The result of correlation coefficient between agronomical traits and chemical composition shows that, the days to 90% maturity was significant ($P<0.001$) and negatively correlated to DM and ash contents, but significant ($P<0.001$) and positively correlated to NDF, ADF and ADL contents both in preliminary and national variety trials.

This indicated that as the plant matured, the fiber content increases, the palatability decreases because of low voluntary intake due to high lignin content. The CP content of chickpea haulm was significant($p<0.001$) and negatively correlated to days to 50% flowering, days to 90% maturity, biomass, grain yield, harvest index and haulm yield , however, it was highly significant ($P<0.001$) and positively correlated to ME and TIVOMD. The grain yield and haulm yield had significant ($p<0.001$) and positively correlated to neutral detergent fiber (NDF) and acid detergent lignin (ADL). Agronomical traits which had relatively very high significant and strong positive and negative correlations were observed in DTM with CP (r= -0.57), ash(r= -0.73), NDF(r= 0.61), ADF(r= 0.57), ADL(r= 0.67), GYLD with CP(r= -0.48). PLHT was significant ($p<0.001$) and positively correlated to NDF (r= 0.23), ADF(r=0.28) and ADL(r= 0.29). In this study, the GYLD was negatively correlated to CP content in both trials. Tolera *et al.* (1999), also found the negative correlation ($p<0.05$) between grain yield and the CP content of the stover.

The CP content of the haulm had very highly significant ($P<0.001$) and negatively correlated to DTM (r= -0.57), GYLD(r= -0.48) and HI (r= -0.25). The ME and TIVOMD had shown significant ($P<0.001$) association with DTM (r= -0.58, r= -0.59), GYLD (r= -0.32, r= -0.36) and HYLD (r= -0.27, r= -0.28). Yirga *et al.* (2015) also indicated that CP content had negative direct effect up on grain yield at both genotypic and phenotypic levels on Dekoko accessions in the highlands of Tigray. Moreover, HI was significant and negatively correlated to ME (r= -0.11, $p<0.05$) and TIVOMD(r= -0.15, $p<0.01$). Haulm yield had shown very highly significant ($P<0.001$) and positively correlated with DTM (r= 0.47), GYD (r= 0.52) and HI(r= 0.33).

The results of this study indicated that the CP content of chickpea haulm had negatively correlated with days to 90% maturity. Since the number of days to mature a plant increased, the composition of CP content in the forage will drop (McDonald *et al.*, 2002; Bilal *et al.* (2007). Besides this, the CP content was negatively correlated with grain yield and harvest index in both trials. Similar results were previously reported for maize grain, crop residue yield and stover quality, wheat straw and Pearl millet stover (Tolera *et al*., 1999 and 2007; Blummel *et al*., 2010). Tolera *et al*., (2007) indicated in his report on wheat straw, when the grain yield is high there could be more translocation of soluble nutrients like nitrogen from the vegetative parts to the seed during grain filling. Therefore, mobilization of more nutrients to the grain made the plant parts lower content of nitrogen in the expense of seed as the demand is high. It is accepted that forage degradation in the rumen is affected mainly by the cell wall content and its lignification, as lignin is an indigestible fraction and acts as a barrier, limiting the access of microbial enzymes to the structural polysaccharides of the cell wall. Our result is in agreement with Ammar (2002) who reported that NDF, ADF and ADL levels were negatively correlated with *in vitro* digestibility. In this study, there was a significant ($p<0.001$) difference in the TIVOMD and ME of the haulm. Differences in the digestibility of haulm from different varieties may be due, not only to the chemical composition (Dias-da-silva & Guedes, 1990) but also to stem leaf and seed ratios (Bhargava *et al*., 1988). Crude protein was positively correlated to IVOMD ($r = 0.75$, $P < 0.001$). Other factors known to affect the composition and digestibility of straw are variety and cultivar (Mould *et al*., 2001; Kafilzadeh & Maleki, 2011), environmental and seasonal effects (Mathison *et al*., 1999) and proportion of morphological fractions of the straw (Agbagla *et al*., 2001).

4.5.2. Relationship among yield and yield components in chickpea

The correlation between agronomic characteristics of chickpea haulm iss indicated in Table 11. All the agronomic traits were significant ($p<0.001$) and positively correlated to BM. Days to 90% maturity was significant ($p<0.001$) and positively correlated to DTF($r= 0.65$), PLHT($r= 0.36$), BM($r= 0.45$), GYLD($r= 0.15$), HYLD($r= 0.56$) but negatively correlated to HSW($r= -0.29$), HI($r= -0.34$).

Table 11. Correlation between agronomic traits of chickpea haulms.

	DTF	DTM	PLHT	HSW	BM	GYLD	HI	HYLD
DTF								
DTM	0.63***							
PLHT	0.29***	0.18***						

HSW	0.05ns	-0.07ns	0.31ns				
BM	0.37***	0.47***	0.19***	-0.1ns			
GYLD	0.13***	0.32***	-0.1ns	-0.21***	0.82***		
HI	-0.29***	-0.1*	-0.39***	-0.23ns	0.04ns	0.56***	
HYLD	0.48***	0.48***	0.36***	0.02ns	0.9***	0.51***	0.56***

*** p<0.001; **P<0.01; *p< 0.05; ns, not significant; DTF, day to 50% flowering; DTM, day to 90% maturity; HSW, hundred seed weight; PLHT, plant height(cm); BM, biomass yield; GYLD; total grain yield; HI, harvest index; HYLD, haulm yield.

The highest correlation coefficient with strong associations were BM with HYLD (r=0.90), BM with GYLD (r=0.82), DTF with DTM (r= 0.63) at P<0.001 significant level. The GYLD was positive and significant (p<0.001) correlation to DTM(r= 0.32) and also highly significant (p<0.001) and negative correlation to HSW(r= -0.21). Similar results were reported previously by Arora and Jeena (1999) that seed yield per plant was significantly and positively correlated with days to maturity. In the present study, the GYLD was significant and positively correlated to days to 50% flowering and not significant to the plant height. On the other hand, Wahid and Ahmed (1998) and Yadav and Sharma (1998) reported that seed yield had negative and significant correlation with days to flowering.

Days to 50% flowering was significant (p<0.001) and negatively correlated to HI. A similar result was reported by Saleem et al. (2005) showed that HSW was negatively correlated to DTF in chickpea. GYLD was significant (p<0.001) and positively correlated to DTF, DTM, BM, HI and HYLD. Similarly, Shrestha *et al*. (2009) indicated that GYLD was positively associated with BM and HI. The HYLD and DTM was significant (p<0.001) and positively correlated to DTF, PLHT, BM, and GYLD. This study was similarity with previously studied reports by (Ahmed, 2011; Aliyi Abdula, 2013 and Rahimi *et al.*, 2013). According to Ahmed (2011), days to 90% maturity was significant and negatively correlated to harvest index and grain yield of chickpea both in stress and non-stress conditions.

Abdula (2013) indicated in his research on chickpea, there was a significant (p<0.001) and positive correlation between grain yield with days to 90% maturity(r=0.322), plant height(r=0.397) and total biomass(r=0.855). However, in the present study the GYLD and PLHT had showed no significant correlation between them in both trials. Rahimi *et al*., (2013) found that there was a significant and positive correlation between grain yield and harvest index and also %CP had a negative and great effect on grain yield. The main purpose of breeders is increase in chickpea yield. Yield and its components are multigenic traits, which are strongly influenced by the environment and other factors both known and yet to be identified (Yücel *et al*., 2006). In addition to this, Fagria *et al*. (1997) described that harvest index varies with variety and environment and has negatively correlated with plant height. In the present study, plant height was positively correlated to the biomass. This was consistent with previously studied reports (Yamakawa *et al*. 2006 and Tahir *et al*., 2008) that showed that plant height is important for biomass and dry matter production and also for grain yield. Kafilzadeh *et al*., (2012) also found that there was a positive correlation between grain yield and total biomass(r=0.83, p<0.001) in different varieties of oat straw.

4.6. Grain yield, haulm quality and quantity traits and Potential Utility Index

The grain, haulm and digestible dry matter yield and potential utility index of all genotypes in five experimental trials are presented in Table 12-14.

Table 12 shows comparison of grain yield, haulm quality and quantity and potential utility index of seventeen genotypes from national variety trial for kabuli type chickpea. From the control varieties, Arerti (2.95t/ha) was significantly (P<0.05) higher than the other genotypes in grain yield. On the other hand, dz2012ck0006 (4.89t/ha and 2.52t/ha), dz2012ck0008 (4.83t/ha and 2.53t/ha), dz2012ck0009 (4.49t/ha and 2.26t/ha) and dz2012ck0007 (4.46t/ha and 2.27t/ha) were significantly (P<0.05) higher in haulm yield and digestible dry matter haulm yield contents than the other tested and control varieties (dz104= 2.33t/ha and1.21t/ha, Ejere= 2.4t/ha and 1.22t/ha, Arerti= 4.03t/ha and 2.03t/ha and Habru=3.31t/ha and 1.65t/ha). The highest value of potential utility index was recorded in control varieties, dz104 (72.07%), Ejere (71.88%), Arerti (71.84%) and Habru (70.66%). However, genotype dz2012ck008 (67.56%) and dz2012ck006 (65.96%) had showed lower value of potential utility index.

Table 12. Grain, haulm and digestible DM yield (t/ha), haulm grain ratio and Potential utility of 17 genotypes of kabuli chickpea for potential environment.

Genotype	GYLD (t/ha)	HYLD (t/ha)	HGR	DDMHYLD (t/ha)	PUI (%)
dz2012ck0006	1.95^{fg}	4.89^{a}	2.5	2.52^{ab}	65.96^{e}
dz2012ck0008	2.16^{b-g}	4.83^{a}	2.24	2.53^{a}	67.56^{de}
dz2012ck0009	2.62^{a-d}	4.49^{ab}	1.71	2.26^{a-c}	69.07^{a-d}
dz2012ck0007	2.69^{ab}	4.46^{a-c}	1.66	2.27^{a-c}	69.57^{a-d}
dz2012ck0001	2.65^{a-c}	4.27^{a-d}	1.61	2.17^{a-d}	69.61^{a-d}
dz2012ck0012	2.58^{a-e}	4.14^{a-d}	1.6	2.07^{a-d}	70.19^{a-d}
dz2012ck0004	2.82^{a}	4.0^{a-d}	1.42	2.0^{a-e}	71.11^{a-c}
Arerti	2.95^{a}	4.03^{a-d}	1.37	2.03^{a-d}	71.84^{ab}
dz2012ck0003	2.12^{c-f}	3.99^{a-d}	1.88	2.08^{a-d}	68.44^{c-e}
dz2012ck0011	2.06^{d-g}	3.95^{a-e}	1.92	2.08^{a-d}	69.40^{a-d}
dz2012ck0005	1.94^{fg}	3.77^{b-e}	1.94	1.99^{b-e}	68.78^{b-e}
dz2012ck0013	1.97^{fg}	3.55^{b-e}	1.8	1.84^{c-e}	69.09^{a-d}
dz2012ck0002	1.77^{g}	3.42^{c-e}	1.93	1.89^{c-e}	68.55^{c-e}
Habru	2.49^{a-f}	3.31^{d-f}	1.33	1.65^{d-f}	70.60^{a-d}
dz2012ck0010	2.07^{d-g}	2.97^{e-g}	1.43	1.50^{ef}	71.29^{a-c}
Ejere	2.03^{e-g}	2.42^{fg}	1.19	1.22^{f}	71.88^{ab}
dz104	1.70^{g}	2.33^{g}	1.37	1.21^{f}	72.07^{a}
Overall mean	2.27	3.81	1.68	1.96	69.71
SE(±)	0.05	0.09		0.04	0.32

GYLD (t/ha), grain yield in ton per hectare; HYLD (t/ha), haulm yield in ton per hectare; HGR, haulm grain ratio; DDMHYLD (t/ha), digestible dry matter haulm yield in ton per hectare; PUI (%), potential utility index.

Table 13 shows comparison of grain yield, haulm quality and quantity and potential utility index of seventeen genotypes for kabuli type chickpea in low moisture stress area. Dz2012ck0024 was significantly ($p<0.05$) higher in grain yield (2.49t/ha) than the other varieties and also the control varieties Ejere (2.26t/ha) and Chefe (2.15t/ha) had significantly ($P<0.05$) higher in grain yield than the other tested and control varieties (Habru= 1.97t/ha and dz104=1.47t/ha). HGR of dz2012ck0018 was relatively higher (3.84) than the other tested varieties listed in the low moisture stress areas.

Table 13. Comparison of haulm quality, quantity, grain yield, haulm grain ratio and potential utility index 17 genotypes of kabuli chickpea for moisture stress area.

Genotype	GYLD (t/ha)	HYLD (t/ha)	HGR	DDMHYLD (t/ha)	PUI (%)
dz2012ck0026	1.55^{c-e}	3.91^{a}	2.52	2.06^{a}	66.72^{ef}
dz2012ck0025	1.99^{bc}	3.66^{ab}	1.84	1.90^{ab}	69.64^{b-e}
dz2012ck0024	2.49^{a}	3.62^{ab}	1.45	1.86^{ab}	73.09^{a}
Ejere	2.26^{ab}	3.29^{a-c}	1.46	1.67^{a-d}	71.81^{a-c}
dz2012ck0018	0.84^{f}	3.23^{a-d}	3.84	1.81^{a-c}	65.11^{f}
Chefe	2.15^{ab}	3.19^{a-d}	1.48	1.62^{a-e}	70.74^{a-d}
dz2012ck0014	1.40^{e}	3.19^{a-d}	2.28	1.72^{a-c}	68.25^{de}
Habru	1.97^{b-d}	3.13^{a-d}	1.59	1.58^{b-e}	70.66^{a-d}
dz2012ck0016	1.47^{e}	2.89^{b-e}	1.97	1.55^{b-f}	67.49^{ef}
dz104	1.47^{e}	2.79^{b-e}	1.89	1.47^{b-f}	68.82^{c-e}
dz2012ck0017	1.80^{b-e}	2.57^{c-e}	1.43	1.34^{c-f}	72.99^{a}
dz2012ck0020	1.58^{c-e}	2.55^{c-e}	1.61	1.35^{c-f}	69.75^{b-e}
dz2012ck0019	1.43^{e}	2.39^{c-e}	1.67	1.22^{d-f}	69.68^{b-e}
dz2012ck0022	1.33^{e}	2.34^{de}	1.76	1.37^{c-f}	72.25^{ab}
dz2012ck0015	1.47^{e}	2.20^{e}	1.49	1.18^{ef}	71.22^{a-d}
dz2012ck0021	1.49^{de}	2.16^{e}	1.45	1.19^{d-f}	73.05^{a}
dz2012ck0023	1.33^{e}	2.06^{e}	1.55	1.09^{f}	72.19^{ab}
Overall mean	1.67	2.94	1.76	1.55	70.08
SE(±)	0.05	0.08		0.04	0.42

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

GYLD (t/ha), grain yield in ton per hectare; HYLD (t/ha), haulm yield in ton per hectare; HGR, haulm grain ratio; DDMHYLD (t/ha), digestible dry matter haulm yield in ton per hectare; PUI (%), potential utility index.

The haulm yield and dry matter digestible haulm yield of dz2012ck0026 (3.91t/ha and 2.02t/ha), dz2012ck0025 (3.66t/ha and 1.9t/ha) and dz2012ck0024 (3.62t/ha and 1.86t/ha) were significantly ($P<0.05$) higher than the other varieties. The potential utility index of tested varieties dz2012ck0024 (73.09%), dz2012ck0021 (73.05%), dz2012ck0017 (72.99%), dz2012ck0022 (72.25%0 and dz2012ck0023 (72.19%) were significantly (P<0.05) higher than control varieties. The haulm yield, digestible dry matter haulm yield and PUI of the control varieties, Ejere (3.29t/ha, 1.67t/ha and 71.81%), Chefe (3.19t/ha, 1.62t/ha and 70.74%), Habru(3.13t/ha, 1.58t/ha and 70.66%) and dz104 (2.79t/h, 1.47t/h and 68.82%), respectively.

Table 14. Comparison of haulm quality, quantity, grain yield, haulm grain ratio and potential utility index 17 genotypes of desi chickpea.

Genotype	GYLD (t/ha)	HYLD (t/ha)	HGR	DDMHYLD (t/ha)	PUI (%)
dz2012ck0031	3.30	4.21[a]	1.26	2.09[a]	72.37
dz2012ck0036	3.50	3.85[ab]	1.1	1.94[ab]	74.47
Natoli	3.17	3.81[ab]	1.2	1.93[ab]	73.19
dz2012ck0029	2.96	3.81[ab]	1.29	1.89[ab]	72.19
dz2012ck0033	2.85	3.68[ab]	1.29	1.87[ab]	72.96
dz2012ck0028	2.67	3.51[ab]	1.31	1.76[ab]	73.39
dz2012ck0030	2.74	3.51[ab]	1.28	1.78[ab]	73.37
Minjar	3.27	3.49[ab]	1.07	1.77[ab]	75.07
dz2012ck0040	3.14	3.49[ab]	1.1	1.75[ab]	74.47
dz2012ck0038	3.25	3.46[ab]	1.06	1.70[ab]	73.73
dz2012ck0035	2.83	3.45[ab]	1.22	1.73[ab]	73.07
dz2012ck0039	2.82	3.39[ab]	1.2	1.71[ab]	73.09
dz2012ck0027	2.72	3.28[ab]	1.2	1.67[ab]	73.07
dz2012ck0032	3.12	3.23[b]	1.04	1.60[b]	74.77
dz2012ck0037	2.97	3.19[b]	1.07	1.64[ab]	75.48
Local check	2.69	3.14[b]	1.17	1.57[b]	74.14
dz2012ck0034	2.94	3.04[b]	1.03	1.48[b]	74.16
Overall mean	2.99	3.5	1.17	1.76	73.71
SE(±)	0.06	0.09		0.04	0.33

Means within column followed by the same letter (s) are not significantly different at P <0.05 level of Duncan multiple tests. GYLD (t/ha), grain yield in ton per hectare; HYLD (t/ha), haulm yield in ton per hectare; HGR, haulm grain ratio; DDMHYLD (t/ha), digestible dry matter haulm yield in ton per hectare; PUI (%), potential utility index.

Table 14 shows comparison of grain yield, haulm quality and quantity and potential utility index of seventeen genotypes for desi type chickpea. The highest value of grain yield, haulm yield and digestible dry matter haulm yield were recorded in dz2012ck0036 (3.5t/ha, 3.85t/ha and 1.94t/ha) and dz2012ck0031 (3.3t/ha, 4.21t/ha and 2.09t/ha) and these genotypes had significantly (p<0.05) higher values than control varieties, Minjar (3.27t/ha, 3.49t/ha and 1.77t/ha), Natoli

(3.17t/ha, 3.81t/ha and 1.93t/ha) and Local check (2.69t/ha, 3.14t/ha and 1.57t/ha). However, the potential utility index of dz2012ck0037(75.48%) was significantly ($p<0.05$) higher than all other varieties and also Minjar(75.07%) variety was better in PUI than other tested and control varieties, Local check(74.14%) and Natoli(73.19%). The HGR in Table 14 indicated that genotype dz2012ck0028 (1.31), dz2012ck0029 (1.29), dz2012ck0030 (1.28) and dz2012ck0033 (1.29) had higher as compared to the other varieties listed desi chickpea.

In the present study, the overall mean of grain yield and digestible haulm dry matter yield in potential environment were higher than low moisture stress area in kabuli chickpea. This result was consistent with previously reported findings by researchers (Chimenti *et al*. (2002); Erdem *et al*. (2006)) who indicated that grain yield and weight of 1000 grains decreased with increasing drought stress. Ahmad *et al*. (2009) reported that plant height and plant dry matter decreased with increasing water stress under controlled conditions. Karam *et al*. (2007) showed that with increasing drought stress leaf area index, grain yield and its component decreased. Relative water content of the leaves decreased under drought stress (Unyayar *et al*., 2004).

Grain is the primary trait that is targeted in all crop improvement programs in Ethiopia. Variability existed among chickpea genotypes under tested locations for grain yield, haulm quality and quantity traits. The overall mean of grain yield, haulm yield and digestible dry matter yield of the haulm were relatively higher in potential environment varieties than low moisture stress area. However, potential utility index was higher in low moisture stress varieties. Desi chickpea were significantly higher grain yield and potential utility index than kabuli chickpea.
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)**,** it was not consistent with fodder traits therefore, the tested genotypes which had shown highest in haulm nutritional values in the present study were not found to be high in their potential utility index because they performed low grain yield. Since Blummel *et al*. (2010) suggested that crude protein and *in vitro* digestibility were significantly inversely related to grain yield in sorghums with weak associations. However, there were some genotypes which combined or compromised moderately high grain and haulm yield better haulm quality traits and ultimately medium potential utility index among the tested varieties. In the trial, haulm grain

ratio was higher in varieties with low potential index, this is due to the disease occurred during the experimental time resulting low grain yield.

5. CONCLUSION AND RECOMMENDATIONS

The current study showed that the mean predicted values of CP, NDF, ADF and ADL, total ash, ME and TIVOMD of chickpea haulm samples by NIRS were very close to those determined by the wet chemistry analysis. Hence, it could effectively be used to predict the nutritional quality of chickpea haulm. There were significant effects of locations and genotypes on haulm nutritional values of the haulm. The current study showed that the presence of considerable varietal differences in the haulm chemical composition, nutritive value and mineral constituents of chickpea haulms. Moreover, with the exception of CP content, both grain yield and haulm yield were not negatively correlated to biomass. This indicates that there is a possibility of selecting varieties of chickpea crop that combine high grain and haulm yield with desirable haulm quality. Thus, to maximize the fodder quantity and quality traits obviously requires that plant breeders should work in collaboration with farmers and animal nutritionists to select varieties that combine high grain yield with superior haulm feeding value to increase whole plant utilization. Exhaustive 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 way leading 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.

The haulms of legumes are very important in the diets of ruminants in the highlands of Ethiopia. Therefore, selection of new chickpea varieties should take into consideration the nutritive value of the haulm as well as the quantities of grain and haulm produced. The observed differences in haulm nutritional values were also consistent across genotypes and locations, comparatively higher CP content of kabuli chickpea than desi type chickpea. Highest CP content was obtained from Debre zeit, Alem Tena and Minjar locations. However, lower CP value and higher percentage of fiber fractions were recorded Akaki and Chefe Donsa locations. Dz2012ck0018 had shown highest (P<0.05) content of CP, ME (MJ/kg DM), TIVOMD (%) and lowest (P<0.05) values of NDF, ADF and ADL values in low moisture stress areas of kabuli chickpea. Dz2012ck0037 was significantly (p<0.001) higher value of PUI (%) and dz2012ck0036 in desi type chickpea was higher grain yield. The CP value of the haulm was significant (p<0.001) and negatively correlated with grain yield, biomass, haulm yield and days to maturity. Moreover; the ME and TIVOMD were negatively correlated to all agronomic traits, except HSW.

The result also indicated NIR spectroscopy is a method of alternatives for the prediction of chemical compositions (CP, NDF, ADF and ADL), *in-vitro* parameters (ME and TIVOMD) with high accuracy and also used to predict the mineral components of chickpea haulm. Therefore, we concluded that NIRS could be more widely used in the evaluation of chickpea haulms for the assessment of their chemical composition, nutritional value and mineral constituents to a similar degree to that of conventional methods of analysis. Since NIRS is simple and safe to operate and allows rapid screening of several quality traits simultaneously.

Genotypes which combined moderately high grain and haulm yield better haulm quality traits and ultimately medium potential utility index were Dz2012ck000024, Ejere, Chefe and Dz2012ck0017 from kabuli for moisture stress area, Dz2012ck0007, Dz2012ck0001, Dz2012ck0012, Arerti and Dz2012ck0004 from kabuli for potential environment, Dz2012ck0036, Dz2012ck0031 and Dz2012ck0029 and Natoli from desi type chickpea. Generally, the study pinpointed the possibility for simultaneous improvement of grain yield and haulm quality traits to address the high demand existing for dual purpose food-feed traits of chickpea genotypes in mixed-livestock system of Ethiopia.

Based on the above conclusion the following recommendations are forwarded. Similar to the haulm, future studies should consider the nutritional value of the grain as human food and correlate with other haulm and yield parameters. The research also need to be conducted over two years period to reach robust conclusion, since it is difficult to give reliable conclusion in one year study due to erratic weather condition that may cause over and under performance. Superior genotypes have to be further evaluated for their effect on animal performance and for their anti-nutritional attributes. Besides the genotype, management (agronomic) factors play a major role on nutritional values of crop residues. Thus, future studies should consider the agronomic practices for quality improvement of crop residues.

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7. APPENDICES

7.1. APPENDX I. Analysis of Variance

Kabuli Chickpea for Potential Environment

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	117.9877944	2.2261848	51.46	<.0001
Error	149	6.4459741	0.0432616		
Corrected Total	202	124.4337685			

R-Square	Coeff Var	Root MSE	ME Mean
0.948198	2.702087	0.207994	7.697537

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	0.2794176	0.0931392	2.15	0.0960
Location	2	105.1177196	52.5588598	1214.91	<.0001
Treatment	16	5.3471226	0.3341952	7.72	<.0001
Location*Treatment	32	6.8119299	0.2128728	4.92	<.0001

Dependent Variable: TIVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	5141.004936	97.000093	52.12	<.0001
Error	149	277.291862	1.861019		
Corrected Total	202	5418.296798			

R-Square	Coeff Var	Root MSE	TIVOMD Mean
0.948823	2.608402	1.364192	52.29990

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	12.852638	4.284213	2.30	0.0795
Location	2	4567.349111	2283.674555	1227.11	<.0001
Treatment	16	225.529695	14.095606	7.57	<.0001
Location*Treatment	32	317.015606	9.906738	5.32	<.0001

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	9350.94282	176.43288	16.77	<.0001
Error	149	1567.83690	10.52240		

Corrected Total	202	10918.77972			

R-Square	Coeff Var	Root MSE	NDF Mean
0.856409	5.664821	3.243824	57.26261

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	61.825595	20.608532	1.96	0.1227
Location	2	8789.220559	4394.610279	417.64	<.0001
Treatment	16	141.574611	8.848413	0.84	0.6377
Location*Treatment	32	310.506091	9.703315	0.92	0.5913

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	6552.141064	123.625303	17.63	<.0001
Error	149	1044.996321	7.013398		
Corrected Total	202	7597.137385			

R-Square	Coeff Var	Root MSE	ADF Mean
0.862449	6.487245	2.648282	40.82291

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	30.405904	10.135301	1.45	0.2320
Location	2	6211.130703	3105.565352	442.80	<.0001
Treatment	16	70.977388	4.436087	0.63	0.8536
Location*Treatment	32	205.051547	6.407861	0.91	0.6040

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	497.6014584	9.3887068	30.43	<.0001
Error	149	45.9768992	0.3085698		
Corrected Total	202	543.5783576			

R-Square	Coeff Var	Root MSE	ADL Mean
0.915418	5.656245	0.555491	9.820837

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.8382424	0.6127475	1.99	0.1186
Location	2	476.8355050	238.4177525	772.65	<.0001
Treatment	16	6.3078539	0.3942409	1.28	0.2185
Location*Treatment	32	9.8926279	0.3091446	1.00	0.4736

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	512.0824536	9.6619331	24.43	<.0001
Error	149	58.9351011	0.3955376		
Corrected Total	202	571.0175547			

R-Square	Coeff Var	Root MSE	Ash Mean
0.896789	8.079888	0.628918	7.783744

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	2.7928405	0.9309468	2.35	0.0744
Location	2	489.5722100	244.7861050	618.87	<.0001
Treatment	16	9.8446449	0.6152903	1.56	0.0879
Location*Treatment	32	9.3348398	0.2917137	0.74	0.8427

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	1478.978574	27.905256	11.48	<.0001
Error	149	362.038943	2.429792		
Corrected Total	202	1841.017516			

R-Square	Coeff Var	Root MSE	CP Mean
0.803348	34.34328	1.558779	4.518818

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Block	3	20.856724	6.952241	2.86	0.0389
Location	2	1360.982543	680.491271	280.06	<.0001
Treatment	16	22.037871	1.377367	0.57	0.9044
Location*Treatment	32	67.835826	2.119870	0.87	0.6652

Kabuli Chickpea for Moisture Stress Areas.

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	475.8346185	8.9780117	16.36	<.0001
Error	137	75.1887396	0.5488229		
Corrected Total	190	551.0233581			

R-Square	Coeff Var	Root MSE	Ash Mean
0.863547	7.812202	0.740826	9.482932

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.0177770	0.3392590	0.62	0.6044
Location	2	314.5227300	157.2613650	286.54	<.0001
Treatment	16	102.0405255	6.3775328	11.62	<.0001
Location*Treatment	32	33.2058023	1.0376813	1.89	0.0064

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	864.979070	16.320360	10.62	<.0001
Error	137	210.507247	1.536549		
Corrected Total	190	1075.486317			

R-Square	Coeff Var	Root MSE	CP Mean
0.804268	19.11613	1.239576	6.414450

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	12.3217528	4.1072509	2.67	0.0499
Location	2	33.4659581	16.7329790	10.89	<.0001
Treatment	16	279.9823289	17.4988956	11.39	<.0001

Location*Treatment	32	537.4461148	16.7951911	10.93	<.0001

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	9042.15789	170.60675	16.63	<.0001
Error	137	1405.84486	10.26164		
Corrected Total	190	10448.00275			

R-Square	Coeff Var	Root MSE	NDF Mean
0.865444	6.147477	3.203380	52.10885

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	109.853759	36.617920	3.57	0.0159
Location	2	4721.323883	2360.661941	230.05	<.0001
Treatment	16	1713.871575	107.116973	10.44	<.0001
Location*Treatment	32	1362.034922	42.563591	4.15	<.0001

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	7415.392453	139.913065	27.99	<.0001
Error	137	684.913297	4.999367		
Corrected Total	190	8100.305750			

R-Square	Coeff Var	Root MSE	ADF Mean
0.915446	5.742936	2.235926	38.93351

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	90.722803	30.240934	6.05	0.0007
Location	2	4770.707198	2385.353599	477.13	<.0001
Treatment	16	1057.405242	66.087828	13.22	<.0001
Location*Treatment	32	586.032089	18.313503	3.66	<.0001

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	413.7500643	7.8066050	23.05	<.0001
Error	137	46.4035786	0.3387123		
Corrected Total	190	460.1536429			

R-Square	Coeff Var	Root MSE	ADL Mean
0.899156	6.604092	0.581990	8.812565

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.8915714	0.6305238	1.86	0.1390
Location	2	276.3005320	138.1502660	407.87	<.0001
Treatment	16	60.4623335	3.7788958	11.16	<.0001
Location*Treatment	32	31.1904431	0.9747013	2.88	<.0001

Dependent Variable: TIVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	4828.406906	91.102017	24.36	<.0001
Error	137	512.327859	3.739619		
Corrected Total	190	5340.734764			

R-Square	Coeff Var	Root MSE	TIVOMD Mean
0.904072	3.546632	1.933810	54.52524

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	24.932708	8.310903	2.22	0.0883
Location	2	3283.448529	1641.724265	439.01	<.0001
Treatment	16	547.500893	34.218806	9.15	<.0001
Location*Treatment	32	492.579155	15.393099	4.12	<.0001

Dependent Variable: ME

Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	53	125.6903192	2.3715155	30.14	<.0001
Error	137	10.7785248	0.0786754		
Corrected Total	190	136.4688440			

R-Square	Coeff Var	Root MSE	ME Mean
0.921018	3.533521	0.280491	7.938010

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	0.50990851	0.16996950	2.16	0.0955
Location	2	89.46112658	44.73056329	568.55	<.0001
Treatment	16	13.39539686	0.83721230	10.64	<.0001
Location*Treatment	32	10.51871559	0.32870986	4.18	<.0001

Desi type Chickpea

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	338.3154738	24.1653910	66.75	<.0001
Error	188	68.0622878	0.3620334		
Corrected Total	202	406.3777616			

R-Square	Coeff Var	Root MSE	Ash Mean
0.832515	6.955107	0.601692	8.651084

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	3.42269315	1.14089772	3.15	0.0262
Location	3	1.31603304	0.43867768	1.21	0.3068
Treatment	2	88.89983833	44.44991916	122.78	<.0001
Location*Treatment	6	4.46192391	0.74365398	2.05	0.0606

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	917.391436	65.527960	35.14	<.0001
Error	188	350.601581	1.864902		
Corrected Total	202	1267.993017			

R-Square	Coeff Var	Root MSE	CP Mean
0.723499	32.91144	1.365614	4.19360

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	32.3337416	10.7779139	5.78	0.0008
Location	3	8.4570364	2.8190121	1.51	0.2129
Treatment	2	208.5734999	104.2867500	55.92	<.0001
Location*Treatment	6	22.5948405	3.7658067	2.02	0.0650

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	3966.095022	283.292502	32.13	<.0001
Error	188	1657.760397	8.817874		
Corrected Total	202	5623.855419			

R-Square	Coeff Var	Root MSE	NDF Mean
0.705227	5.091500	2.969491	58.32251

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	90.3319175	30.1106392	3.41	0.0186
Location	3	23.5192966	7.8397655	0.89	0.4478
Treatment	2	907.3156513	453.6578257	51.45	<.0001
Location*Treatment	6	148.2979808	24.7163301	2.80	0.0123

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	14	2840.418341	202.887024	34.84	<.0001
Error	188	1094.727241	5.823017		
Corrected Total	202	3935.145582			

R-Square	Coeff Var	Root MSE	ADF Mean
0.721808	5.655662	2.413093	42.66685

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	106.2253280	35.4084427	6.08	0.0006
Location	3	25.0716007	8.3572002	1.44	0.2339
Treatment	2	700.6156427	350.3078213	60.16	<.0001
Location*Treatment	6	87.2777492	14.5462915	2.50	0.0239

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	241.6003823	17.2571702	51.45	<.0001
Error	188	63.0639142	0.3354464		
Corrected Total	202	304.6642966			

R-Square	Coeff Var	Root MSE	ADL Mean
0.793005	5.855170	0.579177	9.891724

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	3.25460133	1.08486711	3.23	0.0235
Location	3	0.27112374	0.09037458	0.27	0.8474
Treatment	2	61.40359714	30.70179857	91.53	<.0001
Location*Treatment	6	6.95690809	1.15948468	3.46	0.0029

Dependent Variable: TIVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	2241.343593	160.095971	34.24	<.0001
Error	188	879.021368	4.675646		

Corrected Total	202	3120.364962

R-Square	Coeff Var	Root MSE	TIVOMD Mean
0.718295	4.202623	2.162324	51.45177

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	50.3067830	16.7689277	3.59	0.0148
Location	3	6.8735297	2.2911766	0.49	0.6896
Treatment	2	542.4487766	271.2243883	58.01	<.0001
Location*Treatment	6	70.7553832	11.7925639	2.52	0.0227

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	55.45440777	3.96102913	39.28	<.0001
Error	188	18.96023164	0.10085230		
Corrected Total	202	74.41463941			

R-Square	Coeff Var	Root MSE	ME Mean
0.745208	4.209279	0.317573	7.544581

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	1.06009469	0.35336490	3.50	0.0165
Location	3	0.15520966	0.05173655	0.51	0.6738
Treatment	2	13.78652282	6.89326141	68.35	<.0001
Location*Treatment	6	1.56663437	0.26110573	2.59	0.0196

APPENDICES II. Mean Squares

Table 1. Mean squares of haulm chemical compositions of kabuli and desi type chickpea.

S.O.V.	DF	DM	CP	Ash	NDF	ADF	ADL	ME
Kabuli chickpea (n=31)	1							

Block	3	0.15***	10.77*	0.38ns	51.98*	33.4*	0.97ns	0.23*
Loc	4	0.59***	319.85***	188.9***	3180***	2644.9***	179.1***	47.29***
Treatment	30	0.05***	9.16***	3.68***	61.77***	39.14***	2.26***	0.59***
Lx T	64	0.03*	9.82***	0.69ns	26.23***	12.24***	0.64***	0.27***
Error	291	0.01	1.98	0.47	10.34	6.06	0.32	0.06
Desi chickpea (n=17)								
Block	3	0.01ns	10.45**	1.14*	28.01ns	33.93**	1.08ns	0.33*
Loc	2	0.97***	428.65***	165.1***	1859.1***	1317.7***	115.9***	26.41***
Treatment	16	0.03**	2.84ns	1.17***	12.64ns	11.2*	0.47ns	0.19*
L x T	32	0.02*	3.05*	0.61***	15.23*	9.79*	0.59*	0.15ns
Error	149	0.01	1.59	0.24	7.64	4.79	0.29	0.08

APPENDIX III. Working Document

Chickpea National Variety Trial, Kabuli for Potential Environment 2013/2014

A. Lay out and Randomization

R-IV phase II

68	67	66	65	64	63	62	61	60	59	58	57	56	54	53	52	51
14	10	13	15	17	3	2	4	5	1	7	11	9	6	8	12	16

R-III

35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
11	1	13	10	15	6	9	3	8	14	17	12	16	2	4	7	5

R-II

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

R-I

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

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

N. B. 1. Numbers from 1-68 are plot numbers (the upper)

2. Numbers from 1-17 are treatment codes (the lower)

B. Variety

1. DZ-2012-CK-0001
2. DZ-2012-CK-0002
3. DZ-2012-CK-0003
4. DZ-2012-CK-0004
5. DZ-2012-CK-0005
6. DZ-2012-CK-0006
7. DZ-2012-CK-0007
8. DZ-2012-CK-0008
9. DZ-2012-CK-0009
10. DZ-2012-CK-0010
11. DZ-2012-CK-0011
12. DZ-2012-CK-0012
13. DZ-2012-CK-0013
14. ARERTI (Std)
15. EJERE (Std)
16. HABRU (Std)
17. DZ-10-4

Chickpea National Variety Trial, Desi 2013/2014

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

B. Variety

1. DZ-2012-CK-0027
2. DZ-2012-CK-0028
3. DZ-2012-CK-0029
4. DZ-2012-CK-0030
5. DZ-2012-CK-0031
6. DZ-2012-CK-0032
7. DZ-2012-CK-0033
8. DZ-2012-CK-0034
9. DZ-2012-CK-0035
10. DZ-2012-CK-0036
11. DZ-2012-CK-0037
12. DZ-2012-CK-0038
13. DZ-2012-CK-0039
14. DZ-2012-CK-0040
15. NATOLI(Std)
16. MINJAR(Std)
17. LOCAL CHECK

Chickpea National Variety Trial, Kabuli for Low Moisture Stress 2013/2014

A. Lay out and Randomization

R-IV phase II

68	67	66	65	64	63	62	61	60	59	58	57	56	54	53	52	51
15	9	2	16	14	11	10	5	8	7	3	12	4	17	1	13	6

R-III

35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
8	16	7	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

N. B. 1. Numbers from 1-68 are plot numbers (the upper)

2. Numbers from 1-17 are treatment codes (the lower)

B. Variety

1. DZ-2012-CK-0014
2. DZ-2012-CK-0015
3. DZ-2012-CK-0016
4. DZ-2012-CK-0017
5. DZ-2012-CK-0018
6. DZ-2012-CK-0019
7. DZ-2012-CK-0020
8. DZ-2012-CK-0021
9. DZ-2012-CK-0022
10. DZ-2012-CK-0023
11. DZ-2012-CK-0024
12. DZ-2012-CK-00
13. DZ-2012-CK-0026
14. EJERE(Std)
15. CHEFE(Std)
16. HABRU(Std)
17. DZ-10-4